STATEMENT OF OBJECTION TO ENVIRONMENTAL PERMIT APPLICATION S13/006

Email to: community-safety@calderdale.gov.uk

From: [redacted]
Address: [redacted]

Environmental Permitting (England and Wales) Regulations 2016 (“the Regulations”)

Application for environmental permit for Schedule 13 small waste incineration plant ref S13/006

Calder Valley Skip Hire, Belmont Industrial Estate, Rochdale Road, Sowerby Bridge HX6 3LL

DOCUMENTS included with this Objection:

1. [redacted] **Objection to Environmental Permit 2024**
2. **Decision Calderdale EPR603.pdf**
3. [redacted] **_Final**
4. **Met_Office_email_**[redacted]
5. **Arboriculturists Report 1-4-24.pdf**
6. [redacted] **_Objection to Environmental Permit Appeal Ref APP_EPP_603_FINAL +Documents (Original Objection)**

   Includes these documents:

   1. Air Quality and Permit Review: Calderdale Valley Skip Hire Small Waste Incineration Plant – November 2021 - Air Quality Consultants Limited. Note this is the same as the Appellant has submitted except for the correction of the reference to “unpredicting sites” to “underpredicting sites” in Issue 5. (“AQC Report”)

   2. Advice - October 2022 - by [redacted] **(“Counsel’s Opinion”)**

   3. Technical Note – Calder Valley Skip Hire Small Waste Permit Incineration Plant – October 2022 – Air Quality Consultants Limited (“AQC Technical Note”)

   4. High Court Order granting permission for Judicial Review – 23 July 2021. (“High Court Order”)High Court Order granting permission for Judicial Review – 23 July 2021. (“High Court Order”)

7. **Objection submitted by** [redacted] **in October 2022 in relation to Calder Valley Skip Hire Limited – Environmental Permit Appeal – Reference APP/EPR/603 (“Original Objection”)**
8. **CVSH-HD36-closing**
9. **Appeal Decisions 3205776 3205783 - Copy.pdf**

GROUNDS OF OBJECTION

1. I object to the grant of an Environmental Permit for the reasons set out in this document and attachments.

Background of the Application - ref S13/006

2. In May 2022, Calder Valley Skip Hire ("the **Applicant**") appealed on the ground of a "deemed refusal" due to the failure by regulator to give notice of determination of its previous application for an environmental Permit within the statutory time-period. That Appeal was dismissed on 5 July 2023 by an Inspector appointed by the Secretary of State following a full public inquiry.

3. The Inspector dismissed the Appeal because he was **not satisfied on the evidence adduced that the proposal complies with IED Article 46 1.**, which requires that waste gases from waste incineration plants and waste co-incineration plants shall be discharged in a controlled way by means of a stack the height of which is calculated in such a way as to safeguard human health and the environment.

Furthermore, the Inspector was **unable** to find that the necessary measures have been taken to ensure that waste management would be carried out without endangering **human health, without harming the environment and, in particular without risk to air, in compliance with Article 13 of the Waste Framework Directive 2008/98/EC**.

To quote from the Inspectors decision :

"*42. Taking all the above into account, I consider that the appeal should be dismissed because I am not satisfied on the evidence adduced that the proposal complies with IED Article 46 1., which requires that waste gases from waste incineration plants and waste co-incineration plants shall be discharged in a controlled way by means of a stack the height of which is calculated in such a way as to safeguard human health and the environment. Furthermore, I am unable to find that the necessary measures have been taken to ensure that waste management would be carried out without endangering human health, without harming the environment and, in particular without risk to air, in compliance with Article 13 of the Waste Framework Directive 2008/98/EC.*" ***Decision Calderdale EPR603.pdf Page 9.***

4. In reaching his decision the Inspector John Woolcock made it clear that because he was dismissing the Appeal and the deemed refusal would stand he had **not**:

   a. considered the application of Paragraph 13 of Schedule 5 EPR 2016 which provides that the regulator must refuse an application for the grant of an environmental permit if it considers that, if the permit is granted, the following will not be satisfied; (a) the applicant must be the operator of the regulated facility, and (b) would operate the regulated facility in accordance with the environmental permit.

   b. ruled on the technical objections of third parties.

There is a great deal of important detail explaining the reasons for the Inspectors Appeal decision, not least the statement :

" 38. Given the height and proximity of the trees/woodland in the vicinity of the proposed stack, I am not convinced that it would be **reasonable to rely solely on surface roughness length to properly take into account the likely effect of the trees on the dispersion of emissions from the SWIP**. In the circumstances, I am unable to find that waste gases from the SWIP would be discharged in a controlled way by means of a stack the height of which is calculated in such a way as to safeguard human health and the environment.

39. Because of an error at the planning application stage in the AOD of the proposed stack, a previous run of the model inadvertently assessed a stack height 9 m higher than the correct discharge height.

The results from this modelling do not provide any reassurance about the robustness of the stack height calculation now relied upon by the appellant because that run of the model also dealt with the trees solely by means of surface roughness length." My emphasis from the appeal document ." ***Decision Calderdale EPR603.pdf Page 9.***

Environmental Permit Application - ref S13/006

5. CVSH provide an outline of their reasons for this new application in document CVSH-R-JER1902-LD-SWIP-application-26-jan-2024.pdf ("the Application").
6. The Applicant (CVSH) states that this application is being submitted on the same basis as the original application (06/08/2020) . However, it has added further information to that provided to inform the redetermination in 2022 and certain documents from the hearing sessions in two appeal hearings in November 2022 and May 2023 have been incorporated.

7. To address the Inspector's reason for dismissing the Appeal, the Applicant as they put it have sought *"an independent review of the treatment of trees within the air quality assessment and to provide an expert explanation of how variable surface roughness lengths work within the ADMS model." **(CVSH-R-JER1902-LD-SWIP-application-26-jan-2024.pdf point 1.5.4)***

Considerations in Determining the New Application

8. It is clearly not the case, as CVSH suggest, that the Inspector would have granted the Appeal except for the issues around surface roughness and air quality computer modelling. The Inspectors conclusion repeated above from the Appeal decision show there are many deficiencies within the original application for an environmental permit.

9. The Council (CMBC) agreed with the applicant in both the previous Environmental permit applications, in fact the CMBC closing statement for the Environmental Permit Appeal(31 May 2023) ended ***" Conclusion 1.16 There is no proper basis to conclude that the proposed incinerator cannot be operated in a manner consistent with the EPR***".

   Subsequently the Inspector dismissed the appeal (5th July 2023) and was not satisfied the evidence showed compliance with **IED article 46.1** or **compliance with Article 13 of the Waste Framework Directive 2008/98/EC** as quoted above. The appeal decision shows the case for granting of a new permit application requires more than just an explanation of the surface roughness and the tree height within an air quality assessment..

10. Since this is a new application, Calderdale Metropolitan Borough Council (CMBC) as the regulator responsible for protecting Public health must look at all the relevant issues and cannot simply treat it as a "rubber stamping" of a claimed single outstanding issue from the Appeal. Meanwhile, the elected representatives claim once again "their hands are tied" and look away while officers are expected to approve the application.

11. [redacted] in her objection outlines the fact that the very recent Appeal and the approach taken by the Inspector is a significant material consideration in the consideration of this new Application on nearly identical terms and the Council **must** have due regard to this. The Applicant is out of time to challenge the decision through Judicial Review proceedings as it could have done. The decision and views of the Inspector on the environmental permit appeal are more directly relevant and should carry more weight than that of the February 2020 appeal decisions under the different regulatory regime that looked at planning issues. No matter how often the Applicant argues to the contrary.

12. [redacted]noted in her objection to the Appeal that the Statement of Case of the Appellant which sought to set out the merits of the appeal very much centred around its incorrect contention that it is impermissible for anyone to revisit any of the air quality issues considered by the Planning Inspector ([redacted]) in his planning permission decisions dated 4 February 2020 during the environmental permitting process both as a matter of law and as a matter of Central Government guidance as contained in the National Planning Policy Framework (NPPF).

13. It is a matter of record that t

a. the Appellant sought to persuade the Council (CMBC) and the Inspector hearing the appeal that none of the outstanding matters raised by the Calderdale Council's experts (Tetra Tech) or in the AQC Report could be taken into consideration in the decision as to whether or not to grant an Environmental Permit. The refusal to provide the additional information sought by the Council in relation to these issues appeared to be the primary reason for the submission of the Appeal.

b. Calderdale Council (CMBC),in its Statement of Case to the Appeal **also wrongly accepted the arguments put forward by the Appellant** and conceded the Appeal on the basis that it considered it was prevented from seeking the further information advised by its technical advisors (who were acting under delegated power of the Council as its "competent persons") and on the basis that no further evidence has been put forward to undermine the original quashed decision to grant the Permit. The Council's Statement of Case made no reference whatsoever to the AQC Report and the evidence in that which has been provided to counter the original decision to grant the Environmental Permit.

c. The Inspector who determined the appeal in relation to the Environmental Permit in July 2023 **disagreed** with both the Applicant and the Council in relation to the application of NPPF guidance.

d. He agreed with the position set out in the Counsel's Opinion submitted to him as part of the objections. (7. **Advice - October 2022 - by [redacted] ("Counsel's Opinion")**

Law and Guidance

14. The correct position in relation to the law and guidance on the process that should be followed and the matters that can be taken into account in relation to the determination of an Environmental Permit application and appeal are set out in detail in the Counsel's Opinion and AQC Technical Note attached with this objection. This is presented clearly once again in [redacted] Objection to this latest application (Points 14.- 19) I will not repeat them here but attach the objection for reference. ([redacted]**_Objection to Environmental Permit 2024**)

Relevance of High Court Order granting Permission for Judicial Review

(High Court Order granting permission for Judicial Review – 23 July 2021. ("High Court Order")) Document 6.4.

The Judicial Review brought by myself after the Council erroneously granted the environmental permit in 9th February 2021 was successful on all grounds. It is the case that a Judge must refuse permission to apply for judicial review, unless satisfied that an arguable ground for judicial review **<u>has a reasonable prospect of success</u>**. One of the four grounds for the judicial review (ground 3) was that the application of an alternative test could have made a difference to the outcome. In other words refusal of the Permit was a possibility.

The application ref S13/006 has provided very limited new information and uses the documents from the previous application for which the appeal was dismissed, without significant new information resolving the Inspectors concerns then there can be no good reason for approval of the permit in the face of the Inspectors finding in the dismissed appeal.

Obligations of the Regulator

15. **Pre-determination**, occurs when a decision-maker approaches a decision with a closed mind, making them unable to apply their judgment fully and properly to an issue requiring a decision. It's a

form of bias where the decision-maker has made up their mind before considering all the relevant evidence, which is not allowed and could make the decision unlawful.

a. At a meeting on 21 December 2023 an Officer responsible for environmental health said "if emissions at the stack point monitor were ok there would be no reason to refuse an EP".
b. At each Environmental permit application since Mearclough, the elected members have said their hands are tied with respect to the Permit decision.
c. This whole approach by CMBC **appears** very like pre determination, the very limited updated information in the application limited to the topic already mentioned by the CMBC officer appears to indicate the permit will be granted without attempting to address other concerns raised by the Inspector or residents in their objections.
d. Previously Cabinet members have been disallowed from voting on the Permit application because they are opposed to it.
e. There is a difference between a closed mind and applying judgement to an issue requiring a decision.

16. It is the permitting authority that has the responsibility and statutory obligation to determine whether **operational stack emissions** from regulated facilities covered under the EPR are controlled to prevent significant impacts on human health and the environment. Combined with ensuring statutory minimum emission limit values can be met, predictive air quality assessments are the only data available to the permitting authority at application stage to determine the potential impact on human health and the environment and, consequently, the degree to which emissions are/can be controlled.

17. Irrespective of whether operational air quality effects have been discussed at planning stage, the local authority permitting function, as regulator for SWIPs, can, and must, **ensure** that operational phase assessments of stack emissions are robust. If any aspect of the air quality assessment of operational stack emissions is not considered to be robust, further information should be sought by the local authority permitting function, and provided by the applicant, before determining the application.

18. If the Council considers that it requires further information to determine a duly-made application, it may serve a notice on the applicant specifying the further information and the period within which it must be provided. If the applicant fails to provide the further information in accordance with the notice, the Council may serve a further notice on the applicant stating that the application is deemed to be withdrawn, upon which the application is deemed to be withdrawn.

Outstanding Issues preventing Grant of a Permit

19. As part of the process for the redetermination of the original environmental permit application (2020)the Council appointed Tetra Tech to undertake a further review of the amended permit application and the AQC Report and the outcome was that, acting under the delegated powers of the Council, agreeing with points made by AQC, Tetra Tech required additional information before a decision was taken. Further information was therefore requested by the Council in relation to the assessment of 1-hour mean NO2 concentrations, and a sensitivity test regarding uncertainty within the air quality assessments. CVSH refused to provide that information based on its incorrect assertion of the law and guidance.

20. As part of the redetermination process CVSH instructed RPS to undertake a review of the AQC Report. The subsequent report by RPS was provided by CVSH as part of the Appeal documents and is attached to the AQC Technical Note. That RPS report however ignored the items listed in the AQC Report (1) Uncertainty (3) Stack Height (5) Road Modelling Verification and Model Adjustment (6) Assessment of 1 hour- mean NO2 Concentrations (10) Surface Roughness. The reason it did so was solely because it followed the (incorrect) legal advice from CVSH's lawyers to the effect that it was considered impermissible to revisit the air quality issues determined by the Planning Inspector during the environmental permitting process.

21. It is to be wondered (given the CVSH has sought to address other issues raised by AQC), whether the continued resistance or avoidance of CVSH to address these issues is not so much due to its interpretation of the law and guidance, but the fact that if they are properly addressed now in the terms of the environmental permitting regime, the results would lead to a conclusion that the Environmental Permit should be refused or that a new planning application would be required to facilitate a rise in the stack height.

22. CVSH sought to find an issue with the failure of the AQC Report to list the Planning Inspector's decision. AQC have confirmed in the AQC Technical Note that they reviewed the documents and Planning Inspector's decision. They confirm that, although the planning appeal decision was sent to AQC, it was not considered material for the review of the air quality impacts at permitting stage. They state that*, as previously demonstrated, both in terms of legislation and supporting guidance, it is the permitting regime that must determine whether the assessment of operational air quality effects of stack emissions is robust with respect to controlling emissions under the EPR. The planning regime serves an entirely separate purpose.*

23. Where the further information required by Tetra Tech and the issues raised by AQC ((1) Uncertainty (3) Stack Height (5) Road Modelling Verification and Model Adjustment (6) Assessment of 1 hour-mean NO2 Concentrations (10) Surface Roughness) continue to remain relevant and unresolved they should be addressed as part of this new Application. In particular, AQC have confirmed that the issue they raised in relation to the Stack Height Determination in the ACQ Report (paragraph 3.17 onwards) has not been addressed.

24. I have attached MP Objection February 2023. This sets out further concerns with regard to the environmental permit that were raised during the Appeal. As stated above, the Inspector did not rule on the technical objections of third parties. I put forward the objections set out in the MP Objection February 2023 as matters which the Council **must** consider and respond to in determining this new Application. In the course of the Council's consultation I would expect all technical issues raised by myself and other objectors not only to be noted as previously but to be addressed.

25. It is my view, supported by that of Counsel's Opinion and the AQC Technical Note that a permit should not be granted until they are adequately addressed and found to have satisfactory outcomes. If CVSH continues to refuse to address these points, the Council should serve the formal notice on them to provide this information and if it is not forthcoming then the Application should be treated as withdrawn.

Additional Points

26. **Conflict with IED Article 46 1**: Inspector John Woolcock states very clearly (Point 45 of the Appeal decision) , the imposition of conditions would not overcome the conflict I have identified with IED Article 46 . To be clear IED Article 46 point 1 says " Article 46 Control of emissions 1.Waste gases from waste incineration plants and waste co-incineration plants shall be discharged in a controlled way by means of a stack the height of which is calculated in such a way as to safeguard human health and the environment**".(Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control) (Recast) (Text with EEA relevance) (legislation.gov.uk)**). Throughout the multiple permit applications there remains a question over the stack height, it did not satisfy Inspector Woolcock **("IED Article 46 2. provides that emissions into air from the SWIP shall not exceed the emission limit values set out in Annex VI of the IED, but air quality in the vicinity of the SWIP would also depend upon stack height.")**, it was queried by AQC and Teta Tech for the Council and by multiple objectors.

27. Yet rather than address the point raised directly and demonstrate that the stack height safeguards human health and the environment, the latest application asserts "a height of 12 metres would provide effective dispersion of emissions from the exhaust stack." (CVSH-R-JER1902-LD-SWIP-application-26-jan-2024.pdf point 3.6.24). This does not satisfy IED Article 46 point 1 or the Inspector's concern. The current application fails to address one of the Inspector's main reasons for refusal.

28. **Safeguard human health and the environment (Trees):** The revised application details new information on surface roughness and how to treat the trees in terms of modelling. However I can find no assessment of the impact of the emissions on the trees, this is important since the IED is to safeguard the environment, and the woodland surrounding the site is longstanding and in some cases could be considered ancient woodland. The Incinerator is not neutral in its affects on the woodland and other wildlife and there is no **new** assessment addressing this in terms of the previous dismissed appeal or that allows granting the permit.

29. The affect on the trees was a significant element of the refusal and there has been no attempt to address this. I attach a document which considers this in more detail and shows that this is not simply a minor point. "The proposed development at the Belmont Industrial Estate has significant potential to damage protected trees, both directly and indirectly, and the impacts upon the adjacent woodland have not been assessed in adequate detail to satisfy the requirements of BS 5837: 2012…" **Arboriculturists Report 1-4-24.** This has not been addressed in the light of the appeal dismissal or the Inspectors concerns.

30. **Fire safety:** The CVSH document **240126 R JER1902 LD Calder Valley SWIP Application V1 R2.docx** at paragraph 3.12.2 states that in the event of a fire, contaminated fire water from firefighting would be contained on the site by the use of flood gates which will be deployed across all entrances of the SWIP building to contain all contaminated water from firefighting within the plant building. The MP Objection February 2023 made comments on the proposals for this in the original application and the draft permit conditions. Again, this was never ruled on by the Inspector. However, it is not clear how the newly proposed flood gates only at the entrances will contain water/oil in the event of a fire. This does not address the issues of damage caused by the fire to other parts of the building or damage caused to the floodgates during the fire. As the risk of fire must be considered one of the more likely occurrences (especially given the history of the site) and the severity of the consequences of pollution to the river acknowledged should harmful material from the building escape, then this issue must be addressed sufficiently before a permit is issued and in the permit conditions.

31. There is no detail regarding the storage or control of the fuel oil which is required to start up the incinerator. The oil tank would be in the incinerator shed – in which case what are the fire precautions for that how do the flood gates help?

32. **Planning Permissions linked and one possibly lapsed**: The CVSH document referred to above, also makes reference to one of the the planning permissions for the SWIP granted on appeal in 2020 - Appeal Ref: APP/A4710/W/18/3205776 (for planning permission 17/00113/WAM). There are of course two planning permissions involved in allowing a SWIP to operate on this site, the second being granted under Appeal Ref: APP/A4710/W/18/3205783 (for planning permission 17/00114/VAR to vary conditions 5 and 12 of 04/02712/FUL). It is not possible to implement 17/00113/WAM without amending the terms of conditions 5 and 12 of the original permission for the waste transfer station.

33. The document makes mention of the APP/A4710/W/18/3205776 (17/00113/WAM) planning permission it is not clear if all 22 conditions have been met, the Second Planning permission is not referenced (APP/A4710/W/18/3205783 (for planning permission 17/00114/VAR) nor the 28 conditions attached. It is to be expected that the status of all conditions and permissions will be documented in the CMCB review of the application.

34. The Planning Inspector determined *17/00113/WAM* was acceptable on the basis that *17/00114/VAR* would have to be implemented to allow it to proceed. He also amended other conditions to enable the SWIP use to proceed. He stated in paragraph 115 of his decision in relation to application *17/00114/VAR* : "*The application sought a relaxation of the terms of: condition no. 5, which restricts the hours of use of the premises; and, condition no.12, which prohibits burning on site. The aim was to enable the proposed small waste incinerator plant within the appeal building to burn residual non-recyclable waste and to operate 24 hours/day Monday to Friday inclusive*".

35. In correspondence with the Council , CMBC have indicated that *17/00114/VAR* may not have been implemented and may therefore have expired.

36. **Government guidance** is that planning and environmental permit issues are best considered together. However, both CVSH and the Council appear to want to keep them separate when it suits them. The situation with regard to the planning permissions needs to be settled when making a determination of the permit.

37. There are a number of open issues related to this , based on section 5 of The Government Environmental Permitting Guidance, item 5.4 (a) states that **providing** the plant design and equipment specification must be as a prerequisite for the application for an Environmental Permit. As [redacted] states in his objections, both pre the appeal and regarding the current application there are a number of issues with the design and operation of the Incinerator which have not been clarified with this new application. This is pertinent to the Operational stack emissions ([redacted] **_Final**)

38. **Footpath:** I have made mention of the footpath in previous objections. This is not shown on any plans and no reference is made to it in the latest permit application. Has the revised application now demonstrated:

    a. How will human health be protected for users of the footpath, given that there are no reference points for air quality within the site.
    b. How will human welfare and safety be protected for users of the footpath with incinerator loading taking place regularly across the footpath.

39. **Dispersions on the site**: The assertion in the latest application point 3.6.2, that "a height of 12 metres would provide effective dispersion of emissions from the exhaust stack." Is not demonstrated and in particular at the site location I can still find no modelling or data that demonstrates the emissions at the site location at differing stack heights or why 12 Metres is the best height. It is my understanding from modelling with Plume Plotter, that emissions will likely be at the highest levels at the site and the point measurements used in modelling do not represent the ongoing continued levels of emissions particularly across the site.

    a. How is long-term human and environmental health protected from emissions at the site location?
    b. How are users of the footpath and employee's health and safety protected from emissions?

40. **Weather data** The modelling of the plume is not robust and the data used does not represent the realities of the location (as the met describes it " a very narrow, deep valley (~500m wide)…. that valley would be prone to inversions/cold air pooling,". Even the CERC report suggests that CFD modelling would be a (better) alternative and this is confirmed by the MET office who say they can not nor would not model weather in the valley. (See email from [redacted] Met office). The modelling for the emissions is still based on weather which isn't representative and on a stack height which is not demonstrated to safeguard human health and the environment. This is a significant reason for the dismissal of the appeal and the current application has not changed the inputs or the configuration of the Incinerator. It is essentially the same Incinerator that was dismissed by Inspector John Woolcock. There is no logical reason for the regulator CMBC to approve this revised application.

41. **Conditions:** if in spite of the appeal dismissal and the Inspector comments on the same application documents " 45. Many of the requirements of the IED could be the subject of EP conditions, as was discussed at the Hearing.[44] **However, the imposition of conditions would not overcome the conflict I have identified with IED Article 46 1."**

42. If the Regulator (CMBC) have reasons to approve this application, it would be reassuring to have a condition that Bureau Veritas or similar certify the installation and its emissions and compliance with R1 and all legislation PRIOR to commencement and to engage such certification in an ongoing relationship such that it is certified annually in compliance with the Planning R1 condition. This would also dovetail into the Councils annual reports on the AQMA. Conditions have been covered in many previous objections and I will not labour the point here.

Conclusion:

The Applicant has made this application asserting that rather than raise a Judicial to challenge the decision they consider " in material respects to be perverse as well as procedurally unfair" they have submitted a Environmental Permit Application S13/006, which does not address the matters in the previous application dismissed by an appeal to the Secretary of State.

Judicial review is the correct route for such an issue , however to seek the same application to be determined by CMCB without evidencing any of the reasons for the dismissal of the appeal or the Inspectors concerns would seem to make refusal a certainty.

10. For the previous Environmental permit applications CMBC were quick to agree with the applicant on the technical merits of the applications, and yet overall the arguments and technical competence were shown to be incorrect. The Council stated at the appeal " ***Conclusion 1.16 There is no proper basis to conclude that the proposed incinerator cannot be operated in a manner consistent with the EPR"*** **CVSH-HD36-closing**

This current(third) Environmental Permit application by CVSH is to all intents and purposes the same application as the previous flawed applications and does not significantly appear to address the concerns of the Inspector at the environmental permit appeal (5th July 2023). It does not contain evidence or detail that provides the basis for CMBC to come to any other decision than the same as the Inspector at the appeal.

For these reasons Calderdale Council should refuse the application.

[redacted]

01 April 2024

STATEMENT OF OBJECTION TO ENVIRONMENTAL PERMIT APPLICATION

Email to: community-safety@calderdale.gov.uk

From: [redacted]
Address: [redacted]

Environmental Permitting (England and Wales) Regulations 2016 ("the Regulations")

Application for environmental permit for Schedule 13 small waste incineration plant ref S13/006

Calder Valley Skip Hire, Belmont Industrial Estate, Rochdale Road, Sowerby Bridge HX6 3LL

DOCUMENTS included with this Objection:

1. **Air Quality and Permit Review: Calderdale Valley Skip Hire Small Waste Incineration Plant – November 2021 - Air Quality Consultants Limited.** ("**AQC Report**")

2. **Advice - October 2022 - by Richard Harwood KC ("Counsel's Opinion")**

3. **Technical Note – Calder Valley Skip Hire Small Waste Permit Incineration Plant – October 2022 – Air Quality Consultants Limited ("AQC Technical Note")**

4. **High Court Order granting permission for Judicial Review – 23 July 2021. ("High Court Order")**

5. **Objection submitted by [redacted] in October 2022 in relation to Calder Valley Skip Hire Limited – Environmental Permit Appeal – Reference APP/EPR/603 ("Original Objection")**

6. **Objection submitted by [redacted] in February 2023 in relation to Calder Valley Skip Hire Limited – Environmental Permit Appeal – Reference APP/EPR/603 ("MP Objection February 2023")**

GROUNDS OF OBJECTION

1. I object to the grant of an Environmental Permit for the reasons set out in this document and attachments.

Basis of the Application

2. In May 2022, Calder Valley Skip Hire ("the **Applicant**") appealed on the ground of a "deemed refusal" due to the failure by regulator to give notice of determination of its previous application for the Permit within the statutory time-period. That Appeal was dismissed on 5 July 2023 by an Inspector appointed by the Secretary of State following a full public inquiry.

3. The Inspector dismissed the Appeal because he was not satisfied on the evidence adduced that the proposal complies with IED Article 46 1., which requires that waste gases from waste incineration plants and waste co-incineration plants shall be discharged in a controlled way by means of a stack the height of which is calculated in such a way as to safeguard human health and the environment. Furthermore, he was unable to find that the necessary measures have been taken to ensure that waste management would be carried out without endangering human health, without harming the environment and, in particular without risk to air, in compliance with Article 13 of the Waste Framework Directive 2008/98/EC.

4. In reaching his decision the Inspector made it clear that because he was dismissing the Appeal and the deemed refusal would stand he had not:

    a. considered the application of Paragraph 13 of Schedule 5 EPR 2016 which provides that the regulator must refuse an application for the grant of an environmental permit if it considers that, if the permit is granted, the following will not be satisfied; (a) the applicant must be the operator of the regulated facility, and (b) would operate the regulated facility in accordance with the environmental permit.

    b. ruled on the technical objections of third parties.

5. CVSH provide an outline of its reasons for this new application in document 240126 R JER1902 LD Calder Valley SWIP Application V1 R2.docx ("the **Application**"). The Applicant states that this application is being submitted on the same basis as the original application. However, it has added further information provided to inform the redetermination in 2022 and certain documents from the hearing sessions in two appeal hearings in November 2022 and May 2023 have been incorporated.

6. To address the Inspector's reason for dismissing the Appeal the Applicant appointed a consultant to carry out an independent review of the treatment of trees within the air quality assessment.

Considerations in Determining the New Application

7. It is not the case, as might be suggested, that the Inspector would have granted the Appeal except for the issues around stack height and computer modelling.

8. As this is a new application, Calderdale MB Council must look at all the relevant issues and cannot simply treat it as a "rubber stamping" of a single outstanding issue from the Appeal.

9. The outcome of the very recent Appeal and the approach taken by the Inspector is however a material consideration in the consideration of this new Application on nearly identical terms and the Council must have due regard to this. The Applicant is out of time to challenge the decision through Judicial Review proceedings as it could have done. The decision and views of the Inspector on the environmental permit appeal are more directly relevant and should carry more weight than that of the February 2020 appeal decisions under the different regulatory regime that looked at planning issues.

10. I noted in my objection to the Appeal that the Statement of Case of the Appellant which sought to set out the merits of the appeal very much centred around its incorrect contention that it is impermissible for anyone to revisit any of the air quality issues considered by the Planning Inspector [redacted]) in his planning permission decisions dated 4 February 2020 during the environmental permitting process both as a matter of law and as a matter

of Central Government guidance as contained in the National Planning Policy Framework (NPPF).

11. The Appellant sought to persuade the Council and the Inspector hearing the appeal that none of the outstanding matters raised by the Calderdale Council's experts (Tetra Tech) or in the AQC Report could be taken into consideration in the decision as to whether or not to grant an Environmental Permit. The refusal to provide the additional information sought by the Council in relation to these issues appeared to be the primary reason for the submission of the Appeal.

12. Calderdale Council in its Statement of Case to the Appeal also wrongly accepted the arguments put forward by the Appellant and conceded the Appeal on the basis that it considered it was prevented from seeking the further information advised by its technical advisors (who were acting under delegated power of the Council as its "competent persons") and on the basis that no further evidence has been put forward to undermine the original quashed decision to grant the Permit. The Council's Statement of Case made no reference whatsoever to the AQC Report and the evidence in that which has been provided to counter the original decision to grant the Environmental Permit.

13. The Inspector who determined the appeal in relation to the Environmental Permit in July 2023 disagreed with both the Applicant and the Council in relation to the application of NPPF guidance. He agreed with the position set out in the Counsel's Opinion submitted to him as part of the objections.

Law and Guidance

14. The correct position in relation to the law and guidance on the process that should be followed and the matters that can be taken into account in relation to the determination of an Environmental Permit application and appeal are set out in detail in the Counsel's Opinion and AQC Technical Note attached with this objection.

15. From these documents it is clear that the Planning Inspector in 2020 did <u>not</u> conclude that an Environmental Permit should be granted, or on what terms, and those matters were <u>not</u> within his remit. The Planning Inspector's conclusions on air quality do <u>not</u> bind the Council as regulator dealing with this Environmental Permit Application.

16. Since the planning appeal decision in February 2020, the first Environmental Permit decision has been made and been the subject of expert reports on behalf of CVSH, the Council and local residents as well as subject to a successful judicial review. It has also been the subject of the unsuccessful appeal for non-determination. This new environmental permit decision will need to take the changed circumstances and additional information into account. Consequently, if it is found during the process of reviewing the permit application that the proposal is harmful to health or the environment then the Environmental Permit <u>must</u> be refused.

17. CVSH have mentioned, but not advanced at the Appeal, the possibility of arguing that the planning appeal decision gave rise to an issue estoppel in respect of air quality matters. An issue estoppel arises where a determination of an issue in one set of proceedings binds the parties to those proceedings in the future. Issue estoppel does not arise in relation to judgements as to whether planning permission should be granted. Whilst a grant of planning permission does, of course, give rise to the rights in the permission, it does not bind the parties as to the merits of the application.

Relevance of High Court Order granting Permission for Judicial Review

18. The Statements of Case in the Appeal and in the documents in this Application note that [redacted] (the claimant) brought successful judicial review proceedings against the original grant of the Environmental Permit. The claimant's statement of facts and grounds in the judicial review noted:

> *"61. CVSH take points which are not part of the Council's reasoning and assert erroneously (i) that air quality is not a matter for environmental permitting (when it is the purpose of environmental permitting) and (ii) that the view of a Planning Inspector on planning merits amounts to an issue estoppel. Issue estoppel can only arise in public law decisions which are determinative of an issue, such as the legal grounds in a planning enforcement notice appeal, rather than exercises of discretion or judgments as to future circumstances."*

19. The Council and CVSH resisted the proceedings. Ground 3 concerned regard to environmental permitting guidance. CVSH contended that because of the Planning Inspector's decision '*It would have been unlawful for the Council to seek to refuse the permit on the basis that the proposal would have an impact which was more than negligible' (Summary Grounds, para 29*). To do so would have been '*a flagrant disregard' of what is now paragraph 188 of the National Planning Policy Framework (Summary Grounds, para 29).* A copy of the High Court Order granting permission to apply for judicial review is attached to this objection. <u>Permission to apply was granted on all grounds</u> and these were not just procedural grounds. Permission would not have been granted if the High Court had agreed that CVSH's main argument on this point was correct. Had the High Court agreed with CVSH (and now the Council) it would have been fatal to the grounds which addressed air quality issues previously considered by the Planning Inspector. CVSH and the Council are in error continuing to try to put forward these arguments despite the judgment in the High Court Order.

20. In CVSH's Legal Response to Third Party Objections 18.11.22 in relation to the Appeal it is stated at paragraph 52 in relation to the Judicial Review that "*No assistance can be gained from grounds for which permission was admittedly granted, but which were never conceded, never argued and never ruled upon by the High Court*." I would point out that all the grounds for permission to proceed with a judicial review were argued (at length in writing) and ruled upon by the High Court. It is well settled law (which the Appellant's legal advisors will be familiar with) that a judge must refuse permission to apply for judicial review <u>unless satisfied that there is an arguable ground for judicial review which has a reasonable prospect of success</u>. Even if a claim is arguable, the judge must refuse permission:
    a. unless he or she considers that the applicant has a sufficient interest in the matter to which the application relates; and
    b. <u>if it appears to be highly likely that the outcome for the claimant would not have been substantially different if the conduct complained of had not occurred.</u>

Obligations of the Regulator

21. It is the permitting authority that has the responsibility and statutory obligation to determine whether operational stack emissions from regulated facilities covered under the EPR are controlled to prevent significant impacts on human health and the environment. Combined with ensuring statutory minimum emission limit values can be met, predictive air quality assessments are the only data available to the permitting authority at application stage to determine the potential impact on human health and the environment and, consequently, the degree to which emissions are/can be controlled.

22. Irrespective of whether operational air quality effects have been discussed at planning stage, the local authority permitting function, as regulator for SWIPs, can, and must,

ensure that operational phase assessments of stack emissions are robust. If any aspect of the air quality assessment of operational stack emissions is not considered to be robust, further information should be sought by the local authority permitting function, and provided by the applicant, before determining the application.

23. If the Council considers that it requires further information to determine a duly-made application, it may serve a notice on the applicant specifying the further information and the period within which it must be provided. If the applicant fails to provide the further information in accordance with the notice, the Council may serve a further notice on the applicant stating that the application is deemed to be withdrawn, upon which the application is deemed to be withdrawn.

Outstanding Issues preventing Grant of a Permit

24. As part of the process for the redetermination of the first Environmental Permit application the Council appointed Tetra Tech to undertake a further review of the amended permit application and the AQC Report and the outcome was that, acting under the delegated powers of the Council, agreeing with points made by AQC, Tetra Tech required additional information before a decision was taken. Further information was therefore requested by the Council in relation to the assessment of 1-hour mean NO2 concentrations, and a sensitivity test regarding uncertainty within the air quality assessments. CVSH refused to provide that information based on its incorrect assertion of the law and guidance.

25. As part of the redetermination process CVSH instructed RPS to undertake a review of the AQC Report. The subsequent report by RPS was provided by CVSH as part of the Appeal documents and is attached to the AQC Technical Note. That RPS report however ignored the items listed in the AQC Report (1) Uncertainty (3) Stack Height (5) Road Modelling Verification and Model Adjustment (6) Assessment of 1 hour- mean NO2 Concentrations (10) Surface Roughness. The reason it did so was solely because it followed the (incorrect) legal advice from CVSH's lawyers to the effect that it was considered impermissible to revisit the air quality issues determined by the Planning Inspector during the environmental permitting process.

26. It is to be wondered (given the CVSH has sought to address other issues raised by AQC), whether the resistance of CVSH to address these issues is not so much due to its interpretation of the law and guidance, but the fact that if they are properly addressed now in the terms of the environmental permitting regime, the results would lead to a conclusion that the Environmental Permit should be refused or that a new planning application would be required to facilitate a rise in the stack height.

27. CVSH sought to find an issue with the failure of the AQC Report to list the Planning Inspector's decision. AQC have confirmed in the AQC Technical Note that they reviewed the documents and Planning Inspector's decision. They confirm that, although the planning appeal decision was sent to AQC, it was not considered material for the review of the air quality impacts at permitting stage. They state that*, as previously demonstrated, both in terms of legislation and supporting guidance, it is the permitting regime that must determine whether the assessment of operational air quality effects of stack emissions is robust with respect to controlling emissions under the EPR. The planning regime serves an entirely separate purpose.*

28. Where the further information required by Tetra Tech and the issues raised by AQC ((1) Uncertainty (3) Stack Height (5) Road Modelling Verification and Model Adjustment (6) Assessment of 1 hour- mean NO2 Concentrations (10) Surface Roughness) continue to remain relevant and unresolved they should be addressed as part of this new Application.

In particular, AQC have confirmed that the issue they raised in relation to the Stack Height Determination in the ACQ Report (paragraph 3.17 onwards) has not been addressed.

29. I have attached MP Objection February 2023. This sets out further concerns with regard to the environmental permit that were raised during the Appeal. As stated above, the Inspector did not rule on the technical objections of third parties. I put forward the objections set out in the MP Objection February 2023 as matters which the Council must consider and respond to in determining this new Application.

30. It is my view, supported by that of Counsel's Opinion and the AQC Technical Note that a permit should not be granted until they are adequately addressed and found to have satisfactory outcomes. If CVSH continues to refuse to address these points, the Council should serve the formal notice on them to provide this information and if it is not forthcoming then the Application should be treated as withdrawn.

Additional Points

31. The CVSH document *240126 R JER1902 LD Calder Valley SWIP Application V1 R2.docx* at paragraph 3.12.2 states that *In the event of a fire, contaminated fire water from firefighting would be contained on the site by the use of flood gates which will be deployed across all entrances of the SWIP building to contain all contaminated water from firefighting within the plant building.* The MP Objection February 2023 made comments on the proposals for this in the original application and the draft permit conditions. Again, this was never ruled on by the Inspector. However, it is not clear how flood gates only at the entrances will contain water in the event of a fire. This does not address the issues of damage caused by the fire to other parts of the building or damage caused to the floodgates during the fire. As the risk of fire must be considered one of the more likely occurrences (especially given the history of the site) and the severity of the consequences of pollution to the river acknowledged should harmful material from the building escape, then this issue must be addressed sufficiently before a permit is issued and in the permit conditions.

32. The CVSH document referred to above, also makes reference to the planning permission for the SWIP granted on appeal in 2020 - Appeal Ref: APP/A4710/W/18/3205776 (for planning permission *17/00113/WAM)*. There are of course two planning permissions involved in allowing a SWIP to operate on this site, the second being granted under Appeal Ref: APP/A4710/W/18/3205783 (for planning permission *17/00114/VAR* to vary conditions 5 and 12 of *04/02712/FUL)*. It is not possible to implement 17/00113/WAM without amending the terms of conditions 5 and 12 of the original permission for the waste transfer station.

33. The Planning Inspector determined *17/00113/WAM* was acceptable on the basis that *17/00114/VAR* would have to be implemented to allow it to proceed. He also amended other conditions to enable the SWIP use to proceed. He stated in paragraph 115 of his decision in relation to application *17/00114/VAR* : "*The application sought a relaxation of the terms of: condition no. 5, which restricts the hours of use of the premises; and, condition no.12, which prohibits burning on site. The aim was to enable the proposed small waste incinerator plant within the appeal building to burn residual non-recyclable waste and to operate 24 hours/day Monday to Friday inclusive*".

34. In correspondence with the Council they have indicated that *17/00114/VAR* may not have been implemented and may therefore have expired.

35. Government guidance is that planning and environmental permit issues are best considered together. However, both CVSH and the Council appear to want to keep them separate when it suits them. The situation with regard to the planning permissions needs to be settled when making a determination of the permit.

The Planning Inspectorate

Appeal Decision

Hearing held on 29-30 November 2022 and 31 May 2023

Site visit 1 December 2022

by John Woolcock BNatRes (Hons) MURP DipLaw MRTPI

an Inspector appointed by the Secretary of State [1]

Decision date: 5th July 2023

Appeal Ref: APP/EPR/603
Belmont Industrial Estate, Rochdale Road, Sowerby Bridge
Halifax HX6 3LL

- The appeal is made under Regulation 31 & Schedule 6 of the Environmental Permitting (England and Wales) Regulations 2016 (EPR 2016).
- The appeal is made by Calder Valley Skip Hire Ltd (CVSH) against the deemed refusal of an Environmental Permit (EP) application to operate a Schedule 13 small waste incineration plant (SWIP).
- The application, Refs.S13/005 and MAU/31215, dated 6 August 2020, was not determined by the regulator, Calderdale Metropolitan Borough Council (CMBC), in the relevant period.
- The applicant served a notice on the regulator referring to paragraph 15(1) of Schedule 5 EPR 2016 and so the application was deemed to have been refused on 23 May 2022.
- The appeal form is dated 26 May 2022.

Decision

1. The appeal is dismissed.

Preliminary matters

The EP application

2. The site for the EP application is part of a larger waste management site operated by CVSH at Belmont Industrial Estate, Rochdale Road, Sowerby Bridge, which includes an existing waste transfer station (WTS) regulated by the Environment Agency (EA). At the time of my site visit the building proposed for the SWIP contained plant and equipment for a SWIP.

3. The application form is entitled "Application for a permit to operate Schedule 13 small waste incineration plant". Schedule 13 EPR 2016 applies in relation to; (a) every small waste incineration plant, and (b) every waste incineration plant or waste co-incineration plant, to which Chapter IV of the Industrial Emissions Directive (IED) applies.[2] EPR 2016 defines a "small waste incineration plant" as a waste incineration plant or waste co-incineration plant with a capacity less than or equal to 10 tonnes per day for hazardous waste or

[1] The Secretary of State as 'appropriate authority' has delegated this responsibility. The appointment is as 'appointed person' under paragraph 5 of Schedule 6 EPR 2016.
[2] Industrial Emissions Directive (Directive 2010/75/EU) at CD35.

3 tonnes per hour for non-hazardous waste. A SWIP is a regulated facility for the purposes of EPR 2016.[3]

4. The EP application is for a facility that would burn non-hazardous refuse derived fuel (RDF), with a European Waste Catalogue Code 19 12 10, at a feed rate of up to 2 tonnes per hour with a maximum throughput of 10,000 tonnes per annum. The RDF would be pre-treated within the adjacent WTS. The EP application included three drawings: Emission Points JER1902-PER-001, Illustrative Drawing 9677/17/03C and Existing Drainage Plan 9677/17/35A.[4]

5. The application was the subject of public consultation in 2020 and CMBC received 93 responses. The broad categories of issues raised in these submissions are summarised in the Cabinet Report. These included concerns about the impacts of air pollution on health and the local environment in this valley location, along with concerns about the material to be burned. CMBC considered the Cabinet report, dated 8 February 2021, recommending that the application be approved.[5]

6. On 10 February 2021 CMBC, as the regulator, issued an EP to CVSH pursuant to Schedule 13 EPR 2016 for the operation of a SWIP.[6] This referred to Drawings S13/005/P1a, S13/005/P1b and JER1902-001_D_200702. Due to a procedural error in determining the application a Quashing Order was made by the High Court by consent on 14 September 2021.[7] The application then fell to be redetermined by the regulator.

7. The claimant for judicial review drew attention to the fact that there was a gap between the boundary of the EP for the WTS and the EP boundary for the proposed SWIP.[8] CVSH considered that this gap was of no legal consequence, but in April 2022 submitted a revised drawing JER1902-0002-01 to enclose the gap.[9] The site identified on this drawing is referred to as the 'appeal site' in this decision.

The appeal

8. CVSH served a notice on the regulator referring to paragraph 15(1) of Schedule 5 EPR 2016 and so the application was deemed to have been refused on 23 May 2022. The appeal against the deemed refusal is dated 26 May 2022.

9. CMBC's Statement of Case, which was submitted on 18 August 2022, indicated that the regulator does not seek to resist the grant of an EP that is the subject of this appeal. At the appeal local residents and third parties opposed the grant of an EP.[10]

10. Paragraph 4(1) of Schedule 6 EPR 2016 states that the regulator must, within 10 days after receipt of a copy of a notice of appeal, give notice of it to any person whom the regulator considers is affected by, is likely to be affected by, or has an interest in, the subject matter of the appeal. Paragraph 4(2) of Schedule 6 EPR 2016 provides that representations in writing may be made to

---

[3] EPR 2016 Regulation 8(1)(h).
[4] CD3 with Supporting Statement at CD2 and CD10.
[5] HD23.
[6] CD12.
[7] CO/1295/2021 at CD13.
[8] The High Court did not consider this point as the permit was quashed for another reason.
[9] HD7, CD10 and CD11.
[10] CD22 and HD5.

the appropriate authority within a period of 15 working days after the date of the notice.[11] Notice about the appeal was not given by the regulator in this case until 5 October 2022.

11. During the consultation period at the appeal stage PINS received 90 written submissions. These largely reiterated many of the issues raised in the earlier consultation and included concerns about air quality modelling and stack height calculation. The appellant responded to these submissions prior to the opening of the Hearing.[12]

12. Those attending the Hearing on 29 and 30 November 2022 expressed views about the likely implications of the late notice for the appeal and how best to remedy the procedural defect. The Hearing was adjourned to enable the submission of further written representations.[13]

13. The initial public consultation on the application was on the basis of the drawings included in the application. Drawing JER1902-0002-01 was not subject to formal public consultation at the application stage. However, the draft EP devised by the appellant and the regulator stated, "The boundary of the site is shown in Plan S13/005/P1 and in drawing 'Permit Site Boundary Plan 1902-0002-01' ". This draft EP was submitted on 9 December 2022 and was made available on CMBC's website during the period up to 10 February 2023 for further written representations.[14]

14. The postcode cited for the address of the appeal site in some of the application and appeal documentation is HX6 3BL. This postcode includes the entrance to the appeal site off Rochdale Road, whereas postcode HX6 3LL includes all the appeal site. Concern was raised at the Hearing that use of the HX6 3BL postcode to assess flood risk would have resulted in a different outcome from an assessment based on the HX6 3LL postcode. However, it was confirmed at the Hearing that the submitted Flood Risk Assessment correctly identified the location of the appeal site. The HX6 3LL postcode should be preferred.

15. I have taken into account the written submissions received by 10 February 2023 [15], along with the response to those submissions by CVSH [16]. The Hearing was resumed on 31 May 2023. Following the without-prejudice discussion about suggested EP conditions the Hearing was adjourned to enable revisions to the wording of some conditions to be submitted. The Hearing was closed in writing on 7 June 2023.

16. The permit issued and subsequently quashed by the High Court referred to a 'small waste incinerator plant', but also referred to 'co-incineration' and the 'waste co-incineration plant'.[17] The draft EP submitted by CVSH in the lead up to the opening of the Hearing described the facility as a small waste co-incineration plant.[18] A comparison of the original and draft EPs was submitted by a third party.[19] Following the discussion at the Hearing on 30 November

[11] The appropriate authority has delegated this to the Planning Inspectorate (PINS).
[12] CD28 and CD29.
[13] Any further third party submissions were required to be received by PINS no later than 10 February 2023. The appellant and the regulator were given until 10 March 2023 to respond. HD14, HD19 and HD20.
[14] HD21.1 was submitted when the Hearing was adjourned.
[15] HD25.
[16] HD26.1, HD26.2 and HD26.3.
[17] CD12 Conditions 1.4 and 3.8.
[18] CD36.
[19] HD13.

2022 about suggested conditions the appellant and the regulator submitted an agreed draft EP.[20] This draft was made available on CMBC's website and was the subject of written submissions to PINS during the adjournment. There were further discussions about conditions at the resumed Hearing on 31 May 2023, resulting in an agreed position between the appellant and the regulator.[21]

17. Third parties raised concerns about the adequacy of public consultation throughout the application and appeal process. However, I am now satisfied that the appeal process has provided those who wished to do so a reasonable opportunity for effective participation. Third party submissions are critical of the way CMBC has dealt with the redetermination and the appeal, but that is not an issue for me in determining the appeal on its merits.

Planning appeal and EP for the WTS

18. Planning permission was granted on appeal for the site operated by CVSH in February 2020 for the construction of external flue and change of use of existing building from recycling use (B2) to heat and energy recovery process (*sui generis*) and introduction of mechanical drying of inert soils and aggregates (B2) adjacent to the existing recycling shed together with the installation in underground ducts of pipes connecting the energy recovery plant to a dryer.[22]

19. The EA in April 2021 issued a notice of variation and consolidation of CVSH's EP for the WTS. This authorised CVSH to operate a household, commercial and industrial waste transfer station, including treatment of up to 145,000 tonnes of waste per year. The introductory note to the EP records that the variation notice extended the permitted treatment activities on site by allowing the drying and shredding of non-hazardous waste. It also regularised an installed shredder unit. A drying plant would be utilised to dry inert soils and aggregates from the existing waste transfer activity. Heat for drying activities would be generated by the SWIP that is the subject of the current appeal, with the heat transferred to the drying plant via underground pipework.[23]

Schedule 13 EPR 2016

20. In determining this appeal, I am required by paragraph 4 of Schedule 13 EPR 2016 to ensure compliance with certain provisions of the IED. These include some of the special provisions for waste incineration plants and waste co-incineration plants set out in Chapter IV of the IED.[24] Paragraph 3 of Schedule 13 EPR 2016 states that the regulator must ensure that every application for the grant of an environmental permit includes the information specified in Article 44 of the IED.

21. Objectors argue that the application does not meet the requirements of IED Article 44 to guarantee that the plant is designed, equipped and will be maintained and operated to meet the relevant IED requirements.[25] Article 44

[20] HD21.1.
[21] HD21.2.
[22] Appeal decisions APP/A4710/W/18/3205776 and APP/A4710/W/18/3205783 at CD4.
[23] EPR/SP3196ZQ/V002 at CD20.
[24] IED Article 5(1) and (3); Article 7; Article 8(2); Article 9; Article 42(1); Article 43; Article 45(1), (2) and (4); Article 46; Article 47; Article 48(1) to (4); Article 49; Article 50; Article 51; Article 52; Article 53; Article 54; Article 55; Article 82(5) and (6).
[25] HD34 paragraph 5.

provides that an application shall include a description of the measures which are envisaged to guarantee that the following requirements are met: (a) the plant is designed, equipped and will be maintained and operated in such a manner that the requirements of Chapter IV are met taking into account the categories of waste to be incinerated or co-incinerated; (b) the heat generated during the incineration and co-incineration process is recovered as far as practicable through the generation of heat, steam or power; (c) the residues will be minimised in their amount and harmfulness and recycled where appropriate; (d) the disposal of the residues which cannot be prevented, reduced or recycled will be carried out in conformity with national and Union law. However, the objection omits the reference in Article 44 to measures 'envisaged' to guarantee requirements. I am satisfied that the application reasonably complies with Article 44 because it describes the measures contemplated to guarantee that the specified requirements would be met. Whether those envisaged measures would do so is a matter to be assessed having regard to other relevant Articles of the IED.

22. There is no published guidance for determining Schedule 13 SWIP permit applications. However, I have had regard to the General Guidance Manual on Policy and Procedures for Part A2 and B Installations.[26]

Main issues

23. The main issues in this appeal are the effects of granting an environmental permit for a SWIP on human health and the environment.

Reasons

Environmental Permitting and Planning

24. The appellant's contention, based upon paragraph 188 of the National Planning Policy Framework (NPPF) and the scope of environmental permitting, is that, planning permission having been granted for the particular development including the SWIP, the planning issues, including the air quality issues, should not be revisited through the environmental permitting regime. In the appellant's submission the impact of the SWIP on air quality was undoubtedly a planning issue, and therefore should not be revisited as part of this appeal.[27] CMBC notes that the planning regime and the environmental permitting regime are separate regimes and considers that the findings of the planning appeal serve as a useful background to some of the matters in the current EP appeal.[28]

25. NPPF paragraph 188 provides that the focus of planning decisions should be on whether proposed development is an acceptable use of land, rather than the control of processes or emissions (where these are subject to separate pollution control regimes) and that planning decisions should assume that these regimes will operate effectively. It adds that where a planning decision has been made on a particular development, the planning issues should not be revisited through the permitting regimes operated by pollution control authorities.

[26] SWIPS do not constitute a Part A or Part B permit for the purposes of EPR 2016. However, for local authority-regulated facilities the Environmental permitting: Core guidance refers to the General Guidance Manual on Policy and Procedures for Part A2 and B Installations.
[27] CD28 paragraph 29.
[28] HD36 paragraph 1.4.

26. Appeal decisions APP/A4710/W/18/3205776 and APP/A4710/W/18/3205783 are relevant material considerations in determining this EP appeal, but are binding considerations only insofar as the use and development of land is concerned. With this exception, I do not believe that paragraph 188 means that an extant planning permission fetters the discretion of a pollution control authority in exercising its functions pursuant to EPR 2016. It seems to me that there is a distinction to be drawn between assessing air quality to determine whether a proposal is an acceptable use of land; and determining what is required to control processes or emissions. This is especially so in this case, where IED Article 46 1. provides that waste gases from waste incineration plants and waste co-incineration plants shall be discharged in a controlled way by means of a stack the height of which is calculated in such a way as to safeguard human health and the environment.[29]

27. In any event, the conclusions in the appeal decisions about the effects on air quality were based on a combination of the imposition of planning conditions and the regulatory controls likely to be associated with the required EP.[30] I read this as an acknowledgement by the Planning Inspector that air quality would remain a relevant consideration to be assessed in a separate jurisdiction pursuant to EPR 2016.

28. IED Article 46 2. provides that emissions into air from the SWIP shall not exceed the emission limit values set out in Annex VI of the IED, but air quality in the vicinity of the SWIP would also depend upon stack height.

Stack height calculation

29. The appellant undertook a stack height determination to establish the height at which there is minimal additional environmental benefit associated with the cost of further increasing the height of the stack.[31] This notes that the EA removed its Horizontal Guidance Note EPR H1 (xv) for risk assessments in 2016, but considers that the appellant's approach is consistent with the guidance insofar as it identifies an option that gives acceptable environmental performance but balances costs and benefits.

30. The appellant's ADMS-5 model was run for a range of stack heights between 12 m to 18 m in 1 m increments. Tables D.5 and D.6 in Appendix D of CD21 indicate that the Predicted Environmental Concentrations (PEC) [32] are below the Environmental Assessment Level (EAL) at all stack heights for both the long-term and short-term IED emission limit values, and so according to EA guidance the impacts would be considered not significant at all heights modelled. Appendix D of CD21 also referred to HMIP Technical Guidance Note (Dispersion) D1 Guidelines on Discharge Stack Heights for Polluting Emissions (TGN D1) [33], and applied a 3 m clearance between the roof of the tallest nearby building (9 m) and the top of the stack to arrive at an acceptable stack height of 12 m.

31. Local objectors to the granting of an EP raised questions about the height of the proposed stack and the implications for the health of nearby residents.

---

[29] CD23, CD24, CD25 and CD26.
[30] CD4 paragraphs 57 and 61.
[31] CD21 Appendix D. I have also had regard to CD19, CD27, HD17 and HD24 regarding stack height calculation.
[32] The PEC is calculated as the Process Contribution (PC) added to the Ambient Concentration (AC).
[33] HD32.

There is particular concern that the discharge height would be below the tops of nearby trees and at a lower level than Rochdale Road.[34]

32. At the Hearing the appellant/CMBC proposed deletion of a previously suggested EP condition concerning off-site air quality monitoring. To properly assess the modelling in the absence of such a condition, I required further information about how the appellant's dispersion model deals with the likely effects on the plume emitted from the 12 m high stack due to the height, proximity and density of the nearby trees/woodland.[35] I requested a plan agreed by the appellant and CMBC to show the distance of nearby trees/woodland from the stack, along with the above Ordnance Datum (AOD) height of the top of the trees.[36] The extent to which the tops of existing trees/woodland would exceed the discharge height of the stack is evident from the following table derived from the submitted Tree/Woodland Assessment Plan.[37] This table excludes trees/groups with a life expectancy of '<10 years' and those that are in 'poor' or 'poor/fair' condition.

Tree T Group G	Distance from stack (m)	Difference between AOD of tops of trees and AOD of top of 12 m high stack (m)	Life expectancy of Tree/Group (years)
T2	41	+11	20+
T3	52	+16	20+
T4	36	+12	20+
T5	50	+22	40+
T6	57	+19	40+
T7	58	+19	40+
T8	57	+17	40+
G3	48	+16	20+
G4	60	+17	10+
G5	67	+18	10+
G6	52	+14	40+

The above table indicates that the tops of nearby trees would be significantly higher than the proposed discharge height of the stack, and at relatively close separation distances. Many of these trees have a long life expectancy and so any adverse effect they might have on dispersion of the plume would be likely to persist for a considerable time.

33. In answer to my question whether the existing trees/woodland result in a local reduction in ventilation in the vicinity of the proposed stack, the appellant indicated that the effect of the trees in this location, even though they are tall and in places densely packed and many of them are higher than the discharge height of the stack, is to reduce the velocity of the air flow and increase turbulence. The appellant's response to another of my questions was that the trees/woodland would not result in drag, wake or other aerodynamic effects that would at times be similar to that likely to result from buildings of a comparable size and proximity as the trees/woodland. The appellant considers

[34] Including HD3, HD11 and HD12.
[35] HD27.
[36] HD29.
[37] The distance from the stack to the group of trees is the closest distance between the stack and any tree in the group. The height of the groups of trees is the consistent height of trees within the group at the time of the survey.

that the sensitivity test applied, which involved increasing the surface roughness length around the site to 1.51 m to represent the high density of tall trees, fully accounts for the effect of the trees, and that no further sensitivity testing is necessary.[38]

34. The appellant's model, insofar as the effect of the trees is concerned, relies solely on surface roughness length, and draws on guidance from the ADMS-5 User Guide to support this approach. The guide states; "If there are a large number of buildings on a large site, the user should consider whether to include those that are nearest to/attached to the sources and/or those that will have the greatest effect on dispersion (tallest/largest), or consider a higher surface roughness, which can be entered in the Meteorology screen, as a means of representing the buildings in a complex site". The appellant argues that this indicates that the use of a higher surface roughness is a good approximation of multiple buildings.

35. However, at the Hearing the appellant also argued that the reduced air flow velocity due to the trees would result in better plume rise because higher wind speeds reduce plume rise. But lower wind speeds would also reduce the rate at which emissions were moved away from the discharge location. No specific evidence was adduced at the Hearing about how these effects would be likely to impact on dispersion of emissions from the proposed 12 m high stack, or whether and to what extent these considerations are given effect in the surface roughness length input to the model relied upon by the appellant. Furthermore, there is no evidence to quantify how much the trees would reduce the velocity of the air flow, or how this would compare with the wind speed data used in the model.

36. In the appellant's submission, the trees would not behave like buildings and would not have the effect of causing the undiluted plume to be brought down to the ground. However, in TGN D1, which the appellant cited in the appeal notwithstanding the fact that it was published in 1993, trees are assessed as resulting in half the effect of a building of the same height. Paragraph 5.4.3 of TGN D1, about the effective heights and widths of trees, lattice towers and porous structures, states that trees and dense foliage should be taken as having their actual height, but an effective width of half their actual maximum width in the TGN D1 calculation.[39]

37. TGN D1 and ADMS-5 apply different methodologies. Nevertheless, TGN D1 does indicate that trees can potentially have an effect on a plume that is similar, to some extent, to that which would result from nearby buildings. Although, in respect of trees, ADMS-5 applies an overall turbulence factor by way of surface roughness length, that is not specifically derived from the actual height and proximity of trees in the vicinity of the stack. The appellant considers that the use of a higher surface roughness is a good approximation of multiple buildings (and trees in this case). I am not satisfied that reliance on such an approximation is adequate here. The trees/woodland are so close and so much higher than the 12 m high stack that I consider a more detailed site-specific assessment would be required to properly assess the effects of the trees on the dispersion of emissions.

[38] HD28 paragraph 2.14.
[39] HD32.

38. Given the height and proximity of the trees/woodland in the vicinity of the proposed stack, I am not convinced that it would be reasonable to rely solely on surface roughness length to properly take into account the likely effect of the trees on the dispersion of emissions from the SWIP. In the circumstances, I am unable to find that waste gases from the SWIP would be discharged in a controlled way by means of a stack the height of which is calculated in such a way as to safeguard human health and the environment.

39. Because of an error at the planning application stage in the AOD of the proposed stack, a previous run of the model inadvertently assessed a stack height 9 m higher than the correct discharge height.[40] The results from this modelling do not provide any reassurance about the robustness of the stack height calculation now relied upon by the appellant because that run of the model also dealt with the trees solely by means of surface roughness length.

40. The planning appeal decision acknowledged that the data used had been modified by the models to take account of local topography, surface roughness effects, such as the neighbouring woodland, and building effects.[41] The Planning Inspector would have seen the trees on his site visit, but there is nothing to indicate that the evidence before him included details about the height and proximity of the trees/woodland that is now documented in the Tree/Woodland Assessment Plan at HD29. Furthermore, there is nothing to indicate that the appellant in the planning appeal made the Planning Inspector aware of the fact that the trees reduce the velocity of the air flow. I have determined this EP appeal on the evidence before me.

41. The appellant stated at the Hearing that if I did not have sufficient information about stack height calculation to direct the regulator to grant an EP, I should adjourn the Hearing and request the additional information. However, this would not provide a fair and reasonable opportunity for consultees and third parties to participate in the assessment of the EP application. Consideration of any further information about stack height calculation should be, in the first instance, a matter for the regulator and subject to the consultation procedure required by EPR 2016.

42. Taking all the above into account, I consider that the appeal should be dismissed because I am not satisfied on the evidence adduced that the proposal complies with IED Article 46 1., which requires that waste gases from waste incineration plants and waste co-incineration plants shall be discharged in a controlled way by means of a stack the height of which is calculated in such a way as to safeguard human health and the environment. Furthermore, I am unable to find that the necessary measures have been taken to ensure that waste management would be carried out without endangering human health, without harming the environment and, in particular without risk to air, in compliance with Article 13 of the Waste Framework Directive 2008/98/EC.

Operator competence

43. Paragraph 13 of Schedule 5 EPR 2016 provides that the regulator must refuse an application for the grant of an environmental permit if it considers that, if the permit is granted, the following will not be satisfied; (a) the applicant must be the operator of the regulated facility, and (b) would operate the regulated

[40] CD4 paragraph 5.
[41] CD4 paragraph 45.

facility in accordance with the environmental permit. However, this applies if the permit is granted. Given that I am dismissing the appeal and the deemed refusal will stand, it is not necessary for me to consider the application of paragraph 13 of Schedule 5 EPR 2016.

Other considerations

44. Similarly, as the deemed refusal will stand it is not necessary for me to rule on the technical objections raised by third parties. However, it is necessary to comment on the objectors' concern that CMBC has shown only limited understanding of the regulatory processes and that there is no evidence that CMBC has the technical expertise to regulate this facility.[42] CMBC is the regulator for the proposed SWIP and has statutory responsibilities in this regard. Planning decisions should assume that the pollution control regime will operate effectively.[43] It seems to me that the same assumption should apply to the monitoring and regulation of environmental permits. Local reservations about CMBC's ability to properly regulate the SWIP are no part of my decision to dismiss the appeal.

Environmental Permit conditions

45. Many of the requirements of the IED could be the subject of EP conditions, as was discussed at the Hearing.[44] However, the imposition of conditions would not overcome the conflict I have identified with IED Article 46 1.

Conclusions

46. I have taken into account all other matters raised in the evidence but have found nothing to outweigh the main considerations that lead to my conclusions. I am unable to find that granting an environmental permit for the SWIP would not have an unacceptable adverse effect on human health and the environment.

47. In accordance with Regulation 31(6) EPR 2016 the appeal is dismissed and the deemed refusal stands. This appeal decision, including the above reasons, comprises the determination for the purposes of paragraph 6 of Schedule 6 EPR 2016.

John Woolcock
Inspector

[42] HD34 paragraph 31.
[43] NPPF paragraph 188.
[44] HD21.2.

APPEARANCES

FOR CALDERDALE METROPOLITAN BOROUGH COUNCIL (CMBC):

[redacted]

FOR CALDER VALLEY SKIP HIRE LTD (CVSH):

[redacted]

INTERESTED PERSONS:

[redacted]

Other local residents and objectors joined in the without-prejudice discussion at the Hearing about suggested EP conditions

DOCUMENTS SUBMITTED DURING THE HEARING (HD):

HD	1	Opening submissions on behalf of the appellant
HD	2	Opening on behalf of CMBC
HD	3	Respiratory data for COPD and Asthma 2021 [submitted by Cllr Audrey Smith]
HD	4	CMBC notes on draft EP
HD	5	CMBC note on delegated authority
HD	6	Code for complaints and complaints from 2004 - 2021
HD	7	Joint note from appellant and council on amended permit boundary plan
HD	8	EA invoice for subsistence charges 2020, 2021 and 2022
HD	9	Odour assessment by Environment Agency in 2016
HD	10	Information Update Calder Valley Skip Hire by Environment Agency April 2016
HD	11	Written statement by Cllr Dot Foster
HD	12	Written statement by [redacted]
HD	13	Comparison of original EP and draft EP [submitted by Mr Powell]
HD	14	Written statement by Cllr Steven Leigh MBE
HD	15	Email from CMBC Planning Services dated 30 November 2022 concerning complaint history 2008 - 2020
HD	16	Email from CMBC dated 30 November 2022 concerning complaint history advising that no enforcement sanctions issued
HD	17	Email from Tetra Tech dated 30 November 2022 concerning stack height calculation
HD	18.1	Review of compliance with planning conditions April 2016
	18.2	Analysis of a number of planning conditions [redacted]
HD	19	Inspector's Hearing Note 1 dated 2 December 2022
HD	20	Email from appellant dated 2 December 2022 in response to HD19 clarifying that appellant while pragmatically agreeing with CMBC's position on leaving the Hearing open for further written submissions does not consider that there has been any procedural flaw
HD	21.1	Draft Environmental Permit with conditions agreed by appellant and CMBC
	21.2	Revised suggested conditions agreed by appellant and CMBC submitted on 7 June 2023
HD	22.1	Summary evidence about EA compliance bands
HD	22.2	Extract from EP variation application re: operator competence
HD	23	Cabinet Report dated 8 February 2021 Calder Valley Skip Hire Application Determination
HD	24	WYG's response to Planning Inspector's questions dated 25 November 2019
HD	25	Bundle of 55 third party written representations received by 10 February 2023 including Statement of Objection from 1,017 Residents (personal details omitted) with 12 Appendices
HD	26.1	Legal Response to Statement of Objection with Appendices 1-6
	26.2	RPS Response on behalf of the Appellant to Third Party Representations dated 10 March 2023 with Appendices A and B
	26.3	RPS Response on behalf of the Appellant to Objections re Stack Height and Air Quality dated 10 March 2023
HD	27	Inspector's Hearing Note 2 dated 13 April 2023

HD	28	Appellant's response to HD27 Stack Height Calculation and Air Quality dated 9 May 2023
HD	29	Tree/Woodland Assessment Plan RPS Drawing 800 P03 May 2023
HD	30	Draft Agenda for resumed Hearing 31 May 2023
HD	31	Inspector's without-prejudice questions about draft EP conditions
HD	32	Technical Guidance Note (Dispersion) D1 Guidelines on Discharge Stack Heights for Polluting Emissions HMIP June 1993
HD	33	Objectors' response to Inspector's questions about HD21
HD	34	Closing Position from Objectors
HD	35	Review individual flood risk assessments: standing advice for local planning authorities Gov.UK February 2022
HD	36	Closing on behalf of Calderdale Council

CORE DOCUMENTS (CD):
[Also referred to as 'Appeal Hearing Bundle' pages 1-1,372]

CD	1	Appeal Form
CD	2	SWIP Permit Application
CD	3	Application Form
CD	4	Appeal decisions APP/A4710/W/18/3205776 and APP/A4710/W/18/3205783
CD	5	Noise assessment ES Addendum
CD	6	Other technical documents
CD	7	Chapter 3 ES Addendum to 2017 ES Chapter 7:Air Quality July 2019
CD	8	Residence time calculation
CD	9	Process Flow Diagram
CD	10	Application drawings 1, 2 and 3
CD	11	Revised Permit Application Site Plan drawing number JER1902-0002-01
CD	12	Environmental Permit for SWIP dated 10 February 2021 granted by CMBC
CD	13	High Court Quashing Order dated 14 September 2021
CD	14	Air Quality and Permit Review dated 23 November 2021 prepared by Air Quality Consultants Ltd (AQC) commissioned by local resident
CD	15	Response to AQC Review of Air Quality Assessment dated 15 March 2022 prepared by RPS
CD	16	Human Health Risk Assessment prepared by Gair Consulting Limited February 2022
CD	17	Environmental Management System Addendum for the SWIP prepared by RPS
CD	18	CFD Flow Simulation Report by Solid Solutions submitted to CMBC on 18 March 2022
CD	19	Correspondence between appellant and CMBC including Technical Note dated 17 March 2022 and Report dated May 2022 by Tetra Tech. Including notice of non-determination dated 23 May 2022
CD	20	Consolidated and Varied Environmental Permit issued by the EA dated 21 April 2021 for waste operation adjacent to appeal site
CD	21	ES Addendum Vol 2 Additional Air Quality Assessment July 2019
CD	22	Council's Statement of Case
CD	23	Appellant's Statement of Case
CD	24	Objection by [redacted] October 2022
CD	25	Objection by [redacted] October 2022
CD	26	Advice of [redacted] 21 October 2022

CD	27	Air Quality Consultants Technical Note October 2022
CD	28	Appellant’s legal response to third party objections 18 November 2022
CD	29	Appendix B RPD Response on behalf of the appellants to third party objections 17 November 2022
CD	30	Proof of Evidence Daniel Smyth 12 March 2019
CD	31	Appellant’s closing submissions 28 November 2019
CD	32	Calderdale MBC Air Quality Annual Status Report 2022
CD	33	Extracts from EPR 2016
CD	34	*R (aoa James) v Dover DC and Another* [2022] EWHC 961 (Admin)
CD	35	IED Directive 2010/75/EU (as amended)
CD	36	Draft Environmental Permit prepared by appellant

Objection to Calder Valley Skip Hire application number S13/006. for an Environmental Permit.

28 March 2024.

I object to this application for a number of reasons.

Firstly this application is not a fresh application, it is a resubmission of application report dated 5 August 2020 submitted by RPS on behalf of CVSH That was refused at appeal on 5 July 2023 by John Woolcock on behalf of the Secretary of State. The new application report dated 26 Jan 2024 submitted by RPS on behalf of CVSH states in 1.5.4 That the decision by John Woolcock is "perverse" and "procedurally unfair" . If CVSH objected to the inspectors decision then it was open to them to take it to Judicial Revue.

See "Environmental Permit- guidance on the appeals procedure"
www.gov.uk/government/publications/environmental-permit-appeal-form/environmental-permit-guidance-on-the-appeal-procedure

Section 4.5 . 4.5.1 States that the decision is Final, and section 4.5.2 States that the decision can only be challenged by judicial revue within 3 months of the decision. CVSH say in 1.5.4 of the 26 Jan 2024 application report that they chose not to do this because they were afraid another Inspector may come to the same conclusion. In other words they chose not to go to judicial revue because they thought they would lose and it is now too late, therefore the appeal is lost, and the application refused. If anyone is being perverse and procedurally unfair it is CVSH submitting what they admit is basically the same application, see 1.5.5 in the new application report. This is approaching "abuse of process" by asking the same question over and over until they hope to get the answer that they want from Calderdale Metropolitan Borough Council who they hope will not scrutinise it or have the resources to refuse it instead of taking on the Secretary of State in Judicial Revue

CVSH state that the reason for the refusal was solely down to the treatment of trees. This is not the case in his judgement paras 43 and 44 John Woolcock states:-

Operator competence
43. Paragraph 13 of Schedule 5 EPR 2016 provides that the regulator must refuse an application for the grant of an environmental permit if it considers that, if the permit is granted, the following will not be satisfied; (a) the applicant must be the operator of the regulated facility, and (b) would operate the regulated facility in accordance with the environmental permit. However, this applies if the permit is granted. Given that I am dismissing the appeal and the deemed refusal will stand, it is not necessary for me to consider the application of paragraph 13 of Schedule 5 EPR 2016.

Other considerations
44. Similarly, as the deemed refusal will stand it is not necessary for me to rule on the technical objections raised by third parties. However, it is necessary to comment on the objectors' concern that CMBC has shown only limited understanding of the regulatory processes and that there is no evidence that CMBC has the technical expertise to regulate this facility. CMBC is the regulator for the proposed SWIP and has statutory responsibilities in this regard. Planning decisions should assume that the pollution control regime will operate effectively. It seems to me that the same assumption should apply to the monitoring and regulation of environmental permits. Local reservations about CMBC's ability to properly regulate the SWIP are no part of my decision to dismiss the appeal.

This means he has not made a judgement on either "Operator competence" or "Other considerations" so both operator competence and third party technical objections have not been considered as he found the air quality issues sufficient to refuse. This does not mean that these technical objections are not valid objections. He also states "CMBC is the regulator for the proposed SWIP and has **"Statutory responsibilities in this regard."** CMBC must ensure that they have employed resources that can fulfil this obligation.

Further in para 42 John Woolcock states :-

42. Taking all the above into account, I consider that the appeal should be dismissed because I am not satisfied on the evidence adduced that the proposal complies with IED Article 46 1., which requires that waste gases from waste incineration plants and waste co-incineration plants shall be discharged in a controlled way by means of a stack the height of which is calculated in such a way as to safeguard human health and the environment. Furthermore, I am unable to find that the necessary measures have been taken to ensure that waste management would be carried out without endangering human health, without harming the environment and, in particular without risk to air, in compliance with Article 13 of the Waste Framework Directive 2008/98/EC.

This statement covers more than just the stack height and includes the waste management as an issue.

The final conclusion John Woolcock states :-

Conclusions
46. I have taken into account all other matters raised in the evidence but have found nothing to outweigh the main considerations that lead to my conclusions. I am unable to find that granting an environmental permit for the SWIP would not have an unacceptable adverse effect on human health and the environment.
47. In accordance with Regulation 31(6) EPR 2016 the appeal is dismissed and the deemed refusal stands. This appeal decision, including the above reasons, comprises the determination for the purposes of paragraph 6 of Schedule 6 EPR 2016.

This states that John Woolcock has taken account of other matters raised not just the air modelling.

The Governments Environmental permitting guidance

https://assets.publishing.service.gov.uk/media/5a7c07d2ed915d4147622550/pb-13570-wid-guidance-201003.pdf

For the application, section 5.4 States:- " Applicants should provide the following information as a minimum.
(a) Demonstration that the plant is designed, equipped and operated to meet the requirements of the WID taking account of the categories of waste to be incinerated."

Apart from all the other "minimum" requirements listed under section 5 of The Government Environmental Permitting Guidance, item 5.4 (a) states that providing the **plant design** and therefore equipment specification, layout, interconnection and certification must be a prerequisit for the application for an Environmental Permit. This objection demonstrates that this has not been done adequately.

The new RPS report of 26th Jan 2024 is essentially the same as the original submission dated 5th Aug 2020 , which was refused by John Woolcock apart from some of the following points.

1.2.3 This states that the SWIP is not in a DEFRA air quality management area, however Sowerby Bridge is in an AQMA and is only 670 metres away downwind of the proposed SWIP . So for all practical purposes the proposed SWIP is in the AQMA as that is the direction of the prevailing wind, (SW) taking the plume straight into Sowerby Bridge, a densely populated area with a number of schools.

1.5.2 The planning permission is subject to 22 conditions including the following, in summary. Before first operation the **plans and technical details must be signed off by CMBC.** The actual installation must be checked and signed off by CMBC. CMBC will be responsible for monitoring its operation, including waste management, emissions and permitted hours. Does CMBC have the expertise and resources to do this?

1.5.6 States that an independent revue was done by CERC (Cambridge Environmental Research Consultants) to verify the treatment of trees within the air quality assessment by RPS.
This was not an independent review. CERC are the producers of the ADMS air modelling software that RPS were using for this job. CERC have a vested interest in not showing up problems with their software or upsetting their customers (CVSH). This paragraph also states :-

"In their report they (CERC) confirmed that the approach adopted within the air dispersion modelling is considered appropriate and there would are no other suitable models/software available which would more accurately model the effect of trees."

This is indeed incorrect and in the report from CERC, in task 8, CERC states:-

"The sensitivity studies we have undertaken have shown that the sensitive receptors are all sufficiently far from the source, that pollutant concentrations calculated at these receptors are insensitive to the treatment of trees/surface roughness, or to the fact that the discharge height of the stack is lower than most of the trees. In view of this, it is highly unlikely that the use of more complex modelling approaches, such as a Computational Fluid Dynamics model which might have the capability to treat the trees in more detail, would lead to different conclusions."

This statement actually says that they believe their software to be adequate. NOT that there is no alternative. CERC also states there ARE alternatives such as Computational Fluid Dynamics modeling but that would be more complex and by implication more expensive.

I would also suggest that the reason very similar results that CERC achieves compared to RPS is simply because they are using the same software and using the same parameters and nothing to do with whether it is correct or not. I would also suggest that the similarity of results when varying the surface roughness demonstrates that the software is not sensitive to roughness not that roughness is irrelevant to the calculations, or to real life.

A more accurate model would have been to use Computational Fluid Dynamics as suggested as a possibility by CERC in Task 8. Furthermore I would suggest that the air quality modelling is further compromised by using Meteorological data taken from Leeds Bradford Airport (24Km from Sowerby Bridge 207 m above sea level) and Bingley (12 Km from Sowerby Bridge 262 m above sea level) and both situated on the top of flat topped hills, but the incinerator will be situated in the bottom of a steep sided valley at 90m above sea level surrounded by hills of 200 to 400 metres above sea level.

The paper :-

Realistic Forests and the Modeling of Forest-Atmosphere Exchange

E. J. Bannister[1,2], A. R. MacKenzie[1,2], and X.-M. Cai[2]
[1]Birmingham Institute of Forest Research (BIFoR), University of Birmingham, Birmingham, UK, [2]School of Geography, Earth and Environmental Sciences, University of Birmingham, Birmingham, UK

Indicates the complexities of wind and forest exchanges, it may be downloaded from :-

https://pure-oai.bham.ac.uk/ws/files/161494974/
Reviews_of_Geophysics_2022_Bannister_Realistic_Forests_and_the_Modeling_of_Forest_Atmosphere_Exchange.pdf

This paper is an open access document copyright 2022, and has been written by a prestigious university department of Birmingham University. In the section titled "Plain Language Summary" it indicates that there is complex set of exchanges of gases between atmosphere and forest or trees, particularly where the forest is patchy due to man's intervention. I would suggest that this area around the proposed SWIP perfectly represents that with the roads, buildings and clearings within the trees along the valley bottom and the incinerator stack. The paper then goes on to address some of these complexities and the problems with using "idealised" forests in mathematical models to represent the real life situation. This is a highly academic paper, 47 pages long, I use it to demonstrate that the modelling of the situation compared to real life is not black and white as implied by the reports submitted by CVSH in their application and that there is room for a significant amount of doubt and variation as stated by John Woolcock in his judgement.

A further paper on computer modelling using Computational Fluid Dynamics which is regarded as more accurate but more complex than the model used by the ADMS software, see CERCs report Task 8 above, is presented here:-

Air Pollution Dispersion Modelling in Urban Environment Using CFD: A Systematic Review

Mariya Pantusheva [1], Radostin Mitkov [1], Petar O. Hristov [1,2] and Dessislava Petrova-Antonova [1,*]
[1] GATE Institute, Sofia University "St. Kliment Ohridski", 1113 Sofia, Bulgaria
[2] Institute for Risk and Uncertainty, School of Engineering, University of Liverpool, Liverpool L69 7ZF, UK
* Correspondence: d.petrova@fmi.uni-sofia.bg

A copy of this paper may be downloaded from :- https://www.mdpi.com/2073-4433/13/10/1640

This paper is about the computer modelling of Air Pollution Dispersion using one of the methods that the RPC report states is unavailable or unsuitable. This paper was written for the technical journal "Atmosphere" and was published on 9 Oct 2022. It is another open source document. It is also very academic however it is presented here to show that the subject of computer modelling gas and vapour behaviour is complex and open to debate.

In the above paper Para 3.9 "A note on Verification, Validation and Predictive Capability Estimation." acknowledges that computer modelling while being very valuable as a tool, saving time and costs, it also states "However models are are only approximations of reality and are always built on assumptions." The section goes on later to say "The level of model reliability must instead be demonstrated by critically comparing predictions with experimental data."

I would suggest that we have already done that experiment with the results of the CVSH fire of 4 Jan 2017. Many photographs of the smoke lying in the valleys and streets of Sowerby Bridge for several days exist. The only difference with the effluent from the stack would be that it will be largely transparent, and thus invisible, meaning people would be subject to the residual toxins, many persistant (ie become embeded in the environment and can accumulate without decomposing) without knowing it. The fire was an experiment that would never have been officially sanctioned, however because it was accidental does not make the results any less valid, and they are well documented. As residents we all know that this was not a one off, mist regularly lies in the valley bottom and that will trap effluent with it and hold it there.

The above shows that irrespective of the computer modelling and discussions of validity or otherwise of parameters used, real life experiments irrefutably show that smoke and effluent from the CVSH site will often sit in the valley bottom and drift over the town of Sowerby Bridge, affecting health in an already polluted area, that is already an AQMA, if this permit is granted.

The fact that CVSH could not prove otherwise to his satisfaction, was the main reason for the refusal of the appeal for an Environmental Permit by John Woolcock. The current application is no different in substance from the one refused by John Woolcock.

3.2 CVSH have provided some more detail on proposed storage and sorting of waste.

3.3 New section on proposed waste handling procedures.

3.8 Revised information on Ash handling.

3.11.2 to 3.11.7 Further comments on air assessments. I have dealt with this above.

4.2 Additional information about heat recovery. 4.2.2 RPS state that the ORC is not part of the machinery. If it is not part of the machinery, then how does the Machine as a whole comply with R1? Without including the ORC there is no generation of electricity or export of energy from the SWIP.

5.5.4 This paragraph exists on the August 2020 application but not on the January 2024 application. It states **" CMBC may request copies of the site diary and site inspection records relating to SWIP operations at any time."**

Why has this been removed? I object strongly to that paragraph and requirement being removed. It removes a significant amount of CMBCs ability to monitor the SWIP compliance.

There are no appendices and no drawings in the spaces for them at the end of the report.

Dealing with the documents supplied by CVSH. Many are a bit of a rehash of previous documents.

The brochures supplied for the inciner8 are flyers of the type handed out at trade shows and don't give any real technical detail, just a general concept. Likewise the brochure for the ORC. These brochures or similar have been submitted before.

The dryer location drawing No 9677/17/03 dated Nov 16 has been submitted before.

The flow simulation by Solid Solutions is dated 8/2/22 has been submitted before. Note that this test is done with a loading of 1 ton per hour and the permit is for 2 tons oer hour. This means that the test does not meet regulations for the permit applied for as the application is for double the throughput tested

The process flow diagram by RPS is undated but not contentious.

The Electrical Condition Report covers the electrical installation and distribution within the building and has nothing to do with the SWIP except that I note that in the Schedule 2.2 there is no provision for a generating set for operation in parallel with a public supply. This would be required for the ORC and no information is given for installation of this provision. I also note that this certificate is dated 29/6/2016. This out of date as the recommended period of inspection for industrial properties is 5 years maximum and 3 years in harsh conditions in order to comply with Health and Safety at Work 1974 act and Electricity at Work Regulations 1989 and is probably a requirement of the Insurers. I would suggest that the Belmont site would be defined as harsh. I am a member of the IET who write the regulations. This certificate has been submitted before.

To summarise as stated by RPS " This application is submitted on the same basis as before" in other words it is the same application that John Woolcock refused except a bit more information has been added which is of doubtful value. The removal of para 5.5.4 from the new application is concerning as it removes a useful tool for monitoring CVSH compliance. Why would that be removed unless there was something to hide?

In addition to the above, because the new application has been made on the same basis as the original, I reiterate my objections to the original application that was refused by John Woolcock. Note that John Woolcock did not rule on third party Technical Objections. I include that objection here:-

This objection is to the permit to operate a SWIP that does not appear to be properly installed or certified.

A lot of assumptions have been made about the emissions and operation of this incinerator without documentary evidence. The single engineering drawing (APPENDIX 1.2 DRAWING 9677 32A INTERNAL LAYOUT) has very little information. It gives the manufacturer of the waste heat powered generator, (Triogen ORC engine) but not it's model or version. There is poor information in the form of leaflets for the incinerator and filter system submitted. While the filter system appears to be made by inciner8 this can only be inferred by the inclusion of the leaflets under Technical documents appendix D. Which of the 3 filter systems on the leaflet is specified to be used here, and where is the documentation for the model put forward but not specified?

There seems to be no provision for the storage of the fuel oil required to fire this SWIP. This must be in a suitable tank and it must be appropriately bunded in case of leaks, especially as it is close to the river and liable to flooding.

As this is an assembly of essentially 4 units to make a single unit, the Incinerator (Inciner8or model 18-100), the heat exchanger, the flue gas filter (implied to be Inciner8 but not specified) , and the Triogenic ORC engine. (Arguably the Dryer is also part of this machine as it is integral to the operation of the SWIP) Under HSE guidance this becomes "In situ manufacture or assembly of equipment and plant" (https://www.hse.gov.uk/work-equipment-machinery/manufacturer-in-situ.htm). This means that the whole assembly and installation must comply with the Supply of Machinery (Safety) Regulations 2008. The whole assembly must also comply with the machinery directive.

Looking at the layout I believe that there are significant problems with access for maintenance, The ORC is very close to the side walls and the flue filter preventing good access to either. There does not appear to be enough safe access to remove hot ash from the end of the incinerator, with a risk of the operator being trapped between the hot chamber and the Heat exchanger. Very little room between the building walls and the incinerator for maintenance. Personnel working on hot equipment must have adequate space to escape from hot surfaces (machinery directive). Has the manufacture's recommendations for access space and installation been followed? (no information available) If not the equipment will not comply with the manufacturers standard certification. It is normal for a manufacturer of something this large and complex to insist that it is installed by themselves or an approved contractor in order for them to guarantee any performance specifications. Has this been done? If not then none of the quoted emission specifications are guaranteed and all the air quality calculation are only assumptions. The flow calculations provided by Solid Solutions states that assumptions are made because access was too limited to take measurements. Why did the manufacturer not supply these flow calculations or the detailed drawing with all dimensions for the application? I would suggest that the machine is too big for the shed to give adequate clearances.

No permit to operate should be given until the above has been satisfied and a reputable approved body given written certification that the machine is installed safely and complies with all relevant directives. Until it is assessed as a complete assembly by a recognised competent body, (eg Inciner8 the manufacturer) no guarantees can be given with respect to emissions, safety or performance, all of which form part of the permit to operate. As regulator CMBC will be responsible for the final sign off.

The efficiency of the plant is also part of the permit and the plant must comply with the existing planning for a SWIP Planning Condition 8. In order to achieve this, a calculation was done based on 1 ton per hour of RDF (refuse derived waste) as fuel. See **RPS Report Planning condition 8-R1 Scheme.** This would be 6,250 tons per year absolute maximum not 10,000 tons per year based on 24 hours per day 5 days per week and 52 weeks per year, The actual figure would be significantly less when downtime , start and shutdown time and holidays are taken into account. This was the calculation approved by the Secretary of State see document **DELEGATED REPORT Submission of details to comply with condition 8 on application 17/00113/WAM Reference 17/00113/DISC4 .**

This is because the ORC is running at maximum output at 1 ton per hour, so no extra electricity is generated if extra fuel is burnt. Using the approved calculation at 2 tons per hour R1 would be 0.34, about half the R1 permitted by the planning conditions. In addition the Incinerate leaflet specifies that the burn rate is 1 ton per hour so increasing the loading will probably overload the emission control system (seconary temperature, residence time filters etc.) causing excessive toxic emission from poorly burnt fuel. As regulator CMBC will be responsible for monitoring this loading and monitoring what RFD is going into the SWIP.

To Summarise. This whole installation seems to be an assembly of equipment squeezed into an existing shed. There seems to be no manufacturers approvals for the installation or approval by any other competent body to guarantee performance or safety. There is no provision for the oil fuel supply which forms part of the installation so it must fall within the permit area. All technical information contained in the specification for the equipment in the application is provided as bald statements without any reference to proper manufacturers detailed specifications, therefore all calculations, models and conclusions with respect to this application are based on uncertified information and assumptions provided by CVSH. As regulator CMBC will be responsible for checking this and signing it off according to regulations before it can be operated.

Condition 6 of the planning states that the SWIP is not to be run when the dryer is unavailable. The dryer is unavailable during the night. The cooling air from the heat exchanger that is ducted to the dryer must run at all times that the SWIP is running or else the uncooled flue gas will overheat the filter system. (max temperature 300 degC) This is wasted energy.

In this new application there are no material changes to the machinery or buildings or layout, or the position, or the weather, or the topography of the valley bottom from the application refused by John Woolcock. There is even less technical information provided for the layout and specification of the machinery. What is provided is inconsistant and contradictory. CMBC must take a lead from the Secretary of States representative and refuse this application outright as it is the same as that which has already been refused by John Woolcock on behalf of the Secretary of State. CVSH have missed their opportunity to disagree with him and appeal which they had to do within 3 months of the judgement by law. See the first paragraph of this objection.

Summary:-

The modeling of plume dispersion is not robust, and results are open to discussion, Empirical evidence of the CVSH fire which left smoke in the valley for over 2 days, and regular mist in the valley proves dispersion is often very poor.

Installation of the machinery is suspect and very poorly documented and certification nonexistent.

The calculation of R1 is confused and the approved method under planning condition 8 only allows circa 6,000 tons per annum not the 10,000 applied for on the permit.

Running the incinerator at 2 tons per hour applied for, is twice the loading for the modeling done by Solid Works, and twice the specified loading of the i8-1000 General Incinerator (see leaflet provided Under Technical Documents (Appendix D)). This will adversly affect the residence time and possibly the temperature in the secondary chamber requiring diesel to be burnt to maintain it, and therefore invalidates the Inciner8 specifications for organic emissions which are specified at the cappacity of 1ton per hour. Stack emissions of highly toxic and persistant organic toxins such as dioxins, PCBs and Furans all of which can produce complex health issues such as cancer, reproductive, developmental and birth defects will occur if secondary chamber temperature drops below 850degC and residence time is not more than 2 secs.

According to the planning condition 6 the plant must be shut down each evening when the dryer is unavailable to use.

Note that the IED (Industrial Emissions Directive) Under "Law" states " The IED ensures that the public has a right to participate in the decision-making process, and to be informed of its consequences, by having access to permit applications, permits and the results of the monitoring of releases." CMBC must therefore make all the monitoring data publicaly accessable should they pass this permit.

This Incinerator is the wrong machine poorly specified, badly installed and in the wrong location in a steep sided valley bottom with inadequate plume dispersion. The throughput of 2 tons per hour, asked for in the application, is beyond the machines safe capacity. It has already been refused by a Government Inspector on appeal because of doubts about the safety of the health of people in Sowerby Bridge.

Calderdale Metropolitan Borough Council must stand up for the health and safety of the people of Sowerby Bridge by taking the decision to refuse this permit because there is significant liklyhood that this installation will adversely affect the health of the people of Sowerby Bridge. The presumption must be to protect health and the environment.

[redacted]

[redacted]

From: [redacted]
Sent: 29 March 2024 11:22
To: [redacted]
Subject: Fwd: Met Office Enquiry
Attachments: Outlook-gwq2npll.png

---------- Forwarded message ---------
From: [redacted]
Date: Thu, 28 Mar 2024, 14:59
Subject: Re: Met Office Enquiry
To: [redacted]

Hi [redacted]

Apologise for the delay here but I have been speaking this through with a senior data scientist and he has said the below:

Unfortunately that is exactly the kind of application we ***cannot*** support. That is a very narrow, deep valley (~500m wide) that simply will not be resolved by our analyses or NWP (2km). We could not meaningfully assess conditions within that valley. Meteorological convention would suggest that valley would be prone to inversions/cold air pooling, but I think you would need CFD modelling and/or in-situ observations to be able to judge how often the smoke stack would be above/below.

[redacted] Website:
www.metoffice.gov.uk

My pronouns are: [redacted]

Met Office FitzRoy Road Exeter Devon EX1 3PB United Kingdom

Keep up to date with weather warnings here

contractual, legal or other privilege. If you are not the addressee, you may not use or copy it to any other person. If you receive this e-mail in error, then please contact the sender as detailed above.

From: [redacted]
Sent: Friday, March 15, 2024 11:47 AM
To: [redacted]
Subject: Re: Met Office Enquiry

This email was received from an external source. Always check sender details, links & attachments.

Hi [redacted]
Thank you for your really helpful answer to my question, so am I right in that there is no actual historical data for HX6 3LL, and would rely on data from the nearest weather station. If this is the case how much will it cost for 5 years of data for HX6 3LL and would that include episodes of inversion in the valley?

thanks
[redacted]

On Fri, Mar 15, 2024 at 10:53 AM [redacted] wrote:

> Hi [redacted]
>
> Hope you are well?
>
> Just coming back on your enquiry. We have a large range of weather stations across the UK which provide observations - actual weather conditions for these locations. See link below
>
> [Synoptic and climate stations - Met Office]()
>
> Quite often organisations will be required to use accurate and actual observed data and to do this it would mean finding the nearest weather station to the location in question, which I will assume has happened here. Weather stations also typically hold a large number of years of data to enable a good understanding of climatology for the area.
>
> We are more and more often being asked for site specific historical data sets and ongoing forecasts which we can support with by blending together several super computer weather prediction models which incorporate real-life surface, satellite cloud and radar rainfall observations. By combining the models we are able to cancel many errors and produce more accurate forecasts and best estimates of actual considering the conditions for the site location. We are only able to go back a maximum of 5 years using this process, but this would provide data for the exact location which could be compared with the actual observations for the weather stations being used and give a truer representation of the actual site location conditions.
>
> [redacted] Website: www.metoffice.gov.uk
>
> My pronouns are: [redacted]

Met Office FitzRoy Road Exeter Devon EX1 3PB United Kingdom

Keep up to date with weather warnings here

Privacy Notice
To find out about how the Met Office uses any personal information we collect about you, please see our Privacy Policy.

Confidentiality Notice
This e-mail is intended for the addressee only. Its contents are provided "in confidence" and may be covered by contractual, legal or other privilege. If you are not the addressee, you may not use or copy it to any other person. If you receive this e-mail in error, then please contact the sender as detailed above.

[redacted]

[redacted]

Monday 1st April 2024

Dear [redacted]

I am writing to you following your recent instruction to provide my thoughts on the potential impacts, upon the adjacent trees and woodland, of a proposed development at Calder Valley Skip Hire, Belmont Industrial Estate, Rochdale Road, Triangle, West Yorkshire.

I will also briefly review the arboricultural information which was submitted with the original planning application (Ref: 17/00113/WAM), whilst drawing upon my own observations gained during a walkover survey of the site, which was carried out from public access land.

Local Designations and Habitats

The Belmont Industrial Estate is located approximately 900 m north-west of Rough Hey Wood, which encompasses 13.1 hectares of ancient and semi-natural, and ancient replanted woodland.

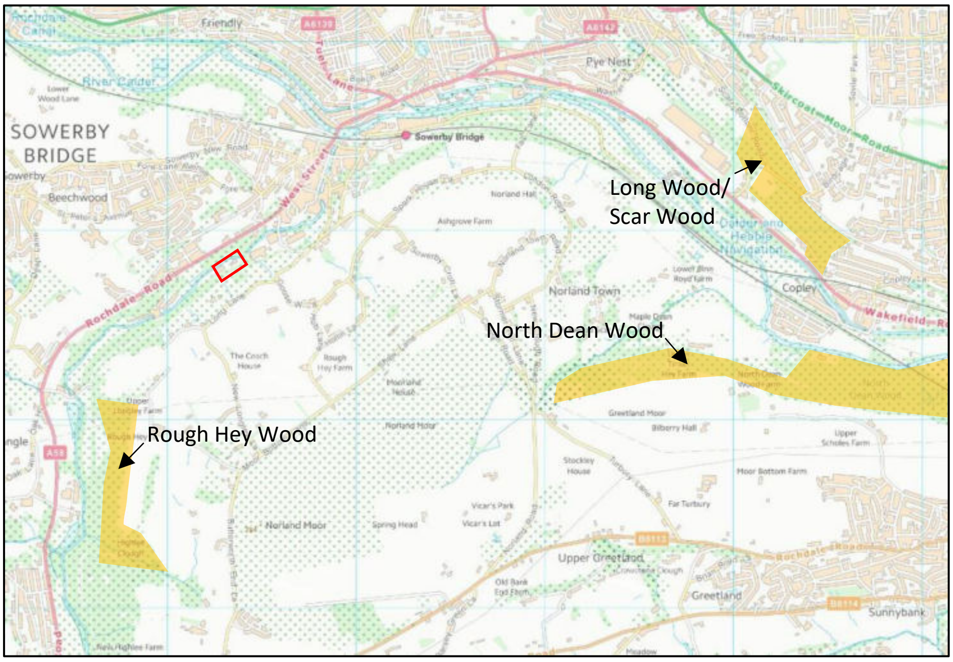


Figure 1: *Plan showing the location of the Belmont Industrial Estate (outlined in red), in relation to ancient woodland sites (shaded in orange), and the Calderdale Council Wildlife Habitat Network (dotted areas)[1].*

Ancient woodlands like Rough Hey Wood are unique, because they have grown and adapted in harmony with native wildlife over many centuries; they provide a range of habitats, which support a

[1] Calderdale Council (2024) *Calderdale Maps: Biodiversity and Geodiversity.* [online]. Available at: >https://new.calderdale.gov.uk/maps/biodiversity-and-geodiversity< [accessed 28th March 2024]

rich diversity of plants and animals. Many woodland species depend entirely for their survival on the continued existence of these ancient woodland habitats.

Although the woodland surrounding the Belmont Industrial Estate is not designated ancient woodland, it forms part of the Calderdale Council Wildlife Habitat Network, and provides a link between Rough Hey Wood and three other ancient woodland sites to the east: North Dean Wood, Long Wood, and Scar Wood (Fig. 1).

Green corridors that connect ancient woodland sites are vital - since ancient woodland covers less than 2.5% of the UK - and they help the associated wildlife to migrate between these increasingly rare habitats, allowing them to feed and breed. Industrial and commercial developments within wildlife habitat networks threaten to further fragment ancient woodland sites - at a time when reconnection is a priority - as climate change makes some places too hot, too dry, or too unpredictable for the associated wildlife to survive.

The trees at the Belmont Industrial Estate site are also afforded statutory protection by three woodland tree preservation orders (TPOs): TPO Ref: 88/00349/C to the north-west, TPO Ref: 87/00307/C to the north-east, and TPO Ref: 86/00228/C to the south.

The purpose of woodland TPOs is to safeguard areas of established woodland that have been identified as valuable, and which fundamentally depend on natural regeneration and/or new planting for their continued existence. All trees and saplings within the defined area of the woodland TPOs at the site are therefore afforded statutory protection, regardless of their size and/or age, including those planted or having seeded naturally since the order was made.

Assessing the Impact of Developments upon Trees

Existing trees are a material consideration in the UK planning system. Where there is potential for existing trees to be impacted by development, an Arboricultural Impact Assessment (AIA) in accordance with *BS 5837: 2012 – Trees in Relation to Design, Demolition and Construction: Recommendations* (hereafter referred to as *BS 5837: 2012*) is usually required as part of the planning application.

A Tree/Woodland Assessment Plan (Drawing Ref: 800, Rev: PO3) was submitted with the application, which divides the surrounding woodland into eight groups, and provides some basic information on the species, age, condition, and life expectancy of trees within each of these.

Although the Tree/Woodland Assessment Plan does contain some information on the distance of the trees from the proposed chimney stack, and the height of the chimney stack in relation to the adjacent trees, the drawing does not sufficiently analyse the impacts of these upon the adjacent woodland. The Tree/Woodland Assessment Plan therefore cannot be deemed to satisfy the requirements - as set out in *BS 5837: 2012* - of an AIA.

An AIA should therefore have been carried out in order to assess the direct and indirect impacts of the proposed development upon the adjacent woodland:

- Direct impacts would include any tree removals and pruning required to facilitate the proposed development, encroachment of permanent structures onto root protection areas (RPAs), and the digging of trenches/ stripping of topsoil within RPAs.
- Indirect impacts would include matters such as alterations to drainage patterns, shading, storage of construction equipment/materials, and soil contamination.

In this instance, the indirect impact of toxic gas emission is a concern, particularly when it is considered that the tops of many nearby trees are likely to be substantially higher than the proposed discharge height of the stack, and at a relatively close separation distance.

The Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories[2] states that the incineration of municipal waste can produce N2O (nitrous oxide) and NO_x (oxides of nitrogen). The potential impacts of elevated atmospheric deposition of nitrogen on woodland ecosystems can include an increased sensitivity to natural stress, impacts on roots, reduced species diversity of the ground vegetation, reduced growth, and unbalanced nutritional status due to eutrophication and acidification[3].

I note that in your recent correspondence with the Met Office, a senior data scientist has stated that the topography of the Ryburn and Calder Valleys could mean that the local area is prone to inversions/cold air pooling. It is sensible to assume that during such conditions, deposition of nitrogen into the adjacent woodland is likely to be increased.

It goes without saying that the emission of toxic gases from the proposed chimney stack at the Belmont Industrial Estate and the potential impacts of these upon the adjacent woodland should be further explored.

A Review of the Supporting Arboricultural Information to Application Ref: 17/00113/WAM

Following my walkover survey - which was carried out from a public right of way to the south of the site - I can conclude that much of the information included within the Tree/Woodland Assessment Plan appears inaccurate, conflicting, or lacking in depth.

For instance, G1 (Fig. 2) and G2 (Fig. 3) have been recorded to consist of goat willow (*Salix caprea*) and common ash (*Fraxinus excelsior*) monocultures, respectively. G1 and G2 were however found to contain far more diverse stands of young, semi-mature, and early-mature native species, including silver birch (*Betula pendula*), wild cherry (*Prunus avium*), elder (*Sambucus nigra*), and holly (*Ilex aquifolium*), in addition to naturalised species such as sycamore (*Acer pseudoplatanus*) and European beech (*Fagus sylvatica*).

Figure 2: *G1*

Figure 3: *G2*

G1 and G2 are also noted to consist of trees with poor/fair condition, with "previous branch failures, broken branches in crown, moderate deadwood in the crown, and squirrel damage". Such features are present to an extent; however, these are not only typical of the woodland setting, but they are also a vital structural element to a healthy and functioning woodland ecosystem.

[2] J. Penman, D. Kruger, I. Galbally, T. Hiraishi, B. Nyenzi, S. Emmanul, L. Buendia, R. Hoppaus, T. Martinsen, J. Meijer, K. Miwa, and K. Tanabe (Eds) (2000). *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories.* Published for the IPPC by the Institute for Global Environmental Strategies, Japan

[3] J. W. Erisman, and w. de Vries (2000). 'Nitrogen deposition and effects on European forests', *Environmental Reviews, Vol. 8 (No. 2), Pg. 65-93.*

It appears that the surveyor has used the features of individual specimens to inform the *BS 5837: 2012* classification of G1 and G2, which have been recorded as category C (low-quality). Woodland groups should however be assessed as a collective, rather than by individual specimens; for this reason, there is a strong argument that G1 and G2 should have instead been classified as *BS 5837: 2012* category B (moderate-quality).

A life expectancy of 10 + years has also been applied to G1 and G2. Considering that both of these groups display natural regeneration of broadleaved trees within the understorey, as well as established semi-mature and early-mature specimens, it seems rather unlikely that these would all suddenly perish within the next 10-20 years. Therefore, a minimum life expectancy of 20-40 years would be more applicable, which would elevate the *BS 5837: 2012* classification of G1 and G2 to category B (moderate-quality).

Figure 4: *G6*

Rather confusingly, G6 (Fig. 4) is predominantly comprised of young and semi-mature European beech (*F. Sylvatica*), has no public access, and is noted to display similar features to G1 and G2, yet has been classified as *BS 5837: 2012* category A (high-quality). The reason for the contrasting *BS 5837: 2012* categorisations of G1 and G2, and G6 are not obvious, nor are they fully explained.

In the Notes section of Tree/Woodland Assessment Plan, it is stated that the document was produced using aerial imagery and ground inspection to provide tree locations. The accuracy of these methods are unreliable, and the locations of the trees/groups in the Tree/Woodland Assessment Plan can therefore be only taken as indicative.

BS 5837: 2012 states that tree location plans should be aided by an accurately measured topographical survey which shows all relevant features, including:

- spot levels at the base of trees and throughout the site at an interval appropriate to meet design requirements, recorded as a grid and interpolated as contours, ensuring that any abrupt changes, embankments, ditch inverts and retaining features are recorded.
- the position of all trees within the site with a stem diameter of 75 mm or more measured at 1.5 m above ground level (In the case of woodlands or substantial tree groups, only individual trees with stem diameters greater than 150 mm usually need be plotted).

Details of how tree crown spreads and heights were measured, and how the distance of the trees from the proposed chimney stack were calculated have also not been provided in the Tree/Woodland Assessment Plan. If these were determined using the indicative tree locations, it is likely that these figures are also substantially out.

Conclusions

The proposed development at the Belmont Industrial Estate has significant potential to damage protected trees, both directly and indirectly, and the impacts upon the adjacent woodland have not been assessed in adequate detail to satisfy the requirements of *BS 5837: 2012*. For these reasons, completion of an AIA should be considered a necessity. The accuracy of any AIA is also reliant upon a topographical survey of the site being provided to the assigned individual or organisation that carries out the work.

The potential impacts of the development extend beyond immediate damage to the adjacent trees and woodland, but also to the wildlife which uses this section of the Calderdale Council Wildlife Habitat Network for commuting, foraging, and/or breeding purposes – including rare species associated with several nearby ancient woodland habitats.

Finally, it is not clear if the Belmont Incinerator is intended to operate on a 24-hour basis, though if this is the case, then the indirect impacts of light and noise pollution upon wildlife would also need to be further investigated by a suitably qualified ecologist.

Yours sincerely,

[redacted]

OBJECTION TO ENVIRONMENTAL PERMIT APPEAL

Email to [redacted]

From: [redacted]
Address: [redacted]

<u>Calder Valley Skip Hire Limited – Environmental Permit Appeal – Reference APP/EPP/603</u>

DOCUMENTS included with this Objection:

1. **Air Quality and Permit Review: Calderdale Valley Skip Hire Small Waste Incineration Plant – November 2021 - Air Quality Consultants Limited.** Note this is the same as the Appellant has submitted except for the correction of the reference to “unpredicting sites” to “underpredicting sites” in Issue 5. (“**AQC Report**”)

2. **Advice - October 2022 - [redacted] (“Counsel’s Opinion”)**

3. **Technical Note – Calder Valley Skip Hire Small Waste Permit Incineration Plant – October 2022 – Air Quality Consultants Limited (“AQC Technical Note”)**

4. **High Court Order granting permission for Judicial Review – 23 July 2021. (“High Court Order”)**

5. **WHO global air quality guidelines: particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. 22 September 2021 Guideline**

6. **CMBC APPEAL STATEMENT -PINS-FINAL 18.08.2022**

7. **Notice-Of-Refusal-Mearclough_S13004RF01-20-6-18**

GROUNDS OF OBJECTION

1. I object to the grant of an Environmental Permit for the reasons set out in this document and attachments.

Basis of the Appeal

2. The Appellant has appealed on the ground of a “deemed refusal” due to the failure by regulator to give notice of determination of the application for the Permit within the statutory time-period. However, the Statement of Case of the Appellant which seeks to set out the merits of the appeal very much centres around its incorrect contention that it is impermissible for anyone to revisit any of the air quality issues considered by the Planning Inspector [redacted]) in his planning permission decisions dated 4 February 2020 during the environmental permitting process both as a matter of law and as a matter of Central Government guidance as contained in the National Planning Policy Framework (NPPF).

3. The Appellant seeks to persuade the regulator and the Inspector hearing this appeal that none of the outstanding matters raised by the Calderdale Council’s experts (Tetra Tech) or in the AQC Report can be taken into consideration in the decision as to whether or not to grant an Environmental Permit. It appears that the refusal to provide the additional information is the primary reason for the submission of the appeal.

4. Calderdale Council in its Statement of Case has wrongly accepted the arguments put forward by the Appellant and conceded the Appeal on the basis that it considers it is prevented from seeking the further information advised by its technical advisors (who were acting under delegated power of the Council as its “competent persons”) and on the basis that no further evidence has been put forward to undermine

the original quashed decision to grant the Permit. The Council's Statement of Case makes no reference whatsoever to the AQC Report and the evidence in that which has been provided to counter the original decision to grant the Environmental Permit.

Law and Guidance

5. The correct position in relation to the law and guidance on the process that should be followed and the matters that can be taken into account in relation to the determination of an Environmental Permit application and appeal are set out in detail in the Counsel's Opinion and ACQ Technical Note attached with this objection.

6. From these documents it is clear that the Planning Inspector did not conclude that an Environmental Permit should be granted, or on what terms, and those matters were not within his remit. The Planning Inspector's conclusions on air quality do not bind the regulator or Inspector who will be dealing with this Environmental Permit appeal.

7. Since the planning appeal decision, the Environmental Permit decision has been made and been the subject of expert reports on behalf of CVSH, the Council and local residents as well as subject to a successful judicial review. The environmental permit decision will need to take the changed circumstances and additional information into account. Consequently, if it is found during the process of reviewing the permit application that the proposal is harmful to health or the environment then the Environmental Permit must be refused.

8. CVSH have mentioned, but not advanced, the possibility of arguing that the planning appeal decision gives rise to an issue estoppel in respect of air quality matters. An issue estoppel arises where a determination of an issue in one set of proceedings binds the parties to those proceedings in the future. Issue estoppel does not arise in relation to judgements as to whether planning permission should be granted. Whilst a grant of planning permission does, of course, give rise to the rights in the permission, it does not bind the parties as to the merits of the application.

Relevance of High Court Order granting Permission for Judicial Review

9. The Statements of Case in this appeal note that [redacted] brought successful judicial review proceedings against the original grant of the Environmental Permit. The claimant's statement of facts and grounds in the judicial review noted:

> *"61. CVSH take points which are not part of the Council's reasoning and assert erroneously (i) that air quality is not a matter for environmental permitting (when it is the purpose of environmental permitting) and (ii) that the view of a Planning Inspector on planning merits amounts to an issue estoppel. Issue estoppel can only arise in public law decisions which are determinative of an issue, such as the legal grounds in a planning enforcement notice appeal, rather than exercises of discretion or judgments as to future circumstances."*

10. The Council and CVSH resisted the proceedings. Ground 3 concerned regard to environmental permitting guidance. CVSH contended that because of the Planning Inspector's decision '*It would have been unlawful for the Council to seek to refuse the permit on the basis that the proposal would have an impact which was more than negligible' (Summary Grounds, para 29*). To do so would have been '*a flagrant disregard' of what is now paragraph 188 of the National Planning Policy Framework (Summary Grounds, para 29).* A copy of the High Court Order granting permission to apply for judicial review is attached to this objection. Permission to apply was granted on all grounds. Permission would not have been granted if the High Court had agreed that CVSH's main argument on this point was correct. Had the High Court agreed with CVSH (and now the Council) it would have been fatal to the grounds which addressed air quality issues previously considered by the Planning Inspector. CVSH and the Council are in error continuing to try to put forward these arguments despite the judgment in the High Court Order.

Obligations of the Regulator

11. It is the permitting authority that has the responsibility and statutory obligation to determine whether operational stack emissions from regulated facilities covered under the EPR are controlled to prevent significant impacts on human health and the environment. Combined with ensuring statutory minimum

emission limit values can be met, predictive air quality assessments are the only data available to the permitting authority at application stage to determine the potential impact on human health and the environment and, consequently, the degree to which emissions are/can be controlled.

12. Irrespective of whether operational air quality effects have been discussed at planning stage, the local authority permitting function, as regulator for SWIPs, can, and must, ensure that operational phase assessments of stack emissions are robust. If any aspect of the air quality assessment of operational stack emissions is not considered to be robust, further information should be sought by the local authority permitting function, and provided by the applicant, before determining the application.

Outstanding Issues preventing Grant of a Permit

13. As part of the process for the redetermination of the Environmental Permit the Council appointed Tetra Tech to undertake a further review of the amended permit application and the AQC Report and the outcome was that, acting under the delegated powers of the Council, agreeing with points made by AQC, Tetra Tech required additional information before a decision was taken. Further information was therefore requested by the Council in relation to the assessment of 1-hour mean NO2 concentrations, and a sensitivity test regarding uncertainty within the air quality assessments. CVSH refused to provide that information based on its incorrect assertion of the law and guidance.

14. As part of the redetermination process CVSH instructed RPS to undertake a review of the AQC Report. The subsequent report by RPS has been provided by the Appellant as part of the appeal documents and is attached to the AQC Technical Note. That RPS report however ignored the items listed in the AQC Report (1) Uncertainty (3) Stack Height (5) Road Modelling Verification and Model Adjustment (6) Assessment of 1 hour- mean NO2 Concentrations (10) Surface Roughness. The reason it did so was solely because it followed the (incorrect) legal advice from CVSH's lawyers to the effect that it was considered impermissible to revisit the air quality issues determined by the Planning Inspector during the environmental permitting process.

15. It is to be wondered (given the Appellant has sought to address other issues raised by AQC), whether the resistance of the Appellant to address these issues is not so much due to its interpretation of the law and guidance, but the fact that if they are properly addressed now in the terms of the environmental permitting regime, the results would lead to a conclusion that the Environmental Permit should be refused.

16. The Appellant seeks to find an issue with the failure of the AQC Report to list the Planning Inspector's decision. AQC have confirmed in the AQC Technical Note that they reviewed the documents and Planning Inspector's decision. They confirm that, although the planning appeal decision was sent to AQC, it was not considered material for the review of the air quality impacts at permitting stage. They state that*, as previously demonstrated, both in terms of legislation and supporting guidance, it is the permitting regime that must determine whether the assessment of operational air quality effects of stack emissions is robust with respect to controlling emissions under the EPR. The planning regime serves an entirely separate purpose.*

17. The further information required by Tetra Tech and the issues raised by AQC ((1) Uncertainty (3) Stack Height (5) Road Modelling Verification and Model Adjustment (6) Assessment of 1 hour- mean NO2 Concentrations (10) Surface Roughness) all continue to remain relevant and unresolved. It is my view, supported by that of Counsel's Opinion and the AQC Technical Note that a permit should not be granted until they are adequately addressed and found to have satisfactory outcomes. Given that the Appellant has refused and continues to refuse to address these points, the appeal should be dismissed, and the permit refused.

Conclusion

18. It is clear that the Council as regulator has once again misdirected itself as to the applicable law, guidance and process for the determination of the Environmental Permit application. The Council has erred in law and consequently acted unlawfully in relying on this error of law in (i) not defending its original decision to require additional information and (ii) not defending the appeal based on the Tetra Tech report that required the additional information before the permit application could be determined. The Council once

again has no rational basis for failing to follow the Tetra Tech recommendation that more information should be obtained as set out above.

19. In those circumstances, I request that the Secretary of State dismisses this appeal and directs the Council to refuse to grant and Environmental Permit to the Appellant for the operation of the SWIP and associated plant at the Appeal Site.

ADDITIONAL POINTS

Mearclough SWIP

20. This Environmental Permit application is not dis-similar to that made at Mearclough by CVSH which was refused by Cabinet (Document 7), one of the reasons in the Cabinet decision was the proposed chimney of a stack height of 17.5m, "*is not sufficient to achieve safe dispersal of potential pollutants*". Additionally, it said "*The proposal depends on theoretical modelling and further changes may be required in the light of actual operation. It is therefore critical that the council would be able to enforce such changes if required, or to require operation to cease*".

21. The incinerator at Mearclough is the same incinerator as is proposed to operate at the Belmont site and yet now the Council consider the possible necessary operational changes to the stack are acceptable and the inability to enforce is also acceptable. There is no apparent reason why they should as the regulator take such a different approach between sites.

Stack Height Uncertainty

22. The stack height proposed at Belmont is 12 metres although the apparent reason given for that, which was given at the Planning Inquiry, is that the height was chosen as the most likely to obtain planning permission. The Council and Appellant (just as in the Mearclough application) suggest this may require monitoring and adjustment in case it does not actually meet modelled air quality standards, there is no documentation as to how this will be controlled, it seems unlikely it will be. Surely it should not be implemented unless it can be shown with certainty that it is and will remain when operational within current standards. If there is insufficient certainty, then the Council as regulator should refuse the application and, in any event, must be able to enforce and control the emissions. This means unless a permit is now refused, for the reasons above, any Environmental Permit granted for Belmont will need additional conditions that require a revised planning application and environmental permit be applied for and operations cease until such times as these are granted, and emissions are within acceptable limits.

Air Quality Issues

23. The proposed incinerator will add to emissions in the Ryburn Valley. We are told they will be within current safe limits, however the guidelines from the WHO propose much lower limits based on the evidence of harm to health from higher emissions see Document 5.

24. Calderdale Council are implementing an Air Quality Strategy which "*is about making sure we consider air quality in everything we do – both as a Council and a community*." This is another reason for refusing the Environmental Permit since on the basis of WHO guidelines it will adversely affect air quality across Calderdale.

Air Quality and Permit Review:
Calderdale Valley Skip Hire Small Waste Incineration Plant

November 2021

Experts in air quality
management & assessment

Document Control

Client	[redacted]	Principal Contacts	[redacted]

Job Number	[redacted]

Report Prepared By:	[redacted]

Document Status and Review Schedule

Report No.	Date	Status	Reviewed by
[redacted]	26 November 2021	Final Report	[redacted]

Air Quality Consultants Ltd
23 Coldharbour Road, Bristol BS6 7JT Tel: 0117 974 1086
12 Airedale Road, London SW12 8SF Tel: 0208 673 4313
aqc@aqconsultants.co.uk

Registered Office: 12 St Oswalds Road, Bristol, BS6 7HT
Companies House Registration No: 2814570

Executive Summary

A review of the Environmental Permit application and associated air quality technical information for the Calder Valley Skip Hire (CVSH) Small Waste Incinerator Plant (SWIP) has been undertaken.

While no 'Major' issues have been found that, individually, are likely to significantly alter the conclusions stated by the applicant within its air quality assessments; there are areas of uncertainty with the applicant's roads modelling verification and assessment of the significance of benzo(a)pyrene emissions that, combined, could affect the conclusions of the assessment. Furthermore, additional justification is considered to be required on the suitability of the proposed stack height. As the air quality assessment is a supporting document of the permit application, these issues affect the determination of the permit and introduce uncertainty as to whether enough information has been requested by CMBC to robustly determine the application.

A number of other 'Moderate' issues have been identified, such as the absence of any assessment of the total bodily intake of polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans (collectively referred to as 'dioxins') and dioxin-like polychlorinated biphenyls (PCBs), and no assessment of impacts on local wildlife sites within 2 km in the latest air quality assessment addendum.

With regard to the Environmental Permit application itself, several areas have been identified that introduce uncertainty with respect to the ability of the plant and/or of the Operator to comply in full with the requirements of Chapter IV of the IED. However, it is expected that such issues could be resolved with further requests for information, rather than a fundamental inability of the plant to meet the requirements of IED and of the permit. Despite this, it is a requirement that all information required to determine an application is provided and the permitting authorities should not determine an application until they are satisfied they have received all relevant information. Therefore, we believe further information is required in order for the permit application to be robustly determined.

Furthermore, there are several areas (such as the transport of Air Pollution Control residues through the WTS installation boundary) where it is advised legal opinion is sought before deciding whether to pursue this as a matter for further consideration.

For ease of reading, the issues have been summarised in the table below; however, these should always be considered in context of the complete discussion points raised in the main body of the report before reaching any conclusions.

Executive Summary Table		
No.	**Issue**	**Conclusion**
Review of Air Quality Assessment		
Moderate Issues		
1	Uncertainty	Uncertainty is an inherent component of any scientific method. The uncertainty assigned to a result represents the range of values around the result in which the true value is expected to lie. The true value is a conceptual term, which can never be exactly determined. The basis for challenge three of the judicial review is that WYG's (acting as expert reviewer for Calderdale Metropolitan Borough Council) sensitivity modelling identified more than negligible impacts as being possible. This focusses on the assumption that either the background or the process contribution from the applicant's site could be greater than that reported in the assessment. The WYG report states that it is possible that moderate adverse effects may occur, but then goes on to discount these without any real justification. While we do not necessarily agree with the way WYG has undertaken its sensitivity analysis (adding arbitrary percentages to different baselines), we do agree that the potential for impacts greater then negligible cannot be immediately discounted. This is based on information provided by the applicant about the baseline and process contribution from the incinerator stack.
2	Benzo(a)pyrene	Within the 2019 additional air quality assessment, the applicant predicts a 'worst-case' Benzo(a)pyrene process contribution, i.e., that relating to emissions from the SWIP processes in isolation, of 9% of the Air Quality Standard, and predicted environmental concentration of 98.4%, i.e., the SWIP process contribution plus contributions from other emission sources. This level of impact is presented at the location of maximum impact anywhere on the modelled grid. The applicant needs to provide more information to justify that the contribution is insignificant.
3	Stack Height Determination	The applicants chosen stack height has not been demonstrated to meet the principle of BAT. The applicant has not demonstrated all pollutant contributions to nearby receptors are insignificant; the stack height should be at a height where the cost of increasing the stack becomes disproportionate to the marginal environmental benefit gained unless an insignificant process contribution can be identified at a lower stack height. This has not been demonstrated in this case.
4	Ecological Impacts	The applicant has not assessed the impacts at nearby ancient woodland and local nature reserve ecological sites within their ES addendum or their 2019 additional Air Quality Assessment. These sites are within the 2 km screening distance for assessment of ecological sites required by the Environment Agency.
5	Roads Modelling Verification and Model Adjustment	Examination of the applicant's verification analysis has shown the model to underpredict at monitoring sites SB20 and SB22 (which are located approximately 35 m from Receptor 8) and overpredict at monitoring sites SB3 and AQS4 (which are located nearly 450 m from Receptor 8). Given that Receptor 8 is close to the underpredicting sites, and is registering at or above the objective (depending on the year chosen), the methodology for the model verification, and approach to calculating the correction factor, may not be suitably precautionary.

Executive Summary Table		
No.	**Issue**	**Conclusion**
6	Assessment of 1-hour mean NO_2 Concentrations	The applicant has not undertaken an assessment against the short-term NO_2 objective using the half-hourly emissions limit within IED and their permit. Rather, the daily average emission concentration has been used for assessing hourly mean impacts. As the plant is permitted to discharge NOx at levels up to 400 mg/Nm^3 for a period of 30-minutes, there is the potential for hourly averaged emission concentrations to exceed the daily averaged emission limit that has been modelled leading to potential underestimation of hourly mean impacts.
7	Human Health Risk Assessment for Persistent Organic Pollutants	No HHRA for dioxins and furans and PCBs has been undertaken. Such an assessment addresses impacts relating to bioaccumulation in the food chain for pollutants which cannot be adequately assessed by referring to ambient air quality standards. In practice, the methods available for such an assessment are relatively crude and thus tend to be over-precautionary, but the results can still provide reassurance as to the scale of impacts. The experience of the reviewers, consistent with research and the latest position of Public Health England, is that waste incineration plant meeting the IED emission limits and with an appropriately optimised stack height, only provide negligible contributions to the TDI and the more precautionary TWI. However, in this case, due to the potential issues identified with the justification of the selected stack height, a HHRA should not just be viewed as a procedural exercise.
Minor Issues		
8	Carbon Monoxide 1-hour EAL	The applicant has not undertaken an assessment against the Carbon Monoxide 1-hour Environmental Assessment Level (EAL) of 30,000 µg/m^3. In the experience of the reviewers, carbon monoxide emissions are generally insignificant compared to the environmental standards. As there are no predicted significant effects towards the 8-hour CO objective, lack of consideration of the 1-hour EAL is unlikely to alter the conclusion of the assessment.
9	TOC Emissions	The applicant has not undertaken an assessment of the likely emissions of total organic compounds (TOC). It is a requirement within chapter IV of IED that emissions to air from waste incineration plants shall not exceed the emission limit value of 10 mg/Nm^3 for TOC; therefore, any robust assessment should consider the sites impact from TOC.
10	Surface Roughness	It is unclear why the applicant has chosen to use such a high surface roughness value within their sensitivity analysis. This has the potential to over represent the turbulence effects in the area.
Review of Permitting Application		
11	Implications of Multiple Permits on the Same Site	The proposed Calder Valley Skip Hire site consists of an existing household, commercial and industrial waste transfer station, including treatment, and the proposed Schedule 13 SWIP. The waste operations in the waste transfer station are regulated by the Environment Agency under Environmental Permit EPR/SP3196ZQ, whilst the operations of the SWIP were to be regulated by Calderdale Metropolitan Borough Council under Environmental Permit S13/005. It is not entirely unusual that multiple permits exist with different regulators on the same site.

Executive Summary Table		
No.	**Issue**	**Conclusion**
		One potential complicating factor of the proposed permitting arrangement at the site relates to the transport of Air Pollution Control residues (APCr). APCr are classed as hazardous waste principally due to their high pH content. The WTS permit does not allow the acceptance of hazardous waste. However, due to the way that the permit boundaries are defined, APCr must be transported through the WTS permitted installation boundary before it leaves the wider site. It is unclear whether the transportation of APCr through the WTS installation boundary would convey a degree of ‘acceptance’, or whether this would simply be considered the same as APCr transport on the wider road network. If this was to constitute ‘acceptance’, then the WTS would be operating outside the conditions of its permit. In any case, it would have been advisable for the Accident Management Plan for the WTS to be updated to reflect that there is the potential for hazardous waste to pass through its installation boundary. However, many of the issues raised in this section, are procedural. Consequently, such matters are best judged by a legal professional.
12	Installation Boundaries	From review of the introductory note in the Environmental Permit for the WTS permit and surrender notice, it is clear the intent was to remove (partial surrender) only the area associated with the SWIP installation from the existing WTS permit. We suspect any apparent area of unregulated land has arisen through accidental omission/interpretation of the figures, rather than specific intent, and better quality images or revised plans could resolve such matters. However, as currently drafted, it does appear there is a small area of land that is not regulated under either permit.
13	Further request for information	There are a number of issues, detailed from Paragraph 4.23 onwards, that require clarification before the robustness of the applicant’s permit application can be suitably determined. Without this further information, it cannot be robustly determined that the applicant’s operation will meet with the requirements of IED, the Environmental Permitting Regulations, or minimise harm to people and the environment.

Contents

1 Introduction

1.1 Air Quality Consultants Ltd (AQC) has been commissioned to review the Environmental Permit application and associated air quality technical information for the Calder Valley Skip Hire (CVSH) Small Waste Incinerator Plant (SWIP).

1.2 This report has been complied by reviewing the following documents:

- Schedule 13 SWIP Permit Application document and associated appendices (written by RPS);
- Schedule 13 Environmental Permit (ref. S13/005) issued by Calderdale Metropolitan Borough Council (CMBC);
- Schedule 5 notice for further information from CMBC to the permit application and the applicant's Schedule 5 response;
- CVSH Environmental Permit for the existing Waste Transfer Station (EPR/SP3196ZQ/V002) and Schedule 7 site plan;
- ES Addendum To 2017 ES Chapter 7: Air Quality (written by RPS);
- Appendix 3.1- Environmental Statement Addendum – Additional Air Quality Assessment (written by RPS); and
- Environmental Permit Application S13/005 Small Waste Incineration Plant Air Quality Considerations (written by WYG).

1.3 The site already has planning permission. An Environmental Permit to operate a Schedule 13 Small Waste Incineration Plant was granted by CMBC under the Environmental Permitting (England and Wales) Regulations 2016, as amended ('EPR'), on 9 February 2021. However, the permit was quashed by the High Court on the 17 September 2021 following an application for judicial review. Four grounds of challenge were put forward, and CMBC and CVSH consented to the permit being quashed on the basis of Ground 1 with the parties reserving their positions in relation to the other grounds:

- **Ground of Challenge 1** - The decision was unlawful because the Council erred in law in believing that, if the application was not determined on 8 February 2021, then it would be deemed to be refused. Consequently, the Council acted unlawfully, by relying on this error of law, in: (a) not having requested further information as an option and in deciding to approve the application without requesting further information; (b) deciding to use urgency to disapply the call-in procedures.
- **Ground of Challenge 2** - The Cabinet had no rational basis for failing to follow the WYG recommendation that more information be obtained on habitats and emissions, including sulphur dioxide.

- **Ground of Challenge 3** - The Council failed to have regard to relevant considerations, namely guidance in the Environmental Permitting General Guidance Manual on Policy and Procedures for A2 and B installations (GGM) on the assessment of harm. It applied a test which was not in the guidance.
- **Ground of Challenge 4** - The SWIP environmental permit and the varied waste management licence permit on most of the remainder of the site leave an unregulated area around the incinerator building. The incinerator could not therefore operate. There is also a series of activities which are part of the incinerator operation, as described in the application, which would take place in the Waste Management Licence ("WML").

1.4 The above grounds of challenge have been considered during writing of this review, with the following also considered:

- whether the air quality assessment is robust;
- whether the reported conclusions are supported by the evidence provided;
- whether the information presented is sufficient to understand the likely air quality impacts of the scheme; and
- whether the permit application is robust in its measures to protect the environment and nearby residents and is in line with the air quality assessment undertaken.

1.5 Where errors or omissions have been identified in the air quality assessment, they have been categorised as either a:

- **Major Issue** - in the opinion of the reviewer, any one individual failing would be highly likely to invalidate the reported conclusions;
- **Moderate Issue** - weaknesses have been identified which, individually, may or may not affect the conclusions; or
- **Minor Issue** - weaknesses have been identified but the professional experience of the reviewers suggests that each one, in isolation, would be unlikely to affect the conclusions of the assessment. There remains, however, the potential for multiple minor issues to combine to invalidate the reported conclusions. Minor issues have also been identified where the material presented is misleading or otherwise inappropriate to inform consultation.

1.6 A review of any material related to the construction phase and to the release of odours has not been undertaken. Both of these impacts can generally be effectively controlled by standard mitigation practices. Additionally, SWIP permits only consider operational phase emissions, not construction.

2 Competence

2.1 [redacted] is a [redacted] with AQC with over eight years' experience in the field of air quality assessment. He has been part of the Environment Agency's Air Quality Modelling and Assessment Unit (AQMAU), which is embedded within the National Permitting Service. He has thus reviewed many technical reports for large installations, including energy from waste facilities, on behalf of Central Government. He has advised Central Government whether the material submitted is sufficient for the granting of permits and has also provided a similar service for local governments. In addition, he regularly undertakes air quality assessments for AQC, covering a mixture of uses, including industrial installations, energy centres and waste facilities. He has experience using a range of dispersion models including ADMS-Roads, ADMS-5 and Breeze AERMOD to complete quantitative modelling assessments, for both planning and permitting purposes. He is a Member of the Institute of Air Quality Management and an Associate Member of the Institution of Environmental Sciences.

2.2 [redacted] is an [redacted] with AQC, with over sixteen years' experience, specialising in industrial emissions. He is a member of the Institute of Air Quality Management, has previously contributed his time to, and authored publications on behalf of, the Energy Institute's Emissions Working Group, and has acted as peer reviewer for the Journal of Air & Waste Management. His expertise includes ambient and stack emissions monitoring, emission inventory development and reporting, atmospheric dispersion modelling, abatement of air emissions, environmental permitting, Best Available Technique (BAT) assessments, cost-benefit analysis and compliance assessment. He has extensive experience in the quantification and assessment of emissions from a variety of releases, covering point source emissions, flare emissions, fugitive emissions and emissions from mobile transport sources, including marine vessels, on-road and off-road vehicles and rail locomotives. He has detailed knowledge of the technologies and techniques to reduce concentrations of combustion and non-combustion related pollutants, including oxides of nitrogen, acid gases (e.g., SO_2, HF, HCl), volatile organic compounds (VOCs), particulates, heavy metals and odour.

2.3 [redacted] is the [redacted] at Air Quality Consultants Ltd. and is thus technical lead of one of the largest specialist air quality teams in the UK. He has more than two decades of experience in air quality modelling and assessment and has been responsible for more than one thousand air quality assessments, covering a range of different types of development, including Energy from Waste facilities. He is a member of the Institution of Environmental Sciences (IES), a member of the Institute of Air Quality Management (IAQM), and a chartered scientist (CSci). He has advised Defra, the Environment Agency, the Joint Nature Conservation Committee (JNCC), Highways England, the Scottish Government, Transport Scotland, Transport for London, and numerous local authorities. He also contributed to several of the air quality guidance documents cited in the ES[1]. He currently advises the UK Government on air quality as part of its Air Quality Expert Group (AQEG). He has recently advised the UK Government on issues related to, amongst others: ultrafine airborne particles; impacts of vegetation on air pollution; air pollution from agriculture; non-exhaust emissions from road traffic; methods for assessing impacts on air quality; emissions of volatile organic compounds; impacts of greenhouse gas reduction measures on UK air quality; and the effects of COVID-19 on UK air quality[2]. His specific area of expertise within AQEG relates to air quality assessment in the development control process, including assessing the air quality impacts of proposed industrial emissions sources on ambient air quality[3].

1 i.e. Defra's Local Air Quality Management Technical Guidance, and guidance documents from the Institute of Air Quality Management (IAQM) on land-use planning and development control, and assessment of dust from demolition and construction.

2 https://uk-air.defra.gov.uk/library/aqeg/publications.

3 https://uk-air.defra.gov.uk/library/aqeg/about

3 Review of Air Quality Assessment

Summary

3.1 Following a review of the documents listed in Paragraph 1.2, no 'Major' issues have been found that are likely to significantly alter the conclusions stated by the applicant within their air quality assessments.

3.2 There are potential uncertainties with the assessment of nitrogen dioxide impacts within the nearby Air Quality Management Area (AQMA), 670 m away, that may suggest greater than *negligible* impacts are possible.

3.3 Other 'Moderate' issues identified include the assessment of the significance of benzo(a)pyrene emissions, justification for the selected stack height, the absence of any assessment of the total bodily intake of polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans (collectively referred to as 'dioxins') and dioxin-like polychlorinated biphenyls (PCBs), and no assessment of impacts on local wildlife sites within 2 km in the latest air quality assessment addendum.

Major Issues

3.4 No major issues have been identified following the review of the air quality assessment and various addenda.

Moderate Issues

Uncertainty

3.5 Uncertainty is an inherent component of any scientific method. The uncertainty assigned to a result represents the range of values around the result in which the true value is expected to lie. The true value is a conceptual term, which can never be exactly determined.

3.6 Dispersion modelling is associated with inherent uncertainties due to the attempts made within the model to replicate atmospheric turbulence, a stochastic process, using deterministic methods. Additional uncertainty arises from assumptions made by the model user in defining e.g., surface characteristics, treatment of building induced effects and treatment of terrain, and uncertainty in the model input data e.g., uncertainty in emission estimates and meteorological input data.

3.7 For some scientific tests, it is relatively straightforward to determine the level of uncertainty. However, when considering the uncertainty associated with the result from a dispersion model, this task is much more complicated, since not only is there uncertainty in the measurements and parameters input to the model, there is also uncertainty associated with imperfect knowledge or approximations made within the model itself. It can be extremely complex to quantify the uncertainty associated with each of these factors and model uncertainty is highly site specific.

3.8 Dispersion models which are used for regulatory applications in the UK are generally expected to achieve a performance of 50% of predicted hourly concentrations being within a factor of two of monitored ambient concentrations.

3.9 However, some factors may decrease the model performance, particularly as the complexity of the model domain increases. For example, the uncertainty in any particular model's prediction is likely to be greater in large, urban areas than compared to predictions made in a flat, rural location away from buildings or other obstructions impeding atmospheric flow. Conversely, other factors may improve model performance; considering the statistics of the modelled and monitored ambient concentrations, which is relevant for regulatory applications, rather than concentrations paired in time and space, increases the performance. Similarly, increasing the averaging time, for instance from hourly to 3-hourly, 24-hour and annual will generally improve the model performance.

3.10 In this case, due to the complexity of the terrain within the modelling domain, as well as monitoring data within the nearby AQMA measuring at or above the NO_2 Air Quality Standard, small levels of uncertainty have the potential to change the categorised impacts and, potentially, the conclusions of the assessment.

3.11 Because of this, the applicant has undertaken a number of sensitivity tests to understand the potential consequences of uncertainty in the modelling. The applicant has generally undertaken the sensitivity tests in accordance with best practice guidance[4] by using multiple dispersion models, multiple sites providing meteorological data, multiple years of meteorological data, assessment of calm meteorological conditions and multiple surface roughness values. While we do not agree with the applicant's surface roughness sensitivity (see Paragraph 3.36), the sensitivity analysis, overall, seems robust.

3.12 The basis for challenge three of the judicial review is that WYG's (acting as expert reviewer for CMBC) sensitivity modelling identified more than negligible impacts as being possible. This focusses on the assumption that either the background or the process contribution from the applicant's site could be greater than that reported in the assessment. The WYG report states that it is possible that moderate adverse effects may occur, but then goes on to discount these without any real justification.

3.13 While we do not necessarily agree with the way WYG have undertaken its sensitivity analysis (adding arbitrary percentages to different baselines), we do agree that the potential for impacts greater then *negligible* cannot be immediately discounted[5]. This is based on the following:

4 Defined by the Environment Agency in its *Environmental permitting: air dispersion modelling reports guidance*. https://www.gov.uk/guidance/environmental-permitting-air-dispersion-modelling-reports#carry-out-sensitivity-analysis

5 Using the impact table (Table 6.3) and methodology contained within the IAQM Land-Use Planning & Development Control: Planning For Air Quality guidance.

- taking the NO_2 value of 40 µg/m^3 measured in 2019 at diffusion tube SB22[6], 35m away from receptor 8 (Mill West), and used within the assessment to identify effects in the AQMA, compounded by the potential issue identified with the applicant's model verification (see Paragraph 3.23), it is not certain that the baseline concentration in the AQMA will be below 37.8 µg/m^3. This value acts as the point at which a 0.2 µg/m^3 (0.5%) increase from baseline conditions could be considered '*slight adverse*' under impact descriptors published by the IAQM.

- at receptor 8 (Mill West), the applicant predicts within their ES chapter addendum a process contribution of 0.09 µg/m^3 (this has been obtained using the AERMOD modelling software and meteorological ('met') data from Leeds Bradford airport). They further predict values of 0.19 µg/m^3 (ADMS, Leeds Bradford met data), 0.2 µg/m^3 (ADMS, Bingley met data), 0.2 µg/m^3 (ADMS, Leeds Bradford met data, variable surface roughness) and 0.2 µg/m^3 (ADMS, Leeds Bradford met data, calm conditions) within their 2019 Additional Air Quality Assessment. It is unclear why the applicant has focussed on results from the AERMOD run, which are lower, without providing justification, especially when the terrain module within the dispersion model appears to have the biggest impact on results. Basing the assessment solely on results from the AERMOD model would also appear contrary to the applicant's own statement in their 2019 Additional Air Quality Assessment (Paragraph F10):

  "Neither model is "better" than the other in terms of their ability to take terrain and topography into account; their algorithms simply provide alternative forecasts. Nevertheless, it could be argued that ADMS has a more sophisticated approach to processing complex terrain, in that it calculates the impacts of terrain on plume spread and allows for the impacts of hill wakes."

  We would agree that ADMS has a more sophisticated treatment of terrain effects, with previous reviews by Carruthers et al. (2011)[7] suggesting that in some situations, because of its less sophisticated treatment of terrain, AERMOD may only "*act as a screening model in this case, whereas ADMS may predict more realistic concentrations*".

- as three of the five modelled scenarios by the applicant results in an increase of 0.2 µg/m^3, coupled with the uncertainty regarding the baseline concentration within the AQMA, using impact descriptor tables within the IAQM planning guidance, it is judged that a *slight adverse* impact is feasible.

---

6 2020 data was not available at the time of writing and could not be used as representative air quality conditions due to the impacts of the Covid-19 pandemic.

7 Carruthers, D.J., Seaton, M.D., McHugh, C.A., Sheng. X., Solazzo, E and Vanvyve, E., (2011). *Comparison of the Complex Terrain Algorithms Incorporated into Two Commonly Used Local-Scale Air Pollution Dispersion Models (ADMS and AERMOD) using a Hybrid Model*. Journal of the Air & Waste Management Association, 61, 1227-1235

Benzo(a)pyrene

3.14 Within the 2019 additional air quality assessment, the applicant predicts a 'worst-case' Benzo(a)pyrene (B(a)P) process contribution (PC), i.e., that relating to emissions from the SWIP processes in isolation, of 9% of the Air Quality Standard (AQS), and predicted environmental concentration (PEC) of 98.4%, i.e., the SWIP process contribution plus contributions from other emission sources. This level of impact is presented at the location of maximum impact anywhere on the modelled grid.

3.15 This prediction is based on an emission concentration of 1 μg/m^3 derived from typical emissions data of B(a)P in the 2006 Waste Incineration BAT Reference (BREF) document. In December 2019, an update to the 2006 BREF was introduced that confirmed B(a)P emissions from 48 reference lines incinerating predominantly municipal wastes ranged from 0.004 ng/Nm^3 to 1 μg/m^3. In that respect, the assumed emission concentration for B(a)P can be viewed as precautionary. However, in combination with the previous discussion on model uncertainty, as the PEC approaches 100% and no evidence is presented about level of significance of this level of impact, it is not considered possible to definitively conclude no significant effects based on the data presented. In particular, the average B(a)P concentration at the Leeds Millshaw monitoring site between 2014 and 2017 has been used to define baseline concentrations, rather than the maximum. The maximum annual mean concentration during this period exceeds the objective.

3.16 However, it is important to recognise that this prediction is made based on the maximum predicted value at any location in the model domain. AQS apply only where there is 'relevant exposure' and, for the purpose of assessing compliance with the B(a)P objective, which is expressed as an annual mean assessment metric, relevant exposure only occurs at e.g., residential properties and schools. It is expected that model predictions at the specific human receptors considered in the assessment would be lower than the maximum predicted value, and could possibly be at a level where no significant effect could be concluded. However, this should be confirmed by the applicant by providing tabulated data for each specified receptor location where there is relevant exposure.

Stack Height Determination

3.17 Appendix D of the 2019 Additional Air Quality Assessment details how the requirement for a 12 m stack was determined. However, this analysis (in Graph D1) shows that the air quality impacts would be appreciably smaller if a taller stack were chosen, even when the stack is increased by just a few metres. A cursory examination of these graphs shows that 12 m does not represent a point at which further height increases have diminishing returns in terms of reduction in the predicted ground level concentration. In practice, the justification for a 12 m stack appears to be that most impacts can, with this stack height, be described as '*negligible*'. However, as identified previously, there are valid reasons to suggest impacts could be greater than negligible.

3.18 The Environment Agency has produced internal draft stack height assessment guidance with a particular emphasis on incineration plants[8]. This guidance has previously been provided by the Environment Agency to the reviewers as an example of a methodology it would accept for determining the minimum required stack height for incineration plants.

3.19 The guidance clarifies that the stack height, according with the principles of Best Available Technique (BAT), can be defined as the 'knee-point' of a graph plotting the reduction in process contribution as a function of increasing stack height (the method actually uses stack costs, but stack height is often used as a proxy for cost). Figure 1 provides an example figure depicting the knee-point (blue arrow) from this guidance document.

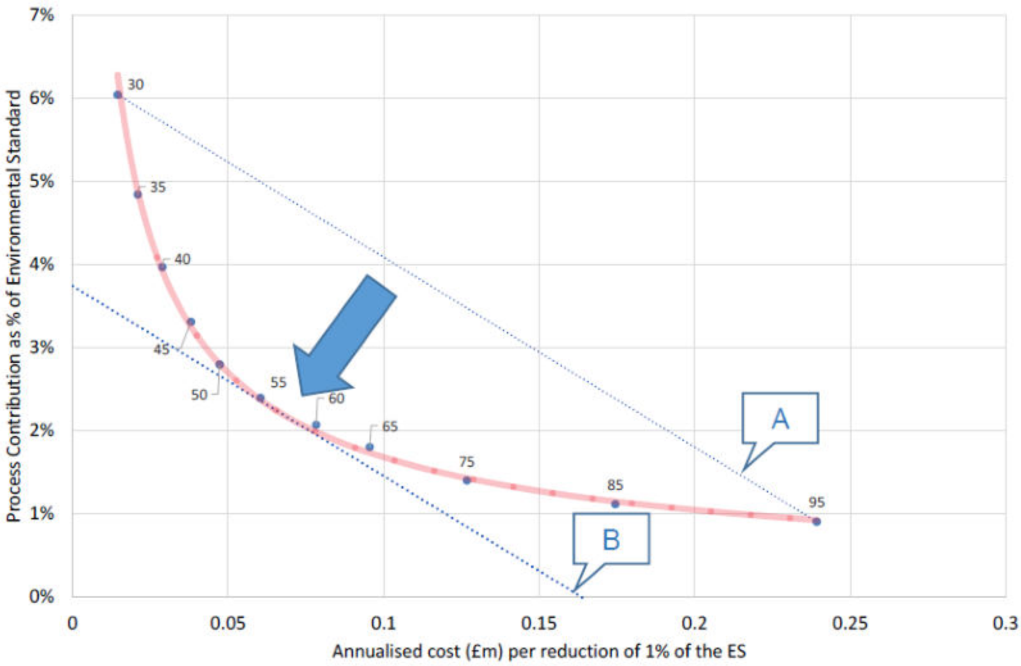


Figure 1: Visual depiction of the 'knee-point' on a stack height assessment graph

3.20 The Environment Agency guidance clarifies that where an impact is defined as 'insignificant' for a particular stack height, i.e., where long-term process contributions are less than 1% of the relevant AQS, or where short-term process contributions are less than 10% of the AQS, further increases in stack height are not necessary as it follows that any further reduction in impact will also be insignificant.

3.21 Hence, it is possible for the BAT stack height to occur before the knee-point. Where this is the case, the shorter stack height would be considered BAT. For this particular plant, it is evident that the selected stack height of 12 m occurs before the knee-point. However, process contributions at 12 m

8 Environment Agency, 2017. EPR Permit – Stack Height Assessment. Environment Agency Internal Guidance (draft) V0.5 November 2017

for several pollutants cannot be defined as insignificant[9]. Consequently, the applicant has failed to demonstrate that a stack height corresponding to the principle of BAT[10] has been selected, and further justification should be provided.

Ecological impacts

3.22 The applicant has not assessed the impacts at nearby ancient woodland and local nature reserve ecological sites within their ES addendum or their 2019 additional Air Quality Assessment. These sites are within the 2 km screening distance for assessment of ecological sites required by the Environment Agency. This assessment has been undertaken for the original 2017 ES chapter; however, this assessment is not considered fully robust as it is not clear if ammonia and hydrogen fluoride emissions have been accounted for when considering the impacts of nutrient nitrogen and acid deposition.

Roads Modelling Verification and Model Adjustment

3.23 We are satisfied that the applicant's use of 28 $\mu g/m^3$ as a background NO_2 concentration is likely to be appropriate due to its location within the study area and its designation as an urban background site. The applicant has further undertaken roads modelling to determine the local baseline exposure at each chosen receptor.

3.24 In accordance with best practice guidance, the applicant has sought to verify the predictions from its road traffic emissions model by comparison with monitoring data. The applicant has applied a correction factor of 1.0704 to their modelled road-NOx concentration before converting to NO_2. Examination of the applicant's verification analysis has shown the model to underpredict at monitoring sites SB20 and SB22 (which are located approximately 35 m from Receptor 8) and overpredict at monitoring sites SB3 and AQS4 (which are located nearly 450 m from Receptor 8). Given that Receptor 8 is close to the underpredicting sites, and is registering at or above the objective (depending on the year chosen), the methodology for the model verification, and approach to calculating the correction factor, may not be suitably precautionary.

3.25 Given the issues previously discussed with respect to model uncertainty and the proximity of the predicted impacts to the annual mean NO_2 objective, it is deemed more appropriate to use a location-specific model adjustment factor for receptors within or in close proximity to the AQMA. This is because monitoring sites SB20 and SB22 clearly provide a better representation of air quality conditions where NO_2 concentrations of 0.2 $\mu g/m^3$ (0.5%) are predicted. The effect of this would be

---

9 This refers to the Environment Agency criteria for insignificance (stated within their online guidance page: https://www.gov.uk/guidance/air-emissions-risk-assessment-for-your-environmental-permit), which is used within internal EA guidance documents to assist in the determination of stack height suitability.

10 Refers to the principle of BAT rather than any specific BAT conclusions (BATc) contained with the BREF documents, which only apply to Part A1 installations, or other BAT requirements in Process Guidance Notes which only apply to Part B installations.

to increase model predictions within and in close proximity to the AQMA. This might, in turn, result in a different classification of impact descriptors as previously discussed.

Assessment of 1-hour mean NO_2 Concentrations

3.26 Annex VI of the Industrial Emissions Directive (IED) provides two sets of emission limit values applicable to waste incineration plant (including SWIP). These are defined as a daily average emission limit and a 100th percentile 30-minute mean emission limit. For emissions of NO_x, the daily average emission limit is 200 mg/Nm^3 and the 30-minute mean emission limit is 400 mg/Nm^3. Both sets of limits were included in the permit that was initially granted for the plant.

3.27 The applicant has not undertaken an assessment against the short-term NO_2 objective using the half-hourly emissions limit within IED and the permit. Rather, the daily average emission concentration has been used for assessing hourly mean impacts. As the plant is permitted to discharge NO_x at levels up to 400 mg/Nm^3 for a period of 30-minutes, there is the potential for hourly averaged emission concentrations to exceed the daily averaged emission limit that has been modelled leading to potential underestimation of hourly mean impacts.

3.28 Similar findings are concluded with respect to e.g., the approach to assessing short-term SO_2 impacts.

Human Health Risk Assessment for Persistent Organic Pollutants

3.29 Dioxins and dioxin-like PCBs are a class of compounds known as Persistent Organic Pollutants (POPs). Whilst generally present at low levels in environmental media i.e., in air, water and soil, due to their persistence in the environment and bioaccumulative nature i.e., the rate of intake of these compounds by an organism exceeds the rate of excretion, dioxins and dioxin-like PCBs can become concentrated in the food chain, particularly in fatty foods such as milk and milk products, and in certain meats and fish.

3.30 As the majority of human exposure to this group of compounds is through ingestion, rather than inhalation, no air quality standards or other ambient air quality guidelines exist. Consequently, it is generally a requirement that any installation discharging these compounds undertake a human health risk assessment (HHRA) that considers exposure through all pathways, i.e., through both inhalation and ingestion, to estimate the total bodily uptake of dioxin and dioxin-like PCBs as a result of installation activities, and compare such predictions against the tolerable daily intake (TDI) established by the Food Standards Agency’s Committee on Toxicity of Chemicals in Food, Consumer Products and the Environment (COT) and the tolerable weekly intake (TWI) established by the European Food Standards Agency.

3.31 No HHRA for dioxins and furans and PCBs has been undertaken. Such an assessment addresses impacts relating to bioaccumulation in the food chain for pollutants which cannot be adequately assessed by referring to ambient air quality standards.

3.32 In practice, the methods available for such an assessment are relatively crude and thus tend to be over-precautionary, but the results can still provide reassurance as to the scale of impacts. The experience of the reviewers, consistent with research and the latest position of Public Health England, is that waste incineration plant meeting the IED emission limits and with an appropriately optimised stack height, only provide negligible contributions to the TDI and the more precautionary TWI. However, in this case, due to the potential issues identified with the justification of the selected stack height, a HHRA should not just be viewed as a procedural exercise.

Minor Issues

Carbon Monoxide 1-hour EAL

3.33 The applicant has not undertaken an assessment against the Carbon Monoxide (CO) 1-hour Environmental Assessment Level (EAL) of 30,000 $\mu g/m^3$. In the experience of the reviewers, carbon monoxide emissions are generally insignificant compared to the environmental standards. As there are no predicted significant effects towards the 8-hour CO objective, lack of consideration of the 1-hour EAL is unlikely to alter the conclusion of the assessment.

TOC Emissions

3.34 The applicant has not undertaken an assessment of the likely emissions of total organic compounds (TOC). It is a requirement within chapter IV of IED that emissions to air from waste incineration plants shall not exceed the emission limit value of 10 mg/Nm^3 for TOC; therefore, any robust assessment should consider the sites impact from TOC.

3.35 As the exact speciation, or composition, of TOC cannot be known, best practice guidance by the Environment Agency suggests comparing TOC impacts against the benzene AQS. Such an assessment was undertaken within the original 2017 ES chapter in respect to the annual mean benzene AQS. The Environment Agency has recently introduced a 24-hour mean benzene environmental assessment level (EAL) of 30 $\mu g/m^3$ which should be assessed against for completeness. However, it is accepted that the air quality assessment was produced before the publication of this new EAL.

Surface Roughness

3.36 It is unclear why the applicant has chosen to use such a high surface roughness value within its sensitivity analysis. The applicant has used a value of 1.0 m (which the ADMS user guide suggests represents cities and woodlands) within their main modelling run. As there is an area of woodland surrounding the site, this is deemed suitable. It is unclear why the applicant, within their sensitivity analysis, has created a variable surface roughness file and used a value of 1.5 m (which the ADMS user guide suggests represents large urban areas) for the nearby woodland. In conjunction with using a value of 1.0 m for the rest of the modelling domain, where the majority of the land is judged representative of a suburban area/small town, where a value of 0.5 m is deemed more appropriate, this has the potential to over represent the turbulence effects in the area.

4 Review of the Environmental Permit and Application

Scope of the Review

4.1 The review of the Environmental Permit and associated application documentation has been performed based on the review team's experience of delivering permit applications for similar facilities and taking into account guidance produced by Defra and the Environment Agency. However, where aspects relate to the interpretation of legislation, the opinion of a legal professional is recommended. AQC does not have the experience or capability to comment on matters concerning legal interpretation.

Summary

4.2 Following a review of the documents supporting the permit application for the SWIP installation, and the Environmental Permit itself, several areas have been identified that introduce uncertainty with respect to the ability of the plant and/or of the Operator to comply in full with the requirements of Chapter IV of the IED. However, it is expected that such issues could be resolved with further requests for information, rather than a fundamental inability of the plant to meet the requirements of IED and of the permit. **Despite this, it is a requirement that all information required to determine an application is provided and the permitting authorities should not determine an application until they are satisfied they have received all relevant information. Consequently, this additional information should have been requested to provide confidence that these conditions can be met and, on that basis, we are in agreement that the first Ground for Challenge is robust**.

4.3 In respect to the fourth Ground for Challenge, a view on this is complicated by the uncertainty in the extents of the installation boundaries for the SWIP permit and the separate waste operations permit. This uncertainty results from the poor image definition of the boundary in the respective installation boundary figures. From review of the introductory note in the Environmental Permit for the other on-site waste operations and surrender notice, it is clear the intent was to remove (partial surrender) only the area associated with the SWIP installation. However, it does appear that there is a small area of land not covered by either permit. We suspect this has arisen through accidental omission, or poor definition of the images, rather than intent, and better quality images could resolve such matters.

4.4 Potential procedural issues have been identified relating to the transport of Air Pollution Control residues through the installation boundary of the adjacent waste transfer station and whether this conveys a degree of acceptance. If such an action did imply acceptance, the waste transfer station would be operating outside of the conditions of its permit, which only allows the acceptance of non-hazardous waste. This is an area where it is strongly advised legal opinion is sought before deciding whether to pursue this as a matter for further consideration.

Permitting Context

4.5 Incineration plants accepting non-hazardous waste and incinerating that waste at a rate less than 3 tonnes per hour are regulated under Schedule 13 of the EPR as SWIP. This requires the plant to comply with certain requirements of IED, including the Chapter IV Special Provisions for Waste Incineration Plants and Waste Co-Incineration Plants[11] and, unless excluded under Article 44, hold a permit to operate that reflects these requirements. As clarified in the Environment Agency's *Environmental permitting guidance: waste incineration*, permits for SWIP are issued by the local authority.

4.6 SWIP are not required to meet the Best Available Technique Conclusions (BATc) for waste incineration as defined by the European Commission; these only apply to incineration plant incinerating waste at a rate greater than 3 tonnes per hour. Additionally, unless the SWIP also meets the definition of a 'Part B' process under Schedule 1, Section 5.1 of the EPR, it does not need to meet the BAT requirements in Defra's Process Guidance Notes. The SWIP at this installation does not meet the definition of a Part B listed activity and, consequently, BAT requirements do not apply.

4.7 It is possible for a permit to cover more than one regulated facility. However, Defra's *Environmental Permitting: Core Guidance* explains this is generally only possible where the regulator is the same for each facility, the operator is the same for each facility, and all the facilities are on the same site. In that sense, the guidance explains that a single environmental permit cannot cover regulated facilities with different regulators, i.e., a single permit cannot generally be granted that covers activities usually regulated separately by the Environment Agency and the local authority.

4.8 However, the guidance also explains that powers are available by an appropriate authority under Regulation 33 of the EPR to direct an Agency or the local authority to assume the functions of the other if this leads to simpler regulation. Where this direction does occur, the aim is to allocate responsibility to the Regulator of the major activity on-site.

4.9 There is no formal guidance that defines the extents of a Schedule 13 SWIP process. The limits of the specified activity are generally taken to be consistent with those defined in permits for larger waste incineration installations e.g., operation of the furnace, boilers and auxiliary burners; facilities for the treatment of exhaust gases; facilities for the receipt, storage and handling of incoming wastes and raw materials (including fuels); facilities for the storage and disposal of surface water and waste process water; facilities for the storage of residues pending off-site disposal/recovery; and facilities for the generation of electricity to be consumed on-site or exported to the Grid.

[11] With the exception of some sub-articles relating to provisions for the categories of waste to be included in the permit which can be co-incinerated in certain categories of waste co-incineration plants, requirements for continuous monitoring of dioxins and heavy metals, and certain communications to the Commission.

Implications of Multiple Permits on the Same Site

4.10 The proposed CVSH site consists of an existing household, commercial and industrial waste transfer station (WTS), including treatment, and the proposed Schedule 13 SWIP. The waste operations in the WTS are regulated by the Environment Agency under Environmental Permit EPR/SP3196ZQ, whilst the operations of the SWIP were to be regulated by CMBC under Environmental Permit S13/005.

4.11 As identified in paragraph 4.7, whilst it is possible for a single permit to cover more than one regulated facility, this is generally not the case where the permit would cover regulated facilities with different regulators unless the Secretary of State confers powers on one regulator to assume the responsibilities of the other. In Defra's *General Guidance Manual on Policy Procedures for A2 and B Installations*, it additionally states:

"*Where several activities from different Parts of Schedule 1 are carried out in or as part of the same installation, the installation will be permitted according to what can be described as the "highest common denominator" (Schedule 1, Part 1, paragraph 2 to the EP regulations). So if Part A1, A2 and B activities were carried out at an installation, it would be permitted as an A1 installation and therefore by the Environment Agency*."

4.12 Like Schedule 13 SWIP facilities, Part B installations are regulated by local authorities. The above guidance suggests it is possible in some circumstances for the Environment Agency to assume the responsibility for regulating installations from the local authority. However, neither the WTS, nor the SWIP are a Part A1, A2 or B installation.

4.13 In that respect, it is not entirely unusual that multiple permits exist with different regulators on the same site.

4.14 In terms of the interlinked nature between the two permits and the ability of each to control operations across the site as a whole, it is necessary first to define the boundary and type of operations covered by each regulated facility.

4.15 The SWIP takes pre-sorted RDF from the WTS. This pre-sorting is a physical treatment activity and the provisions for this activity are covered by Table S1.1 of the WTS environmental permit (*physical treatment including manual and mechanical sorting/separation, screening, shredding, crushing, compaction or drying of non-hazardous waste for disposal (no more than 50 tonnes per day) or recovery*). Temporary storage of the RDF is also accounted for by the R13 and D15 description in Table S1.1 (dependent on whether the RDF is sent for disposal or recovery).

4.16 The SWIP permit limits the type of waste that can be accepted within the SWIP installation to RDF (EWC waste code 19 12 10) and further details that only RDF from the adjacent WTS is to be accepted. Whilst it is clear that the SWIP could not operate without the WTS under these restrictions, there is no requirement from the permitting perspective for the SWIP permit to cover procedures for the acceptance, storage and treatment of the incoming household, commercial and industrial waste to the wider site as these provisions are already made in another operating permit. To introduce such controls in the SWIP permit would lead to double regulation. This is no different in practice to a standalone SWIP taking RDF from an off-site facility, i.e., the SWIP would not be expected to introduce controls that lead to the formulation of RDF at another off-site facility. From the perspective of the SWIP permit, the incoming waste is the RDF, not the household, commercial and industrial waste.

4.17 There is a similar argument to make for the handling of bottom ash residues from the SWIP if the WTS was to temporarily store bottom ash. Condition 6.1 of the SWIP permit requires that, where appropriate, residues are recycled, directly in the plant or outside. The WTS effectively acts as an interim storage facility for ash residues prior to recycling. The WTS permit allows the acceptance of bottom ash through the inclusion of EWC code 19 01 12 in its permit and temporary storage of bottom ash pending off-site recycling would be covered by the R13 description in Table S1.1.

4.18 There is precedent for this permitting approach at larger integrated waste management facilities in the UK where, within the same wider site, a WTS provides pre-sorted/treated waste to an incineration plant, and the WTS handles ash residues from the incineration plant, but with the WTS and incineration plant operating under different permits. The one differentiating factor in these instances is that the incineration plant is much larger, so regulated as a Part A1 installation by the Environment Agency i.e., there is a common regulator.

4.19 However, one potential complicating factor of the proposed permitting arrangement at the site relates to the transport of Air Pollution Control residues (APCr). APCr are classed as hazardous waste principally due to their high pH content. The WTS permit does not allow the acceptance of hazardous waste. However, due to the way that the permit boundaries are defined, APCr must be transported through the WTS permitted installation boundary before it leaves the wider site. It is unclear whether the transportation of APCr through the WTS installation boundary would convey a degree of 'acceptance', or whether this would simply be considered the same as APCr transport on the wider road network. If this was to constitute 'acceptance', then the WTS would be operating outwith the conditions of its permit. In any case, it would have been advisable for the Accident Management Plan for the WTS to be updated to reflect that there is the potential for hazardous waste to pass through its installation boundary.

4.20 The above issue, and indeed many of the issues raised in this section, are procedural. Consequently, such matters are best judged by a legal professional.

Installation Boundaries

4.21 It does appear from initial inspection of the respective installation boundary figures that there could be a small area of land not covered by either permit. However, such an analysis is complicated by the quality/resolution of the images that depict the respective installation boundaries, the different base mapping used and the absence of a scale on the installation boundary in the SWIP permit. As such, it is difficult to identify the potential implications.

4.22 From review of the introductory note in the Environmental Permit for the WTS permit and surrender notice, it is clear the intent was to remove (partial surrender) only the area associated with the SWIP installation from the existing WTS permit. We suspect any apparent area of unregulated land has arisen through accidental omission/interpretation of the figures, rather than specific intent, and better quality images or revised plans could resolve such matters.

Further information requirements

4.23 The following aspects represent additional information which, in the opinion of AQC based on its experience preparing permit applications for similar facilities, should have been provided to enable CMBC to be able to robustly determine the permit application. **Without this information, or without the requirement to supply this information in a pre-operational condition, the permit should not have been determined.**

Waste Acceptance

4.24 Article 52(1) of IED requires Operators of incineration plant to "*take all necessary precautions concerning the delivery and reception of waste in order to prevent or to limit as far as practicable the pollution of air, soil, surface water and groundwater as well as other negative effects on the environment, odours and noise, and direct risks to human health*."

4.25 RDF produced from the adjacent WTS will be delivered to the SWIP building using a front loader and loaded directly into the hopper of the SWIP or temporarily stored within a bunker in the SWIP building. However, other than a general reference to storing materials on a concrete floor that will be maintained, no detailed information has been provided of the measures to prevent loss of containment from the waste bunker and consequent fugitive discharges to land and groundwater. For example, the British Standard to which concrete would be constructed and its tightness class has not been specified. These details are typically requested by the Environment Agency when determining applications for Part A1 waste incineration plant.

4.26 Additionally, no details are provided on any waste acceptance procedures to confirm that the waste received within the SWIP installation boundary is compliant with the conditions of the permit. Whilst the potential risk of receiving non-compliant or off-specification waste will be minimised from the pre-sorting in the WTS, the potential risk of non-compliant wastes entering the SWIP installation boundary cannot be totally discounted. Loading waste directly into the hopper minimises the potential for non-compliant wastes to be identified and removed. Without acceptance measures in place at the SWIP, the SWIP is effectively outsourcing its responsibilities for waste acceptance to the WTS, but the WTS is not covered by this article of IED.

4.27 No details are provided for the location and design measures for a quarantine area for temporarily storing non-compliant waste. Additionally, no details are provided as to how waste arriving at the SWIP will be weighed to ensure it remains compliant with the permitted annual waste throughput, and that the feed rate does not exceed two tonnes per hour. There is, however, a condition in the permit that requires the mass of each type of waste to be determined prior to accepting the waste on-site. If the incoming waste was not weighed, the Operator would be non-compliant with the conditions of the permit and could be subject to enforcement action.

Operational Envelope and Validation of Combustion Conditions

4.28 Natural variation in the composition of waste, in particular its calorific value (CV), can affect the ability of an incineration plant to control combustion. All incinerators have an operational envelope defined by the calorific value of the waste and the waste throughput. In practice, the safe operation of incinerators, particularly those recovering energy, is governed by the thermal input, which is a product of the CV and waste throughput. When the CV is low, it is possible for a higher amount of waste throughput. Conversely, when the CV is high, the waste throughput has to be restricted to maintain a constant thermal input.

4.29 It is common to provide a firing diagram with an application for an incineration plant that identifies the calorific value and waste throughput range over which stable combustion conditions can be maintained. Although RDF is a relatively homogeneous waste stream, certainly compared to municipal waste, natural variations in CV will occur due to the variation in the fractional composition of individual components making up the RDF. No firing diagram has been provided with the application, nor has any information been provided to demonstrate that the plant can operate within the expected range of variation in RDF CV.

4.30 Information on the typical composition of RDF from various literature sources are cited in the Schedule 5 response. This information would have been a suitable proxy if the plant was accepting RDF from a variety of sources. However, the SWIP is limited to accepting RDF produced exclusively in the WTS. As such, it would have been appropriate to request that further information be provided on the composition of RDF obtained from the CVSH WTS, rather than relying on literature values.

4.31 Article 50(2) of IED requires that incineration plants "*…shall be designed, equipped, built and operated in such a way that the gas resulting from the incineration of waste is raised, after the last injection of combustion air, in a controlled and homogeneous fashion and even under the most unfavourable conditions, to a temperature of at least 850 °C for at least two seconds*". The applicant has provided an email which displays the output of a Computational Fluid Dynamics (CFD) model that demonstrates this condition is just met for the specific SWIP to be installed (minimum 2.03 s residence time).

4.32 However, other than an image providing the fluid trajectories and temperature, the email provides no information on the specific method used to develop these calculations, nor does it clarify under which operating conditions, in terms of waste throughput and CV, the predictions are valid for. There can be no certainty, based on the information provided, that the CFD modelling has been based on the most unfavourable conditions under which the SWIP can operate.

4.33 There is a condition (Condition 5.8) that requires the Operator to verify the minimum residence time and temperature requirements using actual measurements within one month of the plant being commissioned. However, the purpose of providing theoretical calculations of these parameters at permit application stage is to demonstrate the plant at least has the ***potential*** of meeting the minimum requirements of Article 50(2).

Accidents and Incidents

4.34 Article 46(5) of IED requires that incineration plant should be designed to prevent the unauthorised and accidental release of any polluting substances into soil, surface water and groundwater. Accidents and incidents are discussed very briefly in Section 5.4 of the permit application. Section 5.4.3 states that an Accident Management Plan has been developed as part of the Environmental Management System for the existing WTS and this will be updated to include aspects associated with the operation of the SWIP. However, beyond that, no details are provided of the potential accident scenarios associated with the operation of the SWIP and an assessment of their environmental risk, nor is there any pre-operational condition that would require the Operator to make available inspection of the updated procedures prior to commissioning of the facility.

4.35 Condition 7.1(2) of the permit requires the Operator to take steps set out in the document 'Accident Management Plan' to limit the environmental consequences and to prevent further accidents or incidents. However, based on information provided to AQC, an update to the Accident Management Plan does not appear to have taken place. As the Competent Authority for Schedule 13 SWIP, it is incumbent of CMBC to review such procedures prior to waste being accepted within the SWIP installation boundary. Risks associated with the current operation of the WTS are materially different to those associated with the operation of the SWIP, and the existing Accident Management Plan cannot be relied upon to adequately mitigate the risks of accidents associated with the SWIP.

4.36 Furthermore, no information has been provided on any fire detection and suppression systems installed within the SWIP building, nor has a formal Fire Prevention Plan (FPP) been produced. The Environment Agency's *Fire prevention plans: environmental permits* guidance clarifies that its Fire Prevention Plan guidance "… *applies to operators that accept* ***any*** *amount of combustible waste*." (emphasis added). Paragraph 2.1.6 in the Schedule 5 response seems to suggest the Operator will rely on the FPP established for the existing WTS for controlling fires at the SWIP. However, this FPP is not considered valid for the SWIP as, whilst it refers to combustible RDF, the SWIP introduces e.g., new potential ignition sources, new operations, and does not explicitly define how fires will be controlled within the SWIP building in response to the change of operations. It would have been advisable that a bespoke FPP for the SWIP was produced.

4.37 Provision of an adequate FPP is not necessarily a minimum requirement for determining a permit application, particularly where a design is still in development. However, where a FPP is not provided with the application, there should at least be a pre-operational condition in place that requires a FPP to be provided for inspection prior to waste being accepted within the installation boundary.

Fugitive Emissions to Land and Groundwater

4.38 As identified above, IED requires the Operator implement measures to prevent the unauthorised release of polluting substances to land and groundwater. In addition to the incoming waste and residues, other polluting substances stored within the SWIP installation boundary include urea for NO_x control and gas oil for start-up and temperature safeguarding.

4.39 No information has been provided in the application of measures in place to contain leaks, spillages or catastrophic failure of the urea and gas oil storage tanks. Consequently, the potential risk of fugitive emissions to land and groundwater is unquantified.

4.40 Best practice guidance for containment systems for the prevention of pollution are described in CIRIA C736. No reference is made in the application to this guidance, or indeed to any other best practice guidance for containment systems to prevent fugitive emissions to land and groundwater.

IN THE MATTER OF AN APPEAL BY CALDER VALLEY SKIP HIRE LIMITED AGAINST THE REFUSAL OF CALDERDALE METROPOLITAN BOROUGH COUNCIL TO GRANT AN ENVIRONMENTAL PERMIT FOR THE OPERATION OF A SMALL WASTE INCINERATION PLANT

AND IN THE MATTER OF LAND AT BELMONT INDUSTRIAL ESTATE, ROCHDALE ROAD, SOWERBY BRIDGE, WEST YORKSHIRE, HX6 3LL

ADVICE

1. I am instructed to advise [redacted] on the relevance of a planning appeal decision to the determination of an environmental permit appeal.

Background

2. The application site is Calder Valley Skip Hire, Belmont Industrial Estate, Rochdale Road, Sowerby Bridge. Despite its name, it is a small, single occupier site at the bottom of the steep sided valley[1] of the River Ryburn. On the north western side of the valley are the residential areas of Sowerby and Sowerby Bridge.

3. On 4th February 2020 a planning Inspector granted permission on appeal for:

> "construction of external flue, and change of use of existing building from recycling use (B2) to heat and energy recovery process (sui generis) and introduction of mechanical drying of inert soils and aggregates (B2) adjacent to the existing recycling shed together with the installation in underground ducts of pipes connecting the energy recovery plant in the said building to the dryer"

4. He also granted planning permission for:

> "Recycling centre with indoor sorting shed and widening of access from Rochdale Road (as amended) without complying with conditions attached to planning permission Ref. 04/02712/FUL"

5. This permission altered hours of operation and lifted a prohibition on burning.

---

[1] A description applied in the 2020 Planning Appeal Decision, para 25.

6. The decision followed an eight day inquiry. Having considered air quality in detail at paragraphs 22 to 64, the Inspector concluded that 'the effect of the proposal on living conditions in the local area, with particular reference to air quality, would be acceptable' (para 64). He said that the lack of material harm would be ensured by 'a combination of the imposition of planning conditions, which I deal with below, and the regulatory controls likely to the associated with the required Environmental Permit' (para 57, 61).

7. Calder Valley Skip Hire Limited ("CVSH") applied for an environmental permit for the incinerator in August 2020. The application was considered by Calderdale Council's Cabinet on 8th February 2021 who resolved to approve it. The permit was issued on 10th February 2021.

8. [redacted] then brought judicial review proceedings against the grant of the permit. The claimant's statement of facts and grounds noted:

> "61. CVSH take points which are not part of the Council's reasoning and assert erroneously (i) that air quality is not a matter for environmental permitting (when it is the purpose of environmental permitting) and (ii) that the view of a Planning Inspector on planning merits amounts to an issue estoppel. Issue estoppel can only arise in public law decisions which are determinative of an issue, such as the legal grounds in a planning enforcement notice appeal, rather than exercises of discretion or judgments as to future circumstances."

9. The Council and CVSH resisted the proceedings. Ground 3 concerned regard to environmental permitting guidance. CVSH contended that because of the Planning Inspector's decision 'It would have been unlawful for the Council to seek to refuse the permit on the basis that the proposal would have an impact which was more than negligible' (Summary Grounds, para 29). To do so would have been 'a flagrant disregard' of what is now paragraph 188 of the National Planning Policy Framework (Summary Grounds, para 29).

10. Paragraph 188 of the NPPF reads:

> "The focus of planning policies and decisions should be on whether proposed development is an acceptable use of land, rather than the control of processes or emissions (where these are subject to separate pollution control regimes). Planning decisions should assume that these regimes will operate effectively. Equally, where

a planning decision has been made on a particular development, the planning issues should not be revisited through the permitting regimes operated by pollution control authorities."

11. Permission to apply for judicial review was granted by [redacted] on all grounds on 23rd July 2021. The Council and CVSH subsequently agreed to the quashing of the environmental permit on the ground that the Council had erroneously believed that the permit application had to be determined on 8th February 2021. The parties' positions on the other grounds were reserved.

12. CVSH have subsequently appealed against the non-determination of the permit application. Their Statement of Case makes extensive reference to the planning appeal decision. At paragraphs 22 to 24 they say:

"22. Paragraph 188 of the NPPF, 2021 explains concisely the different roles played respectively by the planning regime and the environmental permitting regime. Applying that advice when air quality has been made an important planning issue, the planning regime decides whether the proposed development is an acceptable use of land taking into account air quality impacts and in doing so making the assumption that the environmental permitting regime will operate effectively. By contrast, the permitting regime is concerned with the control of processes and/or emissions, in this case the control of the processes of the SWIP and the control of emissions from the stack arising from combustion within the SWIP. It is submitted that because the two regimes have different roles to play, paragraph 188 goes on to state that where a planning decision has been made on a particular development the planning issues should not be re-visited through the permitting regimes operated by pollution control authorities.

23. The practical application of that advice in this case appears clearly from paragraphs 57 and 61 of the Appeal Decisions in which the Inspector, having made his findings on air quality, sets out his conclusions on the effect on air quality of the development and in concluding that it would not materially harm the health and safety of users of the nearby Air Quality Management Area (AQMA2) and the site and its surroundings and the quality and enjoyment of the environment there he stated that it would be possible to ensure that that remained the case through a combination of the planning conditions and the regulatory controls likely to be

associated with the required environmental permit. Accordingly, it is submitted that in determining the permit application the focus should be the setting of the regulatory controls in and by the environmental permit and should not be an attempt to re-visit any of the air quality planning issues which the Inspector decided.

24. Notwithstanding that the Appellant has made submissions to that effect to the Council on a number of occasions and that principle was accepted by the Council's Cabinet when resolving to grant the permit on 8 February 2021 the purported request for further information made by the Council 14 months later on 21 April 2022 seeks to re-visit two of the air quality planning issues, namely, short-term NO2 concentrations and uncertainty, directly contrary to the advice in paragraph 188 of the NPPF, 2021."

13. The Statement of Case does then discuss the information available and the merits of the application. It also says at paragraph 33:

"The Appellant reserves its right to rely upon issue estoppel and related principles of law should the need arise in this appeal to do so."

14. In its Statement of Case the Council concedes that the appeal should be allowed (para 54). Having referred to the NPPF para 188, the Council said (para 40):

"in short, the planning system decides whether the development is an acceptable use of land taking into account air quality impacts. It does so by assuming that the environmental permitting regime will operate effectively."

15. Its position is:

"The Council is advised that following the grant of planning permission for the SWIP and subject to ensuring that the relevant provisions of the Industrial Emissions Directive set out in Schedule 13 to EPR 2016 are satisfied and controlled by permit conditions, the Appellant is entitled to the grant of an environmental permit"

Assessment

16. The principles to be applied to decision making when there are one or more consent regimes governing the site or activity are:

(i) Each consent should be determined in accordance with the criteria relevant to that regime;

(ii) There may be overlaps between regimes: some factors may be considerations under two or more regimes;[2]

(iii) Absent legislation cutting down the scope of one regime in the event of an overlap, a determination under one regime does not prevent the same factors from being considered again but from the perspective of the other regulatory regime;

(iv) The existence of another regime may be relevant to decision making.[3] For example, a planning authority can take into account that an activity will be subject to environmental permitting when determining a planning application;[4]

(v) A regulator may proceed on the basis that other regulatory regimes will be operating effectively;

(vi) However, a regulator is not obliged to assume the existence of another regime will render the impacts addressed by that regime immaterial to its own decisions;[5]

(vii) It does not follow that the grant of the first consent will mean that consent should be granted under the other regulatory regime;[6]

(viii) A decision by regulator A and its findings or reasoning may be relevant to decision making by regulator B. To what extent it is relevant will be affected by:

(a) To what extent the regulators are applying the same criteria, including legislative tests or policy;

---

[2] *Esdell Caravan Park v Hemel Hempstead Rural District Council* [1966] 1 Q.B. 895 at 925 per Lord Denning MR.

[3] In *Esdell* at 923 Lord Denning suggested that planning authorities should deal with caravan applications in outline, leaving the detail of control to caravan site licensing but did not seek to insist on it

[4] *Gateshead Metropolitan Borough Council v Secretary of State for the Environment* [1995] Env LR 37 at 44 per Glidewell LJ.

[5] For example, dust and noise at issue in *Hopkins Developments Ltd v First Secretary of State* [2006] EWHC 2823 (Admin), [2007] Env LR 14 or odours in *Harrison v Secretary of State for Communities and Local Government* [2009] EWHC 3382 (Admin), [2010] Env LR 17 were not immaterial because action could be taken against them by the affected neighbours (in private or statutory nuisance) or regulators (under environmental permits).

[6] *Gateshead* at 49-50 per Glidewell LJ. He said that the then regulator, HM Inspectorate of Pollution 'should not consider that the grant of planning permission inhibits them from refusing authorisation if they decide in their discretion that this is the proper course.'

(b) Whether regulator A's decision relied upon effective regulation by regulator B. In those circumstances the first decision may say very little about what regulator B should decide;

(c) Whether circumstances or available information have changed since the first decision.

The present case

17. The issue of air quality was considered extensively in the planning appeal. The Inspector's conclusion was that any impact would be acceptable in planning terms, given the existence of the environmental permitting regime. He did not conclude that an environmental permit should be granted, or on what terms, and those matters were not within his remit.

18. The Environmental Permit decision on the small waste incinerator plant must be taken so as to ensure compliance with various provisions of the Industrial Emissions Directive.[7] These include that waste gases 'shall be discharged in a controlled way by means of a stack the height of which is calculated in such a way as to safeguard human health and the environment'[8] and that emission limit values to air and water are adhered to.[9]

19. Consequently, if it is found that the proposal is harmful to human health or the environment then the environmental permit must be refused. The planning appeal Inspector's conclusions on air quality do not bind the Inspector who will be dealing with the environmental permit appeal.

20. The environmental permit decision maker will also take into account the relevant government guidance.

21. Since the planning appeal decision the environmental permit application has been made and it has been the subject of expert reports on behalf of CVSH, the Council and local residents as well as a judicial review. The environmental permit decision will need to take the changed circumstances and additional information into account.

[7] Environmental Permitting (England and Wales) Regulations 2016, Sched 13, para 4.
[8] IED, article 46(1).
[9] IED, article 46(2),(3).

Estoppel

22. CVSH have mentioned, but not advanced, the possibility of arguing that the planning appeal decision gives rise to an issue estoppel in respect of air quality matters. An issue estoppel arises where a determination of an issue in one set of proceedings binds the parties to those proceedings in the future. Issue estoppel does not arise in relation to judgements whether planning permission should be granted. Whilst a grant of planning permission does, of course, give rise to the rights in the permission, it does not bind the parties as to the merits of the application.[10]

23. If any matters arise out of this advice, please do not hesitate to contact me in Chambers.

[redacted]

[redacted]

[redacted]

21st October 2022

[10] *Thrasyvoulou v Secretary of State for the Environment* [1990] 2 AC 273 at 290 per Lord Bridge of Harwich where he distinguishes between the fact of a grant of planning permission and the merits judgement in a refusal: 'A decision to grant planning permission creates, of course, the rights which such a grant confers. But a decision to withhold planning permission resolves no issue of legal right whatever. It is no more than a decision that in existing circumstances and in the light of existing planning policies the development in question is not one which it would be appropriate to permit. Consequently, in my view, such a decision cannot give rise to an estoppel per rem judicatam.'

Technical Note:

Calder Valley Skip Hire Small Waste Incineration Plant

October 2022

Experts in air quality management & assessment

Document Control

Client	[redacted]	Principal Contacts	[redacted]

Job Number	[redacted]

Report Prepared By:	[redacted]

Document Status and Review Schedule

Report No.	Date	Status	Reviewed by
[redacted]	24 October 2022	Final Report	[redacted]

Air Quality Consultants Ltd
23 Coldharbour Road, Bristol BS6 7JT Tel: 0117 974 1086
24 Greville Street, Farringdon, London, EC1N 8SS Tel: 020 3873 4780
aqc@aqconsultants.co.uk

Registered Office: 23 Coldharbour Road, Bristol BS6 7JT
Companies House Registration No: 2814570

Contents

1 Introduction

1.1 Air Quality Consultants Ltd (AQC) has been commissioned to provide a professional opinion on air quality regulation of a small waste incineration plant (SWIP) in Calderdale. In particular, the relationship between the Planning and Environmental Permitting Regulation ('EPR') regimes, which in this case, are both regulated by Calderdale Metropolitan Borough Council (CMBC). This note has been produced as part of a representation to the Environmental Permitting Appeal, by Calder Valley Skip Hire Limited (APP/EPR/603) for the operation of the SWIP. This technical note has been completed on behalf of [redacted] and [redacted].

1.2 AQC has previously provided a technical review of the Appellant's (previously Applicant's) permit resubmission air quality information (report ref: J12920/A/F2), with the initial granting of the permit Quashed during a Judicial Review (an overview of the background to the case is presented in Paragraph 1.5).

1.3 Since AQC's previous review, the Appellant has provided additional evidence, produced by their commissioned consultancy RPS, that considers AQC's omission of the planning appeal decision document from its list of reviewed documents as significant. This was judged by RPS as significant due to their view that as air quality was examined at great lengths during the Planning Application and subsequent Planning Appeal, certain aspects need not be revisited under the EPR. RPS's full comments can be seen in Paragraphs 1.2 to 1.7 within the amended report (Appendix A1).

1.4 AQC is not presenting further evidence relating to the assessment of impacts; however, it is AQC's view that a regulatory body should be able to fully understand the air quality impacts of pollution control devices from a potentially regulated facility regardless of how it has been assessed at the Planning stage. In this case, any information relating to the Appellant's stack or other abatement systems, which are the primary measures of emissions control, in this case, come within the remit of the EPR regime, regardless of the view taken by the Planning Authority. AQC's full view is presented in Section 3.

Background

1.5 For context, a summary of the preceding applications and associated decisions have been included below:

Planning Application

- A Planning Application submitted by Calder Valley Skip Hire, dated 1st February 2017, for the operation of a SWIP, was refused by CMBC notice dated 2th January 2018. CMBC gave a single reason for the refusal, which related to air quality.
- Planning Permission for the construction and operation of a SWIP was granted on Appeal by a Decision Letter dated 4th February 2020.

Environmental Permit Application

- Calder Valley Skip Hire submitted an Environmental Permitting Application on 6th August 2020 and permission was granted by a decision of the Council's Cabinet on 8th February 2021, and an Environmental Permit was issued by the Council on 10th February 2021.
- A Judicial Review claim was brought against the Environmental Permitting decision on the 9th April 2021, and granted permission on the 23rd July 2021. A Quashing Order by consent was made by the High Court on 14th September 2021 and entered on 17th September 2021.
- The effect of the Quashing Order was to revert the status of the original Permit Application to that of undetermined, with the Council under a duty to redetermine the Application and either to grant or refuse it. By 23rd May 2022, with the redetermination having not occurred, the Appellant served notice on the Council pursuant to paragraph 15(1) of Schedule 5 to the Environmental Permitting (England and Wales) Regulations 2016 with the effect that the Appellant's Permit Application was deemed to have been refused on that date and giving rise to the Appeal against non-determination.
- The start date of Calder Valley Skip Hire's Appeal to the Planning Inspectorate was Tuesday 21st June 2022. No notice of the appeal was published by Calderdale Metropolitan Borough Council. Interested Parties now have until the 26th October 2022 to submit a representation.

2 Competence

2.1 [redacted] is a [redacted] with AQC with over nine years' experience in the field of air quality assessment. He has been part of the Environment Agency's Air Quality Modelling and Assessment Unit (AQMAU), which is embedded within the National Permitting Service. He has thus reviewed many technical reports for large installations, including energy from waste facilities, on behalf of Central Government. He has advised Central Government whether the material submitted is sufficient for the granting of permits and has also provided a similar service for local governments. In addition, he regularly undertakes air quality assessments for AQC, covering a mixture of uses, including industrial installations, energy centres and waste facilities. He has experience using a range of dispersion models including ADMS-Roads, ADMS-5 and Breeze AERMOD to complete quantitative modelling assessments, for both planning and permitting purposes. He is a Member of the Institute of Air Quality Management and a Member of the Institution of Environmental Sciences.

2.2 [redacted] is an [redacted] with AQC, with over sixteen years' experience, specialising in industrial emissions. He is a member of the Institute of Air Quality Management, has previously contributed his time to, and authored publications on behalf of, the Energy Institute's Emissions Working Group, and has acted as peer reviewer for the Journal of Air & Waste Management. His expertise includes ambient and stack emissions monitoring, emission inventory development and reporting, atmospheric dispersion modelling, abatement of air emissions, environmental permitting, Best Available Technique (BAT) assessments, cost-benefit analysis and compliance assessment. He has extensive experience in the quantification and assessment of emissions from a variety of releases, covering point source emissions, flare emissions, fugitive emissions and emissions from mobile transport sources, including marine vessels, on-road and off-road vehicles and rail locomotives. He has detailed knowledge of the technologies and techniques to reduce concentrations of combustion and non-combustion related pollutants, including oxides of nitrogen, acid gases (e.g., SO_2, HF, HCl), volatile organic compounds (VOCs), particulates, heavy metals and odour.

2.3 [redacted] is an [redacted] with AQC, with more than 20 years' relevant experience in the field of air quality. She has been responsible for numerous assessments for a range of infrastructure developments including power stations, road schemes, ports, airports and residential/commercial developments. The assessments have covered operational and construction impacts, including odours. She also provides services to local authorities in support of their LAQM duties, including the preparation of Review and Assessment and Action Plan reports, as well as audits of Air Quality Assessments submitted with planning applications. She has provided expert evidence to a number of Public Inquiries, and is a Member of the Institute of Air Quality Management and a Chartered Scientist.

3 Technical Statement

3.1 Under Part 3, Regulation 32(5)(c) of the Environmental Permitting (England and Wales) Regulations 2016 ('EPR'), local authorities hold the relevant functions of the "regulator" for discharging the requirements of Schedule 13 of the EPR. Section 3 of the Schedule 13 requires that regulators must ensure that every application for the grant of an environmental permit for a small waste incineration plant (SWIP) includes the information specified in Article 44 of the Industrial Emissions Directive ('IED'), with Article 44(1) requiring that the regulator ensures an application for a permit includes a description of the measures which are envisaged to guarantee that:

"the plant is designed, equipped and will be maintained and operated in such a manner that the requirements of this Chapter [editorial note – this refers to Chapter IV of the IED which sets special provisions for waste incineration and co-incineration plant] are met taking into account the categories of waste to be incinerated or co-incinerated."

3.2 Section 4(1)(h) of the EPR further requires that the local authority permitting function, as regulator, is required to:

"…exercise its relevant functions so as to ensure compliance with the following provisions of the Industrial Emissions Directive… (h) Article 46."

3.3 Article 46(1) within Chapter IV of IED requires that:

"Waste gases from waste incineration plants and waste co-incineration plants shall be discharged in a controlled way by means of a stack the height of which is calculated in such a way as to safeguard human health and the environment."

3.4 Hence, it is clear that, under the EPR, it is the local authority permitting function that is responsible for determining whether the height of a stack serving a SWIP is sufficient to safeguard human health and the environment. To reach a conclusion concerning the acceptability of the proposed stack height, the permitting authority is required to consider the predicted air quality impacts for that stack height. Hence, it has to be satisfied that such an assessment, including its underlying methodology, is robust before determining whether a permit can be granted.

3.5 In Defra's Environmental Permitting: Core Guidance[1], reference is made to the Environment Agency's Guidance[2] for developments requiring planning permission and environmental permits. Within the Environment Agency's guidance, it is stated:

[1] Defra.2020. *Environmental Permitting: Core Guidance. For the Environmental Permitting (England and Wales) Regulations 2016 (SI 2016 No 1154).*

[2] Environment Agency.2012.*Guidance for developments requiring planning permission and environmental permits.*

"Local planning authorities are responsible for determining planning applications… When deciding on a planning application, planning authorities should:

- *Be confident the development will not result in unacceptable risks from pollution when considering if the development is an appropriate use of the land.*
- *Not focus on controlling pollution where it can be controlled by other pollution regulations, such as EPR."*

3.6 Consequently, local authorities responsible for determining applications at planning stage are required to consider whether the proposed development represents an appropriate use of the land, not consider controlling pollution from regulated activities covered under the EPR. Detailed assessment of operational stack emissions with respect to controlling emissions under the EPR is the primary responsibility for the permitting regime, not planning. This is further clarified in the Environment Agency's Draft EPR Permit – Stack Height Assessment guidance:

"The detailed assessment of impact of emissions from the installation is carried out under permitting, not planning. So while a stack height may have been set under planning, it does not necessarily mean the planning authority would not accept a different stack height, or that we are bound to conclude that the height is acceptable just because it is specified in the planning and the ES will not be breached."

3.7 Paragraph 188 of the National Planning Policy Framework states:

"The focus of planning policies and decisions should be on whether proposed development is an acceptable use of land, rather than the control of processes or emissions (where these are subject to separate pollution control regimes). Planning decisions should assume that these regimes will operate effectively. Equally, where a planning decision has been made on a particular development, the planning issues should not be revisited through the permitting regimes operated by pollution control authorities."

3.8 Whilst the NPPF states planning issues should not be revisited through the permitting regimes, it is clear from the statutory responsibility imposed on permitting authorities through the EPR that this should be restricted to aspects of the air quality assessment that determine whether the proposed development represents an acceptable use of the land, not pollution control aspects. This would include, for example, not revisiting aspects related to construction phase assessments, or assessment of vehicle emissions beyond the installation boundary by the permitting authority.

3.9 However, it is the permitting authority that has the responsibility and statutory obligation to determine whether operational stack emissions from regulated facilities covered under the EPR are controlled to prevent significant impacts on human health and the environment. Combined with ensuring statutory minimum emission limit values can be met, predictive air quality assessments are the only data available to the permitting authority at application stage to determine the potential impact on human health and the environment and, consequently, the degree to which emissions are/can be controlled.

3.10 Irrespective of whether operational air quality effects have been discussed at planning stage, the local authority permitting function, as regulator for SWIPs, can, and must, ensure that operational phase assessments of stack emissions are robust. If any aspect of the air quality assessment of operational stack emissions is not considered to be robust, further information should be sought by the local authority permitting function, and provided by the applicant, before determining the application.

3.11 Hence, although the planning appeal decisions document was sent to AQC, it was not considered material for the review of air quality impacts at permitting stage. As previously demonstrated, both in terms of legislation and supporting guidance, it is the permitting regime that must determine whether the assessment of operational air quality effects of stack emissions is robust with respect to controlling emissions under the EPR. The planning regime serves an entirely separate purpose.

A1 RPS's Full Comment

Response to Air Quality Consultants Ltd Review of Air Quality Assessment

Calder Valley Small Waste Incineration Plant

For Calder Valley Skip Hire Ltd

www.rpsgroup.com

Quality Management

Prepared by	[redacted]	15/03/2022
Reviewed & checked by	[redacted]	15/03/2022
Authorised by	[redacted]	15/03/2022
Date of Issue	15/03/2022	**Revision Number** Rev 3
Job Number	[redacted]	

Revision History

Rev	Date	Status	Reason for revision	Comments
0	28/01/2022	-	-	-
1	04/02/2022	-	-	-
2	01/03/2022	-	Legal comments	-
3	15/03/2022	-	-	-

Calculations or models file name, link and location

Prepared by	[redacted]	15/03/2022
Checked by	[redacted]	15/03/2022

DISCLAIMER

RPS has used reasonable skill and care in completing this work and preparing this report, within the terms of its brief and contract and taking account of the resources devoted to it by agreement with the client. We disclaim any responsibility to the client and others in respect of any matters outside the stated scope. This report is confidential to the client and we accept no responsibility to third parties to whom this report, or any part thereof, is made known. The opinions and interpretations presented in this report represent our reasonable technical interpretation of the data made available to us. RPS accepts no responsibility for data provided by other bodies and no legal liability arising from the use by other persons of data or opinions contained in this report.

Except for the provision of professional services on a fee basis, RPS does not have a commercial arrangement with any other person or company involved in the interests that are the subject of this report.

This document has been compiled using the resources and in accordance with the scope of work agreed with the client. No liability is accepted by RPS for any use of this document, other than the purpose for which it was prepared. RPS does not accept any responsibility or liability for loss whatsoever to any third party caused by, related to or arising out of any use or reliance on the document.

Contents

Tables, Figures and Appendices

Tables

Figures

Appendices

1 Introduction

1.1 This report has been produced in response to the comments raised in the Air Quality Consultants Ltd (AQC) review of the Air Quality Assessment. The AQC review highlighted ten potential issues related to the air quality assessment within the context of the redetermination of an application for a Schedule 13 EPR environmental permit (the Permitting Application) for a small waste incineration plant (SWIP). Other potential issues related to the Permitting Application are addressed in a separate report.

1.2 Although AQC refer in passing to the fact that planning permission has already been granted, AQC make no reference to the Appeal Decisions dated 4 February 2020 or to the findings of the detailed assessment of the Inspector appointed by the Secretary of State as set forth in those Appeal Decisions. AQC list the documents which it has reviewed in compiling its report and the list of documents does not include the said Appeal Decisions. The reason for that omission is not known but the omission is considered to be very significant.

1.3 The planning regime and the environmental permitting regime are separate but complementary. Because that is so Central Government has consistently provided guidance on the different roles that each regime plays. It is provided in paragraph 188 of the National Planning Policy Framework (NPPF) 2021 that:

"*The focus of planning policies and decisions should be on whether proposed development is an acceptable use of land, rather than the control of processes or emissions (where these are subject to separate pollution control regimes). Planning decisions should assume that these regimes will operate effectively. Equally, where a planning decision has been made on a particular development the planning issues <u>should not be re-visited</u> through the permitting regimes operated by pollution control authorities.*" (our emphasis).

1.4 That approach has been consistent Government policy in every version of the NPPF since the first version was published in March 2012. As is apparent from the Appeal Decision air quality considerations were front and centre as planning issues for determination in the Appeal Decision made by the Planning Inspector in relation to the SWIP and related development. The Appeal Decision of the Secretary of State's appointed Inspector were issued only after an Environmental Impact Assessment which included air quality and after an extremely thorough Public Inquiry at which the Council was represented on matters that focussed primarily on air quality.

1.5 Where that is the case, it is the purpose of the planning decision to consider air quality impacts in order to determine whether the proposed development is an acceptable use of land. The air quality assessment within that context will assume that emissions to air will be effectively controlled by the environmental permit. Once the planning decision has been made, after consideration of air quality impacts, that the proposed development is an acceptable use of land the role of the regulator considering an environmental permit application is in the case of development of this kind to consider whether, having regard to the plant concerned and the relevant provisions of the Industrial Emissions Directive (IED) listed in Schedule 13 to the EPR, emissions will be effectively controlled by permit conditions so as, amongst other considerations, not to exceed any of the emission limit values in the IED, to impose those conditions which are necessary for that purpose and thereby to put in place the control of emissions upon which the planning decision has been based. It is because the role of the regulator in such circumstances is circumscribed in that manner that the guidance states that where a planning decision has been made on a particular development the planning issues (which in this case included air quality issues) should not be revisited through the environmental permitting regime.

1.6 In conformity with what is set out above Calderdale Metropolitan Borough Council and Calder Valley Skip Hire Ltd (CVSH) agreed in a Statement of Common Ground dated 26 September 2019 that:

“The appeal proposals are centred upon the treatment of residual waste in a small waste incineration plant (SWIP) (as defined in the Environmental Permitting (England and Wales) Regulations 2016). The SWIP together with associated plant will be required to meet all statutory industrial emissions standards and, under the environmental permit, such specific standards as applicable and in force from time to time in relation to incineration plants for the protection of human health and the environment. The control of emissions from the flue or stack associated with the SWIP would be regulated and enforced under the pollution control regime in accordance with such statutory and other regulatory standards and so as to ensure that there is no breach of any applicable emission limit values.”

1.7 As is recorded in paragraph 28 of the Appeal Decisions the Council confirmed that the concerns upon which its reason for refusal of planning permission was based related to Nitrogen Dioxide and not to any of the other potential emissions to air from the scheme. After adding that the Environmental Statement Addendum confirmed that the predicted process contributions of other potential emissions, including PM_{10}, $PM_{2.5}$ and hexavalent chromium (Cr VI), would not be significant, the Inspector stated that he had not been provided with any compelling evidence to the contrary.

1.8 This report addresses four of the potential issues raised by AQC related to the air quality assessment. Issue number 7 relates to the Human Health Risk Assessment which has been considered in a separate report. The said four potential issues are identified in paragraph 1.9 below. If those instructing AQC wished to raise these issues they should have done so and presented evidence in relation to them at the above-mentioned Public Inquiry where they were given ample opportunity to do so. They did not. It would be open to CVSH to take the position that, for that reason, these four potential issues should not be raised in the context of the Permitting Application. Without prejudice to that, this report proceeds to address them for the sake of completeness and transparency. By contrast, issues numbers 1, 3, 5, 6 and 10 have not been considered in this report as they relate to issues which were specifically addressed in the Environmental Statements and the detailed evidence presented and tested at the above-mentioned Public Inquiry, resulting in the fully detailed and reasoned Appeal Decisions granting planning permission for the SWIP and related development, which are unchallenged.

1.9 The four potential issues this report addresses are reproduced below:

- *'Issue 2 – Benzo(a)pyrene - Within the 2019 additional air quality assessment, the applicant predicts a 'worst-case' Benzo(a)pyrene process contribution, i.e., that relating to emissions from the SWIP processes in isolation, of 9% of the Air Quality Standard, and predicted environmental concentration of 98.4%, i.e., the SWIP process contribution plus contributions from other emission sources. This level of impact is presented at the location of maximum impact anywhere on the modelled grid.*

  The applicant needs to provide more information to justify that the contribution is insignificant.

- *Issue 4 – Ecological Impacts - The applicant has not assessed the impacts at nearby ancient woodland and local nature reserve ecological sites within their ES addendum or their 2019 additional Air Quality Assessment. These sites are within the 2 km screening distance for assessment of ecological sites required by the Environment Agency.*

- *Issue 8 – Carbon Monoxide 1-hour EAL - The applicant has not undertaken an assessment against the Carbon Monoxide 1-hour Environmental Assessment Level (EAL) of 30,000 μg/m^3. In the experience of the reviewers, carbon monoxide emissions are generally insignificant compared to the environmental standards. As there are no predicted significant effects towards the 8-hour CO objective, lack of consideration of the 1-hour EAL is unlikely to alter the conclusion of the assessment.*

- *Issue 9 – TOC Emissions - The applicant has not undertaken an assessment of the likely emissions of total organic compounds (TOC). It is a requirement within chapter IV of IED that* *emissions to air from waste incineration plants shall not exceed the emission limit value of 10 mg/Nm³ for TOC; therefore, any robust assessment should consider the sites impact from TOC'.*

1.10 In addressing those four potential issues this report does so entirely without prejudice to what we have set out above and without any intention to revisit in the course of this environmental permitting redetermination process the air quality issues which were determined by the Planning Inspector in the Appeal Decisions referred to above or the findings and detailed assessment of the Planning Inspector on air quality issues set forth in those Appeal Decisions. Further, in addressing those four potential issues in this report it is not the intention to detract from the entitlement of CVSH to rely upon the above-mentioned Statement of Common Ground agreed with Calderdale MBC including the common ground recorded in the Appeal Decisions. This includes, in particular, what is stated in paragraph 6.2 below of this report.

1.11 The additional assessment work undertaken to respond to the issues raised has followed the same methodology as the original assessment work. The policy and legislative context and the assessment methodology are reproduced from the Environmental Statement Addendum, July 2019 in Appendix A for ease of reference. In doing so, we do not place any of the content of Appendix A, particularly the assessment methodology, in issue in this Permitting Application. The methodology was found by the Secretary of State's appointed Inspector to be sound in the above-mentioned Appeal Decisions. The following sections of this report reproduce the relevant extract from the AQC review in italics, followed by the RPS response.

2 Issue 2 – Benzo(a)pyrene

AQC Ltd Comment

2.1 *Within the 2019 additional air quality assessment, the applicant predicts a 'worst-case' Benzo(a)pyrene (B(a)P) process contribution (PC), i.e., that relating to emissions from the SWIP processes in isolation, of 9% of the Air Quality Standard (AQS), and predicted environmental concentration (PEC) of 98.4%, i.e., the SWIP process contribution plus contributions from other emission sources. This level of impact is presented at the location of maximum impact anywhere on the modelled grid.*

2.2 *This prediction is based on an emission concentration of 1 µg/m^3 derived from typical emissions data of B(a)P in the 2006 Waste Incineration BAT Reference (BREF) document. In December 2019, an update to the 2006 BREF was introduced that confirmed B(a)P emissions from 48 reference lines incinerating predominantly municipal wastes ranged from 0.004 ng/Nm^3 to 1 µg/m^3. In that respect, the assumed emission concentration for B(a)P can be viewed as precautionary. However, in combination with the previous discussion on model uncertainty, as the PEC approaches 100% and no evidence is presented about level of significance of this level of impact, it is not considered possible to definitively conclude no significant effects based on the data presented. In particular, the average B(a)P concentration at the Leeds Millshaw monitoring site between 2014 and 2017 has been used to define baseline concentrations, rather than the maximum. The maximum annual mean concentration during this period exceeds the objective.*

2.3 *However, it is important to recognise that this prediction is made based on the maximum predicted value at any location in the model domain. AQS apply only where there is 'relevant exposure' and, for the purpose of assessing compliance with the B(a)P objective, which is expressed as an annual mean assessment metric, relevant exposure only occurs at e.g., residential properties and schools. It is expected that model predictions at the specific human receptors considered in the assessment would be lower than the maximum predicted value, and could possibly be at a level where no significant effect could be concluded. However, this should be confirmed by the applicant by providing tabulated data for each specified receptor location where there is relevant exposure.*

RPS response

2.4 An atmospheric dispersion model was used to predict the Process Contribution (PC) for the stack emission concentrations across a grid of receptors and at selected sensitive receptors. The PC was added to the background Ambient Concentration (AC) to calculate a Predicted Environmental Concentration (PEC). The PC and PEC were compared with the relevant Environmental Assessment Level (EAL).

2.5 The original assessments used an emission concentration for benzo(a)pyrene (B[a]P) of 0.001 mg.Nm^{-3}, which is equivalent to the 1 µg.m^{-3} quoted by AQC Ltd.

2.6 As stated by AQC Ltd, the baseline concentration (the AC) for B[a]P was derived from the average of measured concentrations of polycyclic aromatic hydrocarbons (PAHs) at the Leeds Millshaw monitoring site. B[a]P is one of many PAHs that are potentially emitted from SWIPs.

2.7 The most recently monitored annual-mean PAHs concentrations considered in the assessment are summarised in Table 2.1.

Table 2.1 Annual-Mean PAHs Concentrations (ng.m^{-3})

Monitoring Site	Concentration (ng.m^{-3})				
	2014	2015	2016	2017	Average
Leeds Millshaw	0.26	0.20	0.25	0.19	0.22

2.8 The assessment compared the AC of PAHs added to the PC for B[a]P with the EAL of B[a]P. Therefore, the conclusion that the PEC is below the EAL was conservative.

2.9 Nevertheless, for the purposes of this response the maximum measured concentration of 0.26 ng.m^{-3} (i.e. 2.6E-04 µg.m^{-3}) has been used as the baseline concentration instead of the average of 0.22 ng.m^{-3} used in the original assessment.

2.10 The results using this higher baseline concentration are shown in Section 5.

3 Issue 8 – Carbon Monoxide 1-hour EAL

AQC Ltd Comment

3.1 *The applicant has not undertaken an assessment against the Carbon Monoxide (CO) 1-hour Environmental Assessment Level (EAL) of 30,000 µg/m^3. In the experience of the reviewers, carbon monoxide emissions are generally insignificant compared to the environmental standards. As there are no predicted significant effects towards the 8-hour CO objective, lack of consideration of the 1-hour EAL is unlikely to alter the conclusion of the assessment.*

RPS response

3.2 The AQC comment concludes that consideration of the hourly-mean EAL for CO is unlikely to alter the conclusion of the assessment. Nevertheless, further analysis has been undertaken and the maximum hourly-mean carbon monoxide (CO) PC has been compared with the 1-hour EAL of 30,000 µg.m^{-3} in Section 5.

4 Issue 9 – TOC Emissions

AQC Ltd Comment

4.1 *The applicant has not undertaken an assessment of the likely emissions of total organic compounds (TOC). It is a requirement within chapter IV of IED that emissions to air from waste incineration plants shall not exceed the emission limit value of 10 mg/Nm^3 for TOC; therefore, any robust assessment should consider the sites impact from TOC.*

4.2 *As the exact speciation, or composition, of TOC cannot be known, best practice guidance by the Environment Agency suggests comparing TOC impacts against the benzene AQS. Such an assessment was undertaken within the original 2017 ES chapter in respect to the annual mean benzene AQS. The Environment Agency has recently introduced a 24-hour mean benzene environmental assessment level (EAL) of 30 µg/m^3 which should be assessed against for completeness. However, it is accepted that the air quality assessment was produced before the publication of this new EAL.*

RPS response

4.3 Total organic compounds (TOCs) have been assessed in Section 5.

5 B[a]P, CO and TOC Results

5.1 The plant is designed to meet the emission concentration limits set out in the Industrial Emissions Directive (IED). The emission rates used for TOCs and CO have been derived from the short and long-term emission concentration limits in the IED.

5.2 For B[a]P, the emission concentration was obtained from the IPPC Reference Document on the Best Available Techniques for Waste Incineration (August 2006). The emission concentration is the concentration at the point of release i.e. the top of the stack. These are used to derive an emission rate in $g.s^{-1}$ from the stack. This emission rate is an input to the model which predicts concentrations at receptors, taking into account the dispersion of pollutants after leaving the stack.

5.3 The emission rates for CO and B[a]P are the same as in the 2019 ES Addendum Additional Air Quality Assessment report and have been reproduced in Table 5.1 for ease of reference.

Table 5.1 Emission Rates

Pollutant	Parameter (unit)	Short-term Emission Limit Value – Scenario 1	Long-term Emission Limit Value – Scenario 2
TOCs	IED Emission Limit Value ($mg.Nm^{-3}$)	20*	10*
	Emission rate ($g.s^{-1}$)	0.026	0.012
CO	IED Emission Limit Value ($mg.Nm^{-3}$)	100*	50*
	Emission rate ($g.s^{-1}$)	0.13	0.06
B[a]P	Emission concentrations obtained from the IPPC Reference Document on the Best Available Techniques for Waste Incineration (August 2006) ($mg.Nm^{-3}$)	-	0.001
	Emission rate ($g.s^{-1}$)	-	1.28E-06

Note: $mg.Nm^{-3}$ refers to mg of pollutant per cubic metre at reference conditions (or normalised). The reference conditions are temperature 273 K, pressure 101.3 kPa, 11% oxygen, dry gas
*As outlined in Appendix A, paragraph A.4, for the purposes of this assessment for those pollutants having only one IED emission limit (for a single averaging period), the facility has been assumed to operate at that limit (with the exception of arsenic and Chromium VI, as discussed later in the Appendix). Where more than one limit exists for a pollutant, the half-hourly mean emission limit value has been used to calculate short-term (≤ 24-hour average) peak ground-level concentrations (Scenario 1) (again, with the exception of arsenic and Chromium VI, as discussed later in the Appendix). The daily mean emission limit value has been used for these pollutants to calculate long-term (greater than 24-hour average) mean ground-level concentrations (Scenario 2).
.

5.4 Table 5.2 and Table 5.3 show the maximum predicted Process Contributions across the modelled grid. The modelled grid is outlined in paragraph A.43 of Appendix A. As explained by AQC, the point of maximum impact may not necessarily be a location where there is relevant exposure.

The PCs at sensitive receptors will be lower than the maximum across the grid. These PCs are the predicted concentrations at a receptor and have been compared with the relevant EALs.

Table 5.2 Predicted Maximum Process Contributions (µg.m^{-3}) at Short-Term Emission Limit Values (Scenario 1) – Results Across the Modelled Grid

Pollutant	Averaging Period	EAL (µg.m^{-3})	Max PC (µg.m^{-3})	Max PC as % of EAL	Criteria (%)	AC (µg.m^{-3})	PEC (µg.m^{-3})	Is PC Potentially Significant?	Is PEC Potentially Significant?
CO	1 hour (maximum)	30,000	220.1	1	10	-	-	No	-
TOCs*	24 hour (maximum)	30	26.0	87	10	0.58	26.5	Yes	No

*Consistent with the Environment Agency's *'Air emissions risk assessment for your environmental permit'* guidance, as the substances in the TOCs are unknown, the TOCs are assumed to be 100% benzene. The EAL and AC are for benzene. This is a highly conservative approach.

Table 5.3 Predicted Maximum Process Contributions (µg.m^{-3}) at Long-Term Emission Limit Values (Scenario 2) – Results Across the Modelled Grid

Pollutant	Averaging Period	EAL (µg.m^{-3})	Max PC (µg.m^{-3})	Max PC as % of EAL	Criteria (%)	AC (µg.m^{-3})	PEC (µg.m^{-3})	Is PC Potentially Significant?	Is PEC Potentially Significant?
CO	1 hour (maximum)	30,000	110.0	0	10	-	-	No	-
TOCs*	24 hour (maximum)	30	13.0	43	10	0.58	13.6	Yes	No
	24 hour (annual mean)	5	0.22	4	1	0.29	0.51	Yes	No
B[a]P	1 hour (annual mean)	2.5E-04	2.2E-05	9	1	2.6E-04	2.8E-04	Yes	Yes

*Consistent with the Environment Agency's *'Air emissions risk assessment for your environmental permit'* guidance, as the substances in the TOCs are unknown, the TOCs are assumed to be 100% benzene. The EAL and AC are for benzene. This is a highly conservative approach.

5.5 The maximum hourly mean CO PC does not exceed 10% of the EAL of 30,000 µg.m^{-3} and the impacts can be scoped out as insignificant. This is consistent with AQC's comment that consideration of the hourly-mean EAL for CO would not alter the conclusion of the assessment.

5.6 On the highly conservative basis that all TOC is present in the form of benzene (which is not plausible) the daily mean TOC PC exceeds 10% of the benzene EAL of 30 µg.m^{-3} and the impacts are potentially significant. However, when the PC is added to the AC in both scenario 1 and scenario 2, the daily mean PEC is less than the benzene EAL and the impacts can be scoped out as insignificant.

5.7 The annual-mean TOC PC exceeds 1% of the benzene EAL of 5 µg.m^{-3} and the impacts are potentially significant. When the TOC PC is added to the AC, the PEC of 0.51 µg.m^{-3} is less than the benzene EAL and the impacts can be scoped out as insignificant.

5.8 For B[a]P, when the maximum across the modelled grid is considered, the PC exceeds 1% of the B[a]P EAL. The PEC exceeds the EAL and the impacts across the modelled grid are potentially significant if there is relevant exposure at the point of maximum impact. This is a conservative approach as the AC used is the maximum measured concentration of all PAHs, not just B[a]P, over a four-year period.

5.9 Further analysis has been undertaken for B[a]P to determine the predictions at locations where there is relevant exposure. For TOCs and CO, the predictions at locations with relevant exposure have not been considered further as the maximum PEC across the modelled grid is below the EAL and therefore predictions at relevant exposure will be lower. AQC make this point in issue 2 (reproduced at paragraph 2.3 above).

5.10 Table 5.4 presents the annual-mean B[a]P concentrations predicted at the façades of receptors i.e. locations where there is relevant human exposure.

Table 5.4 Maximum Predicted Annual-Mean B[a]P Impacts at Receptor Locations

Receptor ID	Receptor Name	Annual-Mean PC ($\mu g.m^{-3}$)	PC as % of the EAL*
1	[redacted]	1.20E-06	0
2	[redacted]	5.92E-07	0
3	[redacted]	5.80E-07	0
4	[redacted]	7.18E-07	0
5	[redacted]	1.72E-06	1
6	[redacted]	1.44E-06	1
7	[redacted]	2.27E-05	N/A
8	[redacted]	1.32E-06	1
9	[redacted]	1.61E-06	1
10	[redacted]	1.15E-06	0
11	[redacted]	1.25E-06	1
12	[redacted]	2.48E-07	0
13	[redacted]	2.43E-07	0
14	[redacted]	1.30E-06	1
15	[redacted]	1.65E-06	1
16	[redacted]	1.24E-06	0

*The PC as a percentage of the EAL is rounded to the nearest whole number, in line with the EPUK/IAQM guidance. PCs of <0.5% round down to 0%.
**Annual-mean EALs do not apply at workplaces

5.11 The PC does not exceed 1% of the EAL at all relevant discrete receptors modelled and the resulting effects are not considered to be significant. At receptor 7 Spring Bank Industrial Estate the annual-mean EAL does not apply but the PC has been included for information.

6 Issue 4 – Ecological Impacts

AQC Ltd Comment

6.1 *The applicant has not assessed the impacts at nearby ancient woodland and local nature reserve ecological sites within their ES addendum or their 2019 additional Air Quality Assessment. These sites are within the 2 km screening distance for assessment of ecological sites required by the Environment Agency. This assessment has been undertaken for the original 2017 ES chapter; however, this assessment is not considered fully robust as it is not clear if ammonia and hydrogen fluoride emissions have been accounted for when considering the impacts of nutrient nitrogen and acid deposition.*

RPS response

6.2 Following the Planning Inquiry, the Inspector recorded in paragraph 94 of the Appeal Decisions that Calderdale Metropolitan Borough Council and CVSH agreed that the proposal would not have an adverse impact on sensitive ecological receptors including protected species, habitats and wildlife corridors and would not harm the adjacent woodland. The Inspector also noted in the same paragraph of his Appeal Decisions that he had not been provided with any compelling evidence to the contrary. In those circumstances, there is no justification for either Calderdale or objectors to take any different position in the context of environmental permitting.

6.3 As outlined in AQC's comment, the air quality impacts at ancient woodland and local nature reserves were assessed in the original 2017 ES chapter. In addition, the impacts at the South Pennine Moors were assessed in Appendix E of the 2019 ES Addendum that AQC reviewed.

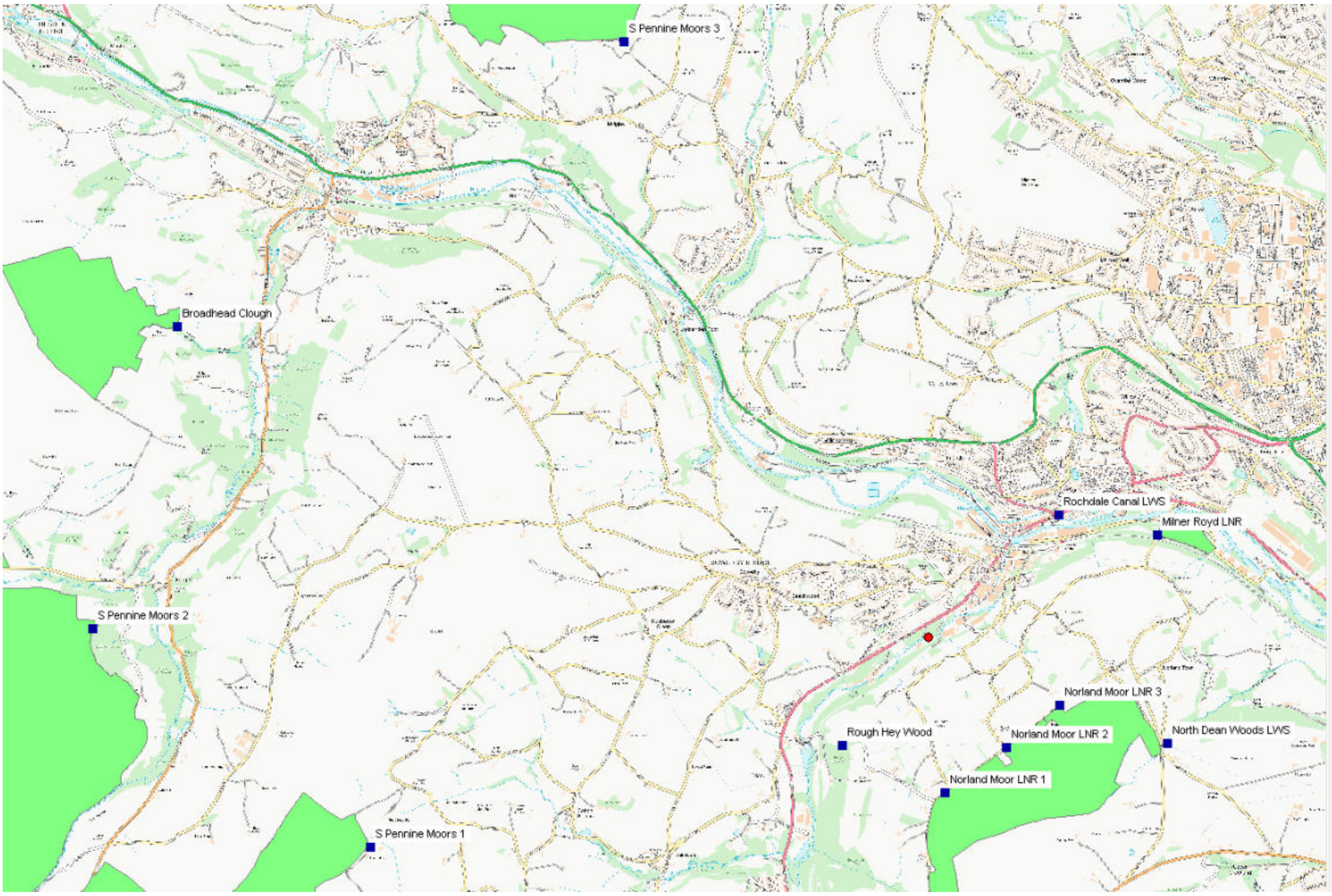
6.4 Air quality impacts have been predicted at discrete locations within the nature designations closest to the source of emissions, at the following sites as shown in Figure 1.

- South Pennine Moors Special Area of Conservation (SAC), Special Protection Area (SPA) and Site of Special Scientific Interest (SSSI)
- North Dean Woods Local Wildlife Site (LWS);
- Norland Moor LWS/ Local Nature Reserve (LNR);
- Milner Royd LNR;
- Rochdale Canal LWS;
- Rough Hey Wood (ancient woodland); and

- Rochdale Canal LWS.

6.5 This covers all the nature designations assessed in the 2017 ES chapter and the 2019 ES Addendum and uses the more detailed terrain data outlined in paragraphs A.36 to A.38 of Appendix A. Whereas the 2017 ES chapter used AERMOD dispersion model and the 2019 ES Addendum used the ADMS dispersion model, the assessment of ecological impacts referred to below has been carried out using the ADMS dispersion modelling software throughout. We address and answer below AQC's comment about ammonia and hydrogen fluoride emissions.

Figure 1 Ecological Receptors Modelled



Critical Levels

6.6 Critical levels are maximum atmospheric concentrations of pollutants for the protection of vegetation and ecosystems and are specified within relevant European air quality directives and corresponding UK air quality regulations. Process Contributions (PCs) and Predicted Environmental Concentrations (PECs) of nitrogen oxides (NOx), sulphur dioxide (SO_2) ammonia (NH_3) and hydrogen fluoride (HF) have been calculated for comparison with the relevant critical levels.

Critical Loads

6.7 Critical loads refer to the quantity of pollutant deposited, below which significant harmful effects on sensitive elements of the environment do not occur, according to present knowledge.

6.8 HF was not considered in the nutrient nitrogen (as it contains no nitrogen) or acid deposition calculations. HF is very reactive and will be preferentially removed by the acid gas abatement. Any deposition from residual HF in the flue gas emissions will occur very close to the stack and HF is unlikely to travel as far as the nearest nature conservation site (approx. 1 km away). On that basis, HF has not been included in the acid deposition calculations. This has been agreed with AQC.

Critical Loads – Nutrient Nitrogen Deposition

6.9 Percentage contributions to nutrient nitrogen deposition have been derived from the results of the ADMS dispersion modelling. Deposition rates have been calculated using empirical methods recommended by the EA, as follows:

- The deposition flux ($\mu g.m^{-2}.s^{-1}$) has been calculated by multiplying the ground level NO_2 and NH_3 concentrations ($\mu g.m^{-3}$) by the deposition velocity. The EA guidance provides deposition velocities of 0.0015 $m.s^{-1}$ for short habitats and 0.003 $m.s^{-1}$ for forests for NO_2 and 0.02 $m.s^{-1}$ for short habitats and 0.03 $m.s^{-1}$ for forests for NH_3.
- Units of $\mu g.m^{-2}.s^{-1}$ have been converted to units of $kg.ha^{-1}.year^{-1}$ by multiplying the dry deposition flux by the standard conversion factor of 96 for NO_2 and the wet deposition flux by 259.7 for NH_3.

6.10 Predicted contributions to nitrogen deposition have been calculated and compared with the relevant critical load range for the habitat types associated with the designated site. These have been derived from the APIS database. Where no 'site relevant critical loads' are available in the APIS database, site specific data has been sourced from the APIS database for the location instead. Where the habitat type is unknown the most sensitive habitat is used. Data sourced from the location are shown with an asterisk.

Critical Loads – Acidification

6.11 The acid deposition rate, in equivalents $keq.ha^{-1}.year^{-1}$, has been calculated by multiplying the dry deposition flux ($kg.ha^{-1}.year^{-1}$) by a conversion factor of 0.071428 for N and adding the deposition rate for S. The acid deposition rate for S has been calculated by multiplying the ground level SO_2 concentration by the deposition velocity to derive the deposition flux $\mu g.m^{-2}.s^{-1}$. For short habitats the deposition velocity is 0.012 $m.s^{-1}$ and for forests it is 0.024 $m.s^{-1}$. This has then been multiplied by a conversion factor of 157.7 and 0.0625 (i.e. 9.86) to determine the acid deposition arising from S (keq.ha^{-1}.year^{-1}). This takes into account the degree to which a chemical species is acidifying, calculated as the proportion of N or S within the molecule.

6.12 The acid contribution from HCl has been added to the S contribution. The acid deposition rate for HCl has been calculated by multiplying the ground level HCl concentration by the deposition velocity to derive the deposition flux in units of µg.m^{-2}.s. For short habitats the deposition velocity is 0.025 m.s^{-1} and for forests it is 0.060 m.s^{-1}. This has then been multiplied by a conversion factor of 8.63 to convert to keq.ha^{-1}.year^{-1}.

6.13 Wet deposition in the near field is not significant compared with dry deposition for N [1] and therefore for the purposes of this assessment, wet deposition has not been considered.

6.14 Predicted contributions to acid deposition have been calculated and compared with the minimum critical load function for the habitat types associated with each designated site as derived from the APIS database.

Significance Criteria

6.15 The PCs and PECs have been compared against the relevant critical level/load for the relevant habitat type/interest feature. Based on current Environment Agency guidelines [2] and the Institute of Air Quality Management *A guide to the assessment of air quality impacts on designated nature conservation sites* [3] the following criteria have been used to determine if the impacts are significant:

- If the long-term PC does not exceed 1% of relevant critical level/load the emission is considered not significant;
- If the short-term PC does not exceed 10% of relevant critical level/load the emission is considered not significant; and
- If the long-term PC exceeds 1% or the short-term PC exceeds 10% but the resulting PEC is below 100% of the relevant critical level/load, the emission is not considered significant.

Results

6.16 The maximum predicted PCs of NOx, SO_2, NH_3 and HF (from ADMS modelling utilising Leeds-Bradford 2013 – 2017 meteorological data) are compared with the relevant Critical Levels in Table 6.1 and Table 6.2.

Table 6.1 Predicted Annual-Mean Nox, SO_2 and NH_3 Concentrations at Designated Habitat Sites

Habitat Receptor	Annual-Mean NO_x PC ($\mu g.m^{-3}$)	NO_x PC/Critical Level (%)	Annual-Mean SO_2 PC ($\mu g.m^{-3}$)	SO_2 PC/Critical Level (%)	Annual-Mean NH_3 PC ($\mu g.m^{-3}$)	NH_3 PC/Critical Level (%)
S Pennine Moors 1	0.01	0	<0.005	0	<0.0005	0
Broadhead Clough	<0.005	0	<0.005	0	<0.0005	0
S Pennine Moors 2	<0.005	0	<0.005	0	<0.0005	0
S Pennine Moors 3	<0.005	0	<0.005	0	<0.0005	0
S Pennine Moors 4	<0.005	0	<0.005	0	<0.0005	0
Rough Hey Wood	0.07	0	0.02	0	0.002	0
Norland Moor LNR 1	0.02	0	0.01	0	0.001	0
Norland Moor LNR 2	0.02	0	0.01	0	0.001	0
Norland Moor LNR 3	0.05	0	0.01	0	0.001	0
Milner Royd LNR	0.09	0	0.02	0	0.002	0
North Dean Woods LWS	0.03	0	0.01	0	0.001	0
Rochdale Canal LWS	0.12	0	0.03	0	0.003	0
Maximum	0.09	0	0.03	0	0.003	0

Annual-Mean NO_X Critical Level = 30 $\mu g.m^{-3}$
Annual-Mean SO_2 Critical Level = 10 $\mu g.m^{-3}$
Annual-Mean NH_3 Critical Level = 1 $\mu g.m^{-3}$

Table 6.2 Predicted HF and Daily-Mean Nox Concentrations at Designated Habitat Sites

Habitat Receptor	Weekly-Mean HF PC (µg.m^{-3})	HF PC/Critical Level (%)	Daily-Mean HF PC (µg.m^{-3})	HF PC/Critical Level (%)	Daily-Mean NOx PC (µg.m^{-3})	NOx PC/Critical Level (%)
S Pennine Moors 1	0.002	0	0.004	0	0.43	1
Broadhead Clough	<0.0005	0	0.002	0	0.19	0
S Pennine Moors 2	0.001	0	0.003	0	0.34	0
S Pennine Moors 3	<0.0005	0	0.001	0	0.07	0
S Pennine Moors 4	<0.0005	0	0.001	0	0.05	0
Rough Hey Wood	0.012	2	0.015	0	1.47	2
Norland Moor LNR 1	0.002	0	0.005	0	0.53	1
Norland Moor LNR 2	0.002	0	0.006	0	0.63	1
Norland Moor LNR 3	0.006	1	0.014	0	1.41	2
Milner Royd LNR	0.004	1	0.008	0	0.81	1
North Dean Woods LWS	0.003	1	0.008	0	0.79	1
Rochdale Canal LWS	0.008	2	0.015	0	1.47	2
Maximum	0.008	2	0.015	0	1.47	2

Weekly-Mean HF Critical Level = 0.5 µg.m^{-3}
Daily-Mean HF Critical Level = 5 µg.m^{-3}
Daily-Mean Nox Critical Level = 75 µg.m^{-3}

6.17 The maximum PCs of nutrient nitrogen (N) deposition are compared against the relevant Critical Loads (CLs) in Table 6.3. As outlined in paragraph 6.9, the N Deposition PC considers the NOx and NH_3 contribution. There are various interest features within the habitat sites that are sensitive to N deposition. Only the results for the most-sensitive interest features are shown. Data on Critical Loads have been obtained from the UK Air Pollution Information System (APIS) database [4].

Table 6.3 Predicted Nitrogen Deposition at Designated Habitat Sites

Designation	Habitat Site	N Deposition Critical Load (kgN.ha^{-1}.yr^{-1})	N Deposition PC (kgN.ha^{-1}.yr^{-1})	N Deposition PC/ Critical Load (%)
SAC	South Pennine Moors (maximum)	5	0.002	0
SPA	South Pennine Moors (maximum)	3	0.002	0
SSSI	South Pennine Moors (maximum)	5	0.002	0

Designation	Habitat Site	N Deposition Critical Load ($kgN.ha^{-1}.yr^{-1}$)	N Deposition PC ($kgN.ha^{-1}.yr^{-1}$)	N Deposition PC/ Critical Load (%)
SSSI	Broadhead Clough	5	0.001	0
Ancient Woodland	Rough Hey Wood	10*	0.029	0
LNR	Norland Moor (maximum)	5*	0.012	0
LNR	Milner Royd	10*	0.022	0
LWS	North Dean Woods	10*	0.013	0
LWS	Rochdale Canal	5*	0.028	1

CLF = Critical Load Function (info at http://www.apis.ac.uk/clf-guidance)
* Where no 'site relevant critical loads' are available in the APIS database, site specific data has been sourced from the APIS database for the location instead. Where the habitat type is unknown the most sensitive habitat is used. Data sourced from the location are shown with an asterisk.

6.18 The maximum PCs of acid deposition are compared against the relevant Critical Loads in Table 6.4. As outlined in paragraph 6.11, the nitrogen component of acid deposition is derived from the N Deposition PC and therefore considers the contribution from NOx and NH_3. Paragraph 6.12 outlines that the sulphur component of acid deposition considers the contribution from SO_2, to which the contribution from HCl concentrations has been added. There are various interest features within the habitat sites that are sensitive to acid deposition. Only the results for the most-sensitive interest features are shown. Data on Critical Loads have been obtained from the UK Air Pollution Information System (APIS) database.

Table 6.4 Predicted Acid Deposition at Designated Habitat Sites

Designation	Habitat Site	Critical Loads ($keq.ha^{-1}.yr^{-1}$)			PC ($keq.ha^{-1}.yr^{-1}$)		PC / CLF (%)
		Min N	Max N	Max S	N	S	
SAC	South Pennine Moors (maximum)	0.32	0.57	0.25	1.66E-04	4.06E-04	0
SPA	South Pennine Moors (maximum)	0.18	0.51	0.19	1.66E-04	4.06E-04	0
SSSI	South Pennine Moors (maximum)	0.22	0.56	0.19	1.66E-04	4.06E-04	0
SSSI	Broadhead Clough	0.22	0.66	0.24	6.62E-05	1.62E-04	0
Ancient Woodland	Rough Hey Wood	0.14*	1.56*	1.413*	2.09E-03	4.09E-03	0
LNR	Norland Moor (maximum)	0.18*	0.67*	0.49*	3.31E-04	8.11E-04	0
LNR	Milner Royd	0.14*	1.56*	1.413*	1.56E-03	3.82E-03	0

Designation	Habitat Site	Critical Loads (keq.ha^{-1}.yr^{-1})			PC (keq.ha^{-1}.yr^{-1})		PC / CLF (%)
		Min N	Max N	Max S	N	S	
LWS	North Dean Woods	0.14*	1.56*	1.413*	9.46E-04	1.85E-03	0
LWS	Rochdale Canal	0.18*	0.67*	0.49*	2.02E-03	4.94E-03	1

CLF = Critical Load Function (info at http://www.apis.ac.uk/clf-guidance)

Conclusion

6.19 The maximum predicted PCs do not exceed 1% of the relevant annual-mean or 10% of the relevant weekly/daily-mean Critical Levels / Critical Loads at all habitat sites. In line with current Environment Agency guidelines [5], the effects can be screened out as insignificant.

Appendix A - Policy and Legislative Context and Assessment Methodology

A.1 The additional assessment work undertaken to respond to the issues raised has followed the same methodology as the original assessment work. Appendix A reproduces the relevant policy and legislative context and the assessment methodology for ease of reference. All table and figure numbers are identical to those in the original assessment report.

Emission Limits

Industrial Emissions Directive Limits

A.2 The plant would be designed and operated in accordance with the requirements of the Industrial Emissions Directive (2010/75/EU) [6], known hereafter as the IED, which requires adherence to emission limits for a range of pollutants.

A.3 Emission limits in the IED are specified in the form of half-hourly mean concentrations; daily-mean concentrations; mean concentrations over a period of between 30 minutes and 8 hours; or, for dioxins and furans, mean concentrations evaluated over a period of between six and eight hours.

A.4 For the purposes of this assessment for those pollutants having only one emission limit (for a single averaging period), the facility has been assumed to operate at that limit (with the exception of arsenic and Chromium VI, as discussed later). Where more than one limit exists for a pollutant, the half-hourly mean emission limit value has been used to calculate short-term (≤ 24-hour average) peak ground-level concentrations (Scenario 1) (again, with the exception of arsenic and Chromium VI, as discussed later). The daily mean emission limit value has been used for these pollutants to calculate long-term (greater than 24-hour average) mean ground-level concentrations (Scenario 2). The IED emission limit values are provided in Table 2.1.

Table 2.1 Relevant Industrial Emissions Directive Limit Values

Pollutant	Scenario 1 Short-Term Emission Limits ($mg.Nm^{-3}$)	Scenario 2 Daily-Mean Emission Limits ($mg.Nm^{-3}$)
Particles	30	10
Hydrogen Chloride (HCl)	60	10
Hydrogen Fluoride (HF)	4	1
Sulphur Dioxide (SO_2)	200	50
Nitrogen Oxides (NO_X)	400	200
Carbon Monoxide (CO)		50
Group 1 metals (a)	-	0.05 (d)
Group 2 metals (b)	-	0.05 (d)

Pollutant	Scenario 1 Short-Term Emission Limits ($mg.Nm^{-3}$)	Scenario 2 Daily-Mean Emission Limits ($mg.Nm^{-3}$)
Group 3 metals (c)	-	0.5 (d)
Dioxins and furans	-	0.0000001 (e)

Notes: All concentrations referenced to temperature 273 K, pressure 101.3 kPa, 11% oxygen, dry gas.
(a) Cadmium (Cd) and thallium (Tl).
(b) Mercury (Hg).
(c) Antimony (Sb), arsenic (As), lead (Pb), chromium (Cr), cobalt (Co), copper (Cu), manganese (Mn), nickel (Ni), and vanadium (V).
(d) All average values over a sample period of a minimum of 30 minutes and a maximum of 8 hours.
(e) Average values over a sample period of a minimum of 6 hours and a maximum of 8 hours. The emission limit value refers to the total concentration of dioxins and furans calculated using the concept of toxic equivalence (TEQ).

A.5 Ammonia (NH_3), polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs) are not specifically regulated under the IED. For the purposes of this assessment, the emission concentrations in Table 2.2 have been used for these pollutants to calculate long-term (greater than 24-hour average) mean ground-level concentrations (Scenario 2).

Table 2.2 Modelled Emission Concentrations for non-IED-Regulated Pollutants

Pollutant	Scenario 2 Emission Concentrations ($mg.Nm^{-3}$)
NH_3	5
PCBs	0.005
B[a]P	0.001

Notes: All concentrations referenced to temperature 273 K, pressure 101.3 kPa, 11% oxygen, dry gas.
Emission concentrations obtained from the IPPC Reference Document on the Best Available Techniques for Waste Incineration (August 2006)

Waste Framework Directive

A.6 Directive 2008/98/EC [7] of the European Parliament and Council on Waste requires member states to ensure that waste is recovered or disposed of without harm to human health and the environment. It requires member states to impose certain obligations on all those dealing with waste at various stages. Operators of waste disposal and recovery facilities are required to obtain a permit, or register a permit exemption. Retention of the permit requires periodic inspections and documented evidence of the activities in respect of waste.

A.7 The Waste Framework Directive (WFD) requires member states to take appropriate measures to establish an integrated and adequate network of disposal installations. The WFD also promotes environmental protection by optimising the use of resources, promoting the recovery of waste over its disposal (the “waste hierarchy”).

A.8 Annex II A and B of the WFD provide lists of the operations which are deemed to be “disposal” and “recovery”, respectively. The terms are mutually exclusive and an operation cannot be a disposal and recovery operation simultaneously. Where the operation is deemed to be a disposal operation, the permit will contain more extensive conditions than for a recovery operation.

A.9 The principal objective of a recovery operation is to ensure that the waste serves a useful purpose, replacing other substances which would have been used for that purpose. Where the combustion of waste is used to provide a source of energy, the operation is deemed to be a recovery operation.

A.10 The EPR 2016 implements the WFD in the UK. As such, the Environment Agency is responsible for implementing the obligations set out in the WFD for most activities and waste operations but local authorities are responsible for implementing the WFD obligations in respect of generally smaller scale facilities including SWIPs.

Ambient Air Quality Legislation and National Policy

Ambient Air Quality Criteria

A.11 There are several European Union (EU) Air Quality Directives and UK Air Quality Regulations that will apply to the operation of the proposed facility. These provide a series of statutory air quality limit values, target values and objectives for pollutants, emissions of which are regulated through the IED.

A.12 There are some pollutants regulated by the IED which do not have statutory air quality standards prescribed under current legislation. For these pollutants, a number of non-statutory air quality objectives and guidelines exist which have been applied within this assessment. The Environment Agency website provides further assessment criteria in its online guidance.

The Ambient Air Quality Directive and Air Quality Standards Regulations

A.13 The 2008 Ambient Air Quality Directive (2008/50/EC) [8] aims to protect human health and the environment by avoiding, reducing or preventing harmful concentrations of air pollutants; it sets legally binding concentration-based limit values, as well as target values. There are also information and alert thresholds for reporting purposes. These are to be achieved for the main air pollutants: particulate matter (PM_{10} and $PM_{2.5}$), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), ozone (O_3), carbon monoxide (CO), lead (Pb) and benzene. This Directive replaced most of the previous EU air quality legislation and in England was transposed into domestic law by the Air Quality Standards (England) Regulations 2010 [9], which in addition incorporates the 4th Air Quality Daughter Directive (2004/107/EC) that sets targets for ambient air concentrations of certain toxic heavy metals (arsenic, cadmium and nickel) and polycyclic aromatic hydrocarbons (PAHs). Member states must comply with the limit values (which are legally binding on the Secretary of State) and the Government and devolved administrations operate various national ambient air quality monitoring networks to measure compliance and develop plans to meet the limit values. The objectives are not legally binding. The statutory air quality limit values are listed in Table 2.3.

Table 2.3 Summary of Relevant Statutory Air Quality Limit Values and Air Quality Objectives

Pollutant	Averaging Period	Objectives/ Limit Values	Not to be Exceeded More Than	Target Date
Nitrogen Dioxide (NO_2)	1 hour	200 µg.m^{-3}	18 times per calendar year	-
	Annual	40 µg.m^{-3}	-	-
Particulate Matter (PM_{10})	24 Hour	50 µg.m^{-3}	35 times per calendar year	-
	Annual	40 µg.m^{-3}	-	-
Particulate Matter ($PM_{2.5}$)	Annual	25 µg.m^{-3}	-	01.01.2020 (a)
				01.01.2015 (b)
Carbon Monoxide	Maximum daily running 8 hour mean	10,000 µg.m^{-3}	-	-
Sulphur Dioxide (SO_2)	15 minute	266 µg.m^{-3}	> 35 times per calendar year	-
	1 hour	350 µg.m^{-3}	> 24 times per calendar year	-
	24 hour	125 µg.m^{-3}	> 3 times per calendar year	-
Lead	Annual	0.25 µg.m^{-3}	-	-
Arsenic (As)	Annual (b)	0.006 µg.m^{-3}	-	-
Cadmium (Cd)	Annual (b)	0.005 µg.m^{-3}	-	-
Nickel (Ni)	Annual (b)	0.02 µg.m^{-3}	-	-

(a) Target date set in UK Air Quality Strategy 2007
(b) Target date set in Air Quality Standards Regulations 2010

Non-Statutory Air Quality Objectives and Guidelines

A.14 The Environment Act 1995 established the requirement for the Government and the devolved administrations to produce a National Air Quality Strategy (AQS) for improving ambient air quality, the first being published in 1997 and having been revised several times since, with the latest published in 2007 [10]. The Strategy sets UK air quality standards and objectives for the pollutants in the Air Quality Standards Regulations plus 1,3-butadiene and recognises that action at national, regional and local level may be needed, depending on the scale and nature of the air quality problem.

A.15 Non-statutory air quality objectives and guidelines also exist within the World Health Organisation Guidelines [11] and the Expert Panel on Air Quality Standards Guidelines (EPAQS) [12]. The non-statutory objectives and guidelines are presented in Table 2.4.

Table 2.4 Non-Statutory Air Quality Objectives and Guidelines

Pollutant	Averaging Period	Guideline	Target Date
Particulate Matter ($PM_{2.5}$)	Annual	Target of 15% reduction in concentrations at urban background locations	Between 2010 and 2020 (a)
	Annual	25 $\mu g.m^{-3}$	2020 (a)
PAHs	Annual (a)	0.00025 $\mu g.m^{-3}$ B[a]P	-
Sulphur Dioxide (SO_2)	Annual (b)	50 $\mu g.m^{-3}$	-
Hydrogen Chloride	1 hour (c)	750 $\mu g.m^{-3}$	-
Hydrogen Fluoride	1 hour (c)	160 $\mu g.m^{-3}$	-

Notes:
(a) Target date set in UK Air Quality Strategy 2007
(b) World Health Organisation Guidelines
(c) EPAQS recommended guideline values

Environmental Assessment Levels

A.16 The Environment Agency's on-line guidance entitled '*Environmental management – guidance, Air emissions risk assessment for your environmental permit*' [13] provides further assessment criteria in the form of Environmental Assessment Levels (EALs).

A.17 Table 2.5 presents all available EALs for the pollutants relevant to this assessment.

Table 2.5 Environmental Assessment Levels (EALs)

Pollutant	Long-Term EAL ($\mu g.m^{-3}$)	Short-Term EAL ($\mu g.m^{-3}$)
Nitrogen Dioxide (NO_2)	40	200
Carbon Monoxide (CO)	-	10,000
Sulphur Dioxide (SO_2)	50	266
Particulates (PM_{10})	40	50
Particulates ($PM_{2.5}$)	25	-
Hydrogen chloride (HCl)	-	750
Hydrogen fluoride (HF)	16 (monthly average)	160
Arsenic (As)	0.003	-
Antimony (Sb)	5	150

Pollutant	Long-Term EAL (µg.m^{-3})	Short-Term EAL (µg.m^{-3})
Cadmium (Cd)	0.005	-
Chromium (Cr)	5	150
Chromium VI ((oxidation state in the PM_{10} fraction)	0.0002	-
Cobalt (Co)	0.2 (a)	6 (a)
Copper (Cu)	10	200
Lead (Pb)	0.25	-
Manganese (Mn)	0.15	1500
Mercury (Hg)	0.25	7.5
Nickel (Ni)	0.02	-
Thallium (Tl)	1 (a)	30 (a)
Vanadium (V)	5	1
PAHs	0.00025 B[a]P	-

Notes: (a) EALs have been obtained from the EA's earlier Horizontal Guidance Note EPR H1 guidance note as no levels are provided in the current guidance.

A.18 Within the assessment, the statutory air quality limit and target values are assumed to take precedence over objectives, guidelines and the EALs, where appropriate. In addition, for those pollutants which do not have any statutory air quality standards, the assessment assumes the lower of either the EAL or the non-statutory air quality objective or guideline where they exist.

Assessment Methodology

A.19 Neither the NPPF nor the NPPG is prescriptive on the methodology for assessing air quality effects or describing significance; practitioners continue to use guidance provided by Defra and non-governmental organisations, including Environmental Protection UK (EPUK) and the Institute of Air Quality Management (IAQM). However, the NPPG does advise that "*Assessments should be proportionate to the nature and scale of development proposed and the level of concern about air quality, and because of this are likely to be locationally specific. The scope and content of supporting information is therefore best discussed and agreed between the local planning authority and applicant before it is commissioned.*" It lists a number of areas that might be usefully agreed at the outset.

A.20 This air quality assessment covers the elements recommended in the NPPG. The approach is consistent with Defra's Local Air Quality Management Technical Guidance: LAQM.TG16 [14]. It includes the key elements listed below:

- assessment of the existing air quality in the study area (existing baseline) and prediction of the future air quality without the development in place (future baseline), using official government estimates from Defra, publicly available air quality monitoring data for the area, and relevant Air Quality Review and Assessment (R&A) documents;

- a quantitative prediction of the future operational-phase air quality impact with the development in place (with any necessary mitigation), focusing on the impacts of the stack emissions on the local area, including Sowerby Bridge AQMA.

A.21 In line with the guidance set out in the NPPG, the Environmental Health Department at CMBC was consulted to agree the scope and methodology for this assessment. The Pollution Control Officer, Tommy Moorhouse, agreed that the approach to the assessment was reasonable [15].

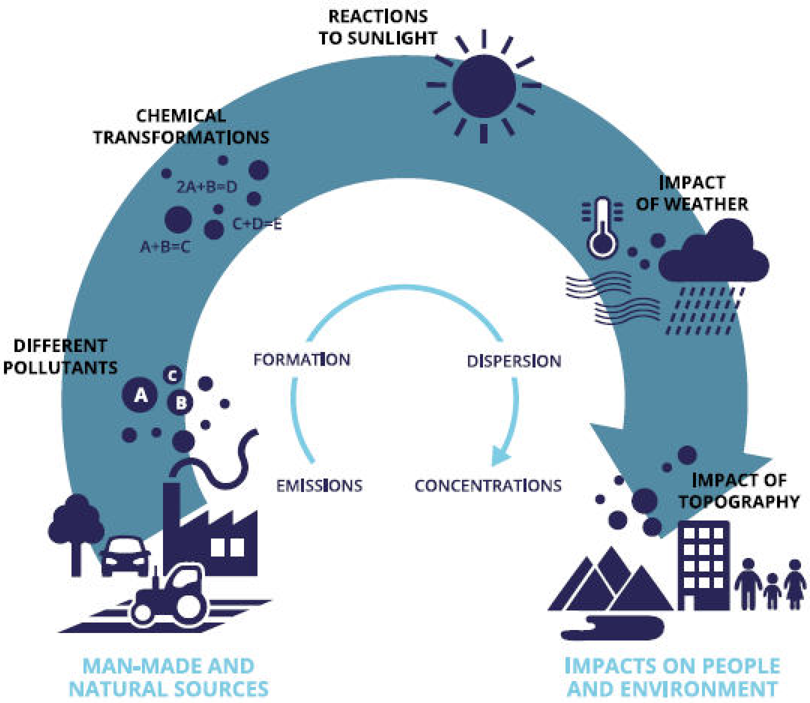
A.22 Air quality guidance advises that the organisation engaged in assessing the overall risks should hold relevant qualifications and/or extensive experience in undertaking air quality assessments. The RPS air quality team members involved at various stages of this assessment have professional affiliations that include Fellow and Member of the Institute of Air Quality Management, Chartered Chemist, Chartered Scientist, Chartered Environmentalist and Member of the Royal Society of Chemistry and have the required academic qualifications for these professional bodies. In addition, the Director responsible for authorising all deliverables has over 25 years' experience.

Operational Phase - Methodology

Atmospheric Dispersion Modelling of Pollutant Concentrations

A.23 In urban areas, pollutant concentrations are primarily determined by the balance between pollutant emissions that increase concentrations, and the ability of the atmosphere to reduce and remove pollutants by dispersion, advection, reaction and deposition. An atmospheric dispersion model is used as a practical way to simulate these complex processes; such a model requires a range of input data, which can include emissions rates, meteorological data and local topographical information. The model used and the input data relevant to this assessment are described in the following sub-sections.

Figure 6.2 Air Pollution: From Emissions to Exposure



Source: European Environment Agency (2016) Explaining Road Transport Emissions: A Non-technical Guide

A.24 The atmospheric pollutant concentrations in an urban area depend not only on local sources at a street scale, but also on the background pollutant level made up of the local urban-wide background, together with regional pollution and pollution from more remote sources brought in on the incoming air mass. This background contribution needs to be added to the fraction from the modelled sources, and is usually obtained from measurements or estimates of urban background concentrations for the area in locations that are not directly affected by local emissions sources. Background pollution levels are described in detail in Section 4.

Dispersion Model Selection

A.25 A number of commercially available dispersion models are able to predict ground level concentrations arising from emissions to atmosphere from elevated point sources. Modelling for this study has been undertaken using ADMS 5, a version of the ADMS (Atmospheric Dispersion Modelling System) developed by Cambridge Environmental Research Consultants (CERC) that models a wide range of buoyant and passive releases to atmosphere either individually or in combination. The model calculates the mean concentration over flat terrain and also allows for the effect of plume rise, complex terrain, buildings and deposition. Dispersion models predict atmospheric concentrations within a set level of confidence and there can be variations in results between models under certain conditions; the ADMS 5 model has been formally validated and is widely used in the UK and internationally for regulatory purposes.

A.26 ADMS comprises a number of individual modules each representing one of the processes contributing to dispersion or an aspect of data input and output. Amongst the features of ADMS are:

- An up-to-date dispersion model in which the boundary layer structure is characterised by the height of the boundary layer and the Monin-Obukhov length, a length scale dependent on the friction velocity and the heat flux at the surface. This approach allows the vertical structure of the boundary layer, and hence concentrations, to be calculated more accurately than does the use of Pasquill-Gifford stability categories, which were used in many previous models (e.g. ISCST3). The restriction implied by the Pasquill-Gifford approach that the dispersion parameters are independent of height is avoided. In ADMS the concentration distribution is Gaussian in stable and neutral conditions, but the vertical distribution is non-Gaussian in convective conditions, to take account of the skewed structure of the vertical component of turbulence;
- A number of complex modules including the effects of plume rise, complex terrain, coastlines, concentration fluctuations and buildings;
- A facility to calculate long-term averages of hourly mean concentration, dry and wet deposition fluxes and radioactivity, and percentiles of hourly mean concentrations, from either statistical meteorological data or hourly average data; and
- A facility to run the main model options of the US EPA-approved dispersion model, AERMOD, using ADMS meteorological data from the ADMS 5 interface.

Model Input Data

Meteorological Data

A.27 The most important meteorological parameters governing the atmospheric dispersion of pollutants are wind direction, wind speed and atmospheric stability as described below:

- Wind direction determines the sector of the compass into which the plume is dispersed;
- Wind speed affects the distance that the plume travels over time and can affect plume dispersion by increasing the initial dilution of pollutants and inhibiting plume rise; and
- Atmospheric stability is a measure of the turbulence of the air, and particularly of its vertical motion. It therefore affects the spread of the plume as it travels away from the source. New generation dispersion models, including ADMS, use a parameter known as the Monin-Obukhov length that, together with the wind speed, describes the stability of the atmosphere.

A.28 For meteorological data to be suitable for dispersion modelling purposes, a number of meteorological parameters need to be measured on an hourly basis. These parameters include wind speed, wind direction, cloud cover and temperature. There are only a limited number of sites where the required meteorological measurements are made.

A.29 The year of meteorological data that is used for a modelling assessment can have a significant effect on source contribution concentrations. Dispersion model simulations have been performed using five years of data from Leeds-Bradford Airport between 2013 and 2017.

A.30 Wind roses have been produced for each of the years of meteorological data used in this assessment and are presented in Figure 1.

Stack Parameters and Emissions Rates used in the Model

A.31 Flue gases are emitted from an elevated stack to allow dispersion and dilution of the residual combustion emissions. The stack needs to be of sufficient height to ensure that pollutant concentrations are acceptable by the time they reach ground level. The stack also needs to be high enough to ensure that releases are not within the aerodynamic influence of nearby buildings, or else wake effects can quickly bring the undiluted plume down to the ground.

A.32 A stack height determination has been undertaken to establish the height at which there is minimal additional environmental benefit associated with the cost of further increasing the stack. The Environment Agency removed their detailed guidance, Horizontal Guidance Note EPR H1 [13] for undertaking risk assessments on 1 February 2016; however, the approach used here by RPS is consistent with that EA guidance which required the identification of "*an option that gives acceptable environmental performance but balances costs and benefits of implementing it*."

A.33 The stack height determination has focused on identifying the stack height required to overcome the wake effects of nearby buildings. This involved running a series of atmospheric dispersion modelling simulations to predict the ground-level concentrations with the stack at different heights: starting at 12 metres and extending up in 1 metre increments, until a height of 18 metres was reached. The stack height determination indicated a 12 m stack height was appropriate.

A.34 Stack emissions characteristics modelled are provided in Table 3.1 and the mass emissions are provided in Table 3.2.

Table 3.1 Stack Characteristics

Parameter	Unit	Value
Stack height	m	12
Internal diameter	m	0.4
Efflux velocity	$m.s^{-1}$	21.3
Efflux temperature	°C	300
Normalised volumetric flow (Dry, 0°C, 11% O_2)	$m^3.s^{-1}$	1.28

Table 3.2 Mass Emissions of Released Pollutants

Pollutant	Short-Term Mass Emission Rate ($g.s^{-1}$)	Long-Term (a) Mass Emission Rate ($g.s^{-1}$)
Particulates	0.04	0.01
HCl	0.08	0.01
HF	5.11E-03	1.28-03
SO_2	0.26	0.06
NO_X	0.51	0.26
CO	0.13	0.06
Group 1 Metals Total (b)	-	6.38E-05
Group 2 Metals (c)	-	6.38E-05
Group 3 Metals Total (d)	-	6.38E-04
Dioxins and furans	-	1.28E-10
NH_3	-	6.38E-03
PCBs	-	6.38E-06
B[a]P	-	1.28E-06

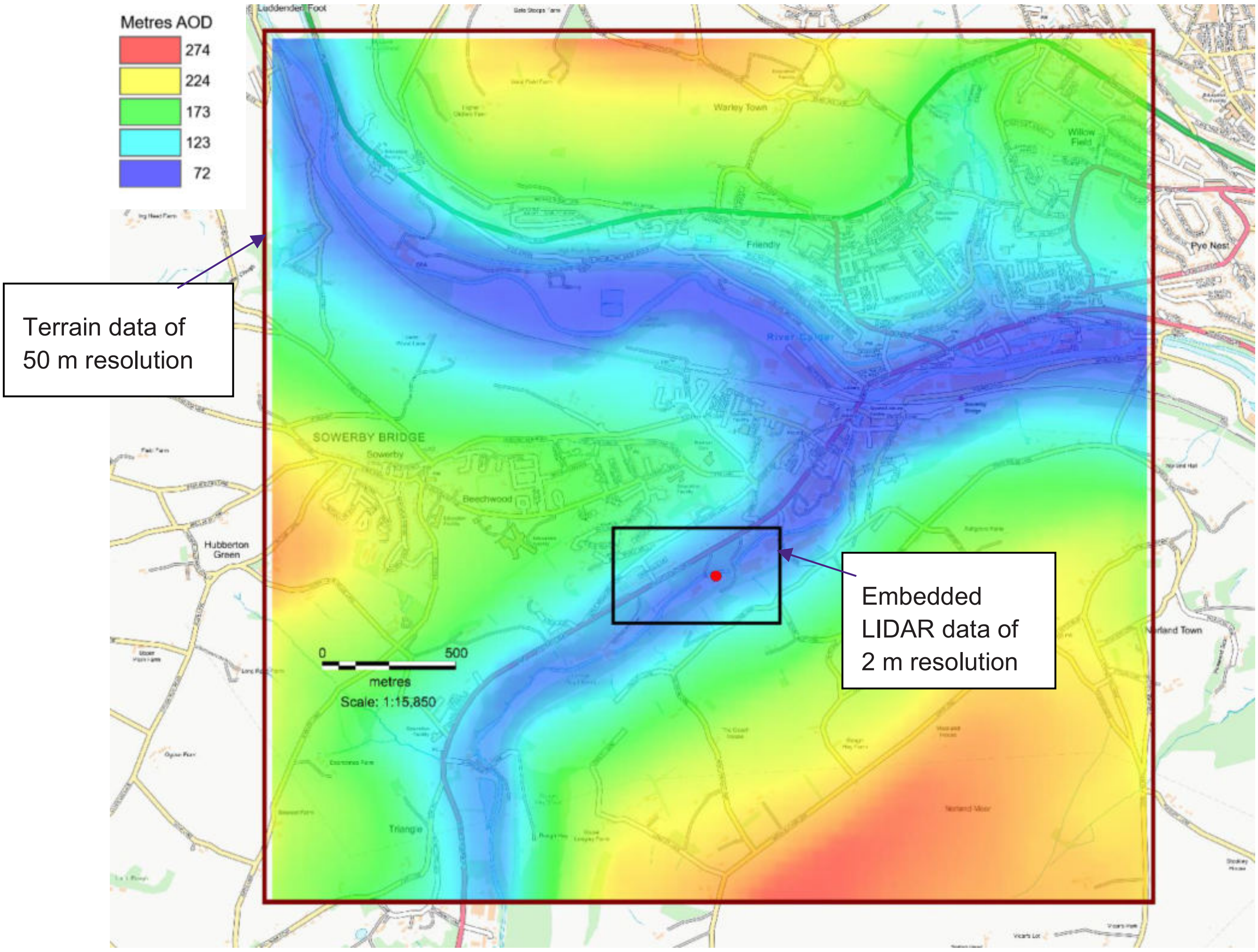
Notes:
(a) For averaging periods of 24 hours or greater.
(b) Cadmium (Cd) and thallium (Tl)
(c) Mercury (Hg)
(d) Antimony (Sb), Arsenic (As), Lead (Pb), Chromium (Cr), Cobalt (Co), Copper (Cu), Manganese (Mn), Nickel (Ni), and Vanadium (V)

A.35 Emission limits in the IED are provided for total particles. For the purposes of this assessment, all particles are assumed to be less than 10 µm in diameter (i.e. PM_{10}). Furthermore, all particles are also assumed to be less than 2.5 µm in diameter (i.e. $PM_{2.5}$). In reality, the PM_{10} and $PM_{2.5}$ concentrations will be a smaller proportion of the total particulate emissions and the $PM_{2.5}$ concentration will be a smaller proportion of the PM_{10} concentration. Therefore, this can be considered a conservative estimate of the likely particulate emissions in each size fraction.

Terrain

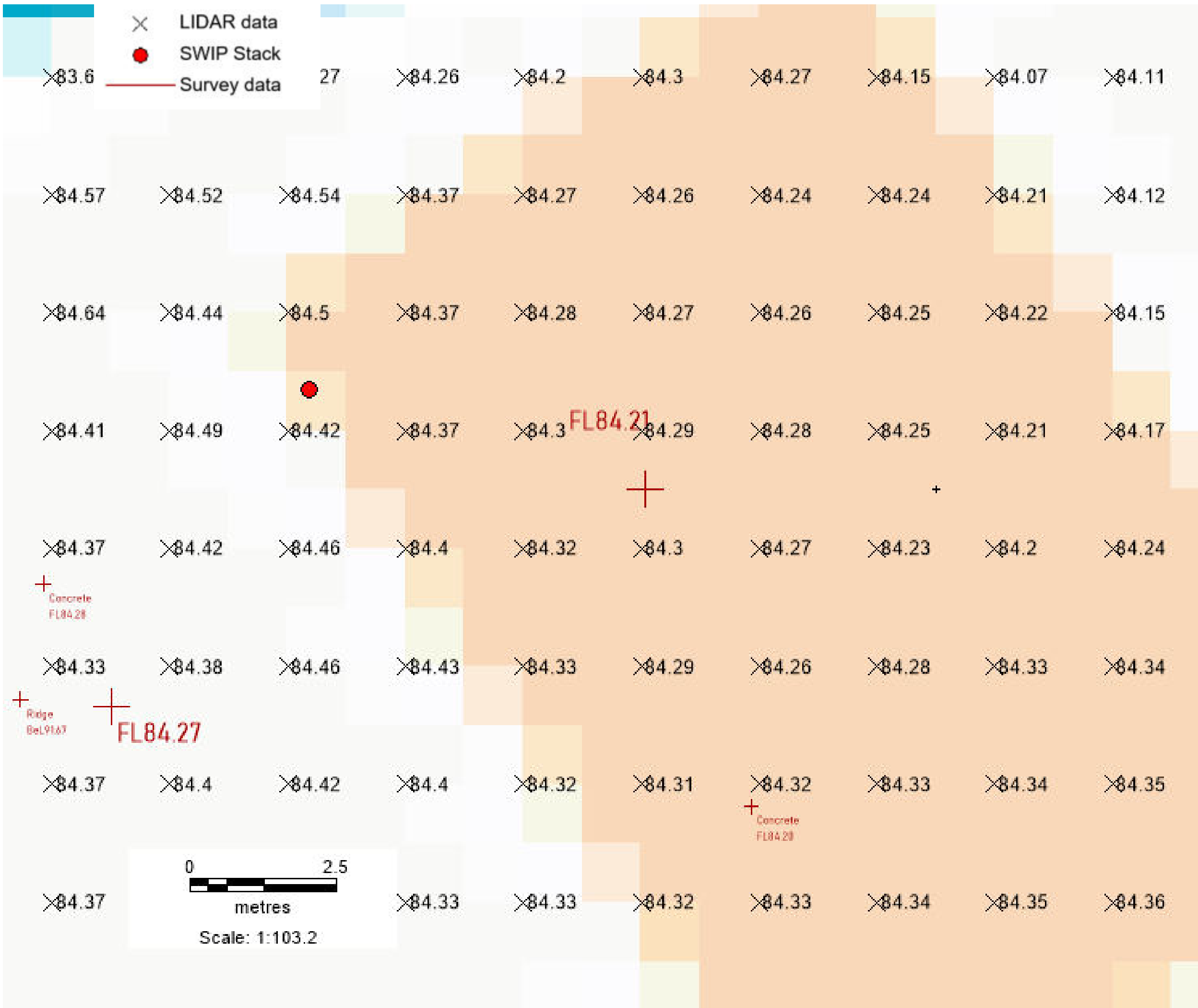
A.36 The presence of elevated terrain can significantly affect (usually increase) ground level concentrations of pollutants emitted from elevated sources such as stacks, by reducing the distance between the plume centre line and ground level and by increasing turbulence and, hence, plume mixing. A complex terrain file was used within the model. The terrain data used in the model comprises terrain data of 50 m resolution for the whole study area, supplemented with 2 m resolution government-published LIDAR data [16] for a smaller area encompassing the Application Site. This is shown graphically in Figure 3.2 below.

Figure 3.2 Complex Terrain Data Used in Model



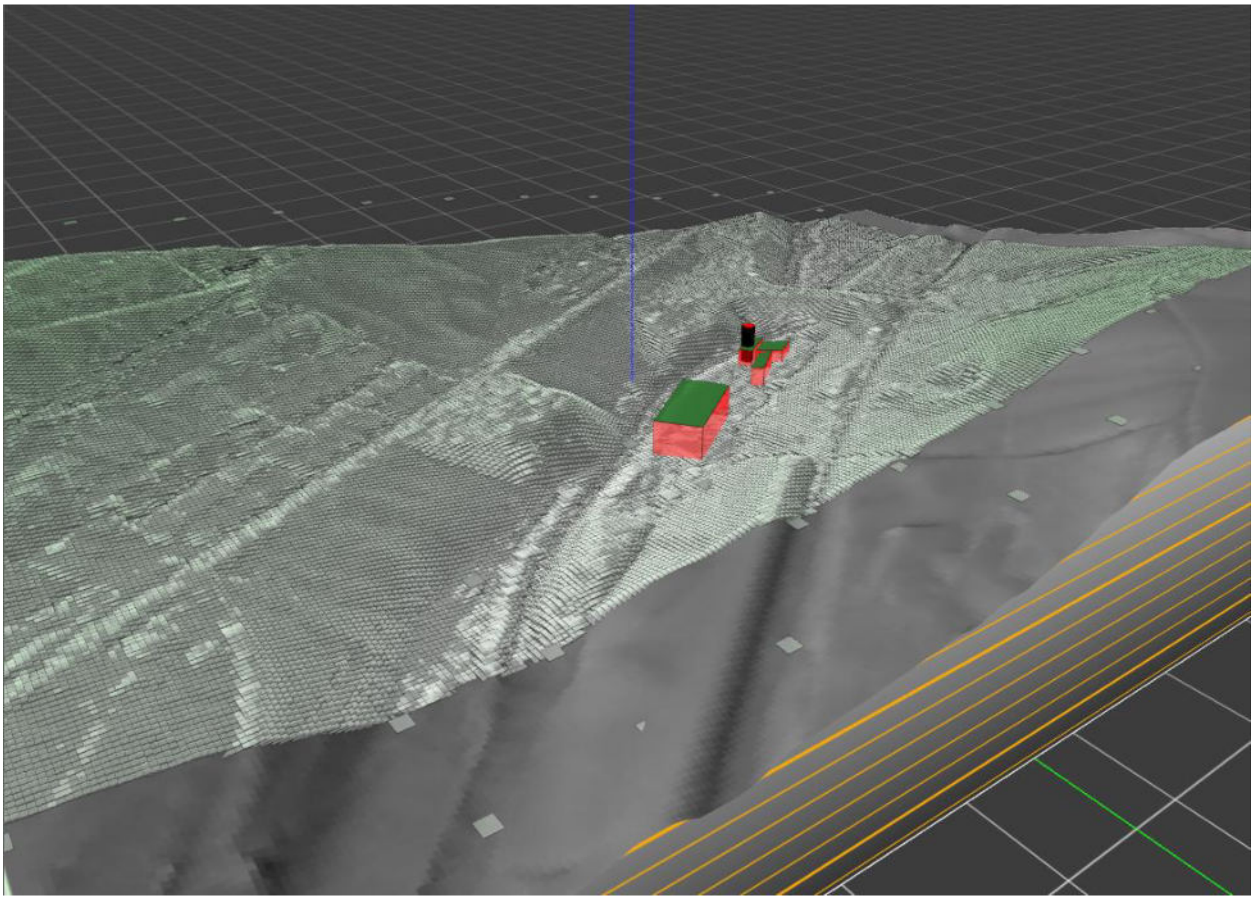
A.37 Figure 3.3 below shows the LIDAR data values and topographical survey values closest to the SWIP stack. This figure shows close agreement between the LIDAR data and the surveyed data. The LIDAR data value closest to the SWIP stack is 84.42 m AOD. This indicates that the stack height would be approximately 96.4 m AOD (i.e., 12 m above ground level).

Figure 3.3 LIDAR Data and Topographical Survey Data Close to SWIP Stack



A.38 Figure 3.4 is a 3D view of the complex terrain file, stack and buildings modelled (note that the stack is not to scale). This figure demonstrates that the high-resolution of the terrain data used represents well the features of the valley in the vicinity of the Application Site.

Figure 3.4 3D View of Complex Terrain Data Used in Model



Surface Roughness

A.39 The roughness of the terrain over which a plume passes can have a significant effect on dispersion by altering the velocity profile with height, and the degree of atmospheric turbulence. This is accounted for by a parameter called the surface roughness length.

A.40 A surface roughness length of 1 m, which the software developer recommends for use in woodland, was used within the ADMS model to represent the average surface characteristics across the study area.

A.41 A sensitivity test has been undertaken using a variable surface roughness file. This is detailed within Appendix F.

Building Wake Effects

A.42 The dominant building structures (i.e. with the greatest dimensions likely to promote turbulence) were confirmed with Paul Nutton at Ryley and are listed in Table 3.3. These were included in the model.

Table 3.3 Dimensions of Buildings Included Within the Dispersion Model

Name	Building Centre (x, y)	Height (m)	Length (m)	Width (m)	Angle (Degrees)
SWIP Process Building	405352, 422842	8	18.5	6.5	57
Feed Storage	405360, 422836	6	13.2	12.2	148
Office	405340, 422821	9	5.9	18.9	142
Recycling Building	405279, 42295	15	20.7	42.8	144

Receptors

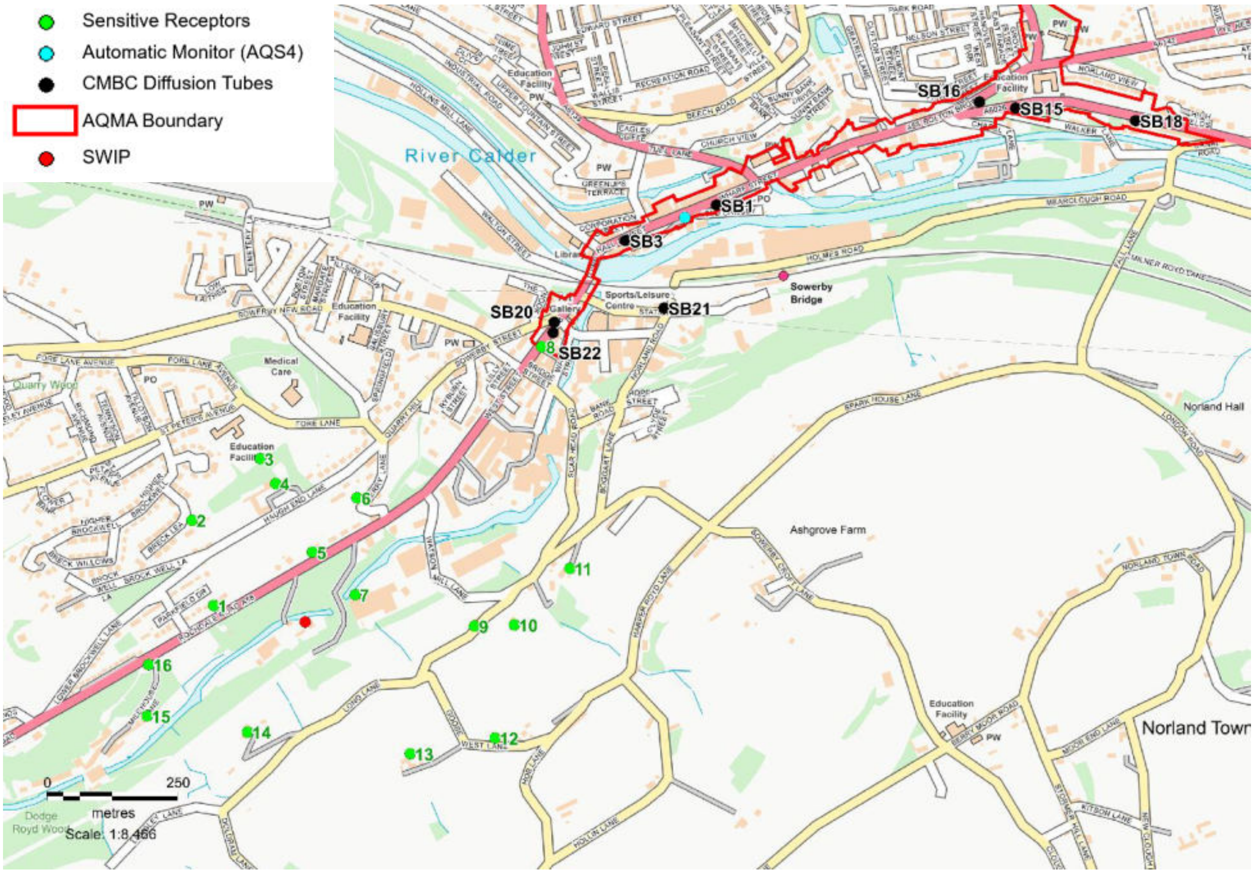
A.43 Concentrations have been modelled across a 1 km by 1 km grid, with a spacing of 20 m, at a height of 1.5 m, centred on the proposed development.

A.44 In addition, concentrations have been modelled at the 16 selected sensitive receptors modelled in the 2017 Environmental Statement. These receptors are listed in Table 3.4 and shown in Figure 3.5.

Table 3.4 Modelled Sensitive Receptors

ID	Description	x	y
1	28 Rochdale Road	405174	422873
2	9 Breck Lea	405133	423036
3	Sacred Heart Catholic Primary School	405263	423154
4	Haugh End House	405293	423106
5	84 Rochdale Road	405363	422975
6	Highfield Jerry Lane	405448	423079
7	Spring Bank Industrial Estate	405445	422894
8	Mill West (AQMA)	405801	423368
9	Ivy Cottage	405673	422834
10	Cottage	405749	422836
11	Black Sowerby Croft	405855	422944
12	Prospect Terrace	405712	422620
13	Hullen Edge	405550	422590
14	Bank House	405239	422631
15	Mill House Farm	405047	422662
16	Mill House Lodge	405050	422760

Figure 3.5 Modelled Sensiitve Receptors and Local Air Quality Monitors



A.45 The annual, daily and hourly-mean AQS objectives apply at the front and rear façades of all residential properties and at Sacred Heart Catholic Primary School. The daily and hourly-mean AQS objectives only, apply at Spring Bank Industrial Estate.

Planning Significance Criteria for Development Impacts on the Local Area

A.46 The Environmental Protection UK (EPUK)/ Institute of Air Quality Management (IAQM) Land-Use Planning & Development Control: Planning For Air Quality document has been used for assessing the impacts of NO_2, and long-term PM_{10} and $PM_{2.5}$, as the pollutants most commonly associated with assessment by that method. (For assessing the significance of other pollutants, the Environment Agency's approach has been used, as discussed later)

A.47 The EPUK & IAQM Land-Use Planning & Development Control: Planning For Air Quality document advises that:

"The significance of the effects arising from the impacts on air quality will depend on a number of factors and will need to be considered alongside the benefits of the development in question. Development under current planning policy is required to be sustainable and the definition of this includes social and economic dimensions, as well as environmental. Development brings opportunities for reducing emissions at a wider level through the use of more efficient technologies and better designed buildings, which could well displace emissions elsewhere, even if they increase at the development site. Conversely, development can also have adverse consequences for air quality at a wider level through its effects on trip generation."

A.48 When describing the air quality impact at a sensitive receptor, the change in magnitude of the concentration should be considered in the context of the absolute concentration at the sensitive receptor. Table 3.5 provides the EPUK & IAQM approach for describing the long-term air quality impacts at sensitive human-health receptors in the surrounding area.

Table 3.5 Impact Descriptors for Individual Sensitive Receptors

Long term average concentration at receptor in assessment year	% Change in concentration relative to Air Quality Assessment Level			
	1	2-5	6-10	>10
75 % or less of AQAL	Negligible	Negligible	Slight	Moderate
76 -94 % of AQAL	Negligible	Slight	Moderate	Moderate
95 - 102 % of AQAL	Slight	Moderate	Moderate	Substantial
103 – 109 % of AQAL	Moderate	Moderate	Substantial	Substantial
110 % or more than AQAL	Moderate	Substantial	Substantial	Substantial

1. AQAL = Air Quality Assessment Level, which may be an air quality objective, EU limit or target value, or an Environment Agency 'Environmental Assessment Level (EAL)'.
2. The table is intended to be used by rounding the change in percentage pollutant concentration to whole numbers, which then makes it clearer which cell the impact falls within. The user is encouraged to treat the numbers with recognition of their likely accuracy and not assume a false level of precision. Changes of 0%, i.e. less than 0.5% will be described as negligible.
3. The table is only designed to be used with annual mean concentrations.
4. Descriptors for individual receptors only; the overall significance is determined using professional judgement. For example, a 'moderate' adverse impact at one receptor may not mean that the overall impact has a significant effect. Other factors need to be considered.
5. When defining the concentration as a percentage of the AQAL, use the 'without scheme' concentration where there is a decrease in pollutant concentration and the 'with scheme;' concentration for an increase.
6. The total concentration categories reflect the degree of potential harm by reference to the AQAL value. At exposure less than 75% of this value, i.e. well below, the degree of harm is likely to be small. As the exposure approaches and exceeds the AQAL, the degree of harm increases. This change naturally becomes more important when the result is an exposure that is approximately equal to, or greater than the AQAL.

7. It is unwise to ascribe too much accuracy to incremental changes or background concentrations, and this is especially important when total concentrations are close to the AQAL. For a given year in the future, it is impossible to define the new total concentration without recognising the inherent uncertainty, which is why there is a category that has a range around the AQAL, rather than being exactly equal to it.

A.49 The human-health impact descriptors above apply at individual receptors. The EPUK & IAQM guidance states that the impact descriptors *"are not, of themselves, a clear and unambiguous guide to reaching a conclusion on significance. These impact descriptors are intended for application at a series of individual receptors. Whilst it maybe that there are 'slight', 'moderate' or 'substantial' impacts at one or more receptors, the overall effect may not necessarily be judged as being significant in some circumstances."*

A.50 The above criteria and matrix are for assessing the long-term impacts; for short term impacts the EPUK/IAQM guidance states that:

"*The Environment Agency uses a threshold criterion of 10% of the short term AQAL as a screening criterion for the maximum short term impact. This is a reasonable value to take and this guidance also adopts this as a basis for defining an impact that is sufficiently small in magnitude to be regarded as having an insignificant effect. Background concentrations are less important in determining the severity of impact for short-term concentrations, not least because the peak concentrations attributable to the source and the background are not additive.*

Where such peak short term concentrations from an elevated source are in the range 10-20% of the relevant AQAL, then their magnitude can be described as small, those in the range 20-50% medium and those above 50% as large. These are the maximum concentrations experienced in any year and the severity of this impact can be described as slight, moderate and substantial respectively, without the need to reference background or baseline concentrations. That is not to say that background concentrations are unimportant, but they will, on an annual average basis, be a much smaller quantity than the peak concentration caused by a substantial plume and it is the contribution that is used as a measure of the impact, not the overall concentration at a receptor. This approach is intended to be a streamlined and pragmatic assessment procedure that avoids undue complexity."

A.51 Professional judgement by a competent, suitably qualified professional is required to establish the significance associated with the consequence of the impacts. This judgement is likely to take into account the extent of the current and future population exposure to the impacts and the influence and/or validity of any assumptions adopted during the assessment process.

Environment Agency Significance Criteria

A.52 For assessing the significance of other pollutants, the on-line Environment Agency (EA) guidance entitled 'Environmental management – guidance, Air emissions risk assessment for your environmental permit' [13] has been used. This guidance provides details for screening out substances for detailed assessment. In particular, it states that:

"To *screen out a PC for any substance so that you don't need to do any further assessment of it, the PC must meet both of the following criteria:*

- *the short-term PC is less than 10% of the short-term environmental standard*
- *the long-term PC is less than 1% of the long-term environmental standard*

If you meet both of these criteria you don't need to do any further assessment of the substance.

If you don't meet them you need to carry out a second stage of screening to determine the impact of the PEC."

A.53 It continues by stating that:

"You must do detailed modelling for any PECs not screened out as insignificant."

A.54 It then states that further action may be required where:

- *"your PCs could cause a PEC to exceed an environmental standard (unless the PC is very small compared to other contributions – if you think this is the case contact the Environment Agency)*
- *The PEC is already exceeding an environmental standard"*

A.55 On that basis, the results of the detailed modelling presented in this report have been used as follows:

- The effects are not considered significant if the short-term PC is less than 10 % of the short-term Air Quality Assessment Level (AQAL) or the PEC is below the AQAL; and
- The effects are not considered significant if the long-term PC is less than 1 % of the long-term AQAL or the PEC is below the AQAL.

A.56 The Air Quality Assessment Level refers to the AQS air quality objective and the EU limit value.

References

1 Approaches to modelling local nitrogen deposition and concentrations in the context of Natura 2000 - Topic 4

2 https://www.gov.uk/guidance/air-emissions-risk-assessment-for-your-environmental-permit#screening-for-protected-conservation-areas

3 IAQM (2019) A guide to the assessment of air quality impacts on designated nature conservation sites

4 Air Pollution Information System, www.apis.ac.uk

5 https://www.gov.uk/guidance/air-emissions-risk-assessment-for-your-environmental-permit#screening-for-protected-conservation-areas

6 Directive 2010/75/EC Of The European Parliament And Of The Council of 24 November 2010 on industrial emissions

7 Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on Waste

8 Council Directive 2008/50/EC of 21 May 2008 on ambient air quality and cleaner air for Europe.

9 Defra, 2010, The Air Quality Standards (Wales) Regulations.

10 Defra, 2007, The Air Quality Strategy for England, Scotland, Wales and Northern Ireland. Volume 2.

11 World Health Organisation Guidelines (http://www.who.int/en/)

12 Expert Panel on Air Quality Standards (www.defra.gov.uk/environment/airquality/panels/aqs/index.htm)

13 Environment Agency 2016, Environmental management – guidance. Air emissions risk assessment for your environmental permit. .gov.uk website: https://www.gov.uk/guidance/air-emissions-risk-assessment-for-your-environmental-permit#environmental-standards-for-air-emissions.

14 Defra (2016) Local Air Quality Management Technical Guidance, 2016 (LAQM.TG16)

15 Email from Tommy Moorhouse (CMBC) to Rosemary Challen (RPS) dated 07/06/2019

16 Defra Digital Terrain Model (DTM) Lidar Data available from: https://environment.maps.arcgis.com/apps/MapJournal/index.html?appid=c6cef6cc642a48838d38e722ea8ccfee

Contact

Kathryn Barker
Senior Air Quality Consultant
RPS Consulting Services Ltd
6-7 Lovers Walk
Brighton
BN1 6AH
T: +44(0) 1237 546 800
E: kathryn.barker@rpsgroup.com

In the High Court of Justice
Queen's Bench Division
Administrative Court

CO Ref: **CO/1295/2021**

In the matter of an application for Judicial Review

The Queen on the application of

[redacted]

Claimant

versus
CALDERDALE METROPOLITAN BOROUGH COUNCIL

Defendant

CALDER VALLEY SKIP HIRE LTD

Interested party

Application for permission to apply for Judicial Review
NOTIFICATION of the Judge's decision (CPR Part 54.11, 54.12)

Following consideration of the documents lodged by the Claimant and the Acknowledgement(s) of service filed by the Defendant and / or Interested Party

Order by HH Judge Kramer sitting as a judge of the High Court

1.Permission is hereby granted on all grounds.

2. CPR Rule 45.43 applies as this is an Aarhus Convention claim

3. The Interested party's application for disclosure for disclosure of the names of the Benbow group and their resources as an aid to an application to vary the costs limits under CPR 45.43 is refused.

Observations concerning the grant of permission:

Grounds 1 and 2

1. There is no dispute but that council was misdirected as to the effect of delaying a decision further. The argument that it made no difference because the council had been informed by the intervener that it would serve a notice deeming refusal if a decision was not made that day is fallacious. The council may or may not have been moved by such information. It may have decided to call the intervenor's bluff if it thought that it could

pursue further enquiries without this resulting in an automatic refusal. The intervenor, in such a circumstance, would have been left to consider whether it was quicker to await the outcome of those enquiries or serve the notice and launch an appeal.

2. That the misdirection had an effect on the council's, decision not to request further information, as suggested by WYG, and to disapply the call-in procedure, is arguable and has a realistic prospect of success.

Ground 3

3. It is arguable, to the request degree, that the council substituted the test of "significant harm" , which appears to be taken form the WYG report, for the Environmental Permitting General Guidance Manual test which focuses on the question as to whether the proposed installation would cause anything beyond a negligible increase. The application of an alternative test in this could have made a difference to the outcome in view of WYG's advice that sensitivity modelling identified more than negligible impacts as being possible.

Ground 4

4. There is a difference of between the parties as to what activities are permitted in the part of the site covered by neither the SWIP or the WML. There is undoubtedly part of the site which is not covered by either which may be subject to activities associated with the proposed incinerator and question as to whether this is a good point and one which has not been taken into account in the decision to grant the SWIP is sufficiently arguable for the grant of permission.

Reason for refusing the interested party's application

5. The identities of the members of the Benbow group and their means is not relevant to a variation application. By analogy with claims in which orders for security or payment-in are said to stifle claims, the question to consider is whether the claimant can obtain funds from other sources not whether his backers could access such funds; for the analogous case of security and payment- in see *Goldrail Travel Ltd v Onur Air Tasimacilik AC[2017] UKSC 57.* The evidence of his access to funds is that relating to the response to the crowd funding appeal. The claimant has Aarhus protection, the object of which is to prevent environmental claims being stifled by costs. That is his position. The fact that there may be others, sympathetic to his cause, who have greater resources than he, does not moderate

the stifling impact of a higher costs cap unless they are prepared to provide him with additional financial support, which they have not done in response to the crowd funding appeal.

Case management directions

1. The defendant and any other person served with the claim form who wishes to contest the claim or support it on additional grounds must file and serve detailed grounds for contesting the claim or supporting it on additional grounds and any written evidence, within 35 days of service of this order.

2. Any reply and any application by the claimant to lodge further evidence must be lodged within 21 days of the service of detailed grounds for contesting the claim.

3. The claimant must file and serve a trial bundle not less than 4 weeks before the date of the hearing of the judicial review, in both hard and soft copy.

4. The claimant must file and serve a skeleton argument not less than 21 days before the date of the hearing of the judicial review.

5. The defendant and any interested party must file and serve a skeleton argument not less than 14 days before the date of the hearing of the judicial review.

6. All skeletons are to be filed in hard and soft copy.

7. The claimant must file an agreed bundle of authorities, not less than 3 days before the date of the hearing of the judicial review in hard and soft copy.

Listing Directions
The application is to be listed for 2 days with a further day for reading; the parties to provide a written time estimate within 7 days of service of this order if they disagree with this direction.

Case NOT suitable for hearing by a Deputy High Court Judge* ☐

Criminal case NOT suitable for hearing by a Single Judge* ☐

[*Tick if applicable]

Directions as to venue, if applicable:

Signed HH Judge Kramer 23rd July 2021

The date of service of this order is calculated from the date in the section below

---

For completion by the Administrative Court Office

On the 29th July 2021 a copy of this order was emailed to

[redacted]

Notes for the Claimant

To continue the proceedings a fee is payable.

For details of the current fee please refer to the Administrative Court fees table at https://www.gov.uk/court-fees-what-they-are. Failure to pay the fee or submit a certified application for fee remission may result in the claim being struck out. The form to make an application for remission of a court fee can be obtained from the Justice website https://www.gov.uk/get-help-with-court-fees

You are reminded of your obligation to reconsider the merits of your claim on receipt of the defendant's evidence.

WHO global air quality guidelines

Particulate matter ($PM_{2.5}$ and PM_{10}), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide

World Health Organization

WHO global air quality guidelines

Particulate matter ($PM_{2.5}$ and PM_{10}), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide

World Health Organization

WHO global air quality guidelines. Particulate matter ($PM_{2.5}$ and PM_{10}), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide.

ISBN 978-92-4-003422-8 (electronic version)

ISBN 978-92-4-003421-1 (print version)

Suggested citation. WHO global air quality guidelines. Particulate matter ($PM_{2.5}$ and PM_{10}), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. Geneva: World Health Organization; 2021. Licence: CC BY-NC-SA 3.0 IGO.

Cataloguing-in-Publication (CIP) data. CIP data are available at http://apps.who.int/iris.

Cover image: Pellegrini

Contents

Foreword

Clean air is fundamental to health. Compared to 15 years ago, when the previous edition of these guidelines was published, there is now a much stronger body of evidence to show how air pollution affects different aspects of health at even lower concentrations than previously understood. But here's what hasn't changed: every year, exposure to air pollution is still estimated to cause millions of deaths and the loss of healthy years of life. The burden of disease attributable to air pollution is now estimated to be on a par with other major global health risks such as unhealthy diets and tobacco smoking.

In 2015, the World Health Assembly adopted a landmark resolution on air quality and health, recognizing air pollution as a risk factor for noncommunicable diseases such as ischaemic heart disease, stroke, chronic obstructive pulmonary disease, asthma and cancer, and the economic toll they take. The global nature of the challenge calls for an enhanced global response.

These guidelines, taking into account the latest body of evidence on the health impacts of different air pollutants, are a key step in that global response. The next step is for policy-makers around the world to use these guidelines to inform evidence-based legislation and policies to improve air quality and reduce the unacceptable health burden that results from air pollution.

We are immensely grateful to all the scientists, colleagues and partners around the world who have contributed time and resources to the development of these guidelines. As with all WHO guidelines, a global group of experts has derived the new recommendations based on a robust and comprehensive review of the scientific literature, while adhering to a rigorously defined methodology. This process was overseen by a steering group hosted and coordinated by the WHO European Centre for Environment and Health.

Although the burden of air pollution is heterogeneous, its impact is ubiquitous. These guidelines come at a time of unprecedented challenges, in the face of the ongoing COVID-19 pandemic and the existential threat of climate change. Addressing air pollution will contribute to, and benefit from, the global fight against climate change, and must be a key part of the global recovery, as prescribed by the WHO Manifesto for a healthy recovery from COVID-19.

A guideline is just a tool. What matters is that countries and partners use it to improve air quality and health globally. The health sector must play a key role in monitoring health risks from air pollution, synthesizing the evidence, providing the tools and resources to support decision-making, and raising awareness of the impacts of air pollution on health and the available policy options. But this is not a job for one sector alone; it will take sustained political commitment and bold action and cooperation from many sectors and stakeholders. The payoff is cleaner air and better health for generations to come.

Dr Tedros Adhanom Ghebreyesus
WHO Director-General

Dr Hans Henri P. Kluge
WHO Regional Director for Europe

Acknowledgements

WHO thanks all members of the steering group, guideline development group, systematic review team and external review group for their invaluable contributions in the guideline development process.

WHO, through its European Centre for Environment and Health, coordinated the development of these guidelines. The work was coordinated by Román Pérez Velasco and Dorota Jarosińska, under the overall supervision of Francesca Racioppi, Head of the European Centre for Environment and Health and Nino Berdzuli, Director of the Division of Country Health Programmes, WHO Regional Office for Europe. María Neira, Director of the Department of Environment, Climate Change and Health, WHO headquarters provided invaluable advice and support throughout the process.

Members of the WHO steering group were Heather Adair-Rohani, Magaran Monzon Bagayoko, Carlos Dora, Sophie Gumy, Mohd Nasir Hassan, Marie-Eve Héroux, Dorota Jarosińska, Rok Ho Kim, Dana Loomis, Mazen Malkawi, Guy Mbayo, Pierpaolo Mudu, Lesley Jayne Onyon, Elizabet Paunović, Genandrialine Peralta, Román Pérez Velasco, Nathalie Röbbel, Agnes Soares da Silva, Nadia Vilahur Chiaraviglio and Hanna Yang (see Annex 1, Table A1.1 for membership periods and affiliations).

Members of the guideline development group were Marwan Al-Dimashki, Emmanuel K.-E. Appoh, Kalpana Balakrishnan, Michael Brauer, Bert Brunekreef, Aaron J. Cohen, Francesco Forastiere, Lu Fu, Sarath K. Guttikunda, Mohammad Sadegh Hassanvand, Marie-Eve Héroux, Wei Huang, Haidong Kan, Nguyen Thi Kim Oanh, Michał Krzyżanowski (co-chair), Nino Künzli, Thomas J. Luben, Lidia Morawska (co-chair), Kaye Patdu, Pippa Powell, Horacio Riojas-Rodríguez, Jonathan Samet, Martin Williams (co-chair), Caradee Y. Wright, Xia Wan and André Zuber (see Annex 1, Table A1.2 for membership periods and affiliations).

The systematic review team consisted of the following experts: Richard Atkinson, Ariel Bardach, Jie Chen, Agustín Ciapponi, Wei-jie Guan, Gerard Hoek, Peijue Huangfu, Mei Jiang, Kuan Ken Lee, Hua-liang Lin, Mark R. Miller, Nicholas L. Mills, Pablo Orellano, Nancy Quaranta, Julieta Reynoso, Anoop S.V. Shah, Nicholas Spath and Xue-yan Zheng (see Annex 1, Table A1.3 for affiliations).

The external review group was composed of the following individual members, who participated at various stages of the guideline development process:

Samir Afandiyev, Mohammad Alolayan, Richard Ballaman, Jill Baumgartner, Hanna Boogaard, David M. Broday, Richard T. Burnett, Jacob Burns, Flemming Cassee, Evan Coffman, Séverine Deguen, Sagnik Dey, Dimitris Evangelopoulos, Mamadou Fall, Neal Fann, Daniela Fecht, Julia Fussell, Davina Ghersi, Otto Hänninen, Barbara Hoffmann, Michael Holland, Yun-Chul Hong, Bin Jalaludin, Meltem Kutlar Joss, Juleen Lam, Kin Bong Hubert Lam, Puji Lestari, Morton Lippmann, Sylvia Medina, Rajen Naidoo, Mark J. Nieuwenhuijsen, Jeongim Park, Rita Pavasini, Annette Peters, Vincent-Henri Peuch, C. Arden Pope III, Reginald Quansah, Xavier Querol Carceller, Matteo Redaelli, Eva Rehfuess, Alexander Romanov, Anumita Roychowdhury, Jason Sacks, Paulo Saldiva, Najat Saliba, Andreia C. Santos, Jeremy Sarnat, Paul T.J. Scheepers, Srijan Lal Shrestha, Mónica Silva González, Kirk R. Smith, Massimo Stafoggia, David M. Stieb, Jordi Sunyer, Duncan C. Thomas, George D. Thurston, Linwei Tian, Aurelio Tobías Garces, Rita Van Dingenen, Sotiris Vardoulakis, Giovanni Viegi, Kuku Voyi, Heather Walton, Paul Whaley and Takashi Yorifuji (see Annex 1, Table A1.5 for affiliations).

The following stakeholder organizations were also part of the external review group and, in particular, provided comments on the draft guideline document: Abu Dhabi Global Environmental Data Initiative, African Centre for Clean Air, Association for Emissions Control by Catalyst, Clean Air Asia, ClientEarth, Concawe, European Environment Agency, European Environmental Bureau, European Federation of Allergy and Airways Diseases Patients' Associations, European Respiratory Society, Health and Environment Alliance, International Society for Environmental Epidemiology, International Transport Forum and South Asia Co-operative Environment Programme (see Annex 1, Table A1.6 for details). Representatives from the European Commission observed the meetings of the guideline development group (Frauke Hoss in 2016 and Thomas Henrichs in 2018–2020).

Special thanks are extended to the guideline development group co-chairs, the experts who contributed to several methodological working groups: Bert Brunekreef, Aaron J. Cohen, Francesco Forastiere, Gerard Hoek, Michał Krzyżanowski, Nino Künzli, Lidia Morawska, Xavier Querol Carceller, Jonathan Samet, Massimo Stafoggia, Aurelio Tobías Garces, Martin Williams and Caradee Y. Wright (see Annex 1, Table A1.7 for details), and the external methodologists Rebecca Morgan and Jos Verbeek (see Annex 1, Table A1.4 for details).

In addition, WHO would like to express special gratitude to the members of the guideline development group who largely drafted the guideline document: Michael Brauer, Bert Brunekreef, Aaron J. Cohen, Francesco Forastiere, Marie-Eve Héroux, Wei Huang, Michał Krzyżanowski, Nino Künzli, Thomas J. Luben, Lidia Morawska, Pippa Powell, Jonathan Samet, Martin Williams and Caradee Y. Wright. The guideline development group worked in collaboration with the members of the WHO Secretariat – Dorota Jarosińska, Pierpaolo Mudu and Román Pérez Velasco to finalize the draft; their contributions are also acknowledged. The draft was reviewed and inputs were provided by all members of the guideline development group and of the external review group. Special thanks are extended to Bert Brunekreef for his continued support in finalizing this task.

WHO is grateful to the authors of the Multi-Country Multi-City study, led by professor Antonio Gasparrini of the London School of Hygiene and Tropical Medicine, United Kingdom, for making available detailed air pollution data for the calculation of ratios of higher percentiles of daily concentrations to annual means, in support of establishing the short-term air quality guideline levels.

Martin Williams (co-chair, guideline development group) and Kirk R. Smith (external review group member) sadly passed away in 2020 before the publication of this document. WHO would like to express our heartfelt appreciation for their leadership and dedicated support to WHO and, in particular, to the development of air quality guidelines throughout the years and of this edition.

WHO gratefully acknowledges funding and in-kind contributions from the European Commission (Directorate-General for Environment), Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (Germany), Federal Ministry of Health (Germany), Government of the Republic of Korea, Federal Office for the Environment (Switzerland) and the United States Environmental Protection Agency.

Glossary

Abatement. The reduction or elimination of pollution, which involves either legislative measures or technological procedures, or both.

Accountability research. Assessment of the effectiveness of interventions. Knowledge gained from such assessments can provide valuable feedback for improving regulatory or other action.

AirQ+. A software tool for health risk assessment of air pollution that looks at the effects of short-term changes in air pollution (based on risk estimates from time-series studies) and of long-term exposures (using the life-tables approach and based on risk estimates from cohort studies).

Air quality guidelines. A series of WHO publications that provide evidence-informed, non-binding recommendations for protecting public health from the adverse effects of air pollutants by eliminating or reducing exposure to hazardous air pollutants and by guiding national and local authorities in their risk management decisions. The current volume is the latest issue of the series.

Air quality guideline level. A particular form of a guideline recommendation consisting of a numerical value expressed as a concentration of a pollutant in the air and linked to an averaging time. It is assumed that adverse health effects do not occur or are minimal below this concentration level. For the purposes of this document, a long-term air quality guideline level is defined as the lowest exposure level of an air pollutant above which the guideline development group is confident that there is an increase in adverse health effects; the short-term air quality guideline level is defined as a high percentile of the distribution of daily values, for example the 99th percentiles equivalent to three to four days a year exceeding this value.

Air quality standard. A given level of an air pollutant (for example, a concentration or deposition level) that is adopted by a regulatory authority as enforceable. Unlike an air quality guideline level, a number of elements in addition to the effect-based level and averaging time must be specified in the formulation of an air quality standard. These elements include:

- measurement technique and strategy
- data handling procedures (including quality assurance/quality control)
- statistics used to derive, from the measurements, the value to be compared with the standard.

The numerical value of a standard may also include a permitted number of exceedances of a certain numerical value in a given time period.

Ambient air pollution. Air pollution in the outdoor environment, that is, in outdoor air, but which can enter or be present in indoor environments.

Averaging time. For the purposes of this document, the duration of the exposure with a given mean concentration associated with certain health effects.

Black carbon. An operationally defined term that describes carbon as measured by light absorption. As such, it is not the same as elemental carbon, which is usually monitored with thermal-optical methods.

Concentration–response function. A statistical function or model based on the results of epidemiological studies to estimate the relative risk from air pollution for a disease or health outcome (e.g. premature death, heart attack, asthma attack, emergency room visit, hospital admission) in a population per unit concentration of an air pollutant.

Dust storm (or sand storm). A mix of dust and/or sand particles that has been elevated to great heights by a strong, turbulent wind and can travel great distances and reduce visibility. Dust or sand readily penetrates into buildings, results in severe soiling and may also cause considerable erosion. The particles are usually lifted to greater heights in a dust storm than in a sand storm.

Good practice statement. A statement formulated when a guideline development group is confident that a large body of diverse evidence, which is hard to synthesize, indicates that the desirable effects of a particular course of action far outweigh its undesirable effects. In other words, there is high certainty that implementing a measure would be beneficial, without the need for conducting numerous systematic reviews and detailed assessments of evidence.

Hot spot. For the purposes of this document, an area where air pollution levels are higher than the average levels in the local environment.

Household fuel combustion. Air pollution generated by the inefficient combustion of fuels in the household environment that results in household air pollution and contributes to local ambient air pollution.

Integrated exposure–response function. Models that combine exposure and risk data for different sources of combustion-related pollution, such as outdoor air, second-hand tobacco smoke, active smoking and household air pollution.

Interim target. An air pollutant concentration associated with a specific decrease of health risk. Interim targets serve as incremental steps in the progressive reduction of air pollution towards the air quality guideline levels and are intended for use in areas where air pollution is high. In other words, they are air pollutant levels that are higher than the air quality guideline levels, but which authorities in highly polluted areas can use to develop pollution reduction policies that are achievable within realistic time frames. The interim targets should be regarded as steps towards ultimately achieving air quality guideline levels, rather than as end targets.

Particulate matter. A mixture of solid and liquid particles in the air that are small enough not to settle out on to the Earth's surface under the influence of gravity, classified by aerodynamic diameter.

Ultrafine particle. Particles of an aerodynamic diameter less than or equal to 0.1 μm (that is, 100 nm). Owing to their small mass, their concentrations are most commonly measured and expressed in terms of particle number concentration per unit volume of air (for example, number of particles per cm^3).

Abbreviations

AAQS	ambient air quality standards
ACTRIS	Aerosol, Clouds and Trace Gases Research Infrastructure
APM	anthropogenic particulate matter
AQG level	air quality guideline level
BC/EC	black carbon or elemental carbon (an indicator of airborne soot-like carbon)
BenMAP-CE	Environmental Benefits Mapping and Analysis Program – Community Edition
CanCHEC	Canadian Census Health and Environment Cohort
CCAC	Climate and Clean Air Coalition
CEN	European Committee for Standardization
CI	confidence interval
CO	carbon monoxide
COMEAP	Committee on the Medical Effects of Air Pollutants
COPD	chronic obstructive pulmonary disease
CRF	concentration–response function
EEA	European Environment Agency
ERG	external review group
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
GBD	Global Burden of Disease (study)
GDG	guideline development group
Global update 2005	Air quality guidelines – global update 2005. Particulate matter, ozone, nitrogen dioxide and sulfur dioxide
GRADE	Grading of Recommendations Assessment, Development and Evaluation
HEI	Health Effects Institute
HR	hazard ratio
ICD-10	International Statistical Classification of Diseases and Related Health Problems, 10th edition
IHD	ischaemic heart disease

ISA	(US EPA) Integrated Science Assessment
MCC	Multi-Country Multi-City
NCD	noncommunicable disease
NDPM	net dust particulate matter
NO_2	nitrogen dioxide
O_3	ozone
PECOS	population, exposure, comparator, outcome and study design
PM	particulate matter
$PM_{2.5}$	particulate matter, where particles have an aerodynamic diameter equal to or less than 2.5 μm
PM_{10}	particulate matter, where particles have an aerodynamic diameter equal to or less than 10 μm
PNC	particle number concentration
ppb	parts per billion
ppm	parts per million
RBPM	regional background particulate matter
REVIHAAP	Review of evidence on health aspects of air pollution (project)
RoB	risk of bias
RR	relative risk
SDG	Sustainable Development Goal
SDS	sand and dust storms
SDS-WAS	Sand and Dust Storm Warning Advisory and Assessment System
SO_2	sulfur dioxide
Swiss TPH	Swiss Tropical and Public Health Institute
UFP	ultrafine particles
UN	United Nations
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
US EPA	United States Environmental Protection Agency
VOC	volatile organic compound
WMO	World Meteorological Organization

Executive summary

The global burden of disease associated with air pollution exposure exacts a massive toll on human health worldwide: exposure to air pollution is estimated to cause millions of deaths and lost years of healthy life annually. The burden of disease attributable to air pollution is now estimated to be on a par with other major global health risks such as unhealthy diet and tobacco smoking, and air pollution is now recognized as the single biggest environmental threat to human health.

Despite some notable improvements in air quality, the global toll in deaths and lost years of healthy life has barely declined since the 1990s. While air quality has markedly improved in high-income countries over this period, it has generally deteriorated in most low- and middle-income countries, in step with large-scale urbanization and economic development. In addition, the global prevalence of noncommunicable diseases (NCDs) as a result of population ageing and lifestyle changes has grown rapidly, and NCDs are now the leading causes of death and disability worldwide. NCDs comprise a broad range of diseases affecting the cardiovascular, neurological, respiratory and other organ systems. Air pollution increases morbidity and mortality from cardiovascular and respiratory disease and from lung cancer, with increasing evidence of effects on other organ systems. The burden of disease resulting from air pollution also imposes a significant economic burden. As a result, governments worldwide are seeking to improve air quality and reduce the public health burden and costs associated with air pollution.

Since 1987, WHO has periodically issued health-based air quality guidelines to assist governments and civil society to reduce human exposure to air pollution and its adverse effects. The WHO air quality guidelines were last published in 2006. *Air quality guidelines – global update 2005. Particulate matter, ozone, nitrogen dioxide and sulfur dioxide* (WHO Regional Office for Europe, 2006) provided health-based guideline levels for the major health-damaging air pollutants, including particulate matter (PM),[1] ozone (O_3), nitrogen dioxide (NO_2) and sulfur dioxide (SO_2). *Global update 2005* has had a significant impact on pollution abatement policies all over the world. Its publication led to the first universal frame of reference.

In various ways, these guidelines have stimulated authorities and civil society alike to increase efforts to control and study harmful air pollution exposures.

[1] That is, $PM_{2.5}$ (particles with an aerodynamic diameter of ≤ 2.5 μm) and PM_{10} (particles with an aerodynamic diameter of ≤ 10 μm).

In response to this growing awareness, the Sixty-eighth World Health Assembly adopted resolution WHA68.8, *Health and the environment: addressing the health impact of air pollution*, which was endorsed by 194 Member States in 2015 (WHO,2015). This resolution stated the need to redouble efforts to protect populations from the health risks posed by air pollution. In addition, the United Nations (UN) Sustainable Development Goals (SDGs) were designed to address the public health threat posed by air pollution via specific targets to reduce air pollution exposure and the disease burden from household and ambient exposure.

More than 15 years have passed since the publication of *Global update 2005*. In that time there has been a marked increase in evidence on the adverse health effects of air pollution, built on advances in air pollution measurement and exposure assessment and an expanded global database of air pollution measurements (discussed in Chapter 1). New epidemiological studies have documented the adverse health effects of exposure to high levels of air pollution in low- and middle-income countries, and studies in high-income countries with relatively clean air have reported adverse effects at much lower levels than had previously been studied.

In view of the many scientific advances and the global role played by the WHO air quality guidelines, this update was begun in 2016.

Objectives

The overall objective of the updated global guidelines is to offer quantitative health-based recommendations for air quality management, expressed as long- or short-term concentrations for a number of key air pollutants. Exceedance of the air quality guideline (AQG) levels is associated with important risks to public health. These guidelines are not legally binding standards; however, they do provide WHO Member States with an evidence-informed tool that they can use to inform legislation and policy. Ultimately, the goal of these guidelines is to provide guidance to help reduce levels of air pollutants in order to decrease the enormous health burden resulting from exposure to air pollution worldwide.

Specific objectives are the following.

- Provide evidence-informed recommendations in the form of AQG levels, including an indication of the shape of the concentration–response function in relation to critical health outcomes, for $PM_{2.5}$, PM_{10}, ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide for relevant averaging times.

These pollutants were chosen because of their worldwide importance. However, this choice does not imply that other air pollutants are irrelevant.

- Provide interim targets to guide reduction efforts towards the ultimate and timely achievement of the AQG levels for countries that substantially exceed these levels.
- Provide qualitative statements on good practices for the management of certain types of PM (i.e. black carbon or elemental carbon (BC/EC),[2] ultrafine particles (UFP), and particles originating from sand and dust storms (SDS)) for which the available information is insufficient to derive AQG levels but indicates risk.

Methods used to develop the guidelines

The guidelines were formulated by following a rigorous process involving several groups with defined roles and responsibilities (Chapter 2). In particular, the different steps in the development of the AQG levels included:

- a determination of the scope of the guidelines and formulation of systematic review questions;
- a systematic review of the evidence and meta-analyses of quantitative effect estimates to inform updating of the AQG levels;
- an assessment of the level of certainty of the bodies of evidence resulting from systematic reviews for the pollutants; and
- the identification of AQG levels, that is, the lowest levels of exposure for which there is evidence of adverse health effects.

In addition, the 2005 air quality interim targets were updated to guide the implementation of the new AQG levels, and good practice statements were formulated to support the management of the specific types of PM of concern. Interim targets are air pollutant levels that are higher than the AQG levels, but which authorities in highly polluted areas can use to develop pollution reduction policies that are achievable within realistic time frames. Therefore, the interim targets should be regarded as steps towards the ultimate achievement of AQG levels in the future, rather than as end targets. The number and numerical values of the interim targets are pollutant specific, and are justified in the relevant sections of Chapter 3.

The process and methods for developing these guidelines are described in detail in Chapter 2.

[2] An indicator of airborne soot-like carbon.

The systematic reviews that informed the formulation of AQG levels and other related evidence discussed during the process are available in a special issue of *Environment International*, entitled *Update of the WHO global air quality guidelines: systematic reviews* (Whaley et al., 2021).

Recommendations on classical air pollutants

In this guideline update, recommendations on AQG levels are formulated, together with interim targets, for the following pollutants: $PM_{2.5}$, PM_{10}, ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide (Table 0.1). The evidence-informed derivation of each AQG level and an indication of the reduction in health risk associated with the achievement of consecutive interim targets can be found in Chapter 3. Only evidence assessed as having high or moderate certainty of an association between a pollutant and a specific health outcome was used to define the recommended AQG levels, and all recommendations are classified as strong according to the adapted Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach (discussed in Chapter 2).

Table 0.1. Recommended AQG levels and interim targets

Pollutant	Averaging time	Interim target				AQG level
		1	2	3	4	
$PM_{2.5}$, μg/m³	Annual	35	25	15	10	5
	24-hour[a]	75	50	37.5	25	15
PM_{10}, μg/m³	Annual	70	50	30	20	15
	24-hour[a]	150	100	75	50	45
O_3, μg/m³	Peak season[b]	100	70	–	–	60
	8-hour[a]	160	120	–	–	100
NO_2, μg/m³	Annual	40	30	20	–	10
	24-hour[a]	120	50	–	–	25
SO_2, μg/m³	24-hour[a]	125	50	–	–	40
CO, mg/m³	24-hour[a]	7	–	–	–	4

[a] 99th percentile (i.e. 3–4 exceedance days per year).
[b] Average of daily maximum 8-hour mean O_3 concentration in the six consecutive months with the highest six-month running-average O_3 concentration.

It is important to note that the air quality guidelines recommended in previous WHO air quality guidelines for pollutants and those averaging times not covered in this update remain valid. This includes the short averaging times for nitrogen dioxide, sulfur dioxide and carbon monoxide that were included in *Global update 2005* and indoor air quality guidelines from 2010 (and not re-evaluated in this update). Table 0.2 shows existing air quality guidelines for nitrogen dioxide, sulfur dioxide and carbon monoxide with short averaging times. The reader is referred to previous volumes of air quality guidelines – *Air quality guidelines for Europe* (WHO Regional Office for Europe, 1987), *Air quality guidelines for Europe, 2nd edition* (WHO Regional Office for Europe, 2000a); and *WHO guidelines for indoor air quality: selected pollutants* (WHO Regional Office for Europe, 2010) – for other pollutants that are not covered in this 2021 update.

Table 0.2. Air quality guidelines for nitrogen dioxide, sulfur dioxide and carbon monoxide (short averaging times) that were not re-evaluated and remain valid

Pollutant	Averaging time	Air quality guidelines that remain valid
NO_2, µg/m³	1-hour	200
SO_2, µg/m³	10-minute	500
CO, mg/m³	8-hour	10
	1-hour	35
	15-minute	100

Good practice statements about other PM types

As yet, insufficient data are available to provide recommendations for AQG levels and interim targets for specific types of PM, notably BC/EC, UFP and SDS. However, due to health concerns related to these pollutants, actions to enhance further research on their risks and approaches for mitigation are warranted. Good practice statements for these pollutants are summarized in Table 0.3. The full text of and rationales for the statements can be found in Chapter 4.

Table 0.3. Summary of good practice statements

	Good practice statements
BC/EC	1. Make systematic measurements of black carbon and/or elemental carbon. Such measurements should not replace or reduce existing monitoring of those pollutants for which guidelines currently exist. 2. Undertake the production of emission inventories, exposure assessments and source apportionment for BC/EC. 3. Take measures to reduce BC/EC emissions from within the relevant jurisdiction and, where appropriate, develop standards (or targets) for ambient BC/EC concentrations.
UFP	1. Quantify ambient UFP in terms of PNC for a size range with a lower limit of ≤ 10 nm and no restriction on the upper limit. 2. Expand the common air quality monitoring strategy by integrating UFP monitoring into the existing air quality monitoring. Include size-segregated real-time PNC measurements at selected air monitoring stations in addition to and simultaneously with other airborne pollutants and characteristics of PM. 3. Distinguish between low and high PNC to guide decisions on the priorities of UFP source emission control. Low PNC can be considered < 1 000 particles/cm^3 (24-hour mean). High PNC can be considered > 10 000 particles/cm^3 (24-hour mean) or 20 000 particles/cm^3 (1-hour mean). 4. Utilize emerging science and technology to advance approaches to the assessment of exposure to UFP for their application in epidemiological studies and UFP management.
SDS	1. Maintain suitable air quality management and dust forecasting programmes. These should include early warning systems and short-term air pollution action plans to alert the population to stay indoors and take personal measures to minimize exposure and subsequent short-term health effects during SDS incidents with high levels of PM. 2. Maintain suitable air quality monitoring programmes and reporting procedures, including source apportionment activities to quantify and characterize PM composition and the percentage contribution of SDS to the overall ambient concentration of PM. This will enable local authorities to target local PM emissions from anthropogenic and natural sources for reduction. 3. Conduct epidemiological studies, including those addressing the long-term effects of SDS, and research activities aimed at better understanding the toxicity of the different types of PM. Such studies are especially recommended for areas where there is a lack of sufficient knowledge and information about the health risk due to frequent exposure to SDS. 4. Implement wind erosion control through the carefully planned expansion of green spaces that considers and is adjusted to the contextual ecosystem conditions. This calls for regional collaboration among countries in the regions affected by SDS to combat desertification and carefully manage green areas. 5. Clean the streets in those urban areas characterized by a relatively high population density and low rainfall to prevent resuspension by road traffic as a short-term measure after intense SDS episodes with high dust deposition rates.

PNC: particle number concentration.

The settings to which these guidelines apply

The present guidelines are applicable to both outdoor and indoor environments globally. Thus, they cover all settings where people spend time. However, as in previous editions, these guidelines do not cover occupational settings, owing to the specific characteristics of the relevant exposures and risk reduction policies and to potential differences in population susceptibility of the adult workforce in comparison with the general population.

What these guidelines do not address

These guidelines do not include recommendations about pollutant mixtures or the combined effects of pollutant exposures. In everyday life, people are exposed to a mixture of air pollutants that varies in space and time. WHO acknowledges the need to develop comprehensive models to quantify the effects of multiple exposures on human health. However, as the main body of evidence on air quality and health still focuses on the impact of single markers of ambient air pollution on the risk of adverse health outcomes, the current guidelines provide recommendations for each air pollutant individually. Achievement of the AQG levels for all these pollutants is necessary to minimize the health risk of the exposure.

Furthermore, these guidelines do not address specific recommendations on policies and interventions because these are largely context specific: what might be effective in one setting might not work in another. Lastly, individual-level interventions, such as the use of personal respiratory protection (e.g. masks, respirators, air purifiers) or behavioural measures, are addressed in another document, *Personal interventions and risk communication on air pollution* (WHO, 2020a).

Target audience

The WHO global air quality guidelines aim to protect populations from the adverse effects of air pollution. They are designed to serve as a global reference for assessing whether, and how much, exposure of a population (including particularly vulnerable and/or susceptible subgroups) to various levels of the considered air pollutants results in health concerns. The guidelines are a critical tool for the following three main groups of users:

- policy-makers, lawmakers and technical experts operating at the local, national and international levels who are responsible for developing and implementing regulations and standards for air quality, air pollution control, urban planning and other policy areas;

- national and local authorities and nongovernmental organizations, civil society organizations and advocacy groups, such as patients, citizen groups, industrial stakeholders and environmental organizations; and
- academics, health and environmental impact assessment practitioners, and researchers in the broad field of air pollution.

These groups are the targets of the information, education and communication strategies outlined in Chapter 5. The strategies, and the tools to implement them, will be essential to ensure that these global guidelines are widely disseminated and considered in policy and planning decisions. In addition, these groups are addressed in Chapter 6, on implementation of the guidelines. This includes the aspects involved in developing air quality standards based on the recommendations and general risk management principles, which are built on decades of experience.

Implementation of the guidelines

While achievement of the AQG levels should be the ultimate goal of actions to implement the guidelines, this might be a difficult task for many countries and regions struggling with high air pollution levels. Therefore, gradual progress in improving air quality, marked by the achievement of interim targets, should be considered a critical indicator of improving health conditions for populations. Key institutional and technical tools supported by human capacity-building are necessary to achieve this goal. Implementation of the guidelines requires the existence and operation of air pollution monitoring systems; public access to air quality data; legally binding, globally harmonized air quality standards; and air quality management systems. Policy decisions to set priorities for action will profit from the health risk assessment of air pollution.

While actions to reduce air pollution require cooperation among various sectors and stakeholders, health sector involvement is crucial for raising awareness of the impacts of air pollution on health and, thus, the economy, and for ensuring that protecting health strongly figures in policy discussions. Monitoring and evaluation are equally crucial to ensure that guidelines are implemented; they are addressed in Chapter 7.

Currently, the accumulated evidence is sufficient to justify actions to reduce population exposure to key air pollutants, not only in particular countries or regions but on a global scale. Nevertheless, uncertainties and knowledge gaps remain. Future research (discussed in Chapter 8) will further strengthen the scientific evidence base for making decisions on clean air policy worldwide.

1

Introduction

The WHO air quality guidelines were last published in 2006: *Air quality guidelines – global update 2005. Particulate matter, ozone, nitrogen dioxide and sulfur dioxide* (hereafter referred to as *Global update 2005*) (WHO Regional Office for Europe, 2006). Since they were issued, air pollution has become recognized as the single biggest environmental threat to human health based on its notable contribution to disease burden. This is particularly true for PM (both $PM_{2.5}$, i.e. particles with an aerodynamic diameter equal to or less than 2.5 μm, and PM_{10}, i.e. particles with an aerodynamic diameter of equal to or less than 10 μm). However, other commonly measured air pollutants such as ozone (O_3), nitrogen dioxide (NO_2), sulfur dioxide (SO_2) and carbon monoxide (CO) are also of concern, as are other components of air pollution.

The burden of disease associated with both ambient and household air pollution exposure is large and growing. The growth is partly due to increases in exposures in low- and middle-income countries,[3] but is in part also due to the rapidly increasing prevalence of NCDs worldwide as a result of population ageing and lifestyle changes. Air pollution especially increases morbidity and mortality from the noncommunicable cardiovascular and respiratory diseases that are the major causes of global mortality; it also increases the disease burden from lower respiratory tract infections and preterm birth and other causes of death in children and infants, which remain a major cause of the disease burden in low- and middle-income countries. Although air quality has improved gradually in high-income countries in the past decades, pollutant concentrations still exceed the levels published in *Global update 2005* for several pollutants in many areas. Air quality has generally deteriorated in most low- and middle-income countries, in step with large-scale urbanization and economic development that has largely relied on the burning of fossil fuels. Disparities in air pollution exposure are, therefore, increasing worldwide.

Science advances and, since the 2005 air quality guidelines were established, many new studies have continued to document the adverse health effects of air pollution. During this time, enormous advances have also occurred in measuring levels and trends in ground-level air pollution concentrations. In particular, the use of satellite remote sensing instruments in combination with advanced chemical transport models and ground-based measurements has substantially improved the understanding of worldwide pollution levels and trends. Studies conducted in low- and middle-income countries where concentrations are high are of great importance; however, equally important are studies in very clean areas, which answer important questions on the effects of low-level exposures and the evaluation of thresholds.

[3] Country income groupings of low, lower-middle, upper-middle and high are determined by the World Bank based on gross national income per capita (World Bank, 2021).

These studies provide critical information on the benefits that might be expected if air pollution levels were reduced worldwide. In view of these many advances, revision of *Global update 2005* was both timely and necessary. This revision benefited from thousands of new studies and from following the rigorous process for developing guidelines outlined in the *WHO handbook for guideline development, 2nd edition* (WHO, 2014a).

Global update 2005 has had a significant impact on abatement policies all over the world. Its publication led to the first universal frame of reference. In various ways, the air quality guidelines have stimulated authorities and civil society alike to increase efforts to control harmful air pollution exposures. Major challenges still exist, however, and it is hoped that this update of the WHO air quality guidelines will continue to inspire and guide pollution reduction policies all over the world.

1.1 Objectives of the guidelines

The overall objective of these guidelines is to offer quantitative health-based recommendations for air quality, expressed as long- or short-term concentrations of a number of key air pollutants. Exceedance of the air quality guideline levels (hereafter referred to as AQG levels) is associated with important risks to public health. These guidelines are not legally binding standards; however, they do provide countries with an evidence-informed tool, which they can use to inform legislation and policy. In addition, the air quality guidelines will be a key component to support air quality policies globally and the development of standards, clean air policies and other tools for air quality management. Ultimately, the goal of these guidelines is to provide guidance to help reduce levels of air pollutants in order to decrease the enormous worldwide health burden resulting from exposure to air pollution.

Specifically, the objectives of these guidelines are the following.

- Provide evidence-informed recommendations in the form of AQG levels, including an indication of the shape of the concentration–response function (CRF) in relation to critical health outcomes, for $PM_{2.5}$, PM_{10}, nitrogen dioxide, ozone, sulfur dioxide and carbon monoxide for relevant averaging time periods. These pollutants were chosen in the process described in section 2.3 because of their worldwide importance. This choice does not imply that other air pollutants are irrelevant.
- Provide interim targets to guide reduction efforts towards the ultimate and timely achievement of the AQG levels for those countries that substantially exceed the AQG levels.

- Provide qualitative statements on good practices for the management of certain types of PM – that is, BC/EC, UFP and particles originating from SDS – for which the available information is insufficient to derive AQG levels but indicates risk.

1.2 Target audience

The WHO guidelines to protect populations from the adverse effects of air pollution are designed to serve as a global reference for an audience of different groups of end-users, including those involved in policy-making, research and advocacy. Broadly, three main groups can be identified:

- policy-makers, lawmakers and technical experts at the local, national and international levels who are responsible for developing and implementing regulations and standards for air quality, air pollution control, urban planning and other policy areas;
- national and local authorities and nongovernmental organizations, civil society organizations and advocacy groups, such as patients, citizen groups, industrial stakeholders and environmental organizations; and
- academics, health and environmental impact assessment practitioners and researchers in the broad field of air pollution.

1.3 Background and rationale for updated guidelines

An update of the global WHO air quality guidelines was required for several reasons. More than 15 years have passed since the publication of *Global update 2005* and in the intervening years knowledge about the exposure of human populations, the adverse health effects of this exposure and the public health threat that it poses has seen a marked increase. Insight into global concentrations of some pollutants such as PM, ozone and nitrogen dioxide has increased dramatically (section 1.3.1). This is also true for insights in sources of emissions (section 1.3.2) and in the contribution of air pollutants to the global burden of disease (section 1.3.3). Much has been learned about the importance of addressing health inequities related to air pollution and of protecting vulnerable groups in society (section 1.3.4). Enormous advances have occurred since the early 2000s in measuring levels and trends in ground-level air pollution concentrations, and section 1.3.5 provides a summary of some major trends and achievements. Finally, there have been significant advances in the worldwide adoption of the air quality guidelines presented in *Global update 2005* (section 1.3.6), and mitigating air pollution has become more central in WHO and UN activities related to achieving the UN SDGs (section 1.3.7).

1.3.1 Global concentrations and trends

Measurement of air pollutant concentrations at fixed-location monitoring sites has been the traditional approach used for air quality management, for assessment of trends and to estimate exposure for epidemiological analyses. However, despite growth in the numbers of monitoring locations globally, even for the most commonly monitored pollutants, coverage is inadequate – that is, it is often restricted to major cities – to accurately estimate exposure in the many different places where people live. There are two major gaps.

The first is a lack of monitoring in many countries of the world and inadequate monitoring in rural areas or outside of major cities in many countries. Although there is increasing coverage of PM monitoring, coverage for other pollutants such as ozone, nitrogen dioxide and sulfur dioxide is less extensive. The second gap relates to inadequate monitoring to characterize the spatial variation in specific air pollutants within cities. In particular, this holds for concentrations of pollutants such as nitrogen dioxide and black carbon and UFP (diameter of ≤ 0.1 μm; or broader quasi-UFP, as discussed in section 4.3 on UFP), which may vary by an order of magnitude over just a few hundred metres (Karner, Eisinger & Niemeier, 2010). Since 2010, there has been a dramatic improvement in the combination of satellite data retrievals and chemical transport models with land-use information and ground measurements to estimate concentrations globally, which have been used to address the first gap (Shaddick et al., 2018; Brauer et al., 2012, 2016; Larkin et al., 2017; de Hoogh et al., 2016; Novotny et al., 2011; Hystad et al., 2011; Knibbs et al., 2014; Chang et al., 2019). To address the second gap, land-use regression models (Hoek et al., 2008) have been used increasingly – these models capture within-city variability, as discussed for example for UFP (Morawska et al., 2008), and have been scaled up to the global context for nitrogen dioxide (Larkin et al., 2017).

Although in many countries, regional and local authorities maintain accessible databases of air quality measurements, the only global databases are the WHO Global Ambient Air Quality Database and OpenAQ. The WHO Global Ambient Air Quality Database provides information on the annual average concentrations of PM_{10} and $PM_{2.5}$ for specific cities based on available measurements (including averages from multiple monitors within a single city, where these are available) (WHO, 2021a). OpenAQ is a non-profit-making effort to maintain an open-source database of aggregated current and archived air quality data gathered in real time from government agencies (OpenAQ, 2021). Despite the progress made in monitoring and in data access, many publicly funded agencies still do not provide easy access to data.

Exposure to air pollutants is heavily dependent on their ambient concentrations. Ambient $PM_{2.5}$ concentrations vary substantially between and within regions of the world. Importantly, more than 90% of the global population in 2019 lived in areas where concentrations exceeded the 2005 WHO air quality guideline of 10 μg/m^3. In 2019 annual population-weighted $PM_{2.5}$ concentrations were highest in the WHO South-East Asia Region, followed by the WHO Eastern Mediterranean Region. Elevated concentrations were also observed in some western African countries, largely due to the impact of Saharan dust. Windblown desert dust sometimes contributes to very high exposures to coarse particles larger than 2.5 μm or10 μm in diameter. This is a prominent issue in many arid areas in the Middle East, northern Africa, the Gobi desert and elsewhere.

Many of the countries with the lowest national $PM_{2.5}$ exposure levels were either in the WHO Region of the Americas or parts of the WHO European Region. Population-weighted $PM_{2.5}$ concentrations averaged 7 μg/m^3 or less in these countries. Trends in $PM_{2.5}$ indicate a relatively stable population-weighted global mean concentration, which reflects both decreases in exposure in the WHO European Region, the WHO Region of the Americas and the WHO Western Pacific Region but increases elsewhere.

Population-weighted ozone concentrations vary less dramatically than is the case for $PM_{2.5}$, for example ranging from 30–50 μg/m^3, mostly in small island nations, to 120–140 μg/m^3 in Asia and the Middle East. Among the world's most populous countries in southern Asia, population-weighted seasonal ozone concentrations range up to approximately 130 μg/m^3. Concentrations in African mega-cities are also likely to be high but there is still comparatively little documentation.

Trends in ozone at a regional scale show little change over time, although decreases within North America and Europe and increases in the Middle East and much of Asia are apparent.

The patterns of ambient nitrogen dioxide concentrations are quite different from those of $PM_{2.5}$ and ozone, with the highest population-weighted concentrations in eastern Asia, the Middle East, North America and much of Europe, reflecting mobile sources (Larkin et al., 2017; Achakulwisut et al., 2019). In addition, nitrogen dioxide displays a distinct urban–rural gradient, with higher concentrations in more densely populated urban areas. This pattern contrasts distinctly from that of ozone, which displays higher concentrations downwind of urban areas, and $PM_{2.5}$, which is more homogeneous regionally due to its longer atmospheric lifetime and diversity of (urban, rural and regional) sources. Trends in population-weighted nitrogen dioxide concentrations (for 1992–2012) indicated sharp decreases (-4.7%/year) in high-income North American countries and somewhat lesser decreases in western Europe (-2.5%/year) and high-income Asia–Pacific countries (-2.1%/year). In contrast, population-weighted nitrogen dioxide concentrations increased dramatically during this period in eastern Asia at a rate of 6.7%/year. Judging from satellite observations, concentrations in Africa seem to be generally low, with some evidence of increases in northern Africa and stable or slightly decreasing levels elsewhere (Geddes et al., 2016). However, there are few actual monitoring data on small-scale spatial variability within mega-cities in Africa.

1.3.2 Sources of emissions and exposure

Air pollution originates from numerous sources of emission, both natural and anthropogenic, with the latter becoming globally dominant since the beginning of industrialization. The process of combustion is the greatest contributor to air pollution, in particular, the combustion of fossil fuels and biomass to generate energy. In indoor environments, the use of polluting fuels in unvented heating and cooking stoves, tobacco combustion and combustion for other purposes, such as cultural or religious practices are also important. Fossil and biomass fuel burning for domestic heating is also an important source of outdoor air pollution in many parts of the world.

Outdoor combustion sources include land, air and water transportation; industry and power generation; and biomass burning, which includes controlled and uncontrolled forest and savannah fires and agricultural waste burning, as well as waste burning in urban areas. Other sources and processes contributing to outdoor pollution are the resuspension of surface dust and construction activities. Long-range atmospheric transport of pollutants from distant sources contributes to local pollution, particularly urban air pollution. Some of the pollutants are emitted directly by combustion sources as primary pollutants (with elemental carbon as the main constituent of PM), and some are formed in the air as secondary pollutants (such as nitrates, sulfates and organic carbon) through complex physicochemical processes involving gaseous precursors originating from combustion sources, agriculture (ammonia), other anthropogenic processes and natural processes such as biogenic emissions.

Comprehensive reviews of sources and concentrations of major outdoor air pollutants have been published by the United States Environmental Protection Agency (US EPA) (2010, 2016, 2017, 2019a, 2020). The European Environment Agency (EEA) every year produces a comprehensive report on air quality in Europe; the latest one from 2020 (EEA, 2020).

In indoor environments, pollution is also generated by combustion sources, mainly cooking and heating with polluting fuels such as coal, wood or dung; and using candles, incense and kerosene lamps (e.g. for light or religious practices). Tobacco smoking is also a significant source of indoor pollution. Non-combustion sources and processes also have a significant impact on indoor air pollution, particularly those that generate volatile and semi-volatile organic compounds (VOCs) and/or ozone. These include the renovation of houses, usage of consumer products (e.g. cleaning products and insecticides) and operation of electric devices such as laser printers. Dust resuspension due to human movement is another significant source in some indoor environments, particularly in schools. However, indoor air pollution is generated not only from indoor sources but also from outdoor air pollutants that are brought indoors in the processes of ventilation and penetration through the building envelope. In indoor environments without indoor sources of pollution, pollutants from outdoors are the main cause of indoor air pollution. Exposure is then further influenced by indoor decay, which is very fast for substances such as ozone (which is very reactive) and very slow for substances such as carbon monoxide (which is fairly inert).

Airborne pollutants originating from the sources and processes listed above include PM (measured as $PM_{2.5}$, PM_{10} and UFP), gaseous pollutants (including ammonia (NH_3), carbon monoxide, nitrogen dioxide, sulfur dioxide and ozone) and organic air pollutants. PM is partly formed in the atmosphere through chemical reactions that produce inorganic nitrates and sulfates, as well as organic compounds summarized as organic carbon. Other airborne pollutants not discussed in this document include radon and its decay products, and biological agents. WHO has developed dedicated air quality guidelines for these and for other selected pollutants, dampness and mould, and household fuel combustion (WHO, 2014b; WHO Regional Office for Europe, 2009, 2010).

The spatial and temporal concentration of pollutants in outdoor air varies according to the spatial distribution of the sources and their pattern of operation (e.g. daily or seasonal), the characteristics of the pollutants and their dynamics (dispersion, deposition, interaction with other pollutants), and meteorological conditions. In urban environments, some pollutants are distributed more homogeneously than others; for example, $PM_{2.5}$ concentration has much less spatial variation compared with the concentration of UFP or gases directly emitted by local combustion sources. Importantly, spatial variation determines to what extent ambient concentrations measured at a single fixed site reflect the outdoor concentrations at other sites in the area. Temporal variation is a very important feature of ambient air pollution.

Emissions often have specific and predictable temporal patterns (e.g. weekdays versus weekends). Most importantly, however, meteorological conditions are very strong determinants of temporal variations, and can have far larger effects than the temporal variation in emission alone. Epidemiological research of short-term health effects capitalizes on these short-term temporal variations in ambient concentrations. It offers opportunities to investigate whether temporally varying markers of health, including the number of adverse health events, correlate with the temporal variation in ambient concentrations of pollutants.

In indoor environments, concentrations of pollutants originating from outdoor air are influenced by their outdoor spatiotemporal patterns of concentration and, in particular, by the proximity of the building to outdoor sources (e.g. busy roads). Furthermore, indoor pollution concentrations depend on the amount of air pollution penetrating from outdoors; this is dependent on the penetration fraction, the ventilation rate and the decay rate. The penetration coefficient varies for different particle size fractions and is highest for $PM_{2.5}$. Finally, indoor pollution concentrations depend on the temporal pattern of operation of outdoor sources (e.g. traffic) but also on indoor sources (e.g. the daily cycle of cooking) and the decay process (in the case of highly reactive gases such as ozone).

People are exposed to air pollution in all the microenvironments in which they spend time, and the exposure puts them at risk. A microenvironment is defined as a three-dimensional space in which the pollutant level is uniform at some specified time. Exposure is a product of the pollutant concentration and the time over which a person is in contact with that pollutant. Assessment of exposure constitutes an element of risk assessment that is schematically represented as a chain of events from emissions through air pollution concentrations, population exposure, and body burden and pollutant dose at the organ or cellular level, to health risk.

In some locations, pollutant concentrations are low but the overall contribution to the exposure is high because of the longer time spent there (e.g. at home); in other locations, pollutant concentrations are very high (e.g. at traffic hot spots), and even short periods of time spent at such locations result in high exposures. When concentration varies with time, the time-averaged concentration is used for exposure calculation. For health risk assessment, exposures are defined on different time domains as (i) lifetime exposure, which is the sum of exposures that occurred in different environments – this is particularly important for carcinogenic pollutants; (ii) long-term exposure, measured as a mean of one or several years; and (iii) short-term exposure, measured over minutes to days.

Considering indoor exposures is important because people spend most of their time in various indoor environments, including home, workplace, school and commuting (where the microenvironment is a bus, car or train). Indoors is also where exposure predominantly occurs for vulnerable population groups, as sick and older people may not venture outside much. Although the exposures occur indoors, they are caused by both outdoor and indoor sources of emissions, since outdoor pollutants penetrate indoors, as discussed above.

The most accurate assessment of the risk caused by total air pollution would be based on the assessment of each individual's personal exposure, which would require pollution measurements in each microenvironment in which the individual spends time and an accurate account of the time spent there (time–activity diary). Yet, the most accurate assessment of exposure to ambient outdoor pollution – which is subject to clean air policy-making – may not necessarily be the measurement of personal exposure, unless the measured indicator of pollution is clearly and solely of outdoor origin. Presently it is not possible to measure all of the relevant pollutants in all microenvironments for each individual; therefore, the approach to exposure assessment is pragmatically based on the purpose of the assessment. For example, for studies on the long-term impact of outdoor air pollution (chronic effects), data are typically sourced from a limited number of monitors operating in some central outdoor locations. This has been shown to effectively represent population exposure to outdoor pollutants that are distributed more homogeneously, such as $PM_{2.5}$ or ozone. More complicated is exposure assessment for studies on the acute effects of air pollution (such as mortality or hospital admissions), where spatiotemporal variations in pollution need to be taken into account. However, for many pollutants, daily concentrations are often very highly correlated temporally across rather large regions and, thus, temporal variation may be well captured by single monitors.

Advanced methods of exposure assessment are available, including not only ground base monitoring of pollution but also the use of satellite observations and various modelling tools such as chemical transport models and land-use regression models. Those modelling approaches have overcome some of the former limitations of reliance on only a few monitoring stations to describe population exposure in space and time.

1.3.3 Disease and economic burden

Air pollution is the leading environmental risk factor globally. WHO estimates show that around 7 million deaths, mainly from noncommunicable diseases, are attributable to the joint effects of ambient and household air pollution (WHO, 2018).

Similar global assessments of ambient air pollution alone suggest between 4 million and 9 million deaths annually and hundreds of millions of lost years of healthy life, with the greatest attributable disease burden seen in low- and middle-income countries (Burnett et al., 2018; GBD 2019 Risk Factors Collaborators, 2020; Vohra et al., 2021; WHO, 2018). To date, strong evidence shows causal relationships between $PM_{2.5}$ air pollution exposure and all-cause mortality, as well as acute lower respiratory infections, chronic obstructive pulmonary disease (COPD), ischaemic heart disease (IHD), lung cancer and stroke (Cohen et al., 2017; WHO, 2018). A growing body of evidence also suggests causal relationships for type II diabetes and impacts on neonatal mortality from low birth weight and short gestation (GBD 2019 Risk Factors Collaborators, 2020). Air pollution exposure may increase the incidence of and mortality from a larger number of diseases than those currently considered, such as Alzheimer's and other neurological diseases (Peters et al., 2019). The burden of disease attributable to air pollution is now estimated to be competing with other major global health risks such as unhealthy diet and tobacco smoking, and was in the top five out of 87 risk factors in the global assessment (GBD 2019 Risk Factors Collaborators, 2020).

At the time of publishing these guidelines, global burden estimates are limited to $PM_{2.5}$ and ozone. Other common pollutants such as nitrogen dioxide and sulfur dioxide are not yet included and, therefore, these figures based on exposure to $PM_{2.5}$ and ozone are likely to underestimate the full health toll from ambient air pollution. For example, an analysis of the disease burden attributable to nitrogen dioxide on one outcome, incident paediatric asthma, indicated that nitrogen dioxide pollution was responsible for 13% of the burden (Achakulwisut et al., 2019). With a spatial pattern quite different than that for $PM_{2.5}$, exposure to nitrogen dioxide resulted in a comparatively high burden in many high-income countries.

Air pollution also leads to health-related economic impacts. Such impacts arise via two major pathways. The first, human health costs, are those related to the incidence of disease and mortality and are estimated by a willingness-to-pay approach. The second is due to lost labour productivity. In 2013 the World Bank estimated a global economic impact of US$ 143 billion in lost labour income and of US$ 3.55 trillion in welfare losses from exposure to $PM_{2.5}$ (World Bank, 2016). The welfare losses ranged from an equivalent of 1% of gross domestic product in low-income countries to 5% in high-income countries not within the Organisation of Economic Co-operation and Development. Apart from the health-related burden, air pollution causes additional economic costs such as through its impact on agricultural crops or through damage to buildings and infrastructure. In addition, there are costs associated with air pollution-related climate change and environmental degradation.

Although some uncertainty surrounding the exact disease burden remains (discussed in Chapter 8), it is clear that the global burden of disease associated with air pollution takes a massive toll on human health and the economy worldwide: exposure to air pollution is estimated to cause millions of deaths and lost years of healthy life, as well as a loss of trillions of dollars annually. Air pollution is now recognized as the single largest environmental threat to human health and well-being.

1.3.4 Inequities and vulnerable and susceptible groups

As already discussed, air pollution from both ambient sources and household use of polluting fuels is a recognized threat to human health, even at low exposures, and causes increased mortality and morbidity worldwide.

This burden of disease is unevenly distributed, often disproportionately affecting the most vulnerable and susceptible populations. The impact of air pollution can be seen on vulnerable individuals with greater exposure levels and susceptible individuals with chronic conditions (such as asthma, COPD, diabetes, heart failure and IHD), as well as children and pregnant women.

According to WHO, health equity is the "the absence of unfair and avoidable or remediable differences in health among population groups defined socially, economically, demographically or geographically" (WHO, 2020b). Health inequities, therefore, involve more than inequality with respect to health determinants, access to the resources needed to improve and maintain health, and health outcomes. They also entail a failure to avoid or overcome inequalities that infringe on fairness and human rights norms.

The fact that this burden of disease and mortality is unevenly distributed also impedes reduction of inequities and progress towards achieving full human rights and the UN SDGs. Global efforts to reduce pollution levels will have a positive impact on lowering inequity (Universal Declaration of Human Rights, Art. 1 and Art. 2) and will promote the right of life and security by ensuring safe and healthy environments (as stated in Art. 3) (UN, 1948).

Successful interventions are feasible, effective and compatible with economic growth. However, only a few studies have looked at equity in health when evaluating intervention delivery. In general, interventions that aim to reduce air pollution in urban areas have a positive impact on air quality and mortality rates, but the documented effect on equity is less straightforward. There is no evidence on whether applied air pollution reduction interventions have reduced health inequalities, since results from studies published to date have been mixed and not all interventions have had a positive distribution of health benefits. Indeed, depending on the health outcome(s) under study and intervention type/study design (simulations of air pollution concentrations or real interventions), more vulnerable groups such as older persons and deprived households were found to benefit more, equally or less than their socially better-off counterparts. For an in-depth review of published studies until the early 2010s, see Benmarhnia et al. (2014).

The largest inequities in air pollution exposure occur on the global rather than the local scale. Indeed, countries with policy-driven improvements in air quality have often seen particularly steep declines in pollution at hot spots since the 1990s, whereas declines have been gradual in regions with already good air quality. However, on a global scale, the steep decline in pollution in the vast majority of high-income countries is paralleled by an unprecedented increase in low- and middle-income countries. As documented by Zhang et al. (2017), the model of globalized movements of goods with inequities in emission and air quality standards contributes to inequity in air quality (UNEP, 2020). Weak policies in low- and middle-income countries allow pollution from the production of goods that are ultimately consumed in part in high-income countries.

1.3.5 Progress on scientific evidence

There has been tremendous progress in the scientific understanding of the health effects of air pollution since the early 2000s.

First of all, health effects of air pollution have now been studied in most WHO regions; in contrast, almost all evidence underpinning *Global update 2005* came from studies in Europe and North America. This is especially true for studies of short-term effects on mortality and morbidity (Chen et al., 2017; Yang J et al., 2020). However, quite a few studies of long-term effects have now also been reported, especially from Asia and Oceania. These studies have generally found relationships between air pollutants and ill-health that are qualitatively similar to those in high-income countries, although the CRFs are sometimes quantitatively different, with less steep relationships at high than at low concentrations (Yang X et al., 2020; Hanigan et al., 2019).

Secondly, air pollution has now been implicated in the development or worsening of several health conditions not considered in previous research. These include, among others, asthma, diabetes, reproductive outcomes and several neurocognitive end-points (Yang B-Y et al., 2020; Paul et al., 2019) (Thurston et al., 2017).

Thirdly, many studies have tried to identify which sources and/or physicochemical characteristics of airborne PM contribute most greatly to toxicity. This is a challenging area of research, given the great heterogeneity of airborne particles, and a definitive set of particle characteristics has yet to be identified. However, in its 2013 review of the evidence (WHO Regional Office for Europe, 2013a), WHO did point out that a focus on primary combustion particles, secondary inorganic aerosols and secondary organic aerosols was warranted (Thurston et al., 2016b; US EPA, 2019a; Lippmann et al., 2013; Vedal et al., 2013).

Lastly, investigators have learned to collaborate on an unprecedented scale. Prior to 2005, there were few examples of multicentre studies in the domain of time-series studies investigating the short-term effects of air pollution; two notable examples are the Air Pollution and Health, a European Approach (APHEA) studies in Europe and the National Morbidity and Mortality Air Pollution Study (NMMAPS) in the United States of America. These were followed after 2005 by the Air Pollution and Health: A European And North American Approach (APHENA) study across Europe, Canada and United States (Samoli et al., 2008); the ESCALA (Estudio de Salud y Contaminación del Aire en Latinoamérica) study in Latin America (Romieu et al., 2012); and the Public Health and Air Pollution in Asia (PAPA) study in Asia (Wong et al., 2008) – all studies of short-term effects. A remarkable culmination is the Multi-Country Multi-City (MCC) Collaborative Research Network (Chen et al., 2021; Liu et al., 2019; Meng et al., 2021; Vicedo-Cabrera et al., 2020), which combines multiyear data from 652 cities across the world in a single joint analysis of the short-term effects of $PM_{2.5}$, ozone, nitrogen dioxide and carbon monoxide, among other studies. Large collaborations have also emerged in studies of long-term effects such as the European Study of Cohorts for Air Pollution Effects (ESCAPE), which includes data from 36 different cohorts (Beelen et al., 2014). Another example is the Global Exposure Mortality Model (GEMM), which includes data from 41 cohorts from 16 countries across the globe (Burnett et al., 2018). Finally, an ongoing collaboration is studying the long-term health effects of low levels of air pollution in Europe (HEI, 2021), Canada and the United States (Brauer et al., 2019; Dominici et al., 2019).

Collectively, these studies have considerably strengthened the evidence for health effects of air pollution by increasing study power and using highly standardized preplanned methods of data collection, analyses and reporting (Brauer et al., 2019; Di et al., 2017a).

Methods of assessing exposure to air pollution have become much more refined. In 2005 the annual air quality guideline for $PM_{2.5}$ was largely based on results from two studies, the Harvard Six Cities study (Dockery et al., 1993) and the

American Cancer Society Cancer Prevention Study II (Pope et al., 2002). In these studies, exposure to $PM_{2.5}$ was assessed from one or a few monitoring sites per city. In addition, advanced chemical transport models, land-use regression models, satellite observations and much more detailed ground-level monitoring have formed the basis for very detailed assessment of exposure to $PM_{2.5}$ (as well as other pollutants) at very fine temporal and spatial scales. This has been useful not only for population studies of health effects but also for estimating the worldwide health impact of air pollution (Hammer et al., 2020; de Hoogh et al., 2018).

These new methods of exposure assessment have facilitated studies of nationwide populations, not only those living in cities but also those living in rural areas where air pollution monitoring is sparse or even absent. Often, these nationwide studies make use of administrative databases, which have increasingly become automated. These include death registers, disease registers, census data and population statistics. Such studies have the advantage of often including large populations of millions or even tens of millions of subjects. In addition, the data included are often more representative of underlying populations than regular cohort studies. A disadvantage of such databases is that they usually do not contain much information on potential confounding and modifying factors such as smoking and diet. However, innovative solutions have been developed to deal with this (e.g. survey results in Medicare and indirect adjustment for covariates in Canadian census studies) (Crouse et al., 2015; Cesaroni et al., 2013). Such databases usually also lack information from biological markers and specimens and, thus, cannot shed light on biological pathways to explain the observed associations.

Advances in statistical analyses techniques and conceptualization of causal modelling in epidemiology have produced new insights into the robustness of epidemiological associations between air pollutants and health effects. Machine learning techniques are increasingly being applied to explain patterns in complex exposure patterns. Most recently, large collaborative studies of the so-called exposome (defined as the totality of exposure individuals experience over their lives and how these exposures affect health) have started in an attempt to understand the effects of lifelong exposures to complex environmental factors on the development of health and disease throughout the life course. In such studies, air pollution is regularly included as one of several sets of complex environmental exposures and is combined with individual data, ranging from the molecular, genetic or cellular level up to the level of social, cultural and lifestyle data (Vrijheid et al., 2020).

Decision-makers have increasingly asked for reliable estimates of the burden of disease caused by air pollution as input for cost–benefit analyses of policy alternatives and as a basis for risk communication. Since 2005, major steps forward have been taken, especially by WHO and the Global Burden of Disease (GBD) project. An innovative, integrated exposure–response function was developed, integrating insights from studies on outdoor air pollution, on the health effects of indoor exposure to household air pollution from solid fuel combustion and environmental tobacco smoke, and on active smoking (Burnett et al., 2014). The integrated exposure–response function formed the basis for the first-ever truly global burden of disease estimate from exposure to $PM_{2.5}$, ozone and household air pollution from solid fuel burning, published in 2012 (Lim et al., 2012). These estimates used the global exposure estimates mentioned in section 1.3.1 and worldwide data on mortality and morbidity. They have been updated several times as new exposure estimates became available, and the integrated exposure–response function was updated based on new study findings (Cohen et al., 2017). The latest version no longer includes studies on active smoking, for instance (GBD 2019 Risk Factors Collaborators, 2020). Widely available software tools, such as WHO AirQ+ (WHO Regional Office for Europe, 2021a) or the US EPA's Environmental Benefits Mapping and Analysis Program – Community Edition (BenMAP-CE) (US EPA, 2021) facilitate similar analysis on a local (city, region, country) level.

Decision-makers have also sought evidence that measures to reduce air pollution actually produce health benefits. So-called accountability research (i.e. assessment of the effectiveness of interventions) addresses the consequences of policy interventions. An early example is a study from Dublin suggesting that a ban on coal burning led to reduced mortality (Clancy et al., 2002; Dockery et al., 2013). A nationwide study from the United States found that life expectancy increased most in areas where fine particle concentrations decreased the most (Pope, Ezzati & Dockery, 2009). A research programme on this subject, developed by the United States-based Health Effects Institute (HEI), showed promise, as well as pitfalls (Boogaard et al., 2017), while a Cochrane review on interventions to reduce ambient air pollution and their effects on health concluded that more research is needed in this area to reduce uncertainty (Burns et al., 2019).

Another issue of great interest to decision-makers is the that the co-benefits of policies aimed at reducing greenhouse gases may also have adverse direct or indirect health effects (e.g. methane, a powerful greenhouse gas and an ozone precursor) or, conversely, that policies aimed at reducing health-relevant air pollutants (such as black carbon) may also have climate forcing capabilities.

1.3.6 Adoption of the 2005 air quality guidelines worldwide

The first two editions of the air quality guidelines in 1987 and 2000 were successful in providing guidance, mostly to European countries, and provided the basis for the European Union (EU) legislation on air quality. *Global update 2005* was intended to be relevant to the diverse conditions within all WHO regions.

Evidence-informed guidance on air quality and associated health effects is necessary so that countries can use this information in standard setting and in providing information to the public. In 2012 a review of the processes followed to establish national ambient air quality standards (AAQS) for PM_{10} and sulfur dioxide (24-hour average) in the period 2007–2008 concluded that WHO air quality guidelines were the resource used most often to establish or revise national standards by the relevant authorities (Vahlsing & Smith, 2012). At that time, 91% of the countries that responded to a survey planned on using *Global update 2005* for future revision of their AAQS; however, this information was only available for 96 countries. In collaboration with WHO, the Swiss Tropical and Public Health Institute (Swiss TPH) has compiled information on the existence of legally binding AAQS for all UN Member States for PM ($PM_{2.5}$, PM_{10} and other relevant types), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide for different averaging times (both long and short term) (Kutlar Joss et al., 2017; WHO, 2021b). This unique update of the current state of AAQS worldwide provides a useful insight into the degree to which the 2005 air quality guidelines and interim targets are used as a basis for legally binding and non-binding AAQS. Information was identified for over 170 countries in the different WHO regions, of which 53 did not define any standards (see Table 1.1). In general, standards for short-term exposure were set more often than annual limit values. Levels varied greatly by country and by air pollutant.

Daily mean standards for PM_{10} and sulfur dioxide (averaging time ≤ 24 hours) and 1-hour maximum values for nitrogen dioxide were most often defined. Although compliance with WHO air quality guidelines was rather low, it was generally higher for short-term than for long-term standards. Among all countries with standards for 24-hour averaging times for $PM_{2.5}$ and PM_{10}, 21% and 46% met the air quality guidelines, respectively. In contrast, only seven countries (2%) adopted the WHO annual mean air quality guidelines for PM_{10} and $PM_{2.5}$. In case of sulfur dioxide (24 hours), only 7% of countries were in line with the air quality guidelines and 16% aligned their standard with the 1-hour guidelines for ozone. Adoption rates were higher for nitrogen dioxide, sulfur dioxide (10-minute averaging time) and carbon monoxide.

In addition, in the EU, WHO guidelines are referenced in the Ambient Air Quality Directive (European Parliament & Council of the European Union, 2008), and several countries use/will use WHO air quality guidelines and/or interim targets within existing and forthcoming legislation.

Analysis of the level of adoption of WHO air quality guidelines (see Table 1.1) shows that many countries have guidelines or standards for at least one air pollutant; however, there are many countries without standards or where information is lacking. The gap between the WHO air quality guidelines and the levels adopted in national regulations reflects the policy-making process. Whereas the WHO guidelines are evidence-informed, health-oriented recommendations, the process of developing legally binding regulations is driven by national policy-makers and the willingness to set environmental standards. This process involves different actors and may be influenced by a range of considerations.

Table 1.1. Adoption of WHO air quality guidelines in different regions

WHO region	**Countries in the region *(n)***	**Countries with standards for at least one pollutant and averaging time**		**Countries without standards**		**Countries with no information**	
		n	%	*n*	%	*n*	%
African Region	47	17	36	21	45	9	19
Region of the Americas	35	20	57	13	37	2	6
South-East Asian Region	11	7	64	3	27	1	9
European Region	53	50	94	2	4	1	2
Eastern Mediterranean Region	21	11	52	1	5	9	43
Western Pacific Region	27	12	44	13	48	2	7
Total	194	117	60	53	27	24	12

Source: Kutlar Joss et al. (2017).

The difficulty of attaining the air quality guidelines for PM and other pollutants was recognized in *Global update 2005*, and a series of interim targets were set to provide milestones for countries on the way to achieving the air quality guidelines. Interim targets were defined as air pollutant levels that are higher than the air quality guidelines, but which authorities in highly polluted areas can use to develop pollution reduction policies that are achievable within realistic time frames. The interim targets should be regarded as steps towards ultimately achieving air quality guidelines in the future, rather than as end targets. The number and numerical values of the interim targets are pollutant specific and they are justified in the relevant sections of Chapter 3.

1.3.7 Air pollution and health in the global agenda

World Health Assembly resolution and road map

In May 2015 the Sixty-eighth World Health Assembly adopted resolution WHA68.8, *Health and the environment: addressing the health impact of air pollution*, which was endorsed by 194 WHO Member States (WHO, 2015). This resolution stated the need to redouble the efforts of Member States and WHO to protect populations from the health risks posed by air pollution. Member States were urged to raise public and stakeholder awareness on the impacts of air pollution on health; provide measures to reduce or avoid exposure; facilitate relevant research; develop policy dialogue, strengthen multisectoral cooperation at national, regional and international levels; and take effective steps to reduce health inequities related to air pollution.

Specifically, the resolution recognized the role of the WHO air quality guidelines, for both ambient and indoor air quality, in providing guidance and recommendations for clean air that protect human health. It requested the Director-General to strengthen WHO capacities in the field of air pollution and health through further development and regular updating of the WHO air quality guidelines to facilitate effective and efficient decision-making, and to provide support and guidance to Member States in their efficient implementation. A road map for implementation of this resolution on air pollution and health was presented at the Sixty-ninth World Health Assembly and approved by Member States (WHO, 2016a).

UN Sustainable Development Agenda and other UN processes

The WHO air quality guidelines support the strategic priorities for NCDs (UN, 2018a), as well as those established in the 2030 Agenda for Sustainable Development, which was adopted at the United Nations Sustainable Development Summit in 2015 (UN, 2015). These priorities emphasize the need to strengthen national capacities to reduce modifiable risk factors, including air pollution, for NCDs and to accelerate countries' responses for their prevention and control. The 17 SDGs contained in the Agenda present an indicator framework for global monitoring and include 169 specific associated targets (UN Statistics Division, 2020).

These, in turn, are divided into indicators, thereby providing a tool for quantitative assessment of achievement towards meeting the goals. This update of the WHO air quality guidelines provides evidence-informed benchmarks on the health impacts of air pollution, and will help assess the following air pollution-related SDG indicators to inform the health trends associated with exposure to air pollution:

- Indicator 3.9.1: Mortality rate attributed to household and ambient air pollution
- Indicator 7.1.2: Percentage of population with primary reliance on clean fuels and technology
- Indicator 11.6.2: Annual mean levels of fine PM (population-weighted).

The health impacts of air pollution are a main driver for action by the environment sector. The UN Environment Assembly adopted the following three resolutions on the topic.

- Resolution 1/7 from the United Nations Environment Programme (UNEP), adopted at its first session in 2014 on Strengthening the role of the United Nations Environment Programme in promoting air quality, highlights the effects of air pollution, especially from a perspective of sustainable development. In particular, it encourages governments to take cross-sectoral action to improve air quality and formulate action plans while establishing (and implementing) nationally determined air quality and emissions standards, taking into account relevant information (e.g. WHO guidelines) (UNEP, 2014).
- Additionally, the UN Environment Assembly presented a resolution, at its second session in 2016, requesting the Executive Director to engage with all relevant UN entities to promote a coordinated approach to combating the challenges of SDS globally by supporting Member States in the identification of relevant data and information gaps, best policy measures, and actions to address the problem and by inviting them to intensify monitoring data collection and knowledge sharing on all relevant aspects of SDS, including their impact on ecosystems and on human health and well-being (UNEP, 2016a).
- Finally, the resolution on Preventing and reducing air pollution to improve air quality globally calls for Member States to take action across sectors to reduce all forms of air pollution. Among its recommendations, the resolution urges Member States to:

> consider joining or cooperating with, as appropriate, relevant global initiatives such as the Climate and Clean Air Coalition and the Global Methane Initiative; [and] facilitate action to reduce air pollution in urban and rural areas including by encouraging cities and local governments to consider participating in, as appropriate, the BreatheLife campaign (UNEP, 2018).

Lastly, a report from 2019 from the UN Special Rapporteur on the Issue of Human Rights Obligations Relating to the Enjoyment of a Safe, Clean, Healthy and Sustainable Environment highlighted the different state obligations in relation to the right to breathe clean air, as well as the specific obligation to protect people and groups in vulnerable situations (UN, 2019a). The Special Rapporteur focused on the right to breathe clean air as one of its components and describes the negative impact of air pollution on the enjoyment of many human rights, in particular the right to life and the right to health, especially by vulnerable groups. The Special Rapporteur identified several good practices implemented worldwide that have helped to improve air quality; offered a number of recommendations to Member States for actions they should consider as part of a national air quality action plan; and urged businesses, in order to fulfil their responsibility in this regard, to contribute to and support efforts to reduce air pollution.

1.4 WHO guidelines relating to air quality

WHO air quality guidelines have been widely used as a reference tool to help decision-makers across the world in setting standards and goals for air quality management. Since the mid-1980s, WHO has coordinated the development of several editions of air quality guidelines for both ambient and indoor air quality. Although the methodologies used and the requirements needed to produce them have evolved over time, these guidelines remain in essence manuals aiming to provide evidence-informed recommendations in the form of air quality guidelines for different averaging times (WHO Regional Office for Europe, 2017).

Since 2009, WHO has issued a separate series of guidelines for indoor air quality, which provide recommendations on biological contaminants of indoor air, selected air pollutants typically measured in indoor settings, and household fuel combustion.

Air quality guidelines for Europe (1987)

The first volume of the air quality guidelines created the initial framework for the scientific rationale for the series. The expert panel formulated guidelines for 28 air pollutants on exposure in both outdoor and indoor environments. In specific cases (e.g. mercury), a guideline level was formulated for indoor settings only. For 19 noncarcinogenic pollutants, recommendations were provided as guideline values using the toxicological concepts of the lowest/no observed adverse effect level and protection factors. In contrast, ranges were provided for cadmium, lead, PM (expressed as black smoke), ozone and sulfur dioxide , with a recommendation to use gravimetric methods for measuring particles.

Because of the impossibility of identifying no-effect levels of exposure, the panel recommended unit risk factors for carcinogenic (genotoxic) pollutants (WHO Regional Office for Europe, 1987).

Air quality guidelines for Europe. second edition (2000)
In response to strengthening of the evidence during the 1990s, the revised air quality guidelines were published in the year 2000. A total of 35 air pollutants were evaluated, including the pollutants covered in the first edition, the additional organic pollutants butadiene, polychlorinated biphenyls and polychlorinated dibenzodioxins/dibenzofurans, and three indoor air pollutants (anthropogenic vitreous fibres, radon and second-hand tobacco smoke). As in the first edition, guidelines were presented in the form of levels/ranges for noncarcinogenic pollutants and as unit risk factors for carcinogenic substances. In contrast, the ozone guideline was formulated as a level and a CRF, whereas the PM guidelines were presented as a CRF alone, this time separately from sulfur dioxide. To aid implementation, a specific chapter was devoted to air quality management and translation of the guidelines into binding standards (WHO Regional Office for Europe, 2000a).

Air quality guidelines – global update 2005. Particulate matter, ozone, nitrogen dioxide and sulfur dioxide (2006)
Global update 2005 provided numerical guideline values for the classical pollutants – PM, ozone, nitrogen dioxide and sulfur dioxide – based on a comprehensive review of all available evidence at the time. Air quality guidelines for PM were presented for the first time, while the nitrogen dioxide levels from previous editions were retained. In addition, the concept of interim targets as "incremental steps in progressive reduction of air pollution" was introduced and used for PM, ozone and sulfur dioxide. Acknowledging that exposure to these pollutants occurs in both outdoor and indoor settings, the guideline levels were meant to apply in all environments, including indoors in households, schools and vehicles. However, the guideline panel recognized the significance of indoor air pollution as a stand-alone risk factor that needed different management approaches to those employed for outdoor air pollution. Therefore, a specific chapter was dedicated to indoor air quality, including a framework for the future development of WHO indoor air quality guidelines (WHO Regional Office for Europe, 2006).

WHO guidelines for indoor air quality: dampness and mould (2009)
This first volume of the series aimed to raise awareness and assist users in identifying and mitigating the health hazards related to biological contamination in all indoor settings. The guidelines included a comprehensive assessment of the evidence on the adverse health effects associated with

dampness and biological agents such as bacteria, mould and fungi. The guideline panel concluded that the most relevant health outcomes of concern were respiratory and immunological, including asthma and allergies. Given a lack of exposure–response relationships, recommendations were formulated as indicators of health risk, such as the persistence of dampness or presence of mould, rather than numerical levels. The guideline panel recommended the prevention/reduction of such indicators on interior surfaces and building structures as an overarching principle that users could follow to manage risks through specific measures (WHO Regional Office for Europe, 2009).

WHO guidelines for indoor air quality: selected pollutants (2010)
The second volume of the series provided recommendations for nine air pollutants either as numerical levels or unit risks, prioritized according to their presence in potentially harmful concentrations indoors and the availability of data for risk assessment. Thus, comprehensive monographs were prepared for benzene, carbon monoxide, formaldehyde, naphthalene, nitrogen dioxide, polycyclic aromatic hydrocarbons, radon, trichloroethylene and tetrachloroethylene. Guidelines for indoor PM were not formulated, since PM had been covered in *Global update 2005,* which was intended for all environments. Although the evidence on indoor nitrogen dioxide was re-evaluated, guideline levels remained the same as before due to a lack of new evidence suggesting a threshold of effect. In addition, some general measures to reduce exposure indoors were proposed, such as controlling sources of emission, ensuring proper ventilation, using low-emission materials and, switching to cleaner fuels and technologies for indoor combustion (WHO Regional Office for Europe, 2010).

WHO guidelines for indoor air quality: household fuel combustion (2014)
Building on previous guidelines for PM and carbon monoxide, modelling and extensive reviews, the latest volume in the series offered recommendations related to household fuel combustion. Using a new WHO guideline development approach, as outlined in the *WHO handbook for guideline development, 2nd edition* (WHO, 2014a), the guideline panel set emission rate targets for $PM_{2.5}$ and carbon monoxide from household fuels combustion, discouraged the use of kerosene and unprocessed coal, and provided guidance for transition to the sustained adoption of clean fuels (e.g. liquefied petroleum gas) and technologies. In addition, risks related to the use of conventional fuels were highlighted, including burns, poisoning, house fires and those related to fuel-wood collection. As overarching principles, the guidelines highlight the importance of reducing outdoor air pollution to achieve indoor air quality guidelines, and of addressing all main household energy end uses to maximize health (WHO, 2014b).

2

Guideline development process

2.1 Introduction

WHO guideline development follows a rigorous process and involves several groups of individuals with well-defined roles, responsibilities and tasks (WHO, 2014a). The process involves the following main steps:

1. formulation of the scope and key questions of the guidelines (section 2.3);
2. systematic review of the relevant evidence (section 2.4);
3. assessment of the certainty level of the body of evidence resulting from systematic reviews (section 2.4.4);
4. formulation of the air quality guideline (AQG) levels (section 2.5); and
5. formulation of other supporting guidance (section 2.5.3).

Throughout the whole process, the principles of the GRADE approach were followed (Schünemann et al., 2013).

The WHO steering group was primarily involved in initiating, structuring and executing the guideline development process; the guideline development group (GDG), composed of leading experts and stakeholders, was mainly responsible for determining the scope of the guidelines and formulating AQG levels and other guidance; the systematic review team conducted the systematic reviews of evidence; and the external review group (ERG) provided input and peer review, as needed. The WHO Guidelines Review Committee reviewed and approved the guideline document prior to publication.

The process of developing this update of the air quality guidelines started in 2016. Following WHO procedures, the WHO Regional Office for Europe's European Centre for Environment and Health in Bonn, Germany obtained planning approval and established the WHO steering group, the GDG, the systematic review team and the ERG.

Several meetings of the GDG were held in Bonn throughout the guideline development process. During the first meeting of the GDG in September 2016, GDG members helped define the scope of the guidelines, prioritized air pollutants and critical health outcomes, formulated the key questions to be addressed and set a timeline for completion of the work.

In March 2018 and June 2019, the GDG and the systematic review team met to discuss the preliminary results of the methods adaptation work and systematic reviews of evidence. Revision and publication of the systematic reviews of evidence was completed in mid-2020. In February and June 2020, the GDG finalized the AQG levels and other elements of guidance.

The external consultation of the draft guideline document took place in November and December 2020 through an online survey. In January 2021, the GDG met to address the comments from the external consultation of the draft guideline document.

Throughout the guideline development process, several ad hoc working groups were established to address specific (methodological) issues. Composed of subject matter and methodological experts, these groups worked through remote meetings and contributed within the adapted approaches for systematic review and guideline development to the air quality and health domain.

The following sections describe the groups of experts involved in, and the different steps of, the guideline development process.

2.2 Groups involved in and general procedures of guideline development

The development of WHO guidelines is carried out by several groups of people with defined roles and responsibilities. These are the WHO steering group, the GDG, the systematic review team and the ERG comprising WHO staff members, external experts and stakeholders. In addition, the process was supported by an external guideline methodologist with expertise in systematic review and certainty assessment methods, and other external consultants, including experts in risk of bias (RoB) assessment and environmental epidemiology (shown in Annex 1, Tables A1.1–A1.7).

2.2.1 WHO steering group

The WHO steering group is composed of a limited number of WHO staff with extensive work experience at technical level in the area of air quality and health, who were recruited from all relevant departments, centres and WHO regional offices. Members of this group provided input during the different stages of planning, selection of members of the other groups, reviewing evidence, formulating draft recommendations and guidance, and overseeing peer review. The complete list of members of the WHO steering group can be found in Annex 1, Table A1.1.

2.2.2 Guideline development group

The GDG included subject matter experts who were convened to appraise the evidence and formulate recommendations and related guidance. The group was selected by the WHO steering group, as informed by the results of a survey of WHO expert networks, with the aim to cover the technical skills, perspectives and geographical representation needed in a global guideline development process.

The GDG assisted in determining the scope of the guidelines, chose the critical health outcomes and defined the key review questions. Members of the GDG contributed to drafting the guideline document and responded to peer reviewers. Details of the members of the GDG and their specific roles, affiliations and areas of expertise are listed in Annex 1, Table A1.2.

2.2.3 Methodological working groups

Members of this GDG also worked with the guideline methodologist, a RoB methodologist and other experts in ad hoc working groups to adapt the methods of systematic review and guideline development to the specific field of air quality and health. In particular, the following working groups were formed:

- Working Group on Risk of Bias Assessment;
- Working Group on Certainty of Evidence Assessment;
- Working Group on Derivation of Air Quality Guideline Levels and Interim Targets; and
- Working Groups on Good Practice Statements.

The external methodologists are listed in Annex 1, Table A1.4, and members of the working groups are listed in Annex 1, Table A1.7.

2.2.4 Systematic review team

The systematic review team consisted of experts in environmental and clinical epidemiology, who were commissioned by WHO to conduct the systematic reviews informing the recommendations. The team also provided input into the adaptation of systematic review methods and tools. The GDG and WHO steering group identified the members of the systematic review team based on their publications in the field and their expertise. Members of the systematic review team are listed in Annex 1, Table A1.3.

2.2.5 External review group

The ERG included technical experts and representatives from stakeholders such as patient organizations, environmental advocacy groups, industry associations and scientific societies. Members were identified among networks of excellence, WHO collaborating centres and partner groups such as Cochrane, with support from the GDG and online searches.

Based on several considerations (expertise, sex, geographical representation), about 100 individual experts from 38 countries and territories across all WHO regions were identified and invited to participate in the ERG. Of these, 65 experts provided input at different stages of the guideline development process, as needed.

In particular, they provided information on specific topics, assessed and translated scientific papers, peer-reviewed the evidence base, and/or commented on the draft guideline document. Likewise, an inclusive mapping exercise took place of stakeholder organizations from all WHO regions, working at either regional or global level. Of the 100 identified organizations, 72 were invited to be members of the ERG. Ultimately, 14 organizations participated in the external consultation of the draft guideline document and provided comments that were all addressed by the GDG and WHO steering group. The individual experts and stakeholder organizations are listed in Annex 1, Table A1.5 and Table A1.6, respectively.

2.2.6 Management of conflicts of interest

Conflicts of interest – with or without bias – can undermine the credibility of a guideline; hence, their appropriate management is crucial in WHO guideline development. The members of the GDG as well as the other experts involved in the guideline development process were asked to complete declaration of interest forms. In addition, all experts received briefings about the types of conflicts of interest (financial, intellectual/academic and non-academic). Declarations from all experts were collected and managed according to the relevant WHO procedures. No experts had to be excluded from their respective roles. Further information about the process for identifying, managing and reporting conflicts of interest can be found in the *WHO handbook for guideline development, 2nd edition* (WHO, 2014a). A summary of declared conflicts of interest is presented in Annex 2.

2.2.7 Decision-making during the process

The members of the GDG agreed to make decisions by consensus, through discussions moderated by the appointed GDG co-chairs. In (very rare) cases where consensus was not possible, informal voting was employed. The view of the majority (90% or more of the GDG members, as a result of the discussions to reach agreement in the group) was implemented in developing the guidelines.

Decisions in the ad hoc working groups were made in the same way among the participating GDG members, the external guideline methodologist and/or other external experts. Consensus could not be reached among the GDG members and the methodologist on one aspect of the certainty of evidence assessment. This was about whether upgrades of the evidence certainty should be allowed in case of downgrades: the GDG members thought so, but the methodologist did not. The view of the majority (in this case, the complete GDG) was taken. The methodologist made the first proposals on derivation of AQG levels and interim targets but did not participate in the phase of final formulation of recommendations. The GDG, supported by a technical consultant (Annex 1, Table A1.7), concluded this work.

The members of the systematic review team conducted the systematic reviews independently, with regular interaction with the working groups and the GDG to ensure that the most important needs of the GDG were addressed appropriately. One member of the systematic review team served as liaison with the GDG and supported the methodological work on AQG levels and interim targets.

2.2.8 Document preparation and external review

The guideline document was drafted in a stepwise manner following the guideline development process. The GDG identified the background and other relevant supporting information early in the preliminary phase. In their second meeting, the WHO steering group and GDG decided on the table of contents, and several of their members started drafting specific sections. At a later stage, a designated technical editor worked towards ensuring consistency and logical flow.

The guideline document went through several rounds of extensive internal and external review. In particular, the external consultation of the draft document was managed through an online survey targeting 71 members of the ERG (48 provided comments and were acknowledged). As prescribed, the procedure focused on the identification of missing data, unclear information, factual errors and issues related to implementation, but not on changing the recommendations. The GDG and WHO steering group considered all comments provided during this external consultation and revised the guideline document where appropriate.

2.3 Determining the scope of the guidelines and formulation of review questions

Determining the scope of the guidelines involved the selection of air pollutants to be considered, as well as the critical health outcomes for each in relation to durations and scale of exposure. This was a multistep procedure in which experts evaluated the strength of the evidence for the pollutants; the causality of pollutant–outcome pairs; and other considerations such as the severity of health outcomes, burden of disease, expected increases in exposure and policy considerations.

The present guidelines are applicable to both outdoor and indoor environments. Thus, they cover all settings in which people spend a significant portion of their time. This has been the case since the publication of the first edition of the guidelines in 1987 and was reinforced in *Global update 2005* and the 2010 guidelines for indoor air quality.

It is important to note that AQG levels recommended in previous WHO air quality guidelines for pollutants or averaging times not re-evaluated in this update remain valid, including those for the short averaging times for nitrogen dioxide, sulfur dioxide and carbon monoxide included in the *2005 Global update* and indoor air quality guidelines from 2010. The reader is referred to previous volumes of air quality guidelines (WHO Regional Office for Europe, 1987, 2000a, 2010) for the other pollutants not covered in this update. As in previous volumes, the guidelines do not cover occupational settings, due to the specific characteristics of the relevant exposures and the potential differences in population susceptibility of the adult workforce in comparison with the general population.

Furthermore, the guidelines do not include recommendations about any kind of multiple exposures. In everyday life, people are often exposed to a mixture of air pollutants at the same time. WHO acknowledges the need to develop comprehensive models to quantify the effects of multiple exposures on human health. However, as the main body of evidence on air quality and health still focuses on the impact of single air pollutants on health outcomes, the current guidelines provide recommendations for each air pollutant individually.

The GDG also decided not to formulate specific recommendations on population-wide interventions because these are largely context specific: what might be effective in one setting might not work in another. Instead, general risk management principles, based on decades of experience, are summarized in Chapter 6, on implementation of the guidelines. In addition, individual-level interventions, such as the use of personal respiratory protection (e.g. masks, respirators), air purifiers and behavioural measures, are not addressed here but in a report from a separate WHO consultation (WHO, 2020a).

2.3.1 Preliminary consultation

Following the conclusions from the Review of evidence on health aspects of air pollution (REVIHAAP) project (WHO Regional Office for Europe, 2013a), WHO organized an expert consultation in Bonn in September–October 2015 as a first step for this update of the air quality guidelines. The objective was to gather expert opinion and guidance in order to identify and discuss the latest available evidence on health effects of air pollutants and interventions to reduce exposure to air pollution for the purpose of informing this update of the air quality guidelines.

Twenty-eight participants – representing a wide array of expertise and geographical locations – attended the consultation, which included not only a review of the available scientific evidence on a number of ambient air pollutants but also methodological issues and the implications of exposure and intervention studies. Experts recommended that a focus of these guidelines on pollutant-specific risk assessment was still appropriate and prioritized 32 air pollutants according to four categories to reflect their relative importance in the context of updating the air quality guidelines. Since reviewing the evidence systematically for all air pollutants was infeasible considering the available resources, experts suggested prioritizing the pollutants $PM_{2.5}$, PM_{10}, ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide for this update. This advice was based on the large body of new health-related evidence that had been published since *Global update 2005* (WHO Regional Office for Europe, 2016a).

2.3.2 Selection of priority pollutants

The final selection of air pollutants took place in September 2016, during the first meeting of the GDG. Prior to the meeting, WHO surveyed GDG members on the final list of air pollutants to be included in this update of the air quality guidelines. The air pollutants identified in the global expert consultation, together with a number of different health outcomes, were included in the survey. In the ensuing discussion, the GDG decided to develop AQG levels for PM_{10}, $PM_{2.5}$, nitrogen dioxide, ozone, sulfur dioxide and carbon monoxide in relation to health outcomes critical for decision-making and for relevant averaging times.

For PM types such as BC/EC and UFP, the GDG agreed that AQG levels for these pollutants could not be formulated owing to the absence of clear quantitative evidence on independent health effects. However, the results of reviews of evidence conducted by other groups would be examined in order to reach a better-informed decision about whether recommendations should be formulated and in which form. Likewise, for SDS, the GDG agreed that any recommendation would likely be qualitative in nature and geared towards guiding countries in moving towards mitigation and adaptation measures.

Following presentations by invited experts, the GDG, at its third meeting, decided to include guidance on BC/EC, UFP and SDS in the form of good practice statements.

2.3.3 Prioritization of health outcomes

In order to define the pollutant–outcome pairs that would be systematically reviewed to inform the formulation of AQG levels, the GDG developed a prioritization framework based on the considerations outlined in Box 2.1.

Box 2.1. Health outcome prioritization framework

- Evidence on causality for a health outcome would be considered first, according to the latest determination (causal or likely causal) from the Health Canada, the International Agency for Research on Cancer, US EPA or other available integrated science assessments. As mandated by the Clean Air Act, the US EPA periodically reviews all scientific evidence about the health effects of so-called criteria pollutants, including all five pollutants considered in this report. These Integrated Science Assessments (ISAs) include a structured analysis of all evidence – including from toxicology – that supports a classification of a specific effect being causal, likely causal, suggestive of a causal relationship, inadequate to infer a causal relationship or not likely to be a causal relationship. For details, see Owens et al. (2017). These classifications have been used in support of identification of the relevant pollutant–outcome associations addressed in this document.
- Where causality is not determined to be proven or likely (e.g. suggestive causality), the precautionary principle would be used when determining which additional most-severe health outcomes could be included. These outcomes would be based on other considerations such as contribution to burden of disease (e.g. prevalence of disease, disability weight), policy implications and expected increase in exposure to a pollutant in the future.
- Causality determination would supersede the severity of a health outcome but, in some cases, two (or more) different health outcomes might be systematically evaluated for the same pollutant (e.g. one with a causal or likely causal link to the pollutant, and another health outcome for which the evidence is suggestive only but which is very severe or prevalent in the population). Severity of disease would be informed by considerations proposed by the latest update of the joint European Respiratory Society and American Thoracic Society policy statement on health effects from air pollution (fatality, persistence of effect, susceptible groups and medical/functional significance, including loss of autonomy and reduced quality of life) (Thurston et al., 2017).
- Lastly, as health outcomes can be assessed in various ways in studies, the specific health outcome measure(s) would be identified, based on evidence and the expert judgement of the GDG, to be used for quantitative health risk assessment in the guidelines.

By applying the prioritization framework, the GDG identified the following critical health outcomes associated with the selected air pollutants:

- all-cause (non-accidental) mortality[4] (hereafter referred to as all-cause mortality);
- cause-specific mortality, as per the International Statistical Classification of Diseases and Related Health Problems, 10th edition (ICD-10), 2016 version (WHO, 2016b): cardiovascular (ICD-10 codes I00–I99), lung cancer (ICD-10 codes C30–C39) and respiratory (ICD-10 codes J00–J99);
- hospital admissions and emergency room visits related to asthma (ICD-10 code J45); and
- hospital admissions and emergency room visits related to IHD (ICD-10 codes I20–I25; ultimately restricted to myocardial infarction, ICD-10 codes I21–I22).[5]

The pollutant–outcome pairs that were included comprise those for which there is broad scientific consensus regarding the causal nature of the reported relationships; others were chosen based on the strength of the epidemiological evidence.

Table 2.1 gives an overview of the different considerations included in the prioritization process. This table was adapted from the document resulting from the population, exposure, comparator, outcome and study design (PECOS) process (see section 2.3.4) finalized in November 2016.

Since then, it was decided to include one more pollutant–outcome pair: the association between exposure to short-term sulfur dioxide and all-cause and respiratory mortality. This was done to provide continuity with *Global update 2005*, as explained below.

The GDG recognizes that associations for many more pollutant–outcome pairs have been reported and reviewed in the literature. It would be practically impossible, given the resources available for the current guideline update, to include all of these for consideration and review.

[4] In an epidemiological study of air quality and health, all-cause mortality (ICD-10 code A00–Z99) refers to all deaths, and non-accidental mortality (ICD-10 code A00–R99) includes all deaths with the exception of deaths due to accidents, murder, suicide, etc. Although all-cause mortality includes accidental deaths, the proportion of deaths causes by accidents, etc. is typically small (< 10%) in comparison with the other causes of death.

[5] The systematic review by Lee et al. (2020) focused on myocardial infarction (ICD-10 codes I21–I22) as the only IHD outcome because it is not possible to establish the precise time of onset of other IHD outcomes. Further, other conditions within the spectrum of IHD are routinely managed in outpatient settings rather than in the emergency room/department or hospital wards.

The GDG, however, sees no grounds for assuming that the AQG levels, as derived in Chapter 3, would be very different if more outcomes would have been considered for the pollutants that were included. Obviously, this does not apply to those pollutants that were not considered at all in the current update. A draft version of this document has been reviewed by a large number of experts and stakeholder organizations, and no examples have been provided that would change this assessment.

The GDG also emphasizes that there has been no separate, independent assessment of the mechanistic, toxicological and human clinical studies relating air pollution to human health. However, comprehensive evaluations by authoritative bodies such the Committee on the Medical Effects of Air Pollutants (COMEAP) in the United Kingdom, Health Canada and the US EPA were taken into account in the development of the AQG levels.

Information about all the specific pollutant–outcome pairs reviewed can be found in the systematic reviews of evidence available in a virtual special issue of *Environment International* entitled *Update of the WHO global air quality guidelines: systematic reviews* (Whaley et al., 2021).

Table 2.1. Air pollutants and health outcomes proposed for systematic review in the guideline development process[a]

LONG-TERM EXPOSURE

Pollutant	Health outcomes used in *Global update 2005*	Health outcomes selected for updating in the 2021 air quality guidelines	Justification for health outcome selection
$PM_{2.5}$ and PM_{10}	Total, cardiopulmonary and lung cancer mortality	• All-cause mortality • Cardiovascular mortality (all, cerebrovascular, IHD) • Respiratory mortality (any, COPD, acute lower respiratory infections) • Lung cancer mortality	**CAUSALITY DETERMINATION (REFERENCE)** **$PM_{2.5}$** • Causal for cardiovascular and respiratory mortality (US EPA, 2009) • Causal for total and cardiovascular mortality (Health Canada, 2013) **PM** • Causal for total mortality in relation to PM (Health Canada, 2013) • Group 1[b] lung cancer for PM (Straif et al., 2013) • Likely causal for lung cancer mortality in relation to PM (Health Canada, 2013) **SUPPORTING CONSIDERATIONS** **PM_{10}** • Health outcome supported by evidence from PM_{10} and $PM_{2.5}$ **OTHER RELEVANT CAUSAL DETERMINATIONS (REFERENCE)** **$PM_{2.5}$** • Likely causal for respiratory effects (US EPA, 2009) • Likely causal for respiratory effects (Health Canada, 2013)

Table 2.1 contd

LONG-TERM EXPOSURE

Pollutant	Health outcomes used in *Global update 2005*	Health outcomes selected for updating in the 2021 air quality guidelines	Justification for health outcome selection
O_3	No long-term guideline provided	• All-cause mortality • Respiratory mortality	**CAUSALITY DETERMINATION (REFERENCE)** • Suggestive causality for mortality (US EPA, 2013) • Suggestive causality for respiratory mortality (Health Canada, 2013) **SUPPORTING CONSIDERATIONS** • Severity of health outcome, burden of disease • Precautionary principle from expected increase of this pollutant due to climate change (policy implications and end-user perspectives) **OTHER RELEVANT CAUSAL DETERMINATIONS (REFERENCE)** • Likely causal for respiratory effects (US EPA, 2013) • Suggestive causality for respiratory effects (Health Canada, 2013)

Table 2.1 contd

LONG-TERM EXPOSURE			
Pollutant	**Health outcomes used in *Global update 2005***	**Health outcomes selected for updating in the 2021 air quality guidelines**	**Justification for health outcome selection**
NO_2	Respiratory effects in children	• All-cause mortality • Respiratory mortality	**CAUSALITY DETERMINATION (REFERENCE)** • Suggestive causality for total mortality (US EPA, 2016)) • Suggestive causality for total mortality (Health Canada, 2016a)) **SUPPORTING CONSIDERATIONS** • Severity of health outcome, burden of disease • Recent studies show associations with respiratory mortality, consistent with likely causality for respiratory effects (see other causal determinations below) • The causal determination of US EPA for mortality is suggestive, in the light of the limited number of studies properly addressing confounding by other transport-related air pollutants • The causal determination of US EPA of likely causal for respiratory effects (see other causal determinations below) takes into account respiratory mortality **OTHER RELEVANT CAUSAL DETERMINATIONS (REFERENCE)** • Likely causal for respiratory effects (US EPA, 2016) • Likely causal for respiratory effects (Health Canada, 2016a)

Table 2.1 contd

SHORT-TERM EXPOSURE			
Pollutant	**Health outcomes used in *Global update 2005***	**Health outcomes selected for updating in the 2021 air quality guidelines**	**Justification for health outcome selection**
CO	COHb levels of below 2% in nonsmokers' blood (also protective for long-term exposure) (WHO Regional Office for Europe, 2000a, 2010)	• Hospital admissions and emergency room visits related to IHD[c]	**CAUSALITY DETERMINATION (REFERENCE)** • Likely causal for cardiovascular effects (US EPA, 2010) • Likely causal for cardiovascular effects (Health Canada, 2010) **SUPPORTING CONSIDERATIONS** • Consistent with WHO indoor air quality guidelines (WHO Regional Office for Europe, 2010) using COHb levels linked to IHD[c]-related symptoms (e.g. ST-segment changes, reduced time to exercise-induced angina) • IHD[c] appears to be the most consistent outcome from cardiovascular effects associated with short-term CO exposure in epidemiological studies (US EPA, 2010)
$PM_{2.5}$ and PM_{10}	COHb levels of below 2% in nonsmokers' blood (also protective for long-term exposure) (WHO Regional Office for Europe, 2000a, 2010)	• All-cause mortality • Cardiovascular mortality • Respiratory mortality	**CAUSALITY DETERMINATION (REFERENCE)** **$PM_{2.5}$** • Causal for all-cause, cardiovascular and respiratory mortality (US EPA, 2009) • Causal for all-cause, respiratory and cardiovascular mortality (Health Canada, 2013)

Table 2.1 contd

SHORT-TERM EXPOSURE			
Pollutant	**Health outcomes used in *Global update 2005***	**Health outcomes selected for updating in the 2021 air quality guidelines**	**Justification for health outcome selection**
$PM_{2.5}$ and PM_{10} **(contd)**			**PM (any size fraction)** • Causal for all-cause mortality (Health Canada, 2013) **SUPPORTING CONSIDERATIONS** • Cardiovascular and respiratory mortality also considered in causal determination of respiratory/cardiovascular effects (US EPA, 2009) (see other relevant causal determinations) • PM_{10}, supported by evidence from $PM_{2.5}$ **OTHER RELEVANT CAUSAL DETERMINATIONS ($PM_{2.5}$) (REFERENCE)** • Likely causal for respiratory effects (US EPA, 2009) • Causal for cardiovascular effects (US EPA, 2009) • Causal for respiratory effects (Health Canada, 2013) • Causal for cardiovascular effects (Health Canada, 2013)

Table 2.1 contd

SHORT-TERM EXPOSURE			
Pollutant	**Health outcomes used in *Global update 2005***	**Health outcomes selected for updating in the 2021 air quality guidelines**	**Justification for health outcome selection**
O_3	Daily mortality	• Hospital admissions and emergency room visits related to asthma • All-cause mortality	**CAUSALITY DETERMINATION (REFERENCE)** • Causal for respiratory effects (US EPA, 2013) • Causal for respiratory effects (Health Canada, 2013) • Likely causal for total mortality (US EPA, 2013) • Likely causal for total mortality (Health Canada, 2013) **SUPPORTING CONSIDERATIONS** • Stronger causal determination for respiratory effects than for mortality outcomes (see other relevant causal determinations below) • Experimental studies demonstrate decreases in lung function at exposures as low as 60–70 ppb O_3 in young healthy adults. Equally strong evidence demonstrates associations of ambient O_3 with asthma hospital admissions and emergency room visits, including for at-risk subpopulations (e.g. children, people with asthma or other pre-existing diseases), who cannot ethically be included in experimental studies

Table 2.1 contd

SHORT-TERM EXPOSURE			
Pollutant	**Health outcomes used in *Global update 2005***	**Health outcomes selected for updating in the 2021 air quality guidelines**	**Justification for health outcome selection**
O_3 **(contd)**			• Mortality also included because of the severity of health outcome, number of exposed individuals and precautionary principle (expected future increase of this pollutant due to climate change, with policy and end-user implications). On the other hand, studies on mortality might target other subgroups of the population such as older people **OTHER RELEVANT CAUSAL DETERMINATIONS (REFERENCE)** • Likely causal for cardiovascular effects (US EPA, 2013) • Suggestive causality for cardiovascular effects (Health Canada, 2013) • Likely causal for cardiopulmonary mortality (Health Canada, 2013)

Table 2.1 contd

SHORT-TERM EXPOSURE			
Pollutant	**Health outcomes used in *Global update 2005***	**Health outcomes selected for updating in the 2021 air quality guidelines**	**Justification for health outcome selection**
NO_2	Bronchial responsiveness in asthmatics	• Hospital admissions and emergency room visits related to asthma • All-cause mortality	**CAUSALITY DETERMINATION (REFERENCE)** • Causal for respiratory effects (US EPA, 2016) • Causal for respiratory effects (Health Canada, 2016a) • Likely causal for total mortality (Health Canada, 2016a) • Suggestive causality for total mortality (US EPA, 2016) **SUPPORTING CONSIDERATIONS** • Stronger causal determination for respiratory effects than for mortality outcomes (see other relevant causal determinations below) • Both Health Canada and US EPA causality assessments for respiratory effects are very recent (2016); limited new evidence might have accumulated since

Table 2.1 contd

SHORT-TERM EXPOSURE			
Pollutant	**Health outcomes used in *Global update 2005***	**Health outcomes selected for updating in the 2021 air quality guidelines**	**Justification for health outcome selection**
NO_2 **(contd)**			• Strongest evidence for relationships of short-term NO_2 exposure with respiratory effects is for asthma exacerbations. More uncertainty exists with independent effect of short-term NO_2 exposure on non-asthma respiratory effects due to less consistent evidence across scientific disciplines and limited evidence to support biological plausibility. Additionally, studies of short-term NO_2 exposure with asthma hospital admissions and emergency room visits include at-risk subpopulations (e.g. children, people with asthma or other pre-existing diseases) who cannot ethically be included in experimental studies • Mortality is also included because of severity of health outcome and number of exposed individuals. On the other hand, studies on mortality might target other subgroups of the population such as older people

Table 2.1 contd

SHORT-TERM EXPOSURE			
Pollutant	**Health outcomes used in *Global update 2005***	**Health outcomes selected for updating in the 2021 air quality guidelines**	**Justification for health outcome selection**
SO_2	All-age mortality and childhood respiratory disease	• Hospital admissions and emergency room visits related to asthma • All-cause mortality[d] • Respiratory mortality[d]	**CAUSALITY DETERMINATION (REFERENCE)** • Causal for respiratory effects (US EPA, 2015) • Causal in adults for respiratory effects (Health Canada, 2016b) **SUPPORTING CONSIDERATIONS** • Experimental studies demonstrate lung function decrements and respiratory symptoms at very short-term exposures • (i.e. 5–10 minutes) to SO_2 in adults with asthma. Studies of hospital admissions and emergency room visits related to asthma, including evidence from at-risk subpopulations (e.g. children, people with asthma or other pre-existing diseases) who cannot ethically be included in experimental studies, report positive associations with shortterm SO_2 exposures, particularly for children

COHb: carboxyhaemoglobin; ppb: parts per billion.
[a] This table was adapted from the document resulting from the PECOS process (see section 2.3.4) finalized in November 2016.
[b] Group 1 means carcinogenic to humans.
[c] Ultimately restricted to myocardial infarction (ICD-10 codes I21 and I22).
[d] In the second GDG meeting held in 2018, the GDG agreed to include the pollutant–outcome pairs SO_2–all-cause mortality and SO_2–respiratory mortality.

In the second GDG meeting in March 2018, the question was raised of why a systematic review of short-term associations between sulfur dioxide and all-cause mortality would be needed in addition to the reviews on PM, ozone and nitrogen dioxide. It was suggested to also review SO_2 and mortality to ensure continuity with the previous *Global update 2005*. If a new review is not feasible, the GDG suggested formulating clear justification as to why mortality attributed to SO_2 is not considered. It was subsequently decided to commission a separate review on short-term associations between sulfur dioxide and all-cause as well as respiratory mortality, to be conducted by the team that had already conducted the review on short-term associations of PM, ozone and nitrogen dioxide with mortality. Therefore, the latest US EPA ISA of causality for this association is mentioned below.

In 2017 the latest US EPA ISA on sulfur oxides was published (US EPA, 2017). This did not change the assessment noted in Table 2.1 of a causal relationship between short-term sulfur dioxide concentrations and respiratory effects. The association between short-term sulfur dioxide concentrations and total mortality was deemed to be suggestive of a causal relationship. This association was not considered by the GDG in 2016, but was added at a later stage, as previously mentioned. Therefore, the causality assessment is not reported in Table 2.1.

The US EPA published an updated ISA of PM in 2019 (US EPA, 2019a). The causality determinations for long- and short-term PM effects on mortality and on respiratory and cardiovascular morbidity were the same as those in the 2009 ISA (US EPA, 2009), which was quoted in Table 2.1.

The US EPA published an updated ISA of ozone in 2020 (US EPA, 2020). The causality determinations for ozone effects on respiratory morbidity were the same as those in the 2009 ISA, which was quoted in Table 2.1. For short-term mortality and for cardiovascular morbidity, the evidence was changed from likely causal to suggestive of a causal relationship, in part because new human exposure studies such as the Multicenter Ozone Study in oldEr Subjects (MOSES) study did not clearly demonstrate the cardiovascular effects of ozone (Frampton et al., 2017; Rich et al., 2020). Other reasons quoted were the lack of control for co-pollutants in epidemiological studies and uncertainty about the short-term effects of ozone on cardiovascular emergency room and hospital admissions.

Although the US EPA ISA was published in 2020, the literature on long- and short-term effects of ozone has grown since then. Chapter 3 includes five new studies on the long-term effects of ozone on mortality and one very large worldwide multicity study on the short-term effects of ozone on mortality, which have provided further evidence of the short- and long-term effects on total and respiratory mortality. The reader is referred to section 3.4 for further details.

The nitrogen dioxide causality assessments shown in Table 2.1 are based on reviews published in 2016. Since then, COMEAP published a report in 2018 entitled *Associations of long-term average concentrations of nitrogen dioxide with mortality*, which is somewhat more supportive of a causal role of long-term nitrogen dioxide in increasing all non-accidental mortality, especially respiratory mortality (PHE, 2018). The 2016 EPA ISA classified the relationship between short-term nitrogen dioxide and respiratory effects as causal and the relationship between long-term nitrogen dioxide and respiratory effects as likely causal. A footnote to the causality determination defined the health outcome as "[a] n array of outcomes is evaluated as part of a broad health effects category: physiological measures (e.g. airway responsiveness), clinical outcomes (e.g. hospital admissions), cause-specific mortality". This suggests the causality determinations also extend to respiratory mortality, although the further detailed assessments in the ISA provide some qualifications for the separate health effects that were evaluated (US EPA, 2016). A 2018 review by the German Environment Agency (in German, with a summary in English) also supports a role for long-term nitrogen dioxide in causing cardiovascular mortality (Schneider et al., 2018).

The GDG notes that one review has specifically investigated how sensitive the associations between long-term nitrogen dioxide concentrations and mortality were to adjustment for different PM metrics (Faustini, Rapp & Forastiere, 2014). Associations with nitrogen dioxide were found to be generally robust.

Since 2016, no authoritative reviews have been published on short-term associations between carbon monoxide and hospital admissions for myocardial infarction.

2.3.4 Formulation of review questions

As per the WHO procedure of developing guidelines (WHO, 2014a), key questions to guide the review of evidence are best developed using the population, intervention, comparator and outcome format.

However, in environmental health risk guidelines such as the WHO air quality guidelines, recommendations are typically given in the form of numerical concentration values to prevent adverse health effects from exposure to environmental pollutants (so-called AQG levels). Typically, the best available evidence from human studies in this field consists mostly, if not exclusively, of observational studies, as opposed to (randomized) controlled trials. Therefore – and as raised by several expert guideline development methodologists dealing with environmental risk guidelines (Collaboration for Environmental Evidence, 2013) – the use of a slightly adapted formulation of the traditional population, intervention, comparator and outcome question was used: a PECOS question. The intervention (I) term was replaced by an exposure (E) term, reflecting the concentration in ambient air of the particular air pollutant under consideration; also, an S was added to define study designs to be considered in evaluating the evidence, resulting in a PECOS question: population, exposure, comparator, outcome and study design (Table 2.2).

The GDG proposed the following PECOS questions (Box 2.2), which were later adapted to the health outcome and specific type of studies relevant for each pollutant and time average (short- or long-term exposure) considered in the updated guidelines.

Box 2.2. Generic PECOS question for long- and short-term exposures

Long-term exposures

In any population, including subgroups of susceptible adults and children (P), what is the increase in risk of health outcome x (O) per unit increase (C) in μg/m³ of long-term exposure (in the order of months to years) to ambient[a] concentration of air pollutant y (E), observed in studies relevant for the health outcome and exposure duration of interest (S)? In these studies, what is the lowest concentration that produces a measurable increase in risk?

Short-term exposures

In any population, including subgroups of susceptible adults and children (P), what is the increase in risk of health outcome x (O) per unit increase (C) in μg/m³ of short-term exposure (in the order of hours to days) to ambienta concentration of air pollutant y (E), observed in studies relevant for the health outcome and exposure duration of interest (S)? In these studies, what is the lowest concentration that produces a measurable increase in risk?

[a] Ambient refers to both outdoor and indoor environments.

These PECOS questions were designed to retrieve the epidemiological evidence necessary to develop updated AQG levels and inform the shape of the CRF for the different pollutant–outcome pairs.

For the specific purpose of updating the WHO air quality guidelines, the PECOS terms were defined as follows (Table 2.2).

Table 2.2. Elements of a PECOS question

Element	Explanation
Population	The general population, all age groups, from developed and developing countries, living both in urban and in rural areas exposed on a daily basis to the pollutant of interest through ambient air (understood as encompassing exposure in both outdoor and indoor environments), and not exclusively in occupational settings or as a result of indoor exposure alone. Population subgroups that are vulnerable to the effects of air pollution would be included, such as those with specific pre-existing health conditions (e.g. respiratory or cardiovascular diseases), pregnant women, newborns, children or older people. Whenever applicable, the considered health effect of exposure to the pollutant of interest in these vulnerable subgroups of the population would be assessed separately
Exposure	Exposure to air pollutants from any source, measured as long term (months to years) or short term (hours to days)
Comparator	Exposure to the lowest levels of air pollutants from any source, measured as long- (months to years) or short-term (hours to days)
Outcome	Health outcome(s) upon which the AQG levels are developed for each air pollutant considered in the guidelines
Study design	Type of studies evaluated, such as cohort and case–control studies (long term) and time-series, case-crossover and panel studies (short term)

2.4 Systematic review of the evidence

To address the PECOS questions posed by the GDG, a preliminary search of the relevant literature was conducted to identify available systematic reviews and meta-analyses on air quality and health. Based on an overview that assessed the quality of reviews in the field (Sheehan et al., 2016), it was decided that included peer-reviewed articles that were of sufficient quality and addressed the formulated PECOS would serve as a starting point for most systematic reviews. Missing elements (e.g. specific assessments or syntheses) would be extracted anew and searches updated to the latest possible date within the process.

Selected members of the systematic review team, who were mostly identified through the above procedure, reviewed and synthesized all the relevant epidemiological literature in the area of air quality and health, following the principles outlined in the *WHO handbook for guideline development*, *2nd edition* (WHO, 2014a) and guidance provided from methodologists and experts in the discipline.

The instruments needed to assess the RoB for individual studies included in the reviews and the overall certainty of evidence across studies were adapted to better reflect the particularities of the air quality and health field.

PECOS questions were formulated for each of the major pollutant–outcome pairs and relevant averaging times. When the same health outcomes and averaging times were assessed, various air pollutants were grouped under the same systematic review, resulting in six systematic reviews.

All systematic reviews followed a common protocol prepared according to the provisions set out by the *WHO handbook for guideline development, 2nd edition* (WHO, 2014a) and later fine-tuned in relation to the specific exposure–outcome averaging time combinations that each review aimed to address.

The protocols for each systematic review are registered on PROSPERO, an international register of systematic reviews, maintained by the University of York (NIHR, 2021).

Furthermore, all systematic reviews used in the derivation of AQG levels are publicly available in a special issue of the journal *Environment International* (Whaley et al., 2021), which are also summarized in Annex 3.

- Long-term exposure to PM and all-cause and cause-specific mortality: a systematic review and meta-analysis (Chen & Hoek, 2020).
- Long-term exposure to NO_2 and O_3 and all-cause and respiratory mortality: a systematic review and meta-analysis (Huangfu & Atkinson, 2020).
- Short-term exposure to particulate matter (PM_{10} and $PM_{2.5}$), nitrogen dioxide (NO_2), and ozone (O_3) and all-cause and cause-specific mortality: systematic review and meta-analysis (Orellano et al., 2020).

- Short-term exposure to sulfur dioxide (SO_2) and all-cause and respiratory mortality: a systematic review and meta-analysis (Orellano, Reynoso & Quaranta, 2021).
- Short-term exposure to ozone, nitrogen dioxide, and sulfur dioxide and emergency room visits and hospital admissions due to asthma: a systematic review and meta-analysis (Zheng et al., 2021).
- Short-term exposure to carbon monoxide and myocardial infarction: a systematic review and meta-analysis (Lee et al., 2020).

The core systematic reviews of adverse health effects were commissioned to address the PECOS questions. To ensure and confirm that no relevant studies in indoor settings had been missed in these reviews (none had been identified in the searches, based on the selected pollutant–outcome pairs), complementary searches were also conducted. In addition, several reviews and analyses were conducted in the context of this update of the guidelines. These included work on the health effects of exposure to particles originating from SDS, the burden of disease attributable to air pollution, the effectiveness of individual-level interventions and the cost–effectiveness of air quality interventions. Relevant review work conducted by other groups was closely monitored (e.g. on the health effects of BC/EC and UFP).[6]

2.4.1 Identification and retrieval of evidence

Based on the PECOS questions, a list of inclusion and exclusion criteria were defined for each systematic review and later fine-tuned by the systematic review team (Table 2.3 and Table 2.4).

Because most of the systematic reviews were based on peer-reviewed papers, the original search strategies were revised to reflect any additional eligibility criteria to ensure that all papers addressing the PECOS questions were identified.

Specific search strategies using both free text and controlled vocabulary terms were run for each database. More details can be found in the systematic reviews published in *Environment International* (Whaley et al., 2021).

All efforts were made to include all relevant papers published, which entailed searching a considerable number of literature sources, the inclusion of papers in languages other than English and the use of time frames spanning from database inception to late 2018.

[6] With the exception of the review and analysis performed by Evangelopoulos et al. (2020) and the review by Fussell & Kelly (2021), none of the reviews conducted in the context of the update of the guidelines have yet been published.

Table 2.3. Generic eligibility criteria for systematic reviews of long-term exposures

PECOS	Inclusion	Exclusion
Population	▪ General human population (including subgroups at risk: children, pregnant women, older people and patients with particular conditions) of all ages, living in developed and developing areas, both urban and rural. No geographical restrictions ▪ Exposure to the pollutant of interest predominantly via inhalation through ambient air (this covers exposures in both outdoor and indoor environments)	▪ Exposure to the pollutant of interest in occupational settings or as a result of indoor exposure exclusively
Exposure	▪ Long-term exposure (in the order of months to years) to ambient air $PM_{2.5}$, PM_{10}, O_3 and NO_2 expressed in a concentration unit (μg/m^3, ppb) ▪ For the NO_2 systematic review, NO_x studies may be included	▪ Less than 1 year of data available ▪ No exclusion criteria applied based on adjustment for co-pollutants
Comparator	▪ Exposure to lowest levels of the air pollutant of interest in the same or a control population	–
Outcome	▪ Health outcomes selected in relation to long-term exposure include (ICD-10 codes (version 2016)): all-cause mortality and cause-specific mortality, including cardiovascular (I00–I99), lung cancer (C30–C39) and respiratory (J00–J99)	–
Study design	▪ Human epidemiological studies such as: - prospective and retrospective studies - cohort studies - case–control and nested case–control studies ▪ Published (or accepted for publication, i.e. in press) studies in peer-reviewed indexed journals in any language (abstract in English language) and grey literature, where relevant.	▪ Qualitative studies ▪ Studies without individual-level data, that is, fully group-level (ecological) covariates ▪ Studies where no original data were analysed ▪ Reviews and methodological papers ▪ Non-human studies (in vivo, in vitro, other)

ppb: parts per billion.

Table 2.4. Generic eligibility criteria for systematic reviews of short-term exposures

PECOS	Inclusion	Exclusion
Population	▪ General human population (including subgroups at risk: children, pregnant women, older people, and patients with particular conditions) of all ages, living in developed and developing areas, both urban and rural. No geographical restrictions ▪ Exposure to the pollutant of interest predominantly via inhalation through ambient air (this covers exposures in both outdoor and indoor environments)	▪ Exposure to the pollutant of interest in occupational settings or as a result of indoor exposure exclusively
Exposure	▪ Short-term exposure (in the order of hours to 7 days) to ambient air $PM_{2.5}$, PM_{10}, O_3, NO_2, SO_2 and CO, from any source expressed in a concentration unit (μg/m^3, ppb) ▪ For NO_2 systematic review, NO_x studies may be included	▪ No exclusion criteria were applied based on adjustment for co-pollutants
Comparator	▪ Exposure to lowest levels of the air pollutant of interest in the same or a control population	–
Outcome	▪ Health outcomes selected for short-term exposure include (ICD-10 codes (version 2016)): all-cause mortality and cause-specific mortality, including cardiovascular (I00–I99) and respiratory (J00–J99), and hospital admissions and emergency room visits related to asthma (J45–J46) and myocardial infarction (I21–I22)	–
Study design	▪ Human epidemiological studies such as: - time-series studies - case-crossover studies - panel studies ▪ Published (or accepted for publication, i.e. in press) studies in peer-reviewed indexed journals in any language (abstract in English language) and grey literature, where relevant	▪ Qualitative studies ▪ Studies without individual-level data, that is, fully group-level (ecological) covariates ▪ Reviews and methodological papers ▪ Non-human studies (in vivo, in vitro, other) ▪ Studies with geographical and temporal overlap during meta-analysis

ppb: parts per billion.

For each of the systematic reviews, two reviewers independently screened titles and abstracts of papers identified with the systematic search and identified those that could be excluded based on the eligibility criteria. The full texts of the remaining articles were independently reassessed by two reviewers to ensure that all eligibility criteria were met. Disagreements among reviewers were resolved by discussion or through consultation with a third reviewer. The reasons for excluding articles were recorded. In addition, references of identified relevant articles (and reviews/guidelines, where relevant) were scanned to identify additional papers matching the PECOS question. The resulting list of papers was circulated with the systematic review team and the GDG to identify any potentially relevant missing studies (published or in press). Lastly, papers identified through the peer review process were incorporated as appropriate, either quantitatively or qualitatively, as feasible.

Two reviewers extracted all relevant data needed for the process using pre-defined forms. Key data included the elements defined by PECOS and declared conflicts of interest, as well as the data necessary to conduct RoB assessments (e.g. confounding factors) and to derive the AQG levels (i.e. for onset of the CRF: 5th–95th percentiles of population exposure, mean/median, and minimum and maximum pollutant concentrations; for shape of the CRF: methods and results of authors' assessments). Where necessary data were missing, the systematic review team obtained them from the authors of the primary studies or calculated them.

2.4.2 RoB assessment of individual studies

To assess RoB for individual studies, a specific instrument was developed by a working group composed of GDG members and methodologists. Based on a review of existing tools, the group agreed to take into account six key domains (confounding, selection bias, exposure assessment, outcome measurement, missing data, selective reporting), each including several subdomains or signalling questions. Judgement options included high, moderate and low RoB. The group also prepared guidance notes to assist the systematic review team in performing the task, including a list of critical and additional potential confounders to consider when making judgements about confounding and key information on the particularities of exposure assessment in the field. To avoid carrying forward the ratings from one domain to the others, the working group considered that an overall judgement of bias at the study level was not appropriate: instead, subgroup analyses were suggested per RoB domain across studies. This approach was considered more suited to identify which particular type of bias had an impact on the pooled effect size, as well as its direction and magnitude (Morgan et al., 2019).

A detailed description of the instrument is available in a dedicated publication (WHO Regional Office for Europe, 2020).

2.4.3 Synthesis of evidence

Meta-analyses were conducted to obtain summary pooled estimates of the risk for an adverse health outcome per unit increase in exposure to a given air pollutant. When three or more studies were identified for the same pollutant and health outcome, a quantitative synthesis was performed. Otherwise, the effect estimates were described qualitatively. Overall, statistical analyses were performed according to the *Guidelines for application of meta-analysis in environmental epidemiology* (Blair et al., 1995), the *Cochrane handbook for systematic reviews of interventions* (Higgins & Green, 2011) or other authoritative guidance. The approach used was the inverse variance method, assuming a linear concentration–response relationship.

When exposure metrics differed among studies, the data were transformed to the same metric, generally the relative risk (RR).

Although no dose–response meta-analytic techniques were employed to assess the shape of the CRF, potential deviations from linearity were assessed by other means, for example, by stratifying by mean pollutant concentrations or qualitatively evaluating the determinations and judgements made by study authors.

Because of differences in populations and pollution composition across populations, it was decided that estimates were to be pooled by means of a random-effects meta-analysis (maximum likelihood approach). Several measures of statistical heterogeneity were calculated, including *I-squared* and *tau-squared*. If considerable heterogeneity was present, attempts were made to explain the source of heterogeneity by subgroup analysis, meta-regression or sensitivity analysis (only possible if enough studies were available).

Other sensitivity analyses included those needed to inform the judgements on RoB, large magnitude of effect size and publication bias within the certainty of evidence approach. Lastly, additional sensitivity analyses were conducted to explore the impact of multipollutant models, conflicts of interest of study authors, population characteristics or lag patterns, where appropriate.

2.4.4 Grading of the certainty of the overall body of evidence

Evaluation of the certainty of evidence is foundational for systematic review, with a focus on the validity and precision of effect estimates. In the clinical realm, evidence-informed review has become the starting point for establishing guidelines for clinical practice, including guidance for therapeutics and diagnostics. Much of the evidence considered in the clinical context comes from randomized controlled trials, where exposures are assigned at random by the investigator to provide some degree of assurance that potential confounders and effect modifiers, both known and unknown, are balanced across treatment groups. In the clinical context, evidence may also come from observational studies, including cohort and case–control studies, case series and other data resources. Given the strength of the randomized controlled trial design for ensuring comparability of treatment and control groups, a hierarchy of evidence sources has been established in which randomized controlled trials (providing the strongest evidence) have the highest ranking and lower rankings are given to other sources.

The GRADE approach has been adopted as the basis for evidence review in support of WHO guidelines (Schünemann et al., 2013; WHO, 2014a). GRADE was implemented for the purpose of evaluating evidence in support of formulation of clinical guidelines and, as such, it divided studies into randomized and non-randomized designs and ranked randomized studies as higher-quality evidence.

The initial certainty level of evidence was determined by the type of study, with randomized controlled trials starting at high certainty and non-randomized studies starting at low certainty. Thereafter, five domains were assessed for downgrading the certainty of the evidence resulting from randomized and non-randomized studies, and three domains were assessed for upgrading the certainty of evidence from non-randomized studies alone (Box 2.3).

Consistent with the standard approach, the certainty of the effect estimate was graded as high, moderate, low or very low. The ratings were subsequently used to select the risk functions used to derive AQG levels.

With the extension of GRADE to topics for which evidence derives largely or totally from observational studies, there are areas for which evidence from randomized designs is not available and decision-making, of necessity, draws on other evidence. For environmental agents, the evidence foundation is diverse and with very few exceptions does not involve a randomized exposure (e.g. air cleaner with filter versus air cleaner without filter). The human evidence is observational, coming from population-level studies (time-series studies, geospatial analyses, cohort studies, case–control studies and cross-sectional studies). A further issue that arises with environmental agents is identifying and summarizing the evidence derived from toxicological studies, in vivo animal bioassays and in vitro work addressing mechanisms.

Box 2.3. GRADE domains

Domains assessed for downgrading the certainty of evidence by one or two levels

- Limitations or RoB in all studies that constitute the body of evidence
- Indirectness of evidence in the studies
- Inconsistency of results between studies
- Imprecision of the pooled effect estimate
- Publication bias detected in the body of evidence.

Domains assessed for upgrading the certainty of evidence by one level

- Large magnitude of the pooled effect estimate
- All plausible confounding shifting the pooled effect estimate towards the null
- Existence of a concentration–response gradient.

Source: adapted from WHO (2014a).

Recognizing these complexities, different groups have made efforts to adapt GRADE for the assessment of evidence on exposures, but limitations were still under discussion at the time of developing these guidelines (National Research Council, 2014; Morgan et al., 2016; Saracci, 2017; Steenland et al., 2020). In this context, a working group was convened to adjust the standard GRADE approach to the field of air quality and health. The current adaptation was not aimed to assess causality through an examination of all the relevant streams of research (Woodruff & Sutton, 2011), but instead aimed to rate how certain one can be that the "true" estimate of the association between an air pollutant and an adverse health effect lies within a particular range (Hultcrantz et al., 2017).

The working group decided to start the rating for air pollution observational studies at moderate rather than high certainty evidence because of the risk of unmeasured confounding in observational research. From this level, the certainty of the evidence was then downgraded or upgraded based on several criteria per GRADE domain.

In addition, the working group recognized the need for taking a more nuanced view of the evidence, as well as for incorporating the following additional criteria to complement or replace existing guidance:

- calculation of an 80% prediction interval, to help assess heterogeneity in conjunction with the 95% confidence interval (CI) (IntHout et al., 2016);
- calculation of the sample size needed for a study based on a specific RR and CI, to help guide judgements about imprecision (Rothman & Greenland, 2018);
- estimation of the extent to which confounding may influence a pooled effect size using the *E-value*, to facilitate judgements for large magnitude of effect size (Mathur & VanderWeele, 2020); and
- additional approaches to help assess publication bias, such as a subgroup analysis of multicentre studies compared with single-city studies in case of evidence based on time-series studies, an analysis of differences in effect estimates from earlier versus later studies, and a comparison with published results of attempts to quantify the magnitude of bias.

A detailed description of the adaptation of GRADE is provided in the supplementary materials of the articles published in the special issue of *Environment International* (WHO Global Air Quality Guidelines Working Group on Certainty of Evidence Assessment, 2020).

2.5 From evidence to recommendations

The GDG decided that the recommendations (AQG levels) would be primarily based on epidemiological evidence. The GDG discussed how to account for contextual factors in formulating the AQG levels. Given the very large variability in exposures, socioeconomic conditions and other policy considerations across the world, the GDG concluded that retaining and enhancing the widely adopted interim targets from the previous guidelines would be a more useful instrument to assist end-users in implementing the recommendations. Contextual factors should instead be considered during the policy-making process at national, regional or local level, as discussed in Chapters 1 and 6 of this document. The recommendations were based on the certainty of evidence judgements alone, whereby low/very low certainty would prevent the GDG from formulating a recommendation for an AQG level. See, however, the caveats about this in sections 2.5.1 and 2.5.2.

Furthermore, two additional elements of guidance are offered in these guidelines. These elements differ from the recommendations in that they are not derived from systematic reviews of evidence of adverse health effects from air pollution.

Instead, they are based on an expert assessment of several types of evidence that included their utility to support end-users in their efforts to improve air quality. These elements of guidance are interim targets and good practice statements. Interim targets are air pollutant levels that are higher than the AQG levels, but which authorities in highly polluted areas can use to develop pollution reduction policies that are achievable within realistic time frames. The interim targets should be regarded as steps towards ultimately achieving AQG levels in the future, rather than as end targets. The number and numerical values of the interim targets are pollutant specific, and they are justified in the relevant sections of Chapter 3.

Contextual factors also did not play a direct role in the formulation of this guidance, although some considerations were described in a qualitative manner where relevant (e.g. burden of disease in relation to interim targets, resource considerations in relation to some good practice statements).

The following sections provide a detailed description of the approaches used by the GDG to formulate the recommendations and the additional guidance.

2.5.1 Formulation of long-term AQG levels

2.5.1.1 Definition

Long-term AQG levels are developed to provide advice to end-users to reduce the adverse effects of long-term exposure to air pollutants and, thereby, reducing associated disease and mortality.

Health outcomes in the current process are restricted to all-cause and respiratory mortality ($PM_{2.5}$, PM_{10}, ozone, nitrogen dioxide). In addition, cardiovascular and lung cancer mortality are considered for some pollutants ($PM_{2.5}$, PM_{10}).

A long-term AQG level is defined as the lowest exposure level of an air pollutant above which the GDG is confident that there is an increase in adverse health effects. Confidence refers primarily to the adapted GRADE qualification confirming that there is high or moderate certainty evidence for an association between a specific pollutant and a specific health outcome. The GRADE certainty rating is based on eight criteria (discussed later in this section). The GDG also took into account additional considerations, including causality determinations.

In principle, AQG levels were developed only for pollutant–outcome pairs with at least moderate certainty data. The GDG recognizes that, following the precautionary principle, conditional recommendations could be considered where the certainty of the evidence is less than moderate.

This would be the case, for instance, when exposure is widespread and the effect on population health is severe. However, as will become evident in Chapter 3, there was at least moderate certainty evidence to support long- and short-term AQG levels for all pollutants considered.

This approach avoids consideration about what level of exposure should be considered safe, given that the available evidence cannot currently identify levels of exposure that are risk free for any of the pollutant–outcome pairs considered in this document. Moreover, the approach also avoids defining a so-called accepted level of risk, which would violate clean air acts or directives in countries where adverse health effects of air pollution are not accepted.[7] It also avoids making inferences for exposure levels below those for which there is solid evidence. The challenge is then to find the lowest level of exposure for which the GDG is still confident that there is at least moderate certainty evidence for adverse health effects. Note that this also requires some consideration of what is an adverse health effect. As a reference for this, the GDG used the latest update of the joint European Respiratory Society and American Thoracic Society policy statement on "what constitutes an adverse health effect of air pollution" (Thurston et al., 2017).

The systematic reviews commissioned by WHO formed the starting point for the body of evidence on which an AQG level is based and, therefore, underpin these guidelines. The systematic reviews each provide a summary estimate of the RR derived from the included meta-analyses for each pair of air pollutant and adverse health effect, a 95% CI for this estimate and a GRADE qualification for the certainty of the evidence. In principle, the GDG used this estimate for guideline derivation only if the 95% CI from a random-effects meta-analysis did not include an RR of 1. However, as air pollution has no known health benefits, the GDG decided in specific, well-argued cases to deviate from this principle.

2.5.1.2 Procedure

To find the lowest level of long-term exposure for which the GDG would be confident of an adverse health effect, a dedicated working group developed a procedure for each pollutant–outcome pair, based on the following eight steps (Table 2.5).

7 For example, the US National Ambient Air Quality Standards are based on the Clean Air Act, which stipulates: "National primary ambient air quality standards, prescribed under subsection (a) shall be ambient air quality standards the attainment and maintenance of which in the judgment of the Administrator, based on such criteria and allowing an adequate margin of safety, are requisite to protect the public health" (42 U.S.C. 7409(a)).

Table 2.5. Eight steps in formulation of long-term AQG levels

Step	Description
Step 1	Assess RR estimates and, when available, CRF for each critical health outcome per pollutant as provided by the systematic review. In its first meeting in 2016, based on an initial survey, the GDG decided that the following health outcomes are critical (depending on air pollutant): (i) all-cause mortality (or all, natural-cause mortality, excluding accidental deaths); (ii) respiratory mortality; (iii) cardiovascular mortality, associated with both long- and short-term exposures; (iv) short-term, day-to-day variations in hospital admissions and emergency room visits related to asthma; and (v) myocardial infarction. The GDG recommends AQG levels for all pollutant–outcome pairs identified in 2016 except for those associations not meeting at least moderate levels of certainty. This includes pairs with different likelihoods of causality, according to authoritative reviews by COMEAP, Health Canada, International Agency for Research on Cancer, US EPA and others
Step 2	Determine the lowest level of exposure measured in the studies included in the systematic review or in the subset of studies in the systematic review that estimate risk at this lowest level. For individual studies that used statistical models to evaluate the shape of the CRF, ensure that the lowest level of exposure is associated with a monotonic increase of the CRF curve
Step 3	Determine the minimal relevant increase in health outcomes
Step 4	Determine the starting point for AQG level determination as the long-term concentration of pollutant from which the minimal relevant amount of the health outcome will result
Step 5	Compare the AQG levels for a specific pollutant across critical health outcomes. Take as the final AQG level the lowest AQG level found for any of the critical health outcomes
Step 6	Assess the certainty of the evidence at low levels of exposure. The adapted GRADE assessment is for the entire body of evidence, not the subset of studies conducted at the lowest exposure levels. The evidence provided by these latter studies needs to be discussed, starting from the RoB assessment that was conducted at individual study level
Step 7	Consider new relevant evidence not included in the systematic reviews in a qualitative or, where possible, quantitative manner
Step 8	Reconsider causality of associations between pollutants and outcomes, taking into account whether or not associations have been classified as causal or likely causal in recent reviews by COMEAP, Health Canada, US EPA, WHO or other authoritative bodies

Each of the eight steps is discussed below.

Step 1. The GDG used the meta-analytic effect estimate that results from the systematic review and the assessment of the certainty of the evidence that underpins this effect estimate according to GRADE. In principle, effect estimates are only used if the 95% CI does not include an RR of 1 in the random-effects meta-analysis of the relevant body of evidence for a specific exposure–outcome pair. In addition, they are only used when underpinned by moderate to high certainty evidence. This is because there would be little confidence in an AQG level based on a non-significant meta-analytic effect estimate or on an effect estimate for which there is only low-certainty evidence.

The GDG recognized that the probability value (*P* value) generated by a test of statistical significance is a continuous measure and that even a statistically non-significant result may be more consistent with a real increased risk than with the null. Therefore, in cases of borderline significance or where significance is restricted to major subgroups, the GDG decided whether or not to proceed with guideline development, regardless of the overall statistical significance. It was noted that in the meta-analyses of the systematic reviews, statistical significance was based on two-sided tests. As the air pollutants under consideration have no known health benefits, this indicated that careful consideration was necessary for any meta-analytic random-effects effect estimate with a two-sided *P* value of less than 0.10.

It is important to realize that the adapted GRADE assessments apply to the whole body of evidence or to some part thereof based on, for example, a selection of studies at low or moderate RoB. No separate GRADE assessments were carried out for the – necessarily smaller number of – studies providing information at the lowest levels of exposure. GRADE assessments for a small number of studies are less robust. Key elements of GRADE such as RoB can be assessed for a smaller number of studies, and this was done where applicable.

Step 2. Since the effect estimates examined in the systematic reviews were generally evaluated using linear models and existing evidence generally supports a linear or supralinear, no-threshold relationship for the pollutant–outcome pairs, there must be a procedure to determine the lowest level of observed (measured or modelled) exposure that is sufficiently underpinned with evidence and can, therefore, be used.

Pragmatically, the GDG used as a starting point the 5th percentile of the exposure distributions from at least a few studies with the lowest levels of exposure (see below).

The rationale was that below the 5th percentile of an exposure distribution, where data density tends to be sparse, there is typically little confidence in the shape of the CRF. This is evident, for example, from the CIs of splines reported in a number of relevant papers. Confidence depends on the study size. When there are no studies with narrow CIs for effect estimates down to the 5th percentile of the exposure distribution, a higher percentile can be chosen as a starting point.

One would hesitate to use the 5th percentile of just one study, but the bodies of evidence considered for AQG level derivation varied considerably in terms of the numbers of studies included in the meta-analyses. In each case, the GDG made a pragmatic choice of studies to include.

Step 3. Next, the GDG determined what amount or increase in mortality or other outcome above the lowest level would be considered a relevant increase. This is an a priori decision based on a judgement by the GDG. The GDG decided to use zero as a baseline when reviewing studies (i.e. any increase of the adverse health risk from the lowest long-term concentration – as defined in step 2 – would be considered relevant). A zero increase represents a figure that comes closest to the ideal of having an AQG level that is based on health arguments only. With a positive slope of the CRF at this lowest exposure level, any increase in exposure will result in a non-zero risk increase. See below, however, for a discussion of what zero means in practical terms, and how that differs for the derivation of long- and short-term AQG levels.

Step 4. The lowest level – the mean of a number of observed 5th percentile concentrations, as defined in step 2 – of measurement is the point above which the GDG assumed (with some confidence) that an increase in risk occurs. Since the GDG decided not to allow any increase in the adverse health risk from the lowest level measured, this is then the starting point for derivation of the AQG level.

Step 5. The GDG established an AQG level for all critical health outcomes associated with a specific pollutant following steps 1–4. Of these, the lowest AQG level is recommended as the WHO AQG level for that pollutant. This will prevent the possibility that, for example, using an AQG level based on all-cause mortality would still allow a substantial amount of asthma to occur. For example, if the AQG level for asthma were lower than the all-cause mortality level, the AQG level based on the asthma outcome would be taken as the WHO AQG level.

Step 6. No separate GRADE assessments were carried out for the relatively few studies reporting the lowest levels of exposure since GRADE was applied to the whole body of evidence and not to single studies.

Nevertheless, a critical discussion was warranted on the merits of studies reporting the lowest exposure levels. This discussion started from an assessment of the RoB, which was conducted at the individual study level. If a study that found a low exposure level was deemed to be at high RoB, then it was excluded from consideration unless the GDG had sound reasons to disagree with this assessment in the relevant systematic review. The GDG also considered whether studies conducted at the lowest exposure levels continued to show increased RRs.

Step 7. The systematic reviews concluded their literature searches in early autumn of 2018. Since then, several relevant studies have been published. The GDG considered new evidence up to the meeting in June 2020 – after verifying that it met the same standards for inclusion as the studies already included.

Step 8. The GDG reconsidered causality of associations for all pollutant–outcome pairs. However, as all pollutant–outcome pairs were considered worthy of further consideration at the start of the process in 2016, such considerations generally did not prevent recommendations of an AQG level whenever the epidemiological evidence was considered to be of moderate or high certainty.

Specifically, the GDG referred to the causality assessments shown in Table 2.1, which formed the basis of the current AQG level development process. The assessment was updated, when necessary, to include newer evaluations published since 2016. These updates are all discussed at the end of section 2.3.3.

The steps outlined above produce a rounded integer value as a starting point for AQG level development. This starting point is not equivalent to a threshold of no effect: it is merely a level below which there is less certainty about the existence of an effect. Where there was no threshold, the starting point level was associated with some effect on health. The magnitude of this effect could be estimated from the meta-analytic effect estimate from the systematic review by assuming that, in the absence of a threshold, any level of exposure increases risk. It was useful to do this as a benchmark for comparing the starting points for long-term AQG levels between the pollutants $PM_{2.5}$, PM_{10}, ozone and nitrogen dioxide. It also provided a benchmark for comparing estimated health effects between long- and short-term AQG levels for the same pollutant.

2.5.2 Formulation of short-term AQG levels

There are fundamental differences between AQG levels for short-term and long-term exposures. For long-term exposures, AQG levels are derived based on the lowest long-term exposures that are, with at least moderate certainty, associated with adverse health effects.

Such guidelines are typically expressed as annual averages. Daily and hourly concentrations vary around the annual average, often in a lognormal distribution. If short-term AQG levels are derived based on lowest short-term exposures that are – with at least moderate certainty – associated with adverse health effects, then much lower values are obtained than those determined for long-term AQG levels. (The caveat about evidence of less than moderate certainty expressed in section 2.5.1 also applies here.) Importantly, the short-term variation in air pollution concentrations is largely driven by meteorology, which cannot be controlled. Short-term guidelines are typically defined as a high percentile of the distribution of daily values, for example the 98th or 99th percentiles equivalent to seven or three days a year exceeding this value (i.e. exceedance days). The rationale for choosing a high percentile and not the maximum is that the maximum of daily values for a given year is a less stable statistic than the high percentiles.

For locations in which concentrations are below the annual mean AQG level, days with such high daily mean concentrations will be rare and a large proportion of days will have concentrations below the annual mean AQG level. Thus, the health burden related to a few days with higher concentrations corresponds to a very small fraction of the total air pollution-related burden.

In contrast, the long-term variation in air pollution concentrations is largely driven by spatial variation in air pollution sources and emissions, which can be controlled, although control for some sources such as desert dust, pose unique and much more considerable challenges. Typically, the magnitude of the health effects associated with variations in long-term exposure is larger, per mass unit, than the magnitude of the health effects associated with short-term variations. As a consequence, long-term AQG levels for most health outcomes are more health protective than short-term AQG levels. In such instances, the long-term AQG level is used to derive a short-term AQG level whenever the same health effect is considered (e.g. mortality) for both long- and short-term exposures.

According to this line of reasoning, all eight steps outlined for long-term AQG level development remain valid for short-term AQG level development, except for step 3: defining the minimal relevant increase in health outcomes.

2.5.2.1 Procedure

In keeping with established practice, as a starting point, short-term AQG levels were considered by the GDG as the 99th percentiles of daily concentrations empirically observed in distributions with a mean equal to the long-term AQG level, for pollutant–outcome pairs for which a long-term AQG level is also being recommended. This is the case for all-cause mortality and $PM_{2.5}$, PM_{10}, ozone and nitrogen dioxide. It is also the case for cause-specific mortality and $PM_{2.5}$ and PM_{10}. The GDG evaluated the percentage of excess daily deaths expected from the meta-analytic linear short-term effect estimate to occur at a day at the 99th percentile of the distribution of daily, 24-hour average concentrations, compared with a day at the annual mean guideline concentration.

In the cases of sulfur dioxide and all-cause mortality and hospital admissions and emergency room visits related to asthma and of carbon monoxide and myocardial infarction, no long-term AQG levels were recommended and there are no long-term AQG levels from 2005. The same approach as described at the beginning of step 2 was followed, by evaluating the percentage of excess daily deaths expected from the meta-analytic linear effect estimate to occur at the 99th percentile, relative to a specified and justified low concentration. The rationale for the long-term reference concentrations of sulfur dioxide and carbon monoxide is discussed in Chapter 3.

Once the starting point for the short-term AQG level was calculated, it was rounded to the nearest integer value.

The rationale for having short-term AQG levels next to long-term AQG levels for the same pollutant is based on the need to provide air quality managers, health-care providers, vulnerable patients and the general population with tools to communicate health risks and short-term emission controls. The GDG notes that there is substantial evidence that some susceptible groups may be harmed by short-term elevations of some pollutants: those with asthma, coronary heart disease, COPD and other chronic conditions and diseases. Overall, these susceptible groups represent a substantial proportion of the population in many countries.

The rationale for having short-term AQG levels in the absence of long-term AQG levels is typically based on documented acute elevation of risk over timescales of minutes to one or a few days.

More detailed advice to policy-makers and air quality managers is provided in Chapter 6 of these guidelines.

In this protocol a distinction is made between three different scenarios (Table 2.6).

Scenario 1. In the first scenario, internally consistent long- and short-term AQG levels is desired, and the argument is that meeting the long-term AQG level protects against serious short-term effects on mortality. This can be shown for PM, nitrogen dioxide and ozone.

Table 2.6. Scenarios in formulation of short-term AQG levels

Scenario	Description
Scenario 1	Development of a short-term AQG level for a pollutant for which a long-term AQG level for the same outcome was developed (e.g. all-cause mortality)
Scenario 2	Development of a short-term AQG level for a pollutant for which a long-term AQG level was developed for another outcome (e.g. hospital admissions and emergency room visits related to asthma versus all-cause mortality)
Scenario 3	Development of a short-term AQG level for a pollutant for which no long-term AQG level was developed

First, for $PM_{2.5}$ and all-cause mortality, in *Global update 2005* the annual mean air quality guideline is 10 µg/m³ and the short-term 99th percentile 24-hour average air quality guideline is 25 µg/m³ so the ratio between short-term and long-term guideline values was 2.5. At the time, this ratio was not empirically underpinned; the ratio was simply said to be 2.5, with some recognition that it may vary from place to place and from time to time. There is now a very large database – including the 652 cities from the Liu et al. (2019) paper – to document the ratios between higher percentiles of the distributions of 24-hour average concentrations and the annual means.

The GDG recommends using the same ratio everywhere for the purpose of deriving a 24-hour average AQG level. The primary motivation is that short-term effect estimates for $PM_{2.5}$ and all-cause mortality do not significantly vary between different regions of the world. (Note that there are differences in effect estimates depending on $PM_{2.5}$ level, but that is not important when deriving AQG levels for relatively low short-term concentrations; it is important when quantifying the health burdens associated with the higher interim target levels.)

The database from the MCC Collaborative Research Network (A. Gasparrini, London School of Hygiene and Tropical Medicine, unpublished data, 23 June 2020) has descriptive data on long time series of daily average $PM_{2.5}$ and PM_{10} concentrations from 384 and 480 cities, respectively. The ratio of the 99th percentile of the daily average concentrations to the multiyear mean is 3.05 for $PM_{2.5}$, 2.85 for PM_{10}, 2.34 for nitrogen dioxide (398 cities), 2.05 for ozone (244 cities), 3.90 for sulfur dioxide (396 cities) and 2.97 for carbon monoxide (349 cities).

Based on this database, the Network has published a series of articles, which are published as open access (Chen et al., 2021; Liu et al., 2019; Meng et al., 2021; Vicedo-Cabrera et al., 2020). When considering long- and short-term AQG levels for ozone, the GDG realized that long-term AQG levels could be based on the mean peak-season ozone levels, which have a different relationship to the 99th percentile of the daily distributions than the annual means.

As an example, the GDG recommended setting the long-term AQG level for $PM_{2.5}$ at 5 µg/m³, and if a ratio of 3 were used to calculate the corresponding 99th percentile of daily means, a 24-hour AQG level of 15 µg/m³ would be derived. All the recommendations can be found in Chapter 3.

Scenario 2. In the second scenario, there may be long-term AQG levels for nitrogen dioxide and ozone based on effect estimates for respiratory mortality, and short-term AQG levels based on effect estimates for all-cause mortality only. For $PM_{2.5}$ and PM_{10}, there are long- and short-term effect estimates for all-cause mortality as well as a number of cause-specific mortalities. In most cases, these are from the same studies, so there are no serious differences between the 5th percentiles of PM in the lowest-level studies for natural-cause and cause-specific mortality. If there are differences, the expectation is that in the smaller numbers of cause-specific mortality studies the 5th percentiles of the concentration distributions are more likely to be higher than lower, compared with the all-cause mortality studies. The general pattern is that effect estimates for both long- and short-term cause-specific mortality are somewhat bigger than those for all-cause mortality. This is always true for $PM_{2.5}$; the picture for PM_{10} is a bit more mixed. Nevertheless, these patterns do not lead to different conclusions for AQG level derivation based on all-cause mortality as compared with AQG levels based on cause-specific mortality. This again assumes that the 5th percentiles from the lowest-level studies are not lower for cause-specific mortality studies than for all-cause mortality studies.

There will be short-term AQG levels for ozone, nitrogen dioxide and sulfur dioxide and hospital admissions and emergency room visits related to asthma, and for carbon monoxide and hospital admissions and emergency room visits related to myocardial infarction. The GDG recommends (for ozone and nitrogen dioxide) to start from the long-term AQG level based on mortality, look at the internally consistent short-term AQG level for mortality and then quantify the effect on hospital admissions and emergency room visits related to asthma at that level. Here, too, data from the Liu et al. (2019) collaboration provide insight into the ratios between 99th percentiles and annual means for ozone as well as for nitrogen dioxide.

A judgement on whether one or the other effect should drive the short-term AQG level is then needed, with potential consequences for consistency between long- and short-term AQG levels. As mentioned before, for ozone and nitrogen dioxide, only short-term CRFs for all-cause mortality are available. Therefore, comparisons (as outlined for PM above) are not always possible.

Scenario 3. Lastly, in the third scenario, a short-term AQG level needs to be derived for a pollutant for which no long-term AQG level is being developed.

A case in point is sulfur dioxide, for which there are systematic reviews of short-term 24-hour associations with all-cause and respiratory mortality and asthma hospital admissions and emergency room visits.

For carbon monoxide, there is a 24-hour AQG level based on the systematic review of associations between 24-hour mean carbon monoxide concentrations and hospital admissions and emergency room visits due to myocardial infarction, which can then be compared with the air quality guideline of 7 mg/m³ for carbon monoxide indoors (WHO, 2014b) and the shorter-term AQG levels as well.

To develop an AQG level for a particular pollutant–outcome pair, the GDG examined external evidence for causality of the pollutant–outcome association. Causality judgements were part of the process that produced the PECOS questions for the current process (Table 2.1).

In the case of hospital admissions and emergency room visits related to asthma and myocardial infarction, further adaptations were needed to compare visits/admissions to deaths. The GDG specified short-term AQG levels for hospital admissions and emergency room visits related to asthma or myocardial infarction based on quantification of the expected increase in such visits/admissions at the proposed short-term AQG level. This recognizes that the health burden related to a few days (three to four per year when using 99th percentiles) with higher concentrations corresponds to a very small fraction of the total air pollution-related burden.

2.5.3 Formulation of interim targets and good practice statements

2.5.3.1 Interim targets

Interim targets were introduced in *Global update 2005* as additional integral elements of guidance, designed to complement the WHO air quality guidelines.

Interim targets may be defined as air pollutant concentrations associated with a specific decrease in health risk that serve as “incremental steps in progressive reduction of air pollution [...] intended for use in areas where pollution is high” (WHO Regional Office for Europe, 2006). As stated in *Global update 2005,* “countries may find these interim targets helpful in gauging progress over time in the difficult process of steadily reducing population exposures [to air pollution]”.

Moreover, interim targets “aim to promote a shift from high air pollutant concentrations, with acute and serious health consequences, to lower concentrations”(WHO Regional Office for Europe, 2006), in line with the AQG levels. Further:

> [i]f these [interim] targets were to be achieved, one could expect significant reductions in risks for acute and chronic human health effects from air pollution. Progress towards the guideline values should, however, be the ultimate objective of air quality management and health risk reduction in all areas (WHO Regional Office for Europe, 2006).

The GDG decided that interim targets, and specifically the 2005 interim targets, should be retained in the updated air quality guidelines for two reasons.

- The first is to promote continuous air quality improvement in places with high levels of ambient air pollution with the goal of achieving AQG levels as expeditiously as possible. Interim targets for reduction of air pollution have been shown to be achievable with abatement measures and have practical value in that several countries have standards equal to some of the interim targets (Kutlar Joss et al., 2017). Importantly, interim targets also have been helpful in achieving AQG levels.
- The second is to maintain continuity. Policy-makers, nongovernmental organizations and the scientific community in low- and middle-income countries are already familiar with the 2005 interim targets and have employed them since their introduction 15 years ago. Changing the interim targets at this point would be confusing and unnecessary because the interim target levels are still globally relevant, although the 2005 air quality guideline would be added as an interim target in the event that the AQG level is lowered.

Descriptors for each interim target have been provided to inform decision-makers of the implications of achieving the corresponding air pollutant concentrations. These are the risk descriptors calculated using updated CRFs.

Lastly, the results of simulating a reduction of the 2016 burden of disease attributable to $PM_{2.5}$ to the interim target and the new AQG level are provided in section 3.9, in order to illustrate the mortality and disability adjusted life-year benefits that could be achieved by expeditiously reducing air pollutant levels (Evangelopoulos et al., 2020).

2.5.3.2 Good practice statements

The *WHO handbook for guideline development, 2nd edition* (WHO, 2014a), provides for the development of good practice statements in certain cases. This occurs when a GDG is confident that a large body of diverse evidence that is difficult to synthesize indicates that the desirable effects of a particular course of action far outweigh its undesirable effects. In other words, when a GDG is confident that implementing a measure would be beneficial with high certainty but when conducting numerous systematic reviews and detailed assessments of evidence would be a poor use of resources (WHO, 2014c).

The evidence considered may be of a diverse nature, including linked or indirect evidence, physical and biochemical properties, ethical principles and human rights conventions (WHO, 2019a). Along these lines, the types of evidence that the GDG may consider in the context of air quality guidelines would also include air quality management principles and good practices implemented by reputable institutions.

The option of developing good practice statements was used to provide much-needed guidance in relation to some specific types of PM identified as critical in the preliminary phase. The GDG chose to closely follow-up major external reviews on BC/EC, UFP and SDS throughout the process. The decision was made to develop good practice statements for these, rather than numerical AQG levels, in the absence of clear quantitative evidence on independent health effects from these pollutants.

3

Recommendations on classical air pollutants

3.1 Introduction

This chapter presents specific recommendations on air quality guideline (AQG) levels for the pollutants $PM_{2.5}$, PM_{10}, ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide, together with the corresponding interim targets.

In Chapter 2, a detailed protocol was described that was followed to derive AQG levels for the pollutants and averaging times. Chapter 2 also provide the rationales for including the specific pollutant–outcome associations that formed the basis for the recommendations given in this chapter. The averaging times considered were long term (annual mean or, for ozone, highest six-month average) and short term (24 hours). Long-term effects were considered only for all-cause and cause-specific mortality ($PM_{2.5}$, PM_{10}, ozone and nitrogen dioxide). For those, any pollutant-attributed increase in long-term mortality was considered harmful. Short-term effects were considered for all non-accidental and cause-specific mortality ($PM_{2.5}$, PM_{10}, ozone, nitrogen dioxide and sulfur dioxide), for asthma hospital admissions and emergency room visits (ozone, nitrogen dioxide and sulfur dioxide), and for myocardial infarction hospital admissions and emergency room visits (carbon monoxide only). When both long- and short-term AQG levels were considered for a pollutant–outcome pair, preference was given to the long-term AQG level and the short-term AQG level was aligned using empirical data on frequency distributions of 24-hour concentrations. When only short-term AQG levels were considered, analogy with other pollutant–outcome pairs was used.

Information about all the specific pollutant–outcome pairs reviewed can be found in the systematic reviews of evidence available in a special issue of *Environment International* (Whaley et al., 2021).

3.2 $PM_{2.5}$

3.2.1 General description

The general description comes from *Global update 2005*.

> PM in urban and non-urban environments is a complex mixture with components having diverse chemical and physical characteristics. Research on PM and the interpretation of research findings on exposure and risk are complicated by this heterogeneity, and the possibility that the potential of particles to cause injury varies with size and other physical characteristics, chemical composition and source(s). Different characteristics of PM may be relevant to different health effects. Newer research findings continue to highlight this complexity and the dynamic nature of airborne PM, as it is formed either primarily or secondarily

> and then continues to undergo chemical and physical transformation in the atmosphere.
>
> Nonetheless, particles are still generally classified by their aerodynamic properties, because these determine transport and removal processes in the air and deposition sites and clearance pathways within the respiratory tract. The aerodynamic diameter is used as the summary indicator of particle size; the aerodynamic diameter corresponds to the size of a unit-density sphere with the same aerodynamic characteristics as the particle of interest. The differences in aerodynamic properties among particles are exploited by many particle sampling techniques (WHO Regional Office for Europe, 2006).

The focus in recent decades has been on particles with aerodynamic diameters of less than or equal to 2.5 μm ($PM_{2.5}$) or 10 μm (PM_{10}).

3.2.2 Recommended AQG level for long-term exposure to $PM_{2.5}$

Based on the methods for deriving an AQG level outlined in the guideline development protocol in Chapter 2, this section provides a recommendation for an annual AQG level for $PM_{2.5}$ that is based on all non-accidental mortality and cause-specific mortality (Table 3.1).

The epidemiological evidence underpinning the AQG level is discussed in a systematic review commissioned by WHO, which is referred to in section 2.4. The review of this pollutant (Chen & Hoek, 2020) was published in *Environment International* (Whaley et al., 2021) as open access.

As discussed in section 2.3, there has been no separate, independent assessment of the mechanistic, toxicological and human clinical studies relating ambient particles to human health.

The recommendations in this chapter follow the eight steps outlined in the protocol for AQG level development in Chapter 2 (section 2.5). The tables and figures mentioned during the eight steps are listed at the end of the discussion of each recommendation.

Step 1. Assess RR estimates and, when available, CRFs

The systematic review on $PM_{2.5}$ and all non-accidental mortality (Chen & Hoek, 2020) reported a meta-analytic effect estimate of RR of 1.08 (95% CI: 1.06–1.09) per 10 μg/m³ $PM_{2.5}$, assuming a linear relationship. The authors found an indication of a supralinear relationship, suggesting a steeper risk increase at lower exposure levels.

The certainty of the evidence was considered high according to GRADE. CRFs were provided by several studies. These are shown in Fig. 3.1, Fig. 3.2, Fig. 3.3 and Fig. 3.4 (which follow a discussion of the eight steps) for the studies with information at low to very low levels of measured exposure (step 2) (Pinault et al., 2016, 2017; Villeneuve et al., 2015; Di et al., 2017a). CRFs were published from four of the six studies with the lowest exposure levels. Two studies did not provide a CRF (Weichenthal et al., 2014; Cakmak et al., 2018). For obvious reasons, the uncertainty in the shape of the CRFs is higher in single than in pooled studies, and higher in small than in large studies. Very large studies such as the study by Di et al. (2017a) provide the best evidence for the shape of the CRF at the low end of the exposure range. These shapes generally show linear relationships down to very low concentrations or somewhat steeper curves at low than at higher concentrations.

Step 2. Determine the lowest level of exposure measured

In 18 of the 25 studies included in the meta-analysis, a 5th percentile of the exposure distribution was reported or could be calculated from the reported mean and standard deviation (Table 3.2). As the concentration distributions are often lognormal, this calculation is not straightforward. Therefore, preference was given to actual reports of the relevant numbers obtained from the published papers or upon request from the study authors. This is indicated in Table 3.2, Table 3.3, Table 3.4 and Table 3.5. The five lowest levels reported or estimated in these studies were 3.0 μg/m³ (Pinault et al., 2016), 3.2 μg/m³ (Cakmak et al., 2018), 3.5 μg/m³ (Pinault et al., 2017), 4.8 μg/m³ (Villeneuve et al., 2015) and 6.7 μg/m³ (Weichenthal et al., 2014). Weichenthal et al. (2014) found no effect. The Villeneuve et al. (2015) study provided no evidence of an effect of $PM_{2.5}$ on all non-accidental mortality below 8 μg/m³. The study by Di et al. (2017a) has the next lowest 5th percentile (7.1 μg/m³) and the study by Hart et al. (2015) the next lowest (7.8 μg/m³). The average $PM_{2.5}$ level across these five studies with the lowest exposure measurements in the systematic review is 4.2 μg/m³. A sensitivity analysis disregarding the Villeneuve et al. (2015) and Weichenthal et al. (2014) studies produced a mean of 4.9 μg/m³ $PM_{2.5}$. The sum of weights in the meta-analysis was > 25%, indicating that these studies were influential in the meta-analysis.

Step 3. Determine the minimal relevant increase in health outcomes

The GDG decided to consider as relevant any increase in risk for an adverse health outcome related to long-term exposure to a pollutant.

Step 4. Determine the starting point for AQG level determination as the long-term concentration of the pollutant from which the minimal relevant amount of the health outcome will result

The average of the five lowest 5th percentile levels measured in these five studies was the starting point for deriving an AQG level (4.2–4.9 μg/m³ $PM_{2.5}$). The data obtained support a long-term AQG level of no more than 5 μg/m³, based on the association between long-term $PM_{2.5}$ and all non-accidental mortality.

Step 5. Compare the AQG level across critical health outcomes: cause-specific mortality

The cause-specific mortality outcomes that were investigated all yielded bigger hazard ratios (HRs) for $PM_{2.5}$ compared with the HR for all non-accidental mortality, with an HR of 1.11 (95% CI: 1.09–1.14) for circulatory mortality, 1.10 (95% CI: 1.03–1.18) for non-malignant respiratory mortality and 1.12 (95% CI: 1.07–1.16) for lung cancer mortality. The certainty of the evidence on $PM_{2.5}$ was rated as high for circulatory and lung cancer mortality and moderate for non-malignant respiratory mortality. Starting points for AQG level determination for these other outcomes would be 4.0–4.3 μg/m³ based on the five studies with the lowest 5th percentiles and 4.1–6.2 μg/m³ based on the five studies documenting positive associations (HR > 1) for these three cause-specific mortality end-points (Table 3.3, Table 3.4 and Table 3.5). The data obtained for cause-specific mortality also support a long-term $PM_{2.5}$ AQG level of no more than 5 μg/m³.

Step 6. Assess certainty of the evidence

None of the studies that make up the lowest levels measured in the all-cause mortality studies were considered to have a high RoB; thus, there is no reason to change the AQG level because of low certainty of the evidence in the lowest-level studies.

Step 7. Consider new evidence

Several new studies were published between autumn 2018 and the summer of 2020. They are discussed in the systematic review by Chen & Hoek (2020). When adding the new studies to the meta-analysis, the joint effect estimate for all-cause mortality and $PM_{2.5}$ was exactly the same as for the studies already included (Fig. A7.43 in Chen & Hoek (2020)). therefore, there is no reason to change the assessment based on the newly published studies. Chen & Hoek (2020) also referred to an analysis of a large number of cohort studies from many different areas of the world, showing a near linear association between annual $PM_{2.5}$ and all-cause mortality, defined as mortality from NCD plus lower respiratory illness, over a range of 2.4–80 μg/m³ (Fig. 3.5; published as Fig. 1 in Burnett et al. (2018)).

Step 8. Reconsider causality

All PM–outcome associations were deemed to be causal or likely causal in the 2016 outcome prioritization framework (see section 2.3.3). These judgements have not changed in more recent authoritative assessments. For more details, see Table 2.1 and additional text in section 2.3.3.

The 5th percentile and mean or median of exposure distributions in studies of $PM_{2.5}$ and the all-cause mortality meta-analysis results are indicated in Table 3.2 based on data from the systematic review by Chen & Hoek (2020). Table 3.3, Table 3.4 and Table 3.5 have the same information for studies on circulatory, non-malignant respiratory and lung cancer mortality, respectively.

3.2.2.1 Interim targets

Interim targets are proposed as incremental steps in a progressive reduction of air pollution and are intended for use in areas where pollution is high. For a more detailed rationale for establishing and using interim targets, see section 2.5.3.

The recommendation is an annual $PM_{2.5}$ AQG level of 5 μg/m³. The GDG recommends maintaining the 2005 interim targets and introducing an interim target 4 at the level of the 2005 air quality guideline, as shown in Table 3.1.

Table 3.1. Recommended annual AQG level and interim targets for $PM_{2.5}$

Recommendation	$PM_{2.5}$ (μg/m³)
Interim target 1	35
Interim target 2	25
Interim target 3	15
Interim target 4	10
AQG level	**5**

If mortality in a population exposed to $PM_{2.5}$ at the AQG level is arbitrarily set to 100, then it will be 124, 116, 108 and 104, respectively, in populations exposed to $PM_{2.5}$ at interim target 1, 2, 3 and 4 levels. These projections are based on the linear HR of 1.08 per 10-μg/m³ increase in $PM_{2.5}$ for all non-accidental mortality reported in the systematic review. At higher concentrations, the CRF may no longer be linear, which would change the numbers in this example.

Table 3.2. Studies on long-term $PM_{2.5}$ exposure and all non-accidental mortality included in the systematic review by Chen & Hoek (2020), ordered by me(di)an concentration

Study	Me(di)an (μg/m³)	SD	P5	P25	HR (95% CI)[a]
Pinault et al. (2016)	5.9	–	3.0[b]	4.2	1.26 (1.19–1.34)
Cakmak et al. (2018)	6.5	2.0	3.2[c]	–	1.16 (1.08–1.25)
Pinault et al. (2017)	7.1	–	3.5[b]	5.4	1.18 (1.15–1.21)
Weichenthal et al. (2014)	9.5	1.7	6.7[c]	–	0.95 (0.76–1.19)
Villeneuve et al. (2015)	9.5	3.5	4.8[b]	–	1.12 (1.05–1.20)
Di et al. (2017a)	11.5	2.9	7.1[b]	9.5	1.08 (1.08–1.09)
Parker, Kravets & Vaidyanathan (2018)	11.8	–	–	10.1	1.03 (0.99–1.08)
Bowe et al. (2018)	11.8	–	7.9[b]	10.2	1.08 (1.03–1.13)
Hart et al. (2015)	12.0	2.8	7.8[b]	10.2	1.13 (1.05–1.22)
Turner et al. (2016)	12.6	2.9	7.8[c]	–	1.07 (1.06–1.09)
Carey et al. (2013)	12.9	1.4	10.6[c]	–	1.11 (0.98–1.26)
Beelen et al. (2014)	13.4	–	7.9[b]	11.3	1.14 (1.03–1.27)
Thurston et al. (2016a)	13.6	3.6	8.9[b]	11.1	1.03 (1.01–1.06)
Hart et al. (2011)	14.1	4.0	7.8[b]	11.8	1.10 (1.02–1.18)
Lepeule et al. (2012)	15.9	–	–	–	1.14 (1.07–1.22)
Bentayeb et al. (2015)	17.0	–	–	–	1.16 (0.98–1.36)
Puett et al. (2011)	17.8	3.4	12.2[c]	–	0.86 (0.72–1.02)
Ostro et al. (2015)	17.9	–	–	13.1	1.01 (0.97–1.05)
Badaloni et al. (2017)	19.6	1.9	16.5[c]	–	1.05 (1.02–1.08)
Enstrom (2005)	23.4	–	–	–	1.01 (0.99–1.03)
Beelen et al. (2008)	28.3	2.1	24.8[c]	–	1.06 (0.97–1.16)
Tseng et al. (2015)	29.6	–	–	–	0.92 (0.72–1.17)
Yin et al. (2017)	40.7	18.6	10.1[c]	–	1.09 (1.08–1.10)
Yang et al. (2018)	42.2	–	–	–	1.06 (1.01–1.10)
McDonnell et al. (2000)	59.2	16.8	31.6[c]	–	1.09 (0.98–1.21)

–, data unavailable; P5: 5th percentile (of the distribution of concentrations assigned to study participants); P25: 25th percentile; HR: hazard ratio; SD: standard deviation.
[a] Per 10 μg/m³.
[b] Reported in paper or by authors on request.
[c] Calculated from mean and standard deviation using the following formula: Me(di)an − 1.645 × SD.

Table 3.3. Studies on long-term $PM_{2.5}$ exposure and circulatory mortality included in the systematic review by Chen & Hoek (2020), ordered by me(di)an concentration

Study	Me(di)an (µg/m³)	SD	P5	P25	HR (95% CI)[a]
Pinault et al. (2016)	5.9	–	3.0[b]	4.2	1.19 (1.07–1.31)
Pinault et al. (2017)	7.1	–	3.5[b]	5.4	1.25 (1.19–1.30)
Crouse et al. (2015)	8.9	–	3.5[b]	6.0	1.06 (1.04–1.08)
Weichenthal et al. (2014)	9.5	1.7	6.7[c]	–	1.15 (0.76–1.73)
Villeneuve et al. (2015)	9.5	3.5	3.7[c]	–	1.32 (1.14–1.52)
Dehbi et al. (2017)	9.9	–	–	9.4	1.30 (0.39–4.34)
Parker, Kravets & Vaidyanathan (2018)	11.8	–	–	10.1	1.16 (1.08–1.25)
Turner et al. (2016)	12.6	2.9	7.8[c]	–	1.12 (1.09–1.15)
Carey et al. (2013)	12.9	1.4	10.6[c]	–	1.00 (0.85–1.17)
Vedal et al. (2013)	12.9	2.8	8.3[c]	–	1.31 (0.94–1.83)
Beelen et al. (2014)	13.4	–	7.9[b]	11.3	0.98 (0.83–1.16)
Thurston et al. (2016a)	13.6	3.6	8.9[b]	11.1	1.05 (0.98–1.13)
Hart et al. (2011)	14.1	4.0	7.8[b]	11.8	1.05 (0.93–1.19)
Laden et al. (2006)	–	–	–	–	1.08 (0.79–1.48)
Bentayeb et al. (2015)	17.0	–	–	–	1.21 (0.72–2.04)
Ostro et al. (2015)	17.9	–	–	13.1	1.05 (0.99–1.12)
Badaloni et al. (2017)	19.6	1.9	16.5[c]	–	1.08 (1.03–1.12)
Beelen et al. (2008)	28.3	2.1	24.8[c]	–	1.07 (0.75–1.52)
Tseng et al. (2015)	29.6	–	–	–	0.80 (0.43–1.49)
Yin et al. (2017)	40.7	18.6	10.1[c]	–	1.09 (1.08–1.10)
Yang et al. (2018)	42.2	–	–	–	1.02 (0.93–1.11)

–, data unavailable; P5: 5th percentile (of the distribution of concentrations assigned to study participants); P25: 25th percentile; SD: standard deviation.
[a] Per 10 µg/m³.
[b] Reported in paper or by authors on request.
[c] Calculated from mean and standard deviation using the following formula: Me(di)an – 1.645 × SD.

Table 3.4. Studies on long-term $PM_{2.5}$ exposure and non-malignant respiratory mortality included in the systematic review by Chen & Hoek (2020), ordered by me(di)an concentration

Study	Me(di)an (μg/m³)	SD	P5	P25	HR (95% CI)[a]
Pinault et al. (2016)	5.9	–	3.0[b]	4.2	1.52 (1.26–1.84)
Pinault et al. (2017)	7.1	–	3.5[b]	5.4	1.22 (1.12–1.32)
Crouse et al. (2015)	8.9	–	3.5[b]	6.0	0.95 (0.91–0.98)
Villeneuve et al. (2015)	9.5	3.5	3.7[c]	–	0.82 (0.61–1.11)
Turner et al. (2016)	12.6	2.9	7.8[c]	–	1.16 (1.10–1.22)
Carey et al. (2013)	12.9	1.4	10.6[c]	–	1.57 (1.30–1.91)
Dimakopoulou et al. (2014)	13.4	–	7.9[b]	11.3	0.79 (0.47–1.34)
Thurston et al. (2016a)	13.6	3.6	8.9[b]	11.1	1.10 (1.05–1.15)
Hart et al. (2011)	14.1	4.0	7.8[b]	11.8	1.18 (0.91–1.53)
Laden et al. (2006)	14.8	–	–	–	1.08 (0.79–1.48)
Bentayeb et al. (2015)	17.0	–	–	–	0.88 (0.57–1.36)
Ostro et al. (2015)	17.9	–	–	13.1	0.99 (0.90–1.09)
Cesaroni et al. (2013)	23.0	4.4	15.8[c]	20.3	1.03 (0.98–1.08)
Beelen et al. (2008)	28.3	2.1	24.8[c]	–	1.04 (0.90–1.21)
Katanoda et al. (2011)	30.5	–	–	–	1.16 (1.04–1.30)
Yang et al. (2018)	42.2	–	–	–	1.11 (1.04–1.19)
McDonnell et al. (2000)	59.2	16.8	31.6[c]	–	1.23 (0.97–1.55)

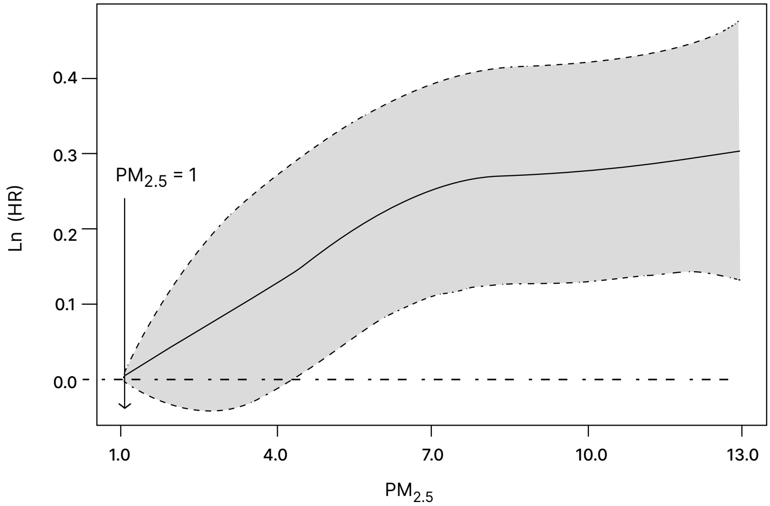
–, data unavailable; P5: 5th percentile (of the distribution of concentrations assigned to study participants); P25: 25th percentile; SD: standard deviation.
[a] Per 10 μg/m³.
[b] Reported in paper or by authors on request.
[c] Calculated from mean and standard deviation using the following formula: Me(di)an − 1.645 × SD.

Table 3.5. Studies on long-term $PM_{2.5}$ exposure and lung cancer mortality included in the systematic review by Chen & Hoek (2020), ordered by me(di)an concentration

Study	Me(di)an (µg/m³)	SD	P5	P25	HR (95% CI)[a]
Pinault et al. (2016)	5.9	–	3.0[b]	4.2	1.17 (0.98–1.40)
Cakmak et al. (2018)	6.5	2.0	3.2[c]	–	1.29 (1.06–1.59)
Pinault et al. (2017)	7.1	–	3.5[b]	5.4	1.16 (1.07–1.25)
Weichenthal et al. (2014)	9.5	1.7	6.7[c]	–	0.75 (0.34–1.65)
Villeneuve et al. (2015)	9.5	3.5	3.7[c]	–	0.97 (0.80–1.18)
Turner et al. (2016)	12.6	2.9	7.8[c]	–	1.09 (1.03–1.16)
Carey et al. (2013)	12.9	1.4	10.6[c]	–	1.11 (0.86–1.44)
Hart et al. (2011)	14.1	4	7.8[b]	11.8	1.05 (0.88–1.26)
Lepeule et al. (2012)	15.9	–	–	–	1.37 (1.07–1.75)
Cesaroni et al. (2013)	23.0	4.4	15.8[c]	20.3	1.05 (1.01–1.10)
Beelen et al. (2008)	28.3	2.1	24.8[c]	–	1.06 (0.82–1.38)
Katanoda et al. (2011)	30.5	–	–	–	1.24 (1.12–1.37)
Yin et al. (2017)	40.7	18.6	10.1[c]	–	1.12 (1.09–1.16)
McDonnell et al. (2000)	59.2	16.8	31.6[c]	–	1.39 (0.79–2.46)
Lipsett et al. (2011)	–	–	–	–	0.95 (0.70–1.28)

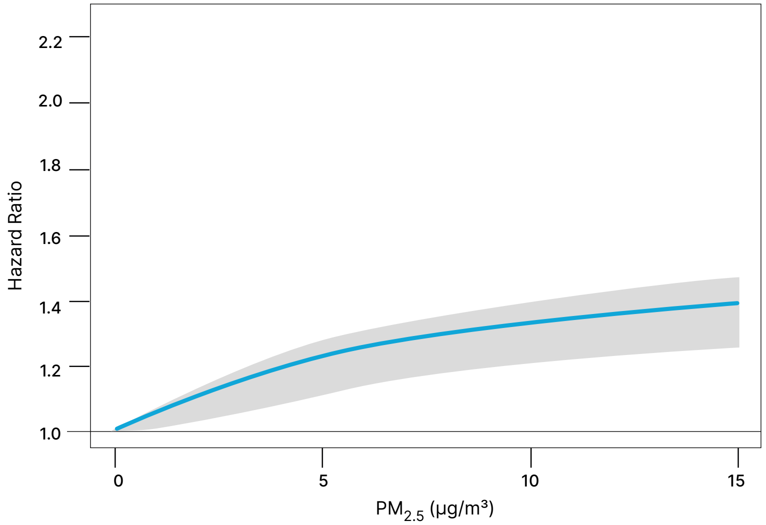
–, data unavailable; P5: 5th percentile (of the distribution of concentrations assigned to study participants); P25: 25th percentile; SD: standard deviation.
[a] Per 10 µg/m³.
[b] Reported in paper or by authors on request.
[c] Calculated from mean and standard deviation using the following formula: Me(di)an – 1.645 × SD.

Fig. 3.1. CRF for long-term $PM_{2.5}$ exposure (μg/m³) and all non-accidental mortality



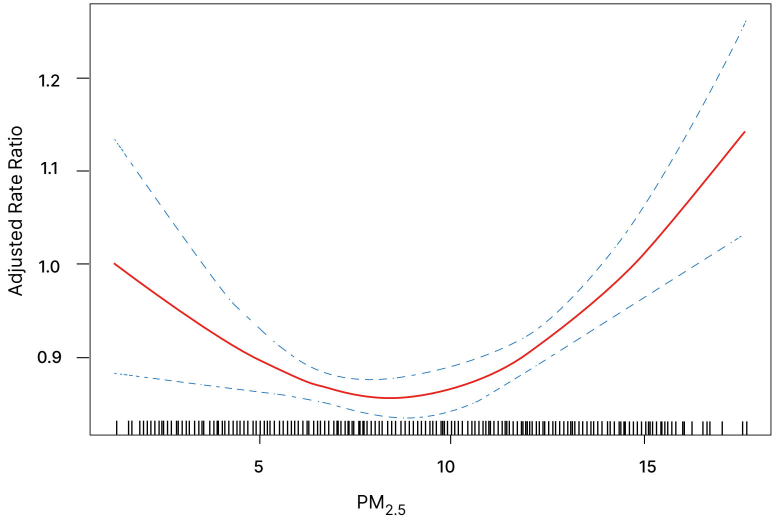
Ln (HR): log HR, with an HR of 1 at a $PM_{2.5}$ concentration of 1 μg/m³.
Source: Pinault et al. (2016).

Fig. 3.2. CRF for long-term $PM_{2.5}$ exposure (μg/m³) and all non-accidental mortality



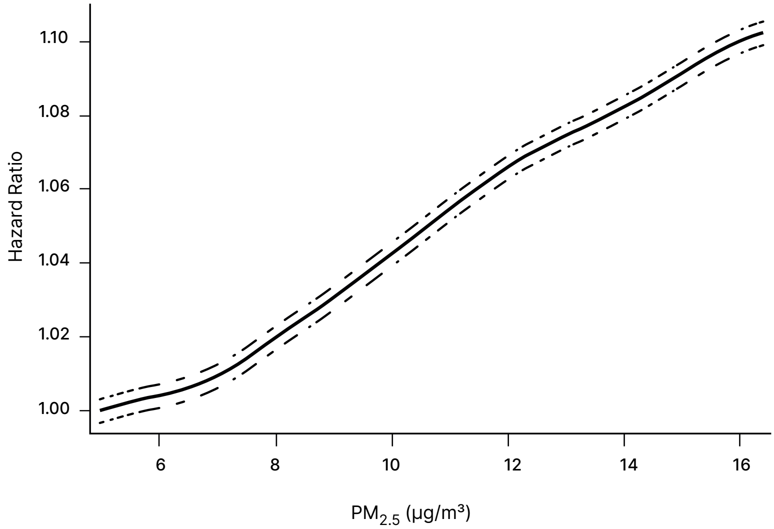
Source: reprinted from Pinault et al. (2017) with permission from Elsevier.

Fig. 3.3. CRF for long-term $PM_{2.5}$ exposure (μg/m³) and all non-accidental mortality



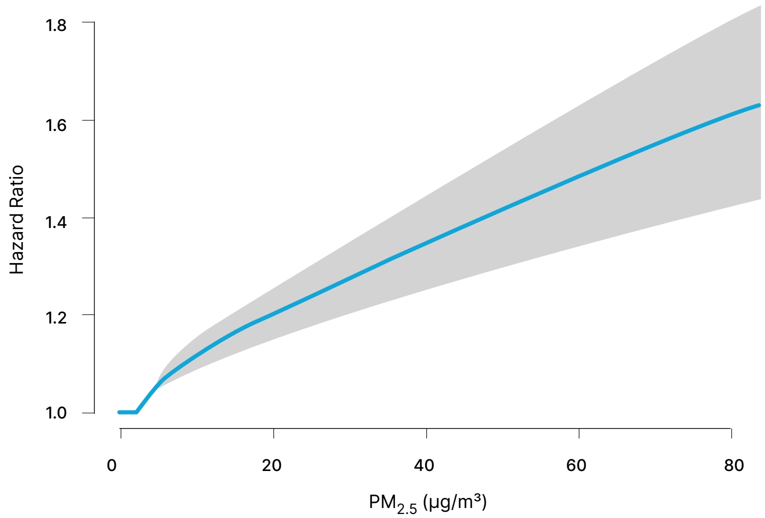
Source: reprinted from Villeneuve et al. (2015) with permission from the publisher. Copyright © 2015 Wolters Kluwer Health, Inc. All rights reserved.

Fig. 3.4. CRF for long-term $PM_{2.5}$ exposure (μg/m³) and all non-accidental mortality



Source: reprinted from Di et al. (2017a) with permission from the Massachusetts Medical Society. Copyright © 2017 Massachusetts Medical Society.

Fig. 3.5. Association between long-term $PM_{2.5}$ exposure (µg/m³) and mortality from NCDs and lower respiratory illness, as observed in an analysis of data from 41 different cohort studies



Notes: The lowest observed $PM_{2.5}$ concentration was 2.4 µg/m³.
Source: Burnett et al. (2018), Fig. 1.

3.2.3 Recommended AQG level for short-term exposure to $PM_{2.5}$

Based on the methods for deriving an AQG level outlined in the guideline development protocol, this section provides a recommended AQG level for short-term, 24-hour average $PM_{2.5}$ that is based on all-cause non-accidental mortality and cause-specific mortality (Table 3.6).

The epidemiological evidence underpinning the AQG level is discussed in a systematic review commissioned by WHO, as explained in more detail in section 2.4. The review (Orellano et al., 2020) was published in *Environment International* (Whaley et al., 2021) as open access.

As discussed in section 2.3, there has been no separate, independent assessment of the mechanistic, toxicological and human clinical studies relating ambient particles to human health.

This section follows the eight steps outlined in the protocol for AQG level development according to scenario 1 for short-term AQG levels (section 2.5.2). Tables and figures mentioned during the eight steps are listed at the end of the discussion of each recommendation.

Step 1. Assess RR estimates and, when available, CRFs

The systematic review by Orellano et al. (2020) on $PM_{2.5}$ and all-cause non-accidental mortality reported a meta-analytic effect estimate of RR of 1.0065 (95% CI: 1.0044–1.0086) per 10 μg/m³ $PM_{2.5}$, assuming a linear relationship. The certainty of the evidence was considered high according to GRADE. The authors found an indication of a supralinear relationship, suggesting a steeper risk increase at lower exposure levels. CRFs were provided by several studies. Examples show that the associations persist to very low levels of exposure (see Fig. 5A of the original study (Di et al., 2017b) and Fig. 3.6 of this document (taken from Liu et al. (2019)).

Step 2. Determine the lowest level of exposure measured

As discussed in the protocol for deriving AQG levels in section 2.5, the lowest concentrations in time-series studies of the effects of daily variations in air pollution concentrations are often very low. Therefore, the 5th percentiles of these daily distributions cannot be used as starting points for AQG level development. In such cases, the protocol suggests identifying the 99th percentile of common distributions of daily air pollution concentrations corresponding to an average long-term concentration equivalent to the annual AQG level. Thus, it is expected that daily means will be higher than the short-term AQG level not more than three to four times per year once air quality complies with the proposed annual mean AQG level. The proposed annual mean AQG level is 5 μg/m³ for $PM_{2.5}$. Common distributions observed in large numbers of cities around the world (data from Liu et al. (2019)) suggest that the 99th percentiles of daily concentrations are about three times higher than the annual mean $PM_{2.5}$ concentration.

Step 3. Determine the minimal relevant increase in health outcomes

The GDG decided to consider as relevant any increase in risk for an adverse health outcome related to long-term exposure to a pollutant. For short-term exposures, the linear CRFs from the systematic review by Orellano et al. (2020) were used to calculate the increase in mortality expected on a day with a $PM_{2.5}$ concentration of 15 μg/m³, compared with a day with a $PM_{2.5}$ concentration of 5 μg/m³. With an RR for all non-accidental mortality of 1.0065 per 10 μg/m³, the estimated excess mortality on such a day would be 0.65%. For locations in which concentrations are below the annual mean AQG level, days with such high daily mean concentrations will be rare and most days will have concentrations below the annual mean AQG level. Thus, the health burden related to a few days with higher concentrations corresponds to a very small fraction of the total air pollution-related burden. The GDG notes that at higher concentrations, the CRFs may no longer be linear but sublinear (e.g. see Liu et al. (2019)) so that the excess mortality will be overestimated by using a linear function.

Step 4. Determine the starting point for AQG level determination as the 99th percentile, as mentioned in step 3

The data presented in the previous three steps support a short-term AQG level of no more than 15 µg/m³, based on the association between short-term $PM_{2.5}$ and all-cause non-accidental mortality.

Step 5. Compare the AQG level across critical health outcomes: cause-specific mortality

The cause-specific mortality outcomes that were investigated all yielded bigger RRs for $PM_{2.5}$ compared with the RR for all-cause mortality, with RRs of 1.0092 (95% CI: 1.0061–1.0123) per 10 µg/m³ for cardiovascular mortality, 1.0073 (95% CI: 1.0029–1.0016) for non-malignant respiratory mortality and 1.0072 (95% CI: 1.0012–1.0132) for cerebrovascular mortality. The certainty of the evidence was rated as high for cardiovascular mortality and moderate for both non-malignant respiratory mortality and cerebrovascular mortality. With these RRs for cause-specific mortality per 10 µg/m³, the estimated excess mortality on such a day would be 0.72–0.92% for $PM_{2.5}$. The same considerations apply as for all-cause non-accidental mortality (as discussed in step 3). The data obtained for cause-specific mortality also support a short-term AQG level of no more than 15 µg/m³ for $PM_{2.5}$.

Step 6. Assess certainty of the evidence

As mentioned in step 1, the certainty of the evidence linking short-term PM concentration variations to short-term mortality variations is high. In addition, as shown in Fig. 5A of Di et al. (2017b), there is evidence that this association persists to very low levels of exposure.

Step 7. Consider new evidence

Several new studies have been published since the autumn of 2018. Only one of these (the 652 cities study by Liu et al. (2019)) is discussed in the systematic review by Orellano et al. (2020). The results of this new, very large study were in line with those of the systematic review. A full search of studies reported since autumn 2018 was not done nor has been reported. As dozens of studies were already included in the systematic review by Orellano et al. (2020) and the Liu et al. (2019) study showed similar results, the GDG does not expect that inclusion of the new studies would change the assessment of the systematic review.

Step 8. Reconsider causality

All PM–outcome associations were deemed to be causal or likely causal in the 2016 outcome prioritization framework (see section 2.3.3). These judgements have not changed in more recent authoritative assessments.

3.2.3.1 Interim targets

Interim targets are proposed as incremental steps in a progressive reduction of air pollution and are intended for use in areas where pollution is high. For a more detailed rationale for establishing and using interim targets, see section 2.5.3.

The recommendation is a short-term (24-hour) $PM_{2.5}$ AQG level of 15 μg/m³, defined as the 99th percentile (equivalent to 3–4 exceedance days per year) of the annual distribution of 24-hour average concentrations.

The GDG recommends maintaining the 2005 interim targets and introducing an interim target 4 at the level of the 2005 air quality guideline, as shown in Table 3.6.

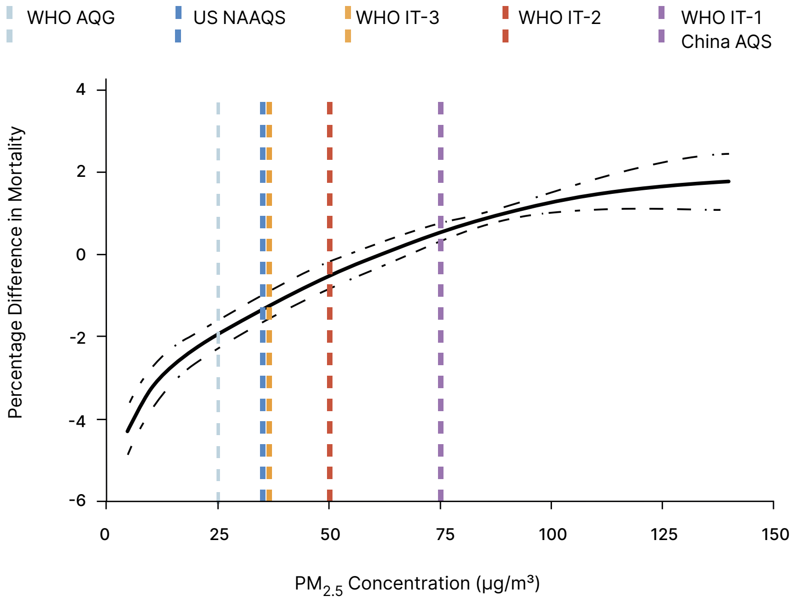
Table 3.6. Recommended short-term (24-hour) AQG level and interim targets for $PM_{2.5}$[a]

Recommendation	$PM_{2.5}$ (μg/m³)
Interim target 1	75
Interim target 2	50
Interim target 3	37.5
Interim target 4	25
AQG level	**15**

[a] Defined as the 99th percentile of the annual distribution of 24-hour average concentrations (equivalent to 3–4 exceedance days per year).

If mortality in a population exposed to $PM_{2.5}$ at the AQG level is arbitrarily set at 100, then it will be 104, 102, 101 and 101, respectively, in populations exposed at $PM_{2.5}$ at interim target 1, 2, 3 and 4 levels. These projections are based on the linear HR of 1.0065 per 10-μg/m³ increase in $PM_{2.5}$ for all non-accidental mortality reported in the systematic review. At higher concentrations, the CRF may no longer be linear, which would change the numbers in this example.

Fig. 3.6. CRF of 24-hour average $PM_{2.5}$ concentrations (μg/m³) and daily all-cause mortality, as observed in a joint analysis of data from 652 cities worldwide[a]



AQG: Air Quality Guidelines; AQS: Air Quality Standard; EU AQD: European Union Air Quality Directive; IT-1: interim target 1; IT-2: interim target 2; IT-3: interim target 3; US NAAQS: United States National Ambient Air Quality Standard.

[a] The y-axis represents the percentage difference from the pooled mean effect on mortality (as derived from the entire range of PM concentrations at each location). Zero on the y-axis represents the pooled mean effect, and the portion of the curve below zero denotes a smaller estimate than the mean effect.

Source: reprinted from Liu et al. (2019) with permission from the Massachusetts Medical Society. Copyright © 2019 Massachusetts Medical Society.

3.3 PM_{10}

3.3.1 Recommended AQG level for long-term exposure to PM_{10}

Based on the methods for deriving an AQG level outlined in the guideline development protocol in Chapter 2, this section provides a recommended AQG level for long-term PM_{10} that is based on non-accidental mortality and cause-specific mortality (Table 3.7).

The epidemiological evidence underpinning the AQG level is discussed in a systematic review commissioned by WHO, as explained in more detail in section 2.4. The review (Chen & Hoek, 2020) was published in *Environment International* (Whaley et al., 2021) as open access.

As discussed in section 2.3, there has been no separate, independent assessment of the mechanistic, toxicological and human clinical studies relating ambient particles to human health.

This section follows the eight steps outlined in the protocol for AQG level development. Tables and figures mentioned during the eight steps are listed at the end of the discussion of each recommendation.

Step 1. Assess RR estimate and, when available, CRFs
The systematic review by Chen & Hoek (2020) on PM_{10} and all non-accidental mortality reported a meta-analytic effect estimate of RR = 1.04 (95% CI: 1.03–1.06) per 10 μg/m³ PM_{10}, assuming a linear relationship.

The certainty of the evidence was considered high according to GRADE. Only one study (Fischer et al., 2015) provided a CRF; it concluded that the association between PM_{10} and non-accidental mortality did not deviate significantly from linear (Fig. 3.7).

Step 2. Determine the lowest level of exposure measured
For 13 of the 17 studies included in the meta-analysis, the 5th percentile of the exposure distribution was reported or could be calculated from the reported mean and standard deviation. As the concentration distributions are often lognormal, this calculation is not straightforward. In all cases where a 5th percentile was reported in the paper or obtained from the study authors upon request, the GDG gave preference to that number (see Table 3.8). The five lowest levels reported or estimated in these studies were 13.7 μg/m³ (Beelen et al., 2014), 15.0 μg/m³ (Bentayeb et al., 2015), 15.1 μg/m³ (Puett et al., 2008), 15.9 μg/m³ (Carey et al., 2013) and 16.0 μg/m³ (Hart et al., 2011). The average 5th percentile across the five studies with the lowest concentrations was 15.1 μg/m³. The sum of weights in the meta-analysis was 21% for the lowest five studies, indicating that they made a significant contribution to the effect estimate from the meta-analysis. All of these studies had positive effect estimates with lower confidence limits of 1.00 or more.

Step 3. Determine the minimal relevant increase in health outcomes
The GDG decided to consider as relevant any increase in risk for an adverse health outcome related to long-term exposure to a pollutant.

Step 4. Determine the starting point for AQG level determination as the long-term concentration of the pollutant from which the minimal relevant amount of the health outcome will result

The average of the five lowest 5th percentile levels measured in these five studies was the starting point for deriving a AQG level: 15.1 μg/m³ PM_{10}.

The data obtained so far support a long-term AQG level of no more than 15 μg/m³, based on the association between long-term PM_{10} and all non-accidental mortality.

Step 5. Compare the AQG level across critical health outcomes: cause-specific mortality
The RRs estimated by the review of Chen & Hoek (2020) meta-analysis for effects of PM_{10} exposure were 1.06 (95% CI: 1.01–1.10) for IHD, 1.12 (95% CI: 1.06–1.19) for respiratory and 1.08 (95% CI: 1.04–1.13) for lung cancer mortality, all per 10 μg/m³. The certainty of the evidence was considered high for respiratory mortality and lung cancer mortality and moderate for IHD mortality, according to GRADE. For the remaining causes of mortality considered (circulatory, COPD and stroke mortality), the estimates of RR exceeded 1 but with 95% CIs that included 1. Most of the studies addressing cause-specific mortality were based on the same populations as the studies of all non-accidental mortality. For the few studies based on different populations, PM_{10} exposure levels were higher than in those used to derive the starting point for AQG level. Therefore, there is no evidence from cause-specific mortality studies supporting a decrease of the AQG level below that suggested by all non-accidental cause mortality studies.

Step 6. Assess certainty of the evidence
None of the studies that reported the lowest levels measured in the studies of all non-accidental mortality were considered at high RoB; thus, there is no reason to change the AQG level because of low certainty of the evidence in the lowest level studies.

Step 7. Consider new evidence
Two new studies were published between autumn 2018 and the summer of 2020 (Fischer et al., 2020; Hvidtfeldt et al., 2019). They are discussed in Chen & Hoek (2020). The effect estimates for PM_{10} (RR = 1.12 (95% CI: 1.09–1.14) and RR = 1.12 (95% CI: 1.03–1.22) respectively) were higher in those studies than the estimates from the meta-analysis of earlier studies, but the PM_{10} exposure levels were higher than those in the studies selected to support the derivation of the AQG level. Therefore, this new evidence does not change the recommended AQG level for long-term PM_{10} concentrations.

Step 8. Reconsider causality
All PM–outcome associations were deemed to be causal or likely causal in the 2016 outcome prioritization framework (see section 2.3.3). These judgements have not changed in more recent authoritative assessments. For more details, see Table 2.1 in section 2.3.3.

The 5th percentile and mean or median of the exposure distributions in studies on PM_{10} and mortality meta-analysis is indicated in Table 3.8 based on data from the systematic review by Chen & Hoek (2020).

3.3.1.1 Interim targets

Interim targets are proposed as incremental steps in a progressive reduction of air pollution and are intended for use in areas where pollution is high. For a more detailed rationale for establishing and using interim targets, see section 2.5.3.

The recommendation is an annual PM_{10} AQG level of 15 µg/m³. This is based on an evaluation of the studies on the long-term effects of PM_{10} on mortality only, without taking into consideration that a large proportion of PM_{10} is made up of $PM_{2.5}$. As in most situations $PM_{2.5}$ is about 50–80% of PM_{10} by weight, the annual PM_{10} AQG level of 15 µg/m³ is less protective than the annual AQG level for $PM_{2.5}$. In all situations where both $PM_{2.5}$ and PM_{10} measurements are available, preference should be given to the $PM_{2.5}$ AQG level.

The GDG recommends maintaining the 2005 interim targets and introducing an interim target 4 at the level of the 2005 air quality guideline, as shown in Table 3.7.

Table 3.7. Recommended annual mean AQG level and interim targets for PM_{10}

Recommendation	**PM_{10} (µg/m³)**
Interim target 1	70
Interim target 2	50
Interim target 3	30
Interim target 4	20
AQG level	**15**

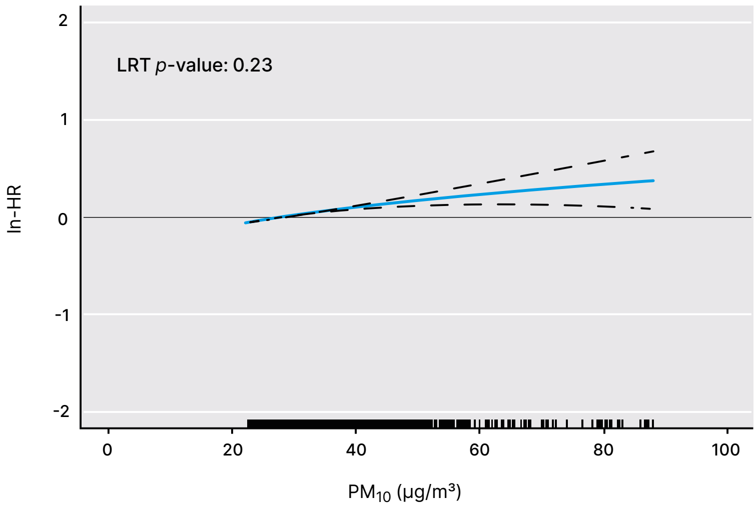
If mortality in a population exposed to PM_{10} at the AQG level were arbitrarily set at 100, then it will be 122, 114, 106 and 102, respectively, in populations exposed to PM_{10} at the interim target 1, 2, 3 and 4 levels. These projections are based on the linear HR of 1.04 per 10-µg/m³ increase in PM_{10} for all non-accidental mortality reported in the systematic review. At higher concentrations, the CRF may no longer be linear, which would change the numbers in this example.

Table 3.8. Studies on long-term PM_{10} exposure and all non-accidental mortality included in the systematic review by Chen & Hoek (2020), ordered by me(di)an concentration

Study	Me(di)an (µg/m³)	SD	P5	P25	HR (95% CI)[a]
Carey et al. (2013)	19.7	2.3	15.9[b]	–	1.07 (1.00–1.14)
Hansell et al. (2016)[c]	20.7	2.5	16.5[b]	–	1.24 (1.15–1.32)
Beelen et al. (2014)	20.9	–	13.7[b]	17.1	1.04 (1.00–1.09)
Puett et al. (2008)	21.6	4.3	15.1[b]	–	1.16 (1.05–1.28)
Bentayeb et al. (2015)	25.0	5.5	15.0[b]	–	1.18 (1.06–1.32)
Hart et al. (2011)	26.8	6.0	16.0[b]	–	1.07 (1.02–1.11)
Puett et al. (2011)	27.9	5.8	19.1[b]	–	0.92 (0.84–0.99)
Dockery et al. (1993)	28.9	–	–	–	1.09 (1.03–1.15)
Fischer et al. (2015)	29.0	–	24.0[b]	–	1.08 (1.07–1.09)
Lipsett et al. (2011)	29.2	9.7	18.2[b]	–	1.00 (0.97–1.04)
Ueda et al. (2012)	34.9	–	–	–	0.98 (0.92–1.04)
Badaloni et al. (2017)	36.6	5.1	28.2[d]	–	1.02 (1.01–1.03)
Heinrich et al. (2013)	43.7	–	–	39.8	1.22 (1.06–1.41)
Abbey et al. (1999)	51.2	16.6	23.9[d]	–	1.01 (0.94–1.08)
Kim, Kim & Kim (2017)	56.0	6.5	45.3[d]	–	1.05 (0.99–1.11)
Zhou et al. (2014)	104.0	–	–	–	1.02 (1.01–1.03)
Chen et al. (2016)	144.0	3.6	–	126.0	1.01 (1.01–1.01)

–, data unavailable; P5: 5th percentile (of the distribution of concentrations assigned to study participants); P25: 25th percentile; SD: standard deviation.
[a] Per 10 µg/m³.
[b] Reported in paper or by authors.
[c] Study classified as having high RoB due to potentially insufficient control for confounding.
[d] Calculated from mean and standard deviation using the following formula: Me(di)an – 1.645 × SD.

Fig. 3.7. Estimated concentration–response curve for non-accidental mortality and annual PM_{10} exposure (μg/m³)



ln: natural logarithm; LRT: likelihood ratio test.
Note: Solid blue line: estimated concentration–response curve; dashed lines: 95% CIs.
Source: reproduced from Fischer et al. (2015) with the permission of the lead author.

3.3.2 Recommended AQG level for short-term exposure to PM_{10}

Based on the methods for deriving an AQG level outlined in the guideline development protocol in Chapter 2, this section provides a recommended AQG level for short-term, 24-hour average PM_{10} that is based on all-cause non-accidental mortality and cause-specific mortality (Table 3.9).

The epidemiological evidence underpinning the AQG level is discussed in a systematic review commissioned by WHO, as explained in more detail in section 2.4. The review (Orellano et al., 2020) was published in *Environment International* (Whaley et al., 2021) as open access.

As discussed in section 2.3, there has been no separate, independent assessment of the mechanistic, toxicological and human clinical studies relating ambient particles to human health.

This section follows the eight steps outlined in the protocol for AQG level development. Tables and figures mentioned during the eight steps are listed at the end of the discussion of each recommendation.

Step 1. Assess RR estimates and, when available, CRFs

The systematic review by Orellano et al. (2020) on PM_{10} and all-cause non-accidental mortality reported a meta-analytic effect estimate of RR = 1.0041 (95% CI: 1.0034–1.0049) per 10 μg/m³ PM_{10}, assuming a linear relationship. The evidence was considered to be of high certainty according to GRADE. The authors found an indication of a supralinear relationship, suggesting a steeper risk increase at lower exposure levels. In contrast to $PM_{2.5}$, no individual studies published graphical representations of CRFs.

Step 2. Determine the lowest level of exposure measured

As discussed in the protocol for deriving AQG levels, the lowest concentrations in time-series studies of effects of daily variations in air pollution concentrations are often very low. Therefore, the 5th percentiles of these daily distributions cannot be used as starting points for AQG level development. In such cases, the protocol suggests identifying the 99th percentile of common distributions of daily air pollution concentrations corresponding to an average long-term concentration equivalent to the annual AQG level. Thus, once the air quality complies with the proposed annual mean AQG level, daily means would be expected to be higher than the short-term AQG level not more than three to four times per year. The proposed annual mean AQG level is 15 μg/m³ for PM_{10}. Common distributions observed in large numbers of cities around the world (data from Liu et al. (2019)) suggest that the 99th percentiles of daily concentrations are about three times higher than the annual mean PM_{10} concentration.

Step 3. Determine the minimal relevant increase in health outcomes

The GDG decided to consider as relevant any increase in risk for an adverse health outcome related to long-term exposure to a pollutant. For short-term exposures, the CRFs from the systematic review by Orellano et al. (2020) were used to calculate the increase in mortality expected on a day with a PM_{10} concentration of 45 μg/m³ compared with a day with a PM_{10} concentration of 15 μg/m³. With an RR for all-cause mortality of 1.0041 per 10 μg/m³, the estimated excess mortality on such a day would be 1.23%. Under compliance with the annual mean AQG level, days with such high daily mean concentrations will be rare and most days will have concentrations below the annual mean AQG level. Thus, the health burden related to a few days with higher concentrations corresponds to a very small fraction of the total air pollution-related burden.

Step 4. Determine the starting point for AQG level determination as the 99th percentile, as mentioned in step 3

The data obtained support a short-term AQG level of no more than 45 μg/m³, based on the association between short-term PM_{10} and all-cause non-accidental mortality.

Step 5. Compare the AQG level across critical health outcomes: cause-specific mortality

All cause-specific mortality outcomes that were investigated yielded slightly bigger RRs for PM_{10} compared with the RR for all-cause mortality. The certainty of the evidence was rated as high for cardiovascular mortality and moderate for cerebrovascular mortality and non-malignant respiratory mortality. The data obtained for cause-specific mortality also support a short-term AQG level of no more than 45 μg/m³ for PM_{10}.

Step 6. Assess certainty of the evidence

As mentioned in step 1, the evidence linking short-term PM concentration variations to short-term mortality variations was of high certainty.

Step 7. Consider new evidence

The GDG noted that several new time-series studies, almost all from Asia, were published after the inclusion deadline of September 2018. A full search of studies reported since autumn 2018 was not done or has not been reported. As dozens of studies were already included in the systematic review by Orellano et al. (2020), the GDG did not expect that inclusion of new studies would change the assessment of the systematic review.

Step 8. Reconsider causality

All PM–outcome associations were deemed to be causal or likely causal in the 2016 outcome prioritization framework (see section 2.3.3). These judgements have not changed in more recent authoritative assessments.

3.3.2.1 Interim targets

Interim targets are proposed as incremental steps in a progressive reduction of air pollution and are intended for use in areas where pollution is high. For a more detailed rationale for establishing and using interim targets, see section 2.5.3.

The recommendation is a short-term (24-hour) PM_{10} AQG level of 45 μg/m³, defined as the 99th percentile (equivalent to three to four exceedance days per year) of the annual distribution of 24-hour average concentrations.

The GDG recommends maintaining the 2005 interim targets and introducing an interim target 4 at the level of the 2005 air quality guideline, as shown in Table 3.9.

Table 3.9. Recommended short-term (24-hour) AQG level and interim targets for PM_{10}[a]

Recommendation	PM_{10} (µg/m³)
Interim target 1	150
Interim target 2	100
Interim target 3	75
Interim target 4	50
AQG level	**45**

[a] Defined as the 99th percentile of the annual distribution of 24-hour average concentrations (equivalent to 3–4 exceedance days per year).

If mortality in a population exposed to PM_{10} at the AQG level is arbitrarily set at 100, then it will be 104, 102, 101 and 100.2, respectively, in populations exposed to PM_{10} at the interim target 1, 2, 3 and 4 levels. These projections are based on the linear HR of 1.0041 per 10-µg/m³ increase in PM_{10} for all non-accidental mortality reported in the systematic review. At higher concentrations, the CRF may no longer be linear, which would change the numbers in this example.

3.4 Ozone

3.4.1 General description

The general description comes from *Global update 2005*.

> Ozone (O_3) and other photochemical oxidants are pollutants that are not directly emitted by primary sources. Rather, they encompass a group of chemical species formed through a series of complex reactions in the atmosphere driven by the energy transferred to nitrogen dioxide (NO_2) molecules when they absorb light from solar radiation ….
>
> The precursors that contribute most to the formation of oxidant species in polluted atmospheres are nitrogen dioxide and non-methane volatile organic compounds (VOCs), especially unsaturated VOCs. Methane is much less reactive than the other VOCs but is present at much higher concentrations, having risen in concentration over the past 100 years owing to its increasing use as fuel, and is released from rice fields and farm animals. Photochemistry involving methane accounts for much of the rise in ozone over the oceans and remote land areas, from about 30 µg/m³ to about 75 µg/m³ (WHO Regional Office for Europe, 2006).

Conversion factors for ozone: at 20 °C and 1013 hPa, 1 part per million (ppm) = 1.9957 mg/m³ and 1 mg/m³ = 0.5011 ppm.

3.4.2 Recommended AQG level for long-term exposure to ozone

Based on the methods for deriving an AQG level outlined in the guideline development protocol, this section provides an AQG level for long-term, peak-season ozone that is based on all non-accidental mortality and respiratory mortality (Table 3.10).

The epidemiological evidence underpinning the AQG level is discussed in a systematic review commissioned by WHO, as explained in more detail in section 2.4. The review (Huangfu & Atkinson, 2020) was published in *Environment International* (Whaley et al., 2021) as open access.

As discussed in section 2.3, there has been no separate, independent assessment of the mechanistic, toxicological and human clinical studies relating ambient ozone to human health.

The long-term AQG level for ozone is linked to the so-called peak-season exposure. Peak season is defined as the six consecutive months of the year with the highest six-month running-average ozone concentration. In regions away from the equator, this period will typically be in the warm season within a single calendar year (northern hemisphere) or spanning two calendar years (southern hemisphere). Close to the equator, such clear seasonal patterns may not be obvious, but a running-average six-month peak season will usually be identifiable from existing monitoring or modelling data.

This section follows the eight steps outlined in the protocol for AQG level development. Tables and figures mentioned during the eight steps are listed at the end of the discussion of each recommendation.

Step 1. Assess RR estimates and, when available, CRFs

The systematic review by Huangfu & Atkinson (2020) on ozone and all non-accidental mortality reported a meta-analytic effect estimate of RR = 1.01 (95% CI: 1.00–1.02) per 10 μg/m³ increase in peak-season average of daily maximum 8-hour mean ozone concentrations, assuming a linear relationship. For ozone, it is customary to calculate daily maximum of 8-hour mean concentrations rather than 24-hour averages because of the strong diurnal variation in ozone concentration. In most of the quoted studies, peak season was defined as the warm season, that is, the warmest five or six months of the year, for example May–September in studies from Canada and April–September in several of the studies from the

United States. The certainty of the evidence was considered moderate according to GRADE. CRFs were provided in one study (Di et al., 2017a), which documented a linear function starting from the 5th percentile of the observed warm-season concentrations of about 60 μg/m³ (Fig. 3.8). From the series of Canadian Census Health and Environment Cohort (CanCHEC) studies, the more recent Cakmak et al. (2018) study was included instead of the earlier study by Crouse et al. (2015), which did document a monotonic dose–response relationship (Fig. 3.9).

Step 2. Determine the lowest level of exposure measured

For all seven studies included in the meta-analysis, a 5th percentile of the exposure distribution was reported or could be calculated from the reported mean and standard deviation. As the concentration distributions are often lognormal, this calculation is not straightforward. Therefore, in most cases it was replaced by actual reports of the relevant numbers obtained from the study authors (for details, see Table 3.11 and Table 3.12). The three lowest 5th percentile concentrations reported or estimated in these studies were the peak-season averages of 55 μg/m³ (Weichenthal, Pinault & Burnett, 2017), 56 μg/m³ (Cakmak et al., 2018) and 68 μg/m³ (Di et al., 2017a). The study by Weichenthal, Pinault & Burnett (2017) was considered in the systematic review to be at high RoB. If this study is ignored, then the next lowest 5th percentile concentration was 68 μg/m³ (Lipsett et al., 2011). The average of the three lowest 5th percentile values is either approximately 60 or 64 μg/m³ (depending on whether or not the study by Weichenthal, Pinault & Burnett (2017) is included). Three of these four studies found statistically significant positive associations between ozone and all non-accidental mortality. The sum of weights of these four studies in the meta-analysis was well over 60%.

Step 3. Determine the minimal relevant increase in health outcomes

The GDG decided to consider as relevant any increase in risk for an adverse health outcome related to long-term exposure to a pollutant.

Step 4. Determine the starting point for AQG level determination as the long-term concentration of the pollutant from which the minimal relevant amount of the health outcome will result

Thus, the average of the three lowest 5th percentile levels measured in these studies was the starting point for deriving an AQG level: 60 μg/m³ ozone, based on the average concentrations of either 60 μg/m³ or 64 μg/m³. The data obtained support a long-term, peak-season AQG level of no more than 60 μg/m³, based on the association between long-term ozone and all non-accidental mortality.

Step 5. Compare the AQG level across critical health outcomes: respiratory mortality

The other outcome that was investigated was respiratory mortality, which yielded a bigger RR for peak-season ozone, compared with the RR for all non-accidental mortality, with an RR of 1.02 (95% CI: 0.99–1.05) per 10 μg/m³. The certainty of the evidence, however, was rated low for non-malignant respiratory mortality because the prediction interval of 0.96–1.08 included unity and was exactly twice the meta-analytic 95% CI. For an explanation of the prediction interval, see section 2.4.4. In addition, because none of the studies had explicitly considered the shape of the CRF, no upgrade was applied for dose–response. Table 3.12 shows the findings for non-malignant respiratory mortality. The starting points for AQG level determination for this additional health outcome would not be further supported by including respiratory mortality, although three of the four studies are included in the all non-accidental mortality analysis and the fourth is on the same cohort as all-cause mortality (Crouse et al. (2015) versus Cakmak et al. (2018)). For further discussion, see step 7.

Step 6. Assess certainty of the evidence

The certainty of the evidence was rated as moderate for non-accidental mortality and low for respiratory mortality. One of the studies that made up the lowest levels measured in all non-accidental mortality studies (Weichenthal, Pinault & Burnett, 2017) was considered at high RoB, so the GDG calculated the starting point for AQG level determination with and without that study, as previously mentioned.

Step 7. Consider new evidence

Several new studies were published between autumn 2018 and the summer of 2020. The systematic review discussed these but did not include them in the assessment, so the GDG made its own assessment of these studies. These new studies are largely the same as those identified and included in the revision of the systematic review of long-term PM effects on mortality (Chen & Hoek, 2020). Table 3.13 shows these studies, ordered by mean or median exposure level for all non-accidental mortality. These include two studies from Canada (Brauer et al., 2019; Pappin et al., 2019) and three new studies from the United States (Lefler et al., 2019; Lim et al., 2019; Kazemiparkouhi et al., 2020). Two of the five were administrative database studies with no adjustment (Brauer et al., 2019) or with area-level adjustment (Kazemiparkouhi et al., 2020) for lifestyle factors such as smoking. The other three were cohort studies with adequate information on lifestyle covariates. Adding these studies to the meta-analysis produced an HR of 1.013 (95% CI: 1.002–1.023) for non-accidental mortality. The effect estimate from the systematic review was 1.01 (95% CI: 1.00–1.02; see step 1).

The Kazemiparkouhi et al. (2020) study was based on 1-hour maximum concentrations, not 8-hour maximum concentrations. The 8-hour maximum concentrations usually correlate very highly with the 1-hour maximum concentrations but are 10–40% lower. Therefore, in principle, one would expect effect estimates expressed over the same concentration range to be somewhat higher when using 8-hour maximum concentrations as the denominator. However, a large study from Europe (Gryparis et al., 2004) found no difference in effect estimates based on 1-hour versus 8-hour maximum concentrations and expressed over the same concentration range. Therefore, the GDG did not change the effect estimate from the Kazemiparkouhi et al. (2020) study. Adding these studies to the meta-analysis produced an HR of 1.013 (95% CI: 1.006–1.021) and a prediction interval of 0.997–1.030. For an explanation of the prediction interval, see section 2.4.4. Note that this prediction interval includes unity and is slightly larger than twice the HR 95% CI, so this would justify a downgrade of the certainty of evidence due to inconsistency. As argued before, the GDG finds the evidence of dose–response sufficient for an upgrade of certainty, so that the net result for the association between peak-season ozone and non-accidental mortality would be moderate certainty.

Two cohort studies also reported effect estimates for respiratory mortality (Table 3.14). Adding these studies to the meta-analysis produced an HR for respiratory mortality of 1.023 (95% CI: 1.007–1.038) with a prediction interval of 0.993–1.053. As this prediction interval is less than twice the meta-analytic 95% CI, there is no need to downgrade the certainty of the evidence due to inconsistency. The effect estimate from the systematic review was an RR of 1.02 (95% CI: 0.99–1.05) per 10 μg/m³. In addition, as Fig. 3.10 shows, one of the new studies (Lim et al., 2019) supports a dose–response for respiratory mortality down to slightly less than 60 μg/m³.

The GDG notes that these very recent studies almost doubled the number of studies available for inclusion. If they had been part of the review, the AQG level starting point based on the three lowest 5th percentile values, excluding the studies at high RoB, would be even somewhat lower, at (50 + 56 + 62) / 3 = 56 μg/m³. There is no reason, based on these new findings, to change the proposed long-term AQG level.

Step 8. Reconsider causality

The long-term ozone-outcome associations were deemed to be likely causal (for respiratory effects) or suggestive of being causal (for total mortality) in the 2016 outcome prioritization framework (see section 2.3.3). These judgements were primarily based on the 2013 US EPA ISA of ozone (US EPA, 2013) and a 2013 Health Canada report (Health Canada, 2013). The 2020 EPA ISA (US EPA,

2020) did not change these classifications. As discussed in step 7 and shown in Table 3.13 and Table 3.14, a number of very recent studies have provided further support for associations between long-term ozone concentrations and both total and respiratory mortality.

The 5th percentile and mean or median of exposure distributions in studies in the ozone and mortality meta-analyses are shown in Table 3.11 and Table 3.12 based on data from the systematic review by Huangfu & Atkinson (2020) and in Table 3.13 and Table 3.14 for the new studies that were identified.

3.4.2.1 Interim targets

Interim targets are proposed as incremental steps in a progressive reduction of air pollution and are intended for use in areas where pollution is high. For a more detailed rationale for establishing and using interim targets, see section 2.5.3.

Interim targets were not specified for long-term ozone in *Global update 2005*. The GDG recommends a peak-season average ozone concentration of 100 μg/m³ as interim target 1, as this is a level already shown to be achievable in many parts of the world. As interim target 2, a concentration of 70 μg/m³ is proposed; this is the threshold in the widely used SOMO35 metric. SOMO35 is the accumulated ozone concentration (daily maximum 8-hour mean) in excess of 35 parts per billion (ppb; equivalent to 70 μg/m³) (EEA, 2020).

The recommendation is a peak season ozone AQG level of 60 μg/m³ (the average of daily maximum 8-hour mean ozone concentrations). The peak season is defined as the six consecutive months of the year with the highest six-month running-average ozone concentration. In regions away from the equator, this period will typically be in the warm season within a single calendar year (northern hemisphere) or spanning two calendar years (southern hemisphere). Close to the equator, such clear seasonal patterns may not be obvious, but a running-average six-month peak season will usually be identifiable from existing monitoring or modelling data.

An interim target 1 of 100 μg/m³ and an interim target 2 of 70 μg/m³ are proposed, as shown in Table 3.10.

If mortality in a population exposed to ozone at the AQG level is arbitrarily set at 100, then it will be 104 and 101, respectively, in populations exposed to ozone at the interim target 1 and 2 levels. These projections are based on the linear HR of 1.01 per 10-μg/m³ increase in ozone of all non-accidental mortality reported in the systematic review. For respiratory mortality, the numbers will be 108 and 102, respectively, at the interim target 1 and 2 levels, based on the linear HR of 1.02 of respiratory mortality reported in the systematic review. At higher concentrations, the CRF may no longer be linear, which would change the numbers in this example.

Table 3.10. Recommended peak season[a] AQG level and interim targets for ozone

Recommendation	O_3 (μg/m³)
Interim target 1	100
Interim target 2	70
AQG level	**60**

[a] Average of daily maximum 8-hour mean O_3 concentration in the six consecutive months with the highest six-month running-average O_3 concentration.

Table 3.11. Studies on peak-season, long-term ozone exposure and all non-accidental mortality included in the systematic review by Huangfu & Atkinson (2020), ordered by me(di)an concentration

Study	Me(di)an (μg/m³)	SD	P5	P25	HR (95% CI)[a]
Weichenthal, Pinault & Burnett (2017)[b]	76.6	–	55.2[c]	67.3	1.0290 (1.024–1.033)
Cakmak et al. (2018)	78.4	13.4	56.4[d]	–	1.0400 (1.010–1.070)
Di et al. (2017a)	90.0	14.0	68.0[c]	–	1.0115 (1.011–1.012)
Turner et al. (2016)	94.2	11.8	71.4[c]	88.4	1.0100 (1.010–1.015)
Lipsett et al. (2011)	96.2	17.4	67.6[d]	–	0.9900 (0.990–1.000)
Bentayeb et al. (2015)	101.0	8.5	87.0[d]	–	0.9800 (0.900–1.060)
Lipfert et al. (2006)	173.4	18.6	142.8[d]	–	1.0000 (0.990–1.020)

–, data unavailable; P5: 5th percentile (of the distribution of concentrations assigned to study participants); P25: 25th percentile; SD: standard deviation.
[a] Per 10 μg/m³.
[b] Considered to be at high RoB.
[c] Reported in paper or by authors on request.
[d] Calculated from mean and standard deviation using the following formula: Me(di)an – 1.645 × SD.

Table 3.12. Studies on peak-season, long-term ozone exposure and respiratory mortality included in the systematic review by Huangfu & Atkinson (2020), ordered by me(di)an concentration

Study	Me(di)an (μg/m³)	SD	P5	P25	HR (95% CI)[a]
Weichenthal, Pinault & Burnett (2017)[b]	76.6	–	55.2[c]	67.3	1.020 (1.006–1.035)
Crouse et al. (2015)	78.0	–	56.0[d]	68.6	0.985 (0.975–0.994)
Turner et al. (2016)	94.2	11.8	71.4[c]	88.4	1.05 (1.035–1.060)
Lipsett et al. (2011)	96.2	17.4	67.6[e]	–	1.02 (0.990–1.040)

–, data unavailable; P5: 5th percentile (of the distribution of concentrations assigned to study participants); P25: 25th percentile; SD: standard deviation.
[a] Per 10 μg/m³.
[b] Considered to be at high RoB.
[c] Reported in paper or by authors on request.
[d] Similar distribution assumed as in the paper by Weichenthal, Pinault & Burnett (2017), based on the same CanCHEC cohort.
[e] Calculated from mean and standard deviation using the following formula: Me(di)an – 1.645 × SD.

Table 3.13. New studies on peak-season, long-term ozone exposure and all non-accidental mortality published since autumn 2018, ordered by me(di)an concentration

Study	Me(di)an (μg/m³)	SD	P5	P25	HR (95% CI)[a]
Brauer et al. (2019) – CanCHEC subjects	72.0	15.0	52.3[b]	–	1.036 (1.034–1.036)
Brauer et al. (2019) – CCHS subjects	72.0	15.0	50.0[b]	–	1.025 (1.015–1.035)
Lim et al. (2019)	92.4	15.2	62.3[b]	–	1.000 (0.995–1.005)
Lefler et al. (2019)	94.9	10.6	77.5[c]	–	1.016 (1.010–1.022)
Kazemiparkouhi et al. (2020)	110.0	–	–	100.0	1.006 (1.006–1.007)

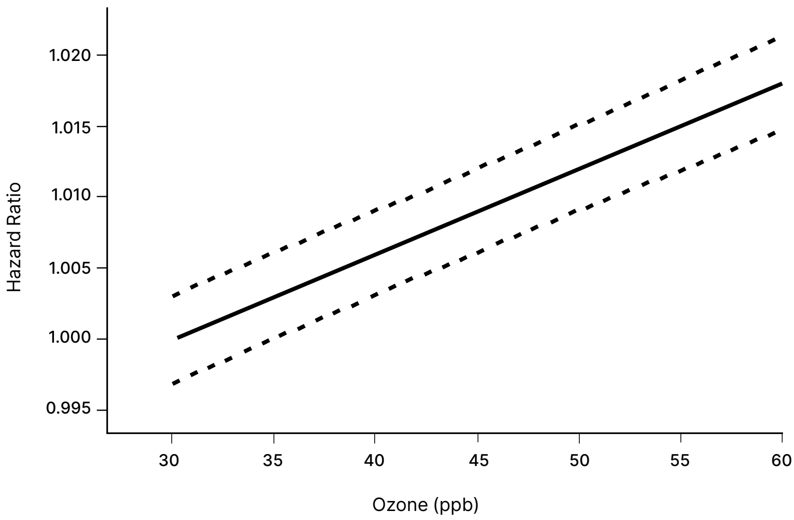
–, data unavailable; CCHS: Canadian Community Health Survey; P5: 5th percentile (of the distribution of concentrations assigned to study participants); P25: 25th percentile; SD: standard deviation.
[a] Per 10 μg/m³.
[b] Reported in paper or by authors on request.
[c] Calculated from mean and standard deviation using the following formula: Me(di)an – 1.645 × SD.

Table 3.14. New studies on peak-season, long-term ozone exposure and respiratory mortality published since autumn 2018, ordered by me(di)an concentration

Study	Me(di)an (μg/m³)	SD	P5	P25	HR (95% CI)[a]
Lim et al. (2019)	92.4	15.2	62.3[b]	–	1.040 (1.020–1.060)
Kazemiparkouhi et al. (2020)	110.0	–		100.0	1.018 (1.016–1.020)

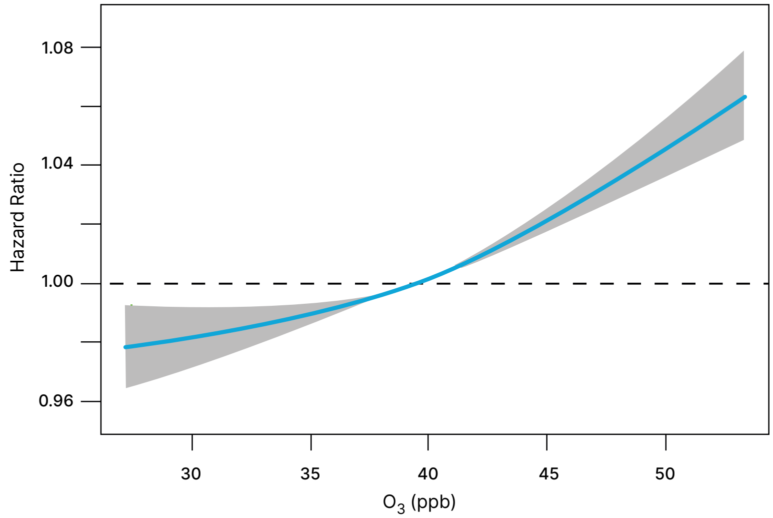
–, data unavailable; P5: 5th percentile (of the distribution of concentrations assigned to study participants); P25: 25th percentile; SD: standard deviation.
[a] Per 10 μg/m³.
[b] Reported in paper or by authors on request.

Fig. 3.8. Association between peak-season, long-term ozone exposure (ppb) and all non-accidental mortality[a]



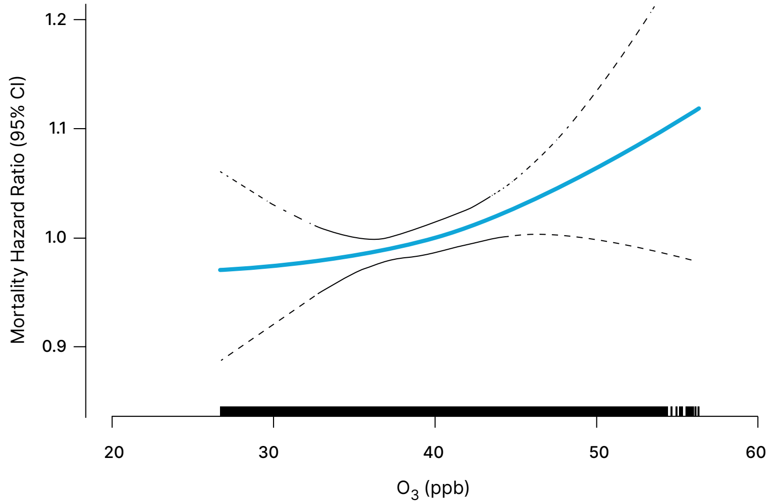
[a] Note that the units for ozone are in ppb; these need to be multiplied by 2 to arrive at concentrations expressed in μg/m³. HR is expressed relative to the 5th percentile of the distribution of ozone concentrations, which was 30 ppb.
Source: reprinted from Di et al. (2017a) with permission from the Massachusetts Medical Society. Copyright © 2017 Massachusetts Medical Society.

Fig. 3.9 The association between peak-season, long-term ozone exposure (ppb) and all-cause mortality[a]



[a] Note that the units for ozone are in ppb; these need to be multiplied by 2 to arrive at concentrations expressed in μg/m³. HRs are expressed relative to the mean ozone concentration of 39.6 ppb.
Source: reproduced from Crouse et al. (2015) with permission of the lead author.

Fig. 3.10 The association between peak-season, long-term ozone exposure (ppb) and respiratory mortality[a]



[a] Note that the units for ozone are in ppb; these need to be multiplied by 2 to arrive at concentrations expressed in μg/m³. HRs are expressed relative to the mean ozone concentration of 46.2 ppb.
Source: adapted from Lim et al. (2019) with permission of the American Thoracic Society. Note that the authors, editors and the American Thoracic Society are not responsible for errors or omissions in adaptations.

3.4.3 Recommended AQG level for short-term exposure to ozone

Based on the methods for deriving an AQG level outlined in the guideline development protocol, this section provides an AQG level for short-term, daily maximum 8-hour average ozone that is based on all-cause non-accidental mortality (Table 3.15).

The epidemiological evidence underpinning the AQG level is discussed in a systematic review commissioned by WHO, as explained in more detail in section 2.4. The review (Orellano et al., 2020), was published in *Environment International* (Whaley et al., 2021) as open access.

As discussed in section 2.3, there has been no separate, independent assessment of the mechanistic, toxicological and human clinical studies relating ozone to human health. However, comprehensive evaluations by authoritative bodies such Health Canada, the United Kingdom's Committee on Medical Effects of Air Pollution and US EPA were taken into account in the development of the AQG levels. This was especially relevant when assessing causality of the associations examined in the systematic reviews (see step 8).

This section follows the eight steps outlined in the protocol for AQG level development. Tables and figures mentioned during the eight steps are listed at the end of the discussion of each recommendation.

Step 1. Assess RR estimates and, when available, CRFs

The systematic review by Orellano et al. (2020) on ozone and all-cause non-accidental mortality reported a meta-analytic effect estimate of RR = 1.0043 (95% CI: 1.0034–1.0052) per 10 μg/m³ ozone, assuming a linear relationship. This effect estimate is for 8-hour maximum concentrations. The certainty of the evidence was considered high according to GRADE. CRFs were provided by several studies. Many studies have found that associations persisted at daily levels of 100 μg/m³ ozone or lower. An example is provided in Fig. 5B of the original study (Di et al., 2017b), which was a very large study conducted in the United States of the entire Medicare population. Another example is from the multicity study by Vicedo-Cabrera et al. (2020), which was published after the systematic review search was completed (Fig. 3.11). This was a worldwide study combining evidence from 406 locations in 20 countries.

Step 2. Determine the lowest level of exposure measured

As discussed in the protocol for deriving AQG levels, the lowest concentrations in time-series studies of effects of daily variations in air pollution concentrations are often very low.

Therefore, the 5th percentiles of these daily distributions cannot be used as starting points for AQG level development.

In such cases, the protocol suggests identifying the 99th percentile of common distributions of daily air pollution concentrations corresponding to an average long-term concentration equivalent to the annual AQG level. The proposed long-term AQG level is 60 μg/m³ for ozone, as a warm-season average of daily maximum 8-hour concentrations. Common distributions observed in large numbers of cities around the world (data from Vicedo-Cabrera et al. (2020)) suggest that the 99th percentiles of daily concentrations are on average 2.05 (rounded to 2) times higher than the annual mean ozone concentrations. However, the long-term AQG level for ozone is for a peak-season average, which is always higher than the annual average. Note that the definitions of peak season and warm season vary slightly from study to study, sometimes restricted to the three summer months, sometimes using the (northern hemisphere) May–September period. A study from the United States (Turner et al., 2016) observed an annual mean of modelled daily 8-hour maximum ozone concentrations of 76.4 μg/m³ and a warm-season mean of 94.2 μg/m³ (ratio of 1.23). A very large database from Europe documented a ratio of 1.24 based on actual ozone measurements (de Hoogh et al., 2018). Therefore, using this ratio, the chosen peak-season AQG level of 60 μg/m³ corresponds to an annual mean of 48.7 μg/m³. Calculating the short-term AQG level using a ratio of 2 between the 99th percentile and annual mean produced a value of 120 μg/m³, and dividing that number by the 1.24 ratio of the peak (warm) season to annual average concentrations produced a value of 97 μg/m³, which was rounded up to a proposed short-term AQG level of 100 μg/m³.

Step 3. Determine the minimal relevant increase in health outcomes

The GDG decided to consider as relevant any increase in risk for an adverse health outcome related to long-term exposure to a pollutant. For short-term exposures, the CRFs from the systematic review by Orellano et al. (2020) were used to calculate the increase in mortality expected on a day with an 8-hour maximum ozone concentration of 100 μg/m³ compared with a day with an 8-hour maximum ozone concentration of 60 μg/m³. With an RR for all-cause mortality of 1.0043 per 10 μg/m³, the estimated excess mortality on such a day would be 1.72%. However, under compliance with the long-term peak-season AQG level, days with concentrations close to 100 μg/m³ will correspond to the far upper tail of the distribution of daily exposures. Most days will have much lower values and almost half will have concentrations below or far below the peak-season AQG level. The health burden related to a few days with higher concentrations corresponds to a very small fraction of the total air pollution-related burden.

Step 4. Determine the starting point for AQG level determination as the 99th percentile, as mentioned in step 3

The data obtained support a short-term AQG level of no more than 100 μg/m³, based on the association between short-term ozone and all-cause non-accidental mortality.

Step 5. Compare the AQG level across critical health outcomes: cause-specific mortality and asthma hospital admissions and emergency room visits

Studies on short-term associations and cause-specific mortality were not reviewed. However, another systematic review assessed the evidence for associations between ozone and daily hospital and emergency room admissions for asthma (Zheng et al., 2021). The review found an effect estimate of RR = 1.012 (95% CI: 1.008–1.016) per 10 μg/m³, which would produce an excess morbidity of 4.8% for a day at the proposed short-term AQG level of 100 μg/m³ compared with a day at the proposed long-term AQG level of 60 μg/m³. As mentioned in step 3, such days will be rare events under compliance with the peak-season long-term AQG level; thus, the short-term burden due to the few days with higher values is relatively small.

Step 6. Assess certainty of the evidence

As mentioned in step 1, the certainty level is high for evidence linking short-term ozone concentration variations to short-term mortality variations. In addition, as shown in Fig. 5B of Di et al. (2017b) and Fig. 3.11, there is evidence that this association persists to very low levels of exposure.

Step 7. Consider new evidence

Several new studies have been published since autumn 2018. Of note is the very large study conducted by Vicedo-Cabrera et al. (2020). This study reported an effect estimate of RR = 1.0018 (95% CI: 1.0012–1.0024) per 10 μg/m³, which is considerably lower than the RR of 1.0043 reported by Orellano et al. (2020). Whereas this new effect estimate would lower the estimated excess mortality at the proposed short-term AQG level, it would not change the proposed AQG level because this was calculated according to the methods explained in section 2.5.

Step 8. Reconsider causality

The association between short-term ozone concentrations and all-cause mortality was judged as likely causal in the 2016 outcome prioritization framework (see section 2.3.3). This judgement was changed in the US EPA ISA of 2020 to suggestive of a causal relationship. A discussion of these changes is provided in section 2.5 of this report. The relationship between short-term ozone and respiratory effects (including mortality) was classified as causal.

As mentioned in step 7, new results from a very large worldwide study (Vicedo-Cabrera et al., 2020) provide further support for an association between short-term ozone and all-cause mortality. The GDG judged it prudent to propose a short-term AQG level for ozone, also in view of the large proportions of the world population exposed to relatively high ozone concentrations and the prospect that concentrations may go up rather than down as a result of climate change.

3.4.3.1 Interim targets

Interim targets are proposed as incremental steps in a progressive reduction of air pollution and are intended for use in areas where pollution is high. For a more detailed rationale for establishing and using interim targets, see section 2.5.3.

The recommendation is a short-term daily maximum 8-hour ozone AQG level of 100 μg/m³, defined as the 99th percentile (equivalent to three to four exceedance days per year) of the annual distribution of daily maximum 8-hour average concentrations.

An interim target 1 of 160 μg/m³ is retained from *Global update 2005*. An interim target 2 of 120 μg/m³ is also proposed, as shown in Table 3.15.

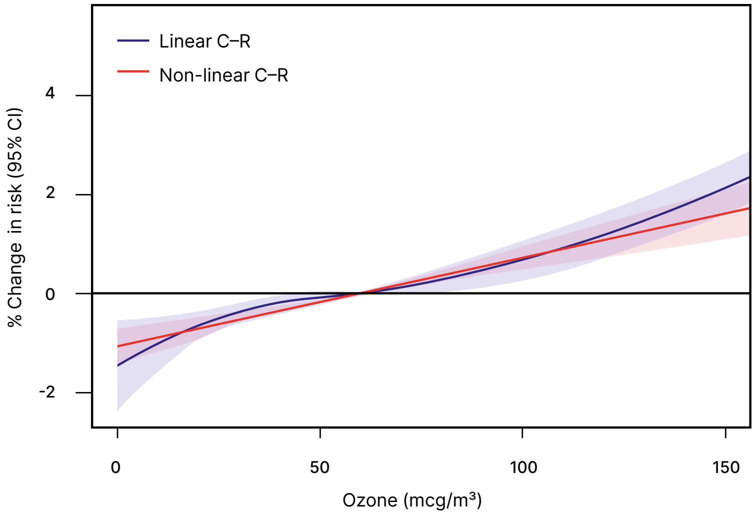
Table 3.15. Recommended short-term (8-hour) daily maximum AQG level and interim targets for ozone[a]

Recommendation	O_3 (μg/m³)
Interim target 1	160
Interim target 2	120
AQG level	**100**

[a] Defined as the 99th percentile of the annual distribution of daily maximum 8-hour average concentrations (equivalent to 3–4 exceedance days per year).

If mortality in a population exposed, on a given day, to ozone at the AQG level is arbitrarily set at 100, then it will be 103 and 101, respectively, in populations exposed, on a given, high pollution day to ozone at the interim target 1 and 2 levels. These projections are based on the linear HR of 1.0043 per 10-μg/m³ increase in ozone for all non-accidental mortality reported in the systematic review. At higher concentrations, the CRF may no longer be linear, which would change the numbers in this example.

Fig. 3.11. Exposure–response curve for 8-hour ozone exposure (μg/m³) and all-cause mortality[a]



C–R: concentration–response.
[a] The change in risk is expressed relative to a mean ozone concentration of about 60 μg/m³.
Source: Vicedo-Cabrera et al. (2020).

3.5 Nitrogen dioxide

3.5.1 General description

The general description comes from *Global update 2005*.

> Many chemical species of nitrogen oxides exist, but the air pollutant species of most interest from the point of view of human health is nitrogen dioxide. Nitrogen dioxide is a reddish brown gas with a characteristic pungent odour. Nitric oxide spontaneously produces the dioxide when exposed to air. Nitrogen dioxide gas is a strong oxidant, and reacts with water to produce nitric acid and nitric oxide.
>
> Nitrogen dioxide is an important atmospheric trace gas not only because of its health effects but also because: (*a*) it absorbs visible solar radiation and contributes to impaired atmospheric visibility; (*b*) it absorbs visible radiation and has a potentially direct role in global climate change; (*c*) it is, along with nitric oxide, a chief regulator of the oxidizing capacity of the free troposphere by controlling the build-up and fate of radical species, including hydroxyl radicals; and (*d*) it plays a critical role in determining ozone concentrations in the troposphere because the photolysis of nitrogen dioxide is the only key initiator of the photochemical formation of ozone, whether in polluted or in non-polluted atmospheres (US EPA, 1993, 1995).

> Nitrogen dioxide is subject to extensive further atmospheric transformations that lead to the formation of strong oxidants that participate in the conversion of nitrogen dioxide to nitric acid and sulfur dioxide to sulfuric acid and subsequent conversions to their ammonium neutralization salts. Thus, through the photochemical reaction sequence initiated by solar-radiation-induced activation of nitrogen dioxide, the newly generated pollutants are an important source of organic, nitrate and sulfate particles currently measured as PM_{10} or $PM_{2.5}$. For these reasons, nitrogen dioxide is a key precursor of a range of secondary pollutants whose effects on human health are well-documented (WHO Regional Office for Europe, 2006).

Conversion factors: at 20 °C and 1013 hPa, 1 ppm = 1.914 mg/m³ and 1 mg/m³ = 0.523 ppm.

3.5.2 Recommended AQG level for long-term exposure to nitrogen dioxide

Based on the methods for deriving an AQG level outlined in the guideline development protocol, this section provides a recommendation for an AQG level for long-term nitrogen dioxide that is based on all non-accidental mortality and cause-specific, respiratory mortality (Table 3.16).

The epidemiological evidence underpinning the AQG level is discussed in a systematic review commissioned by WHO, as explained in more detail in section 2.4. The review (Huangfu & Atkinson, 2020) was published in *Environment International* (Whaley et al., 2021) as open access.

As discussed in section 2.3, there has been no separate, independent assessment of the mechanistic, toxicological and human clinical studies relating nitrogen dioxide to human health.

This section follows the eight steps outlined in the protocol for AQG level development. Tables and figures mentioned during the eight steps are listed at the end of the discussion of each recommendation.

Step 1. Assess RR estimates and, when available, CRFs

The systematic review by Huangfu & Atkinson (2020) on nitrogen dioxide and all non-accidental mortality reported a meta-analytic effect estimate of RR = 1.02 (95% CI: 1.01–1.04) per 10 μg/m³ nitrogen dioxide, assuming a linear relationship. The certainty of the evidence was considered moderate according to GRADE. The authors found an indication of a supralinear relationship, suggesting a steeper risk increase at lower exposure levels. CRFs were provided by a few studies.

They are shown in Fig. 3.12 and Fig. 3.13 for those studies with information on low to very low levels of exposure measured (step 2).

Step 2. Determine the lowest level of exposure measured

For 19 of the 24 studies included in the meta-analysis, the 5th percentile of the exposure distribution was reported or could be calculated from the reported mean and standard deviation (Table 3.17). As the concentration distributions are often lognormal, this calculation is not straightforward. Therefore, in most cases it was replaced by actual reports of the relevant numbers obtained from the study authors. The three lowest levels reported or estimated in these studies are -2.7 μg/m³ (Yorifuji et al., 2013) and 4.0 μg/m³ (Bentayeb et al., 2015) (both estimated) and 6.3 μg/m³ (Weichenthal, Pinault & Burnett, 2017). The GDG ignored these three numbers because the first two were a function of very high standard deviations in studies with otherwise not very low mean concentrations. The GDG ignored the third study because it was considered to be at a high RoB (see below). The next five lowest 5th percentile concentrations were 7.3 μg/m³ (Tonne & Wilkinson, 2013), 8.3 μg/m³ in two separate studies (Hart et al., 2011, 2013), 9.6 μg/m³ (Turner et al., 2016) and 10.3 μg/m³ (Carey et al., 2013). The average of these five 5th percentile values was 8.8 μg/m³; all of these studies found positive associations between nitrogen dioxide and all non-accidental mortality, of which three were statistically significant by themselves. The sum of weights in the meta-analysis was > 25%, indicating that these studies made an important contribution to the meta-analysis.

Step 3. Determine the minimal relevant increase in health outcomes

The GDG decided to consider as relevant any increase in risk for an adverse health outcome related to long-term exposure to a pollutant.

Step 4. Determine the starting point for AQG level determination as the long-term concentration of the pollutant from which the minimal relevant amount of the health outcome will result

Thus, the average of the five lowest 5th percentile levels measured in these five studies was the starting point for deriving an AQG level: 8.8 μg/m³ nitrogen dioxide. The data obtained support a long-term AQG level of no more than 10 μg/m³, based on the association between long-term nitrogen dioxide and all non-accidental mortality.

Step 5. Compare the AQG level across critical health outcomes: cause-specific mortality

The cause-specific mortality outcomes that were investigated all yielded bigger RRs than the RR for all non-accidental mortality, with RRs of 1.03 (95% CI: 1.01–1.04), 1.03 (95% CI: 1.01–1.05) and 1.06 (95% CI: 1.02–1.10) per 10 μg/m³ for COPD, respiratory and acute lower respiratory infection mortality, respectively. The certainty of the evidence was rated as high for COPD mortality and moderate for non-malignant respiratory mortality and acute lower respiratory infection mortality. Table 3.18 shows the findings for non-malignant respiratory mortality. Starting points for AQG level determination for this additional health outcome would not change the analysis much, as the studies are essentially a large proportion of those in Table 3.17. Therefore, the data obtained for cause-specific mortality also support a long-term AQG level of no more than 10 μg/m³.

Step 6. Assess certainty of the evidence
One of the studies that made up the lowest levels measured in the non-accidental mortality studies (Weichenthal, Pinault & Burnett, 2017) was considered at high RoB, so the GDG did not include that study in further calculations.

Step 7. Consider new evidence
Several new studies were published between autumn 2018 and the summer of 2020. The systematic review did not include these, so the GDG had to make its own overview of these studies. These new studies were largely the same as those identified and included in the revision of the systematic review of long-term PM effects on mortality (Chen & Hoek, 2020). As they were included in the PM review, they are now also discussed in the context of nitrogen dioxide. Table 3.19 shows these studies, ordered by the mean or median exposure level for all non-accidental mortality. These include two studies from Australia (Dirgawati et al., 2019; Hanigan et al., 2019) and two from Canada (Brauer et al., 2019; Pappin et al., 2019), all of which had mean or median nitrogen dioxide levels well below 20 μg/m³. There are two new studies from the United States (Lefler et al., 2019; Eum et al., 2019), one from Denmark (Hvidtfeldt et al., 2019) and one from the Netherlands (Klompmaker et al., 2020). Two of these were administrative database studies with no adjustment (Brauer et al., 2019) or with area-level adjustment (Eum et al., 2019) for lifestyle factors such as smoking. The last three studies also reported effect estimates for respiratory mortality (Table 3.20).

There was no reason, based on these new findings, to change the calculation of the proposed AQG level or the assessment of the certainty of the evidence.

Step 8. Reconsider causality
Most nitrogen dioxide–outcome associations were deemed to be suggestive of being causal or likely causal in the 2016 outcome prioritization framework (see Table 2.1 in section 2.3.3). COMEAP published a report in 2018, Associations of long-term average concentrations of nitrogen dioxide with mortality, which

is somewhat more supportive of a causal role for long-tern nitrogen dioxide in increasing all non-accidental and, especially, respiratory mortality (PHE, 2018). A 2018 review by the German Environment Agency (in German, with a summary in English) also supports a role for long-term nitrogen dioxide in causing cardiovascular mortality (Schneider et al., 2018). None of the more recent reviews were able to include the rather large number of new studies listed in Table 3.19 and Table 3.20, which provided further support for associations between long-term nitrogen dioxide concentrations and all-cause and respiratory mortality.

The GDG noted that one review specifically investigated how sensitive the associations between long-term nitrogen dioxide concentrations and mortality were to adjustment for different PM metrics (Faustini, Rapp & Forastiere, 2014). Associations with nitrogen dioxide were found to be generally robust.

The 5th percentile (where available) and mean or median of exposure distributions in studies included in the nitrogen dioxide and mortality meta-analysis are indicated in Table 3.17 and Table 3.18 based on data from the Huangfu & Atkinson (2020) systematic review and in Table 3.19 and Table 3.20 for the newly identified studies.

3.5.2.1 Interim targets

Interim targets are proposed as incremental steps in a progressive reduction of air pollution and are intended for use in areas where pollution is high. For a more detailed rationale for establishing and using interim targets, see section 2.5.3.

Interim targets were not specified for nitrogen dioxide in *Global update 2005*. As evident from Table 3.17, Table 3.18, Table 3.19 and Table 3.20, the mean or median concentrations of nitrogen dioxide were well below 40 μg/m³ in most studies.

The GDG recommends using the long-term air quality guideline from *Global update 2005* of 40 μg/m³ as interim target 1, as this is a level already shown to be achievable in many parts of the world.

As interim target 2, a level of 30 μg/m³ is proposed and, as interim target 3, a level of 20 μg/m³ is proposed. Proposing two additional interim targets provides reasonable guidance to policy-makers on how to bridge the gap between the 2005 air quality guideline and the new, much lower, AQG level.

The recommendation is an annual nitrogen dioxide AQG level of 10 μg/m³.

An interim target 1 of 40 μg/m³, an interim target 2 of 30 μg/m³ and an interim target 3 of 20 μg/m³ are proposed, as shown in Table 3.16.

Table 3.16. Recommended AQG level and interim targets for nitrogen dioxide

Recommendation	NO_2 (μg/m^3)
Interim target 1	40
Interim target 2	30
Interim target 3	20
AQG level	**10**

If all-cause mortality in a population exposed to nitrogen dioxide at the AQG level is arbitrarily set at 100, then it will be 106, 104 and 102, respectively, in populations exposed to nitrogen dioxide at the interim target 1, 2 and 3 levels. For respiratory mortality, the numbers would be 109, 106 and 103, respectively, at the interim target 1, 2 and 3 levels. These projections are based on the linear HRs of 1.02 and 1.03 per 10-μg/m^3 increase in nitrogen dioxide for all non-accidental and respiratory mortality, respectively, as reported in the systematic review. At higher concentrations, the CRF may no longer be linear, which would change the numbers in this example.

Table 3.17. Studies on long-term nitrogen dioxide exposure and all non-accidental mortality included in the systematic review by Huangfu & Atkinson (2020), ordered by me(di)an concentration

Study	Me(di)an (μg/m^3)	SD	P5	P25	HR (95% CI)[a]
Tonne & Wilkinson (2013)	18.5	6.8	7.3[b]	–	1.01 (0.98–1.04)
Weichenthal, Pinault & Burnett (2017)[c]	21.6	–	6.3[d]	12.1	1.04 (1.03–1.04)
Crouse et al. (2015)	21.8	–	–	11.3	1.03 (1.03–1.04)
Turner et al. (2016)	21.8	9.6	9.6[d]	–	1.02 (1.01–1.03)
Yorifuji et al. (2013)	22.0	15.0	-2.7[b]	–	1.12 (1.07–1.18)
Carey et al. (2013)	22.5	7.4	10.3[b]	–	1.02 (1.00–1.05)
Beelen et al. (2014)	22.2	–	15.3[d]	19.9	1.01 (0.99–1.03)

Table 3.17 contd

Study	Me(di)an (μg/m³)	SD	P5	P25	HR (95% CI)[a]
Hart et al. (2013)	26.1	–	8.3[d]	19.0	1.01 (1.00–1.03)
Hart et al. (2011)	26.7	13.3	8.3[d]	–	1.05 (1.02–1.08)
Bentayeb et al. (2015)	28.0	14.6	4.0[b]	–	1.07 (1.00–1.15)
Krewski et al. (2003)	30.3	–	–	–	1.08 (1.02–1.14)
Fischer et al. (2015)	31.0	–	19.0[d]	26.0	1.03 (1.02–1.04)
Hartiala et al. (2016)	35.9	3.4	30.3[b]	–	1.00 (0.75–1.34)
Filleul et al. (2005)	36.5	–	–	–	1.14 (1.03–1.26)
Lipfert et al. (2006)	37.2	–	16.5[d]	–	1.03 (0.99–1.07)
Brunekreef et al. (2009)[b]	38.0	–	22.0[d]	–	1.03 (1.00–1.05)
Jerrett et al. (2009)	39.1	–	32.0[d]	–	1.23 (1.00–1.51)
Chen et al. (2016)	40.7	1.6	38.1[b]	27.1	0.92 (0.90–0.95)
Cesaroni et al. (2013)[b]	43.6	8.4	29.8[b]	38.5	1.03 (1.02–1.04)
Desikan et al. (2016)[b]	44.6	4.3	37.5[b]	41.8	0.94 (0.76–1.17)
Rosenlund et al. (2008)[b]	48.5	–	–	–	0.95 (0.89–1.02)
Lipsett et al. (2011)	63.1	18.0	33.5[b]	–	0.98 (0.95–1.02)
Abbey et al. (1999)	69.2	24.4	29.1[a]	–	1.00 (0.99–1.01)
Yang et al. (2018)	104.0	–	–	91.0	1.00 (0.99–1.01)

–, data unavailable; P5: 5th percentile (of the distribution of concentrations assigned to study participants); P25: 25th percentile; SD: standard deviation.
[a] Per 10 μg/m³.
[b] Calculated from the mean and SD using the following formula: Me(di)an – 1.645 * SD.
[c] Considered to be at high RoB.
[d] Reported in paper or by authors on request.

Table 3.18. Studies on long-term nitrogen dioxide exposure and respiratory mortality included in the systematic review by Huangfu & Atkinson (2020), ordered by me(di)an concentration

Study	Me(di)an (μg/m³)	SD	P5	P25	HR (95% CI)[a]
Weichenthal, Pinault & Burnett (2017)[b]	21.6	–	6.3[c]	12.1	1.06 (1.04–1.08)
Crouse et al. (2015)	21.8	–	–	11.3	1.02 (1.01–1.04)
Turner et al. (2016)	21.8	9.6	9.6[d]	–	1.02 (1.00–1.04)
Yorifuji et al. (2013)	22.0	15.0	-2.7[d]	–	1.19 (1.06–1.34)
Dimakopoulou et al. (2014)	22.2	–	15.3[c]	19.9	0.97 (0.89–1.04)
Carey et al. (2013)	22.5	7.4	10.3[d]	–	1.08 (1.04–1.13)
Hart et al. (2011)	26.7	13.3	8.3[c]	–	1.04 (0.95–1.14)
Fischer et al. (2015)	31.0	–	19.0[c]	26.0	1.02 (1.01–1.03)
Katanoda et al. (2011)	32.0	–	–	–	1.07 (1.03–1.12)
Brunekreef et al. (2009)[a]	38.0	–	22.0[c]	–	1.11 (1.00–1.23)
Jerrett et al. (2009)	39.1	–	32.0[c]	–	1.08 (0.64–1.84)
Cesaroni et al. (2013)[a]	43.6	8.4	29.8[d]	38.5	1.03 (1.00–1.06)
Lipsett et al. (2011)	63.1	18.0	33.5[d]		0.96 (0.86–1.08)
Abbey et al. (1999)	69.2	24.4	29.1[d]		0.99 (0.98–1.01)
Yang et al. (2018)	104.0	–	–	91.0	1.00 (0.97–1.02)

–, data unavailable; P5: 5th percentile (of the distribution of concentrations assigned to study participants); P25: 25th percentile; SD: standard deviation.
[a] Per 10 μg/m³.
[b] Considered to be at high RoB.
[c] Reported in paper or by authors on request.
[d] Calculated from mean and standard deviation using the following formula: Me(di)an – 1.645 × SD.

Table 3.19. New studies on long-term nitrogen dioxide exposure and all non-accidental mortality published since autumn 2018, ordered by me(di)an concentration

Study	Me(di)an (μg/m³)	SD	P5	P25	HR (95% CI)[a]
Dirgawati et al. (2019)	13.4	4.1	6.7[b]	–	1.060 (1.000–1.120)
Brauer et al. (2019) – CCHS subjects	16.2	11.1	7.2[c]	–	1.024 (1.016–1.040)
Brauer et al. (2019); Pappin et al. (2019) – CanCHEC subjects	16.2	–	5.9[c]	–	1.004 (1.002–1.007)
Hanigan et al. (2019)	17.8	4.8	9.9[b]	14.3	1.060 (0.960–1.140)
Lefler et al. (2019)	20.1	10.7	2.5[b]	–	1.010 (1.002–1.017)
Klompmaker et al. (2020)	23.1	–	–	19.3	0.990 (0.960–1.010)
Hvidtfeldt et al. (2019)	25.0	–	17.9[c]	–	1.070 (1.040–1.100)
Eum et al. (2019)	26.7	–	–	18.2	1.027 (1.027–1.029)

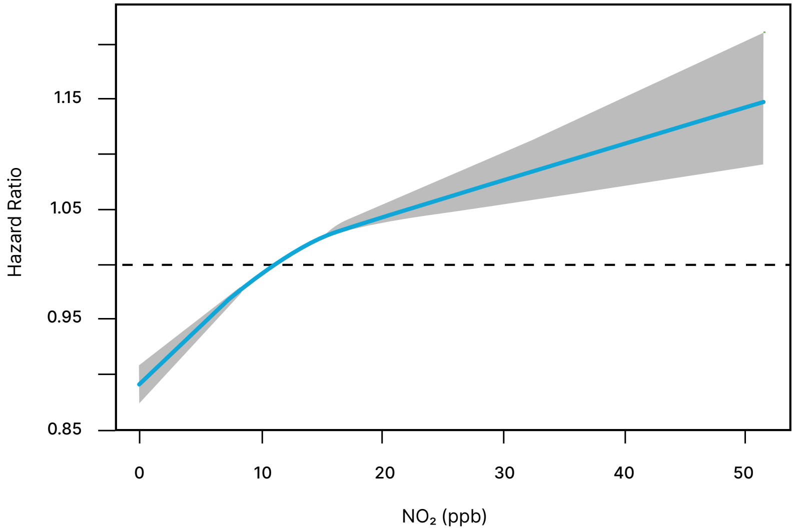
–, data unavailable; CCHS: Canadian Community Health Survey; P5: 5th percentile (of the distribution of concentrations assigned to study participants); P25: 25th percentile; SD: standard deviation.
[a] Per 10 μg/m³.
[b] Calculated from the mean and SD using the following formula: Me(di)an – 1.645 * SD.
[c] Reported in paper or by authors on request.

Table 3.20. New studies on long-term nitrogen dioxide exposure and respiratory mortality published since autumn 2018, ordered by me(di)an concentration

Study	Me(di)an (μg/m³)	SD	P5	P25	HR (95% CI)[a]
Klompmaker et al. (2020)	23.1	–	–	19.3	0.980 (0.890–1.070)
Hvidtfeldt et al. (2019)	25.0	–	17.9[b]	–	1.030 (0.970–1.100)
Eum et al. (2019)	26.7	–	–	18.2	1.027 (1.023–1.030)

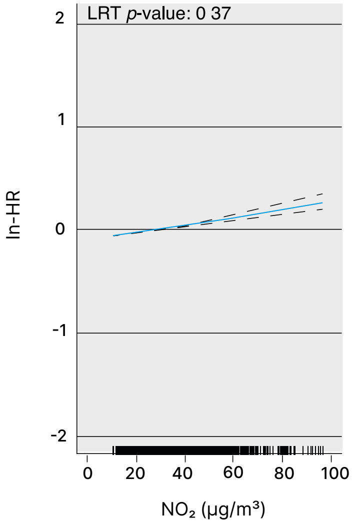
–, data unavailable; P5: 5th percentile (of the distribution of concentrations assigned to study participants); P25: 25th percentile; SD: standard deviation.
[a] Per 10 μg/m³.
[b] Reported in paper or by authors on request.

Fig. 3.12. CRFs for long-term nitrogen dioxide exposure (ppb) and all non-accidental mortality in Canada[a]



[a] HRs are relative to the mean concentration of 11.6 ppb (= 22.9 μg/m³).
Source: reproduced from Crouse et al. (2015) with permission of the lead author.

Fig. 3.13. CRFs for long-term nitrogen dioxide exposure (μg/m³) and all non-accidental mortality in the Netherlands[a]



ln: natural logarithm; LRT: likelihood ratio test.
[a] ln-HR = log HR, relative to the mean nitrogen dioxide concentration. The likelihood-ratio test P value indicates that there was no significant deviation from linearity.
Source: reproduced from Fischer et al. (2015) with permission of the lead author.

3.5.3 Recommended AQG level for short-term exposure to nitrogen dioxide

Based on the methods for deriving an AQG level outlined in the guideline development protocol, this section provides an AQG level for short-term, daily average nitrogen dioxide that is based on all-cause non-accidental mortality and asthma hospital admissions and emergency room visits (Table 3.21).

The epidemiological evidence underpinning the AQG level is discussed in two systematic reviews commissioned by WHO, as explained in more detail in section 2.4. The reviews, conducted by Orellano et al. (2020) and Zheng et al. (2021), were published in *Environment International* (Whaley et al., 2021) as open access.

As discussed in section 2.3, there has been no separate, independent assessment of the mechanistic, toxicological and human clinical studies relating nitrogen dioxide to human health. However, comprehensive evaluations by authoritative bodies such COMEAP, Health Canada and US EPA were taken into account in the development of the AQG levels. This was especially relevant when assessing causality of the associations examined in the systematic reviews (see step 8).

This section follows the eight steps outlined in the protocol for AQG level development. Tables and figures mentioned during the eight steps are listed at the end of the discussion of each recommendation.

Step 1. Assess RR estimates and, when available, CRFs

The systematic review by Orellano et al. (2020) on 24-hour average nitrogen dioxide and all-cause non-accidental mortality reported a meta-analytic effect estimate of RR = 1.0072 (95% CI: 1.0059–1.0085) per 10 μg/m^3 nitrogen dioxide, assuming a linear relationship. The certainty of the evidence was considered high according to GRADE. CRFs were provided by several studies. An example from a study in Austria shows an association between nitrogen dioxide and all-cause mortality at very low levels of exposure (Fig. 3.14) (Moshammer et al., 2020).

Step 2. Determine the lowest level of exposure measured

As discussed in the protocol for deriving AQG levels, the lowest concentrations in time-series studies of effects of daily variations in air pollution concentrations are often very low. Therefore, the 5th percentiles of these daily distributions cannot be used as starting points for AQG level development. In such cases, the protocol suggests identifying the 99th percentile of common distributions of daily air pollution concentrations corresponding to an average long-term concentration equivalent to the proposed annual AQG level. This is 10 μg/m^3 for nitrogen dioxide.

Common distributions observed in large numbers of cities around the world (data from Liu et al. (2019)) suggest a ratio of about 2.5 for 99th percentiles of daily concentrations to the annual mean nitrogen dioxide. Therefore, a short-term AQG level of 25 μg/m³ is suggested.

Step 3. Determine the minimal relevant increase in health outcomes

The GDG decided to consider as relevant any increase in risk for an adverse health outcome related to long-term exposure to a pollutant. For short-term exposures, the CRFs from the systematic review by Orellano et al. (2020) were used to calculate the increase in mortality expected on a day with a 24-hour nitrogen dioxide concentration of 25 μg/m³ compared with a day with a 24-hour nitrogen dioxide concentration of 10 μg/m³. With an RR for all-cause mortality of 1.0072 per 10 μg/m³, the estimated excess mortality on such a day would be 1.1%. However, under compliance with the long-term AQG level, days with concentrations close to 25 μg/m³ will correspond to the far upper tail of the distribution of daily exposures. Most days will have much lower values, with close to half having concentrations below or far below the annual AQG level. The health burden related to a few days with higher concentrations corresponds to a very small fraction of the total air pollution-related burden.

Step 4. Determine the starting point for AQG level determination as the 99th percentile, as mentioned in step 3

The data obtained support a short-term AQG level of no more than 25 μg/m³, based on the association between short-term nitrogen dioxide and all-cause non-accidental mortality.

Step 5. Compare the AQG level across critical health outcomes: cause-specific mortality and asthma hospital admissions and emergency room visits

Studies on short-term associations and cause-specific mortality were not reviewed. However, another systematic review commissioned by WHO assessed the evidence for associations between nitrogen dioxide and daily hospital admissions for asthma (Zheng et al., 2021). This review found an effect estimate of RR = 1.014 (95% CI: 1.009–1.019) per 10 μg/m³, which would produce an excess morbidity 2.1% on a day at the proposed short-term AQG level of 25 μg/m³ compared with a day at the proposed long-term AQG level of 10 μg/m³. As is the case when considering mortality in step 3, under compliance with the long-term AQG level, days with concentrations close to 25 μg/m³ will correspond to the far upper tail of the distribution of daily exposures. Most days will have much lower values, with close to half having concentrations below or far below the annual AQG level. The health burden related to a few days with higher concentrations corresponds to a very small fraction of the total air pollution-related burden.

Step 6. Assess certainty of the evidence
As mentioned in step 1, the certainty level is high for the evidence linking short-term nitrogen dioxide concentration variations to short-term mortality variations. In addition, as shown in Fig. 3.14, there is evidence that this association persists to very low levels of exposure.

Step 7. Consider new evidence
Several new studies have been published since autumn 2018. The GDG did not made an inventory of all new time-series studies. The MCC Collaborative Research Network has reported new findings from a very large database on short-term mortality effects of $PM_{2.5}$ and ozone (Liu et al., 2019; Vicedo-Cabrera et al., 2020); an analysis from the same database on short-term effects of nitrogen dioxide was also published (Meng at al., 2021). The effect estimates from this new analysis are in agreement with those from the WHO-commissioned systematic review.

Step 8. Reconsider causality
The association between short-term nitrogen dioxide concentrations and all-cause mortality was judged to be suggestive of a causal relationship in the 2016 outcome prioritization framework (see section 2.3.3), following authoritative evaluations by Health Canada, US EPA and other bodies. However, the association between short-term nitrogen dioxide concentrations and respiratory effects was judged to be causal. This judgement provides strong support for a short-term AQG level for nitrogen dioxide in view of the reported association with asthma hospital admissions and emergency room visits.

The GDG noted that one review specifically investigated how sensitive the associations between short-term nitrogen dioxide and mortality were to adjustment for different PM metrics (Mills et al., 2016). Associations with nitrogen dioxide were found to be generally robust.

3.5.3.1 Interim targets

Interim targets are proposed as incremental steps in a progressive reduction of air pollution and are intended for use in areas where pollution is high. For a more detailed rationale for establishing and using interim targets, see section 2.5.3.

An interim target 1 of 120 μg/m³ is proposed – which is roughly comparable to the existing 1-hour 2005 air quality guideline of 200 μg/m³. An interim target 2 of 50 μg/m³ is also proposed. Both interim targets use the same definition of 99th percentiles of the distribution of 24-hour concentrations over a one-year period.

The recommendation is a short-term (24-hour) nitrogen dioxide AQG level of 25 μg/m³, defined as the 99th percentile (equivalent to three to four exceedance days per year) of the annual distribution of 24-hour average concentrations.

An interim target 1 of 120 μg/m³ and an interim target 2 of 50 μg/m³ are proposed, as shown in Table 3.21.

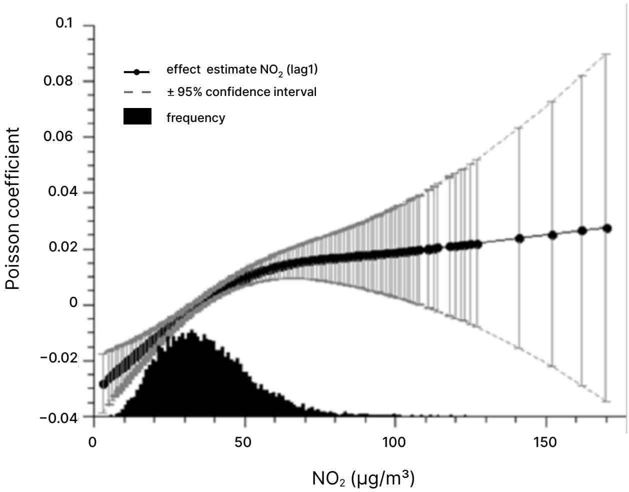
Table 3.21. Recommended short-term (24-hour) AQG level and interim targets for nitrogen dioxide[a]

Recommendation	NO_2 (μg/m³)
Interim target 1	120
Interim target 2	50
AQG level	**25**

[a] Defined as the 99th percentile of the annual distribution of 24-hour average concentrations (equivalent to 3–4 exceedance days per year).

If mortality in a population exposed to nitrogen dioxide for a day at the AQG level of 25 μg/m³ is arbitrarily set at 100, then it will be 107 and 102, respectively, in populations exposed to nitrogen dioxide at the interim target 1 and 2 levels. These projections are based on the linear HR of 1.0072 HR per 10-μg/m³ increase in nitrogen dioxide of all non-accidental mortality reported in the systematic review. At higher concentrations, the CRF may no longer be linear, which would change the numbers in this example.

Fig. 3.14. Association between 24-hour average nitrogen dioxide concentrations (μg/m³) and mortality in Vienna, Austria[a]



[a] The corresponding linear effect estimate is a 0.21% increase in total mortality per previous-day NO_2 increase of 10 μg/m³.
Source: Moshammer et al. (2020).

3.6 Sulfur dioxide

3.6.1 General description

The general description comes from *Global update 2005*.

> Historically, sulfur dioxide and PM derived from the combustion of fossil fuels have been the main components of air pollution in many parts of the world. The most serious problems have been experienced in large urban areas where coal has been used for domestic heating or for poorly controlled combustion in industrial installations. In such situations, the complex of pollutants has generally been considered collectively, drawing on findings from epidemiological studies carried out decades ago in areas formerly heavily polluted. Guidelines developed in this way had been related to averaging times of 24 hours in respect of acute effects and one year in respect of chronic effects.
>
> Separate attention has been paid to sulfur dioxide alone, based largely on findings from controlled human exposure studies. These allow guidelines to be developed in terms of shorter averaging periods of the order of one hour. These are relevant to exposures to peak concentrations that may arise from sources burning coal or heavy oil, whether or not accompanied by substantial concentrations of PM.

> Epidemiological studies published in the last decade [i.e. 1995–2004] provide suggestive evidence on the health effects of sulfur dioxide. Thus, a section has been introduced in this revision focusing on epidemiological results in locations where the sources of sulfur dioxide are mainly motor vehicles and various industries.
>
> Sulfur dioxide is derived from the combustion of sulfur-containing fossil fuels and is a major air pollutant in many parts of the world. Oxidation of sulfur dioxide, especially at the surface of particles in the presence of metallic catalysts, leads to the formation of sulfurous and sulfuric acids. Neutralization, by ammonia, leads to the production of bisulfates and sulfates.
>
> Sulfur dioxide is a colourless gas that is readily soluble in water. Sulfuric acid is a strong acid formed from the reaction of sulfur trioxide (SO_3) with water. Sulfuric acid is strongly hygroscopic. As a pure material it is a colourless liquid with a boiling point of 330 °C. Ammonium bisulfate (NH_4HSO_4), which is also a strong acid but is less acidic than sulfuric acid as a pure material, is a crystalline solid with a melting point of 147 °C. The formation of very small droplets of sulfuric acid occurs by nucleation. Many vapours are able to condense on the surface of existing very fine nuclei and lead to the growth of composite particles. (WHO Regional Office for Europe, 2006).

Conversion factors: at 20 °C and 1013 hPa, 1 ppm = 2660 μg/m^3 and 1 mg/m^3 = 0.3759 ppm.

3.6.2. Recommended AQG level for 24-hour exposure to sulfur dioxide

Based on the methods for deriving an AQG level outlined in the guideline development protocol, the GDG recommends an AQG level for short-term, 24-hour mean sulfur dioxide concentration based on its relationship with asthma hospital admissions and emergency room visits, daily non-accidental mortality and respiratory mortality (Table 3.22). As discussed in Chapter 2, the association between sulfur dioxide and mortality was added to the list of pollutant–outcome pairs at a later stage to improve continuity with *Global update 2005*.

The epidemiological evidence underpinning the AQG level is discussed in a systematic review commissioned by WHO on asthma hospital admissions and emergency room visits (Zheng et al., 2021) and another on daily sulfur dioxide mortality (Orellano, Reynoso & Quaranta, 2021). These reviews were published in *Environment International* (Whaley et al., 2021) as open access.

As discussed in section 2.3, there has been no separate, independent assessment of the mechanistic, toxicological and human clinical studies relating sulfur dioxide to human health.

This section follows the eight steps outlined in the protocol for AQG level development. Tables and figures mentioned during the eight steps are listed at the end of the discussion of each recommendation.

Step 1. Assess RR estimates and, when available, CRFs

The systematic review by Zheng et al. (2021) on sulfur dioxide and asthma hospital admissions and emergency room visits reported a meta-analytic effect estimate of RR = 1.010 (95% CI: 1.001–1.020) per 10 μg/m³ sulfur dioxide, assuming a linear relationship. The certainty of the evidence was considered low according to GRADE. More elaborate analyses of the CRF shape were not provided by any of the studies on asthma included in the systematic review. The systematic review by Orellano, Reynoso & Quaranta (2021) on sulfur dioxide and daily mortality reported a meta-analytic effect estimate of RR = 1.0059 (95% CI: 1.0046–1.0071) per 10 μg/m³ sulfur dioxide, assuming a linear relationship. For respiratory mortality, the meta-analytic effect estimate was RR = 1.0067 (95% CI: 1.0025–1.0109) per 10 μg/m³ sulfur dioxide, assuming a linear relationship. The certainty of the evidence was considered high according to GRADE for all non-accidental mortality and moderate for respiratory mortality.

Step 2. Determine the lowest level of exposure measured

As discussed in the protocol for deriving AQG levels, the lowest concentrations in time-series studies of effects of daily variations in air pollution concentrations are often very low. The minimum concentration reported by most of the studies included in the systematic reviews by Zheng et al. (2021) and Orellano, Reynoso & Quaranta (2021) was below 1 μg/m³. The protocol suggests identifying as the daily AQG level the 99th percentile of a distribution of daily air pollution concentrations corresponding to an average long-term concentration equivalent to the annual AQG level. However, in the case of sulfur dioxide, there is no annual AQG level that can be used as a point of departure, so this approach cannot be applied.

Step 3. Determine the minimal relevant increase in health outcomes

The GDG decided to consider as relevant any increase in risk for an adverse health outcome related to long-term exposure to a pollutant. For short-term exposures, the assumption of a linear CRF and a risk coefficient from the systematic reviews by Zheng et al. (2021) and Orellano, Reynoso & Quaranta (2021) were used to calculate the increase in asthma hospital admissions and emergency room visits and daily non-accidental mortality and respiratory mortality relative to a daily mean sulfur dioxide concentration of 0 μg/m³. With an RR of 1.010 per 10 μg/m³, any 10-μg/m³ increase would produce a 1% increase in asthma hospital admissions and emergency room visits. The increases in non-accidental mortality and respiratory mortality would be 0.6% and 0.7%, respectively, per 10 μg/m³.

Step 4. Determine the starting point for AQG level determination as the 99th percentile, as mentioned in step 3

In the proposed short-term AQG levels for $PM_{2.5}$, PM_{10}, ozone and nitrogen dioxide, a comparison was made between the expected excess deaths or asthma hospital admissions and emergency room visits at the 99th percentiles of daily distributions corresponding to a distribution that is in compliance with the proposed long-term AQG levels for these pollutants. For non-accidental mortality, these excess estimates were up to 1.72% for deaths related to ozone and 4.8% for asthma hospital admissions and emergency room visits related to ozone. Similar percentage increases related to sulfur dioxide, relative to a 0 μg/m³ concentration, would be expected at a daily mean of about 30 μg/m³ (3% increase in asthma hospital admissions and emergency room visits, 1.8% increase in daily non-accidental mortality). The MCC Collaborative Research Network database (A. Gasparrini, London School of Hygiene and Tropical Medicine, unpublished data, 23 June 2020; Liu et al., 2019) documented a ratio of 3.9 between the 99th percentile of daily concentrations and the annual mean sulfur dioxide concentration across hundreds of cities from all over the world. Following the same logic used for pollutants for which there is a proposed long-term AQG level, the starting point for a short-term sulfur dioxide AQG level would be 40 μg/m³. The rationale is that with a ratio of about 4 between the 99th percentile and annual mean, 40 μg/m³ would correspond to an increase of 30 μg/m³ over an annual mean of 10 μg/m³, which is about the same as the overall mean concentration observed across almost 400 locations worldwide in the MCC Collaborative Research Network database (A. Gasparrini, London School of Hygiene and Tropical Medicine, unpublished data, 23 June 2020; Liu et al., 2019). The GDG recognizes that the choice for a background of 10 μg/m³ is, to some extent, arbitrary but notes that the estimated excess mortality at days with concentrations at the recommended AQG level is small and is roughly comparable across all pollutants considered in this report.

Step 5. Compare the AQG level across critical health outcomes

No other health outcomes were evaluated in the systematic reviews.

Step 6. Assess certainty of the evidence

As mentioned in step 1, the evidence base supporting an association between 24-hour average sulfur dioxide and asthma hospital admissions and emergency room visits was considered to be of low certainty. For all non-accidental mortality, it was considered to be of high certainty.

Step 7. Consider new evidence

No new studies on the relation between sulfur dioxide exposure and asthma hospital admissions and emergency room visits and non-accidental or respiratory mortality were considered.

Step 8. Reconsider causality

The association between short-term sulfur dioxide concentrations and asthma hospital admissions and emergency room visits was judged to be causal for respiratory effects in the 2016 outcome prioritization framework (see section 2.3.3), based on assessments by Health Canada and the US EPA. The US EPA published a new ISA on sulfur oxides in 2017 (US EPA, 2017) that did not change that assessment, and which classifies the short-term association with mortality as suggestive of a causal relationship.

3.6.2.1 Interim targets

Interim targets are proposed as incremental steps in a progressive reduction of air pollution and are intended for use in areas where pollution is high. For a more detailed rationale for establishing and using interim targets, see section 2.5.3.

Recommended interim targets are the same as in *Global update 2005*. There are still some places in the world where such high sulfur dioxide concentrations occur, and these areas would benefit from maintaining the existing interim targets.

The recommendation is a short-term (24-hour) sulfur dioxide AQG level of 40 μg/m³, defined as the 99th percentile (equivalent to three to four exceedance days per year) of the annual distribution of 24-hour average concentrations.

An interim target 1 of 125 μg/m³ and an interim target 2 of 50 μg/m³ are proposed, as shown in Table 3.22.

If mortality in a population exposed to sulfur dioxide for a day at the AQG level of 40 μg/m³ is arbitrarily set at 100, then it will be 105 and 101, respectively, in populations exposed to sulfur dioxide at the interim target 1 and 2 levels. These projections are based on the linear HR of 1.0059 per 10-μg/m³ increase in sulfur dioxide of all non-accidental mortality reported in the systematic review. At higher concentrations, the CRF may no longer be linear, which would change the numbers in this example.

Table 3.22. Recommended short-term (24-hour) AQG level and interim targets for sulfur dioxide[a]

Recommendation	SO_2 (µg/m³)
Interim target 1	125
Interim target 2	50
AQG level	**40**

[a] Defined as the 99th percentile (equivalent to 3–4 exceedance days per year) of the annual distribution of 24-hour average concentrations.

3.7 Carbon monoxide

3.7.1 General description

The general description comes from the *WHO guidelines for indoor air quality: selected pollutants*.

> Carbon monoxide (CO) is a colourless, non-irritant, odourless and tasteless toxic gas. It is produced by the incomplete combustion of carbonaceous fuels such as wood, petrol, coal, natural gas and kerosene. ...
>
> The molecular weight of carbon monoxide is similar to that of air (28.01 vs approximately 29). It mixes freely with air in any proportion and moves with air via bulk transport. It is combustible, may serve as a fuel source and can form explosive mixtures with air. It reacts vigorously with oxygen, acetylene, chlorine, fluorine and nitrous oxide. Carbon monoxide is not detectible by humans either by sight, taste or smell. It is only slightly soluble in water, blood serum and plasma; in the human body, it reacts with haemoglobin to form carboxyhaemoglobin (COHb) (WHO Regional Office for Europe, 2010).

Conversion factors: at 20 °C and 1013 hPa, 1 ppm = 1.165 mg/m³ and 1 mg/m³ = 0.858 ppm.

3.7.2 Recommended AQG level for 24-hour exposure to carbon monoxide

Based on the methods for deriving an AQG level outlined in the guideline development protocol, this section provides an AQG level for short-term, 24-hour mean carbon monoxide concentration based on its association with hospital admissions and mortality from myocardial infarction (Table 3.23).

The epidemiological evidence underpinning the AQG level is discussed in a systematic review commissioned by WHO, as explained in more detail in section 2.4. The review, conducted by Lee et al. (2020), was published in *Environment International* (Whaley et al., 2021) as open access.

As discussed in section 2.3, there has been no separate, independent assessment of the mechanistic, toxicological and human clinical studies relating carbon monoxide to human health.

This section follows the eight steps outlined in the protocol for AQG level development. Tables and figures mentioned during the eight steps are listed at the end of the discussion of each recommendation.

Step 1. Assess RR estimates and, when available, CRFs
The systematic review by Lee et al. (2020) on carbon monoxide and hospital admissions and mortality from myocardial infarction reported a meta-analytic effect estimate of RR = 1.052 (95% CI: 1.017–1.089) per 1 mg/m^3 carbon monoxide, assuming a linear relationship. The certainty of the evidence was considered moderate according to GRADE. More elaborate analyses of the CRF shape were not provided by any of the myocardial infarction studies included in the systematic review. However, the effects were seen mostly in studies with higher carbon monoxide levels, with the effect estimate being RR = 1.019 (95% CI: 1.011–1.027) in studies with a median carbon monoxide level exceeding 1.15 mg/m^3 compared with RR = 1.00 (95% CI: 0.998–1.003) in the rest of the studies.

Step 2. Determine the lowest level of exposure measured
As discussed in the protocol for deriving AQG levels, the lowest concentrations in time-series studies of effects of daily variations in air pollution concentrations are often very low. The minimum concentration reported by most of the studies included in the systematic review by Lee et al. (2020) was below 0.5 mg/m^3 and the mean carbon monoxide level ranged from 0.35 mg/m^3 to 4.56 mg/m^3; in half of the studies, the median carbon monoxide level was below 1.15 mg/m^3. The protocol suggests identifying as the daily AQG level the 99th percentile of a distribution of daily air pollution concentrations corresponding to an average long-term concentration equivalent to the annual AQG level. However, in the case of carbon monoxide, there is no annual AQG level that can be used as a point of departure, so this approach cannot be applied.

Step 3. Determine the minimal relevant increase in health outcomes
The GDG decided to consider as relevant any increase in risk for an adverse health outcome related to long-term exposure to a pollutant. For short-term exposures,

the assumption of a linear CRF and a risk coefficient from the systematic review by Lee et al. (2020) were used to calculate the increase in myocardial infarction hospital and emergency room admissions and mortality relative to a daily mean carbon monoxide concentration of 0 mg/m³. With an RR of 1.052 per 1 mg/m³, any 1 mg/m³-increase would produce a 5.2% increase in events. However, the Lee et al. (2020) review showed that the magnitude of the RR estimate was highly dependent on inclusion of three partly overlapping studies from East Asia conducted in low carbon monoxide, high nitrogen dioxide and high PM atmospheres (Hsieh et al., 2010; Cheng, Tsai & Yang, 2009; Tsai et al., 2012). Excluding these studies produced an RR of 1.016 (95% CI: 1.009–1.023). In addition, the review showed that there were only three effect estimates for myocardial infarction mortality, none of which suggested an effect from carbon monoxide. The additional exclusion of these estimates produced an RR for myocardial infarction admissions of 1.015 (95% CI: 1.007–1.024). As previously mentioned, the effects were mostly seen in studies with higher carbon monoxide levels, with an effect estimate of RR = 1.019 (95% CI: 1.011−1.027) in studies with a median carbon monoxide level exceeding 1.15 mg/m³ compared with RR = 1.00 (95% CI: 0.998−1.003) in the rest of the studies. For guideline development, the GDG considered the RR of 1.019 that was observed in studies with a median carbon monoxide of more than 1.15 mg/m³ to be more relevant because it excludes obvious outliers, is focused on one outcome (myocardial infarction admissions) rather than two (admissions plus mortality) and is restricted to the concentration range over which effects were actually demonstrated. Using this RR, the expected excess myocardial infarctions would be 5.4% on a 4-mg/m³ day compared with a day with a carbon monoxide concentration of 1.15 mg/m³. The excess would be 11.1% at the 2010 WHO indoor 24-hour guideline for carbon monoxide of 7 mg/m³ (WHO Regional Office for Europe, 2010).

Step 4. Determine the starting point for AQG level determination as the 99th percentile, as mentioned in step 3

A 99th percentile of 4 mg/m³ corresponds to an estimated annual mean of 1.33 mg/m³, based on a 3 : 1 ratio between the 99th percentile and annual mean observed in the large MCC Collaborative Research Network database (A. Gasparrini, London School of Hygiene and Tropical Medicine, unpublished data, 23 June 2020; Liu et al., 2019; Chen et al., 2021). Such a mean would roughly correspond to the median of 1.15 mg/m³, above which the studies included in Lee et al. (2020) showed an elevated risk of exposure. In the development of the short-term AQG levels for $PM_{2.5}$, PM_{10}, ozone and nitrogen dioxide, a calculation was always made of the differences in events between the mean and the 99th percentile. In the case of carbon monoxide, that difference would be 5.1%. The GDG recommends a short-term AQG level, defined as 99th percentile of daily mean concentrations in a year, of no more than 4 mg/m³, based on the association between short-term carbon monoxide and hospital admissions and emergency room visits for myocardial infarctions. Although the risk of myocardial infarction hospital admissions and emergency room visits is expected to be elevated by about 5% on such days, the overall health burden related to a few days with higher concentrations corresponds to a very small fraction of the total air pollution-related burden.

Step 5. Compare the AQG level across critical health outcomes
No other health outcomes were evaluated in the systematic review.

Step 6. Assess certainty of the evidence
As mentioned in step 1, the evidence base supporting an association between 24-hour average carbon monoxide and hospital admissions and emergency room visits due to myocardial infarction was considered to be of moderate certainty.

Step 7. Consider new evidence
No new studies were found on the relation between myocardial infarction admissions/deaths and carbon monoxide exposure.

Step 8. Reconsider causality
The association between short-term carbon monoxide concentrations and myocardial infarctions was judged to be likely causal in the 2016 outcome prioritization framework (see section 2.3.3), based on assessments by Health Canada and US EPA, both of which date back to 2010 and have not been revised since. Of note, US EPA did not develop a standard for 24-hour carbon monoxide at the time, despite evidence of associations persisting at levels below 1 mg/m³ or 2 mg/m³ (Bell et al., 2009).

3.7.2.1 Interim targets

Interim targets are proposed as incremental steps in a progressive reduction of air pollution and are intended for use in areas where pollution is high. For a more detailed rationale for establishing and using interim targets, see section 2.5.3.

The recommendation is a short-term (24-hour) carbon monoxide AQG level of 4 mg/m³, defined as the 99th percentile (equivalent to three to four exceedance days per year) of the annual distribution of 24-hour average concentrations.

An interim target 1 of 7 mg/m³ is proposed, as a point of reference to the existing 24-hour indoor WHO air quality guideline.

Table 3.23. Recommended short-term (24-hour) AQG level and interim targets for carbon monoxide[a]

Recommendation	CO (mg/m³)
Interim target 1	7
AQG level	4

[a] Defined as the 99th percentile (equivalent to 3–4 exceedance days per year) of the annual distribution of 24-hour average concentrations.

If the number of myocardial infarctions in a population exposed to carbon monoxide for a day at the AQG level of 4 mg/m³ is arbitrarily set at 100, the number will be 106 in populations exposed to carbon monoxide at the interim target 1 level. This projection is based on the linear HR of 1.019 per 1-mg/m³ increase in carbon monoxide for hospital admissions due to myocardial infarction. At higher concentrations, the CRF may no longer be linear, which would change the numbers in this example.

3.8 Summary of recommended air quality guideline levels and interim targets

Table 3.24 summarizes the recommended AQG levels and interim targets for all pollutants. The evidence underlying all of the recommended AQG levels was rated as of high or moderate certainty and all recommendations are classified as strong according to the adapted GRADE approach (discussed in Chapter 2).

Table 3.25 shows the air quality guidelines for nitrogen dioxide, sulfur dioxide and carbon monoxide for short averaging times that were not re-evaluated and, therefore, remain valid.

Table 3.24. Summary of recommended long- and short-term AQG levels and interim targets

Pollutant	Averaging time	Interim target 1	Interim target 2	Interim target 3	Interim target 4	AQG level
$PM_{2.5}$, µg/m³	Annual	35	25	15	10	5
	24-hour[a]	75	50	37.5	25	15
PM_{10}, µg/m³	Annual	70	50	30	20	15
	24-hour[a]	150	100	75	50	45
O_3, µg/m³	Peak season[b]	100	70	–	–	60
	8-hour[a]	160	120	–	–	100
NO_2, µg/m³	Annual	40	30	20	–	10
	24-hour[a]	120	50	–	–	25
SO_2, µg/m³	24-hour[a]	125	50	–	–	40
CO, mg/m³	24-hour[a]	7	–	–	–	4

[a] 99th percentile (i.e. 3–4 exceedance days per year).
[b] Average of daily maximum 8-hour mean O_3 concentration in the six consecutive months with the highest six-month running-average O_3 concentration.

Table 3.25. Air quality guidelines for nitrogen dioxide, sulfur dioxide and carbon monoxide (for short averaging times) that remain valid

Pollutant	Averaging time	Air quality guideline that remain valid
NO_2, µg/m³	1-hour	200
SO_2, µg/m³	10-minute	500
CO, mg/m³	8-hour	10
	1-hour	35
	15-minute	100

Table 3.26 shows a side-by-side comparison of the 2005 air quality guidelines and the 2021 AQG levels.

Table 3.26. Recommended 2021 AQG levels and 2005 air quality guidelines

Pollutant	Averaging time	2005 air quality guideline	2021 AQG level
$PM_{2.5}$, µg/m³	Annual	10	5
	24-hour[a]	25	15
PM_{10}, µg/m³	Annual	20	15
	24-hour[a]	50	45
O_3, µg/m³	Peak season[b]	–	60
	8-hour[a]	100	100
NO_2, µg/m³	Annual	40	10
	24-hour[a]	–	25
SO_2, µg/m³	24-hour[a]	20	40
CO, mg/m³	24-hour[a]	–	4

[a] 99th percentile (i.e. 3–4 exceedance days per year).
[b] Average of daily maximum 8-hour mean O_3 concentration in the six consecutive months with the highest six-month running-average O_3 concentration.

3.8.1 Important AQG level updates to *Global update 2005*

The most important updates in these guidelines are listed below.

1. The $PM_{2.5}$ annual AQG level has been lowered from 10 µg/m³ to 5 µg/m³. This reflects the new evidence of effects on mortality occurring at concentrations below 10 µg/m³. In this update of the air quality guidelines, an analysis was introduced to identify the most appropriate level of the long-term air quality guidelines that is more formalized than what was used in 2005. However, the change from 10 µg/m³ to 5 µg/m³ primarily reflects the new evidence about effects occurring at low levels of exposure.

2. The 24-hour AQG level for $PM_{2.5}$ changed from 25 µg/m³ to 15 µg/m³. In 2005 a ratio of 2.5 was assumed between the 99th percentile of 24-hour average concentrations and annual averages. This ratio was changed to 3 based on empirical data from the very large MCC Collaborative Research Network (A. Gasparrini, London School of Hygiene and Tropical Medicine, unpublished data, 23 June 2020; Liu et al., 2019).

3. The PM_{10} annual AQG level has been reduced from 20 µg/m³ to 15 µg/m³. This reflects the new evidence of effects on mortality occurring at concentrations below 20 µg/m³. In this update of the air quality guidelines, an analysis was introduced to identify the most appropriate level of the long-term air quality guidelines that is more formalized than what was used in 2005. However, the change from 20 µg/m³ to 15 µg/m³ primarily reflects the new evidence about effects occurring at low levels. It is important to note that the assessment of PM_{10} was based on studies that had actually measured PM_{10}, without taking into consideration the ratios between PM_{10} and $PM_{2.5}$. In 2005 based on empirical data, a PM_{10} : $PM_{2.5}$ ratio of 2 was used to establish the PM_{10} AQG levels. The GDG notes that the empirical PM_{10} : $PM_{2.5}$ ratios have not changed, but the method used to derive the AQG levels has changed. The resulting PM_{10} annual AQG level is less protective than the $PM_{2.5}$ annual AQG level in most practical circumstances.

4. The 24-hour AQG for PM_{10} changed from 50 µg/m³ to 45 µg/m³. In 2005 a ratio of 2.5 was assumed between the 99th percentile of 24-hour average concentrations and annual averages. This ratio was changed to 3 based on empirical data from the very large MCC Collaborative Research Network (A. Gasparrini, London School of Hygiene and Tropical Medicine, unpublished data, 23 June 2020; Liu et al., 2019). As a result of the combined effects of the new derivation procedure and the changed ratio, the 24-hour AQG level for PM_{10} is not much lower in 2021 than in 2005. The resulting PM_{10} 24-hour AQG level is less protective than the $PM_{2.5}$ 24-hour AQG level in most practical circumstances.

5. A new long-term peak-season average ozone AQG level has been established. This is based on new evidence on the long-term effects of ozone on total mortality and respiratory mortality. The short-term AQG level was re-calculated using the protocols outlined in section 2.5. The resulting short-term AQG level of 100 µg/m³ is the same as the 2005 short-term air quality guideline, which was based on morbidity and lung function effects. Therefore, in practical terms, the guidance for ozone has not changed.

6. The annual AQG level for nitrogen dioxide changed from 40 µg/m³ to 10 µg/m³. This was primarily because this update of the air quality guidelines is based on the effects of long-term nitrogen dioxide on all-cause mortality and respiratory mortality. The 2005 air quality guideline was based on morbidity effects observed in children exposed indoors to nitrogen dioxide from gas cooking. The chosen level was originally proposed in a document prepared by the International Labour Organization, UNEP and WHO (International Programme on Chemical Safety, 1997). It was justified as follows:

> On the basis of a background level of 15 μg/m³ (0.008 ppm) and the fact that significant adverse health effects occur with an additional level of 28.2 μg/m³ (0.015 ppm) or more, an annual guideline value of 40 μg/m³ (0.023 ppm) is proposed. This value will avoid the most severe exposures (International Programme on Chemical Safety, 1997).

As is evident from this quotation, the annual AQG of 40 μg/m³ was in fact expected to be associated with "significant adverse health effects". A background of 15 μg/m³ is not all that different from the AQG level of 10 μg/m³ that is recommended in this report.

7. Following the protocol established in section 2.5, a new 24-hour AQG level of 25 μg/m³ for nitrogen dioxide was recommended. The 2005 1-hour AQG level of 200 μg/m³ was not re-evaluated. The GDG points out that in most practical circumstances, the 24-hour AQG level in this update is more stringent than the 2005 1-hour AQG level.

8. Following the protocol established in section 2.5, a 24-hour AQG level for sulfur dioxide of 40 μg/m³ was recommended. This is based on a new evaluation of the effects of short-term sulfur dioxide concentrations on all-cause mortality and respiratory mortality. This AQG level is higher than the 2005 24-hour air quality guideline of 20 μg/m³. The 2005 air quality guideline was also primarily based on an evaluation of the short-term effects of sulfur dioxide on mortality. No formal method was applied to derive a guideline value in 2005. The considerations at the time were:

> In consideration of (a) the uncertainty of sulfur dioxide in causality, (b) the practical difficulty of reaching levels that are certain to be associated with no effects and (c) the need to provide greater degrees of protection than those provided by the guidelines published in 2000, and assuming that reduction in exposure to a causal and correlated substance is achieved by reducing sulfur dioxide concentrations, there is a basis for revising the 24-hour guideline for sulfur dioxide downwards, adopting a prudent precautionary approach (WHO Regional Office for Europe, 2006).

The GDG argues that in comparison the recommended 24-hour AQG level of 40 μg/m³ is better justified, and coherent with the approaches followed in the recommendations for short-term AQG levels for the other pollutants covered in this report.

9. Following the protocol established in section 2.5, a 24-hour AQG level for carbon monoxide of 4 mg/m³ was recommended. This is based on a new evaluation of the effects of short-term carbon monoxide concentrations on hospital admissions for myocardial infarction.

3.9 Supporting burden of disease calculations

To support discussions on the updating of AQG levels, WHO performed a rapid scenario analysis to explore the reductions in disease burden attributable to annual ambient $PM_{2.5}$ globally (WHO, 2018) that would occur if the 2016 levels were reduced to the current interim target 1 (35 μg/m³), interim target 2 (25 μg/m³), interim target 3 (15 μg/m³), interim target 4 (10 μg/m³) and AQG levels.

The methods and results are described in more detail in Evangelopoulos et al. (2020). The methodology of this calculation was the same as in the GBD 2016 study, which used a set of non-linear, cause-specific exposure–response functions. These are not directly comparable to the linear CRFs reported in the systematic reviews produced for the purpose of AQG level derivation in this document. In addition, Evangelopoulos et al. (2020) did not perform a scenario analysis for the current AQG level, which was decided after their publication. However, the analysis was conducted for this document. For further methodological details, see GBD 2016 Risk Factors Collaborators (2017).

Table 3.27 illustrates the total estimated number of deaths attributable to ambient $PM_{2.5}$ in 2016 by WHO region and worldwide. In all these scenarios, the indicated levels are assumed to reflect the population-weighted mean exposure. The population-weighted mean is the average concentration in a sub-area (region or country) weighted by the distribution of the population within that sub-area, relative to its total population. This accounts for spatial relationships between locations of populations and concentrations, in contrast to area-weighting, which is simply the average concentration within a sub-area, irrespective of where the population may reside.

As an illustration, results show that if interim target 4 (equivalent to the 2005 air quality guideline) had been achieved in 2016, then in terms of population-weighted average, the estimated burden of disease would have been reduced substantially: achievement of interim target 4 would have resulted in a 47.8% decrease in total deaths attributed to $PM_{2.5}$ exposure compared with the number calculated using the 2016 levels of exposure worldwide. The highest impact would have been observed in the WHO South-East Asia and African regions (reductions of 57% and 60%, respectively).

Meeting the interim targets would also have had a notable benefit on health, especially in those regions where exposures far exceed interim targets. Even if interim target 1 had been met, reductions of 20% and 14%, respectively, in burden of disease attributable to ambient $PM_{2.5}$ would have been observed in the South-East Asia and Eastern Mediterranean regions.

Table 3.27. Region-specific and global deaths attributable to ambient $PM_{2.5}$ under 2016 air pollution levels and percentage reduction through achievement of the recommended interim targets or AQG level[a]

WHO region	Global/regional deaths & % reduction through achievement of interim target or AQG level[a]					
	Air pollution level, 2016	**Interim target 1**	**Interim target 2**	**Interim target 3**	**Interim target 4**	**AQG level**
African Region						
n (UI), in 000s	474 (411–547)	403 (329–481)	349 (270–429)	255 (182–351)	188 (126–284)	60 (30–142)
% reduction (UI)	–	14.5 (9.5–21.9)	26.2 (17.4–37.0)	45.9 (32.0–59.1)	60.4 (44.0–72.0)	87.3 (71.6–93.6)
Region of the Americas						
n (UI), in 000s	249 (204–306)	249 (204–306)	247 (202–304)	230 (185–286)	203 (159–258)	89 (49–144)
% reduction (UI)	–	0.0 (0.0–0.0)	0.6 (0.4–0.9)	7.4 (5.6–9.5)	18.2 (14.4–22.5)	64.1 (50.6–79.4)
South-East Asian Region						
n (UI), in 000s	1 351 (1 193–1 515)	1 078 (940–1 244)	948 (804–1 110)	742 (610–906)	580 (460–732)	223 (128–353)
% reduction (UI)	–	19.7 (16.3–25.1)	29.5 (24.7–36.55)	44.6 (38.0–52.8)	56.8 (49.3–64.5)	83.3 (74.8–90.3)
European Region						
n (UI), in 000s	464 (383–552)	463 (382–551)	457 (376–545)	436 (356–523)	385 (308–471)	157 (85–253)
% reduction (UI)	–	0.2 (0.1–0.2)	1.5 (1.2–1.9)	6.2 (5.1–7.7)	17.1 (14.2–20.4)	65.9 (52.0–81.5)

Table 3.27 contd

WHO region	Global/regional deaths & % reduction through achievement of interim target or AQG level[a]					
		Interim target 1	Interim target 2	Interim target 3	Interim target 4	AQG level
Eastern Mediterranean Region						
n (UI), in 000s	336 (301–369)	289 (255–322)	253 (220–287)	199 (169–236)	158 (130–194)	64 (37–96)
% reduction (UI)	–	13.8 (11.5–16.9)	24.3 (20.4–28.9)	40.4 (34.4–46.4)	52.6 (45.7–58.9)	80.7 (72.2–88.4)
Western Pacific Region						
n (UI), in 000s	1 278 (1 119–1 449)	1 160 (1 009–1 324)	1 024 (876–1 191)	818 (673–978)	643 (512–796)	248 (138–386)
% reduction (UI)	–	9.2 (7.9–11.2)	19.8 (17.2–23.9)	36.1 (31.7–42.5)	49.7 (44.2–56.5)	80.6 (71.8–88.8)
Global						
n (UI), in 000s	4 155 (3 685–4 662)[b]	3 646 (3 179–4 188)	3 276 (2 818–3 840)	2 677 (2 237–3 222)	2 155 (1 736–2 674)	848 (484–1 310)
% reduction (UI)	–	12.0 (9.7–15.5)	20.8 (17.0–26.1)	35.2 (29.4–42.3)	47.8 (40.8–55.2)	79.5 (70.1–87.9)

UI: uncertainty interval.
[a] Based on 2016 figures and assuming all other relevant health factors remain unchanged.
[b] These values are slightly different than the ones reported in the WHO Burden of Disease 2016 report (WHO, 2018) due to rounding.
Note: for the definition of uncertainty interval, see WHO (2018).

The scenario analysis showed that if the interim targets were achieved, the greatest benefit in terms of reduced health impact would be observed in countries with high $PM_{2.5}$ concentrations and large populations. If population-weighted concentrations were to comply with the AQG level, then premature mortality could be reduced by as much as 45–50 deaths per 100 000 people.

On the other hand, much smaller changes in premature mortality would occur in high-income countries because in most cases the ambient $PM_{2.5}$ concentrations are already below the interim targets.

The derived reductions in the health burden relate to national or WHO regional level, population-weighted mean concentrations. However, policy-makers may require compliance with the AQG level not just at the level of the population average but in all areas where people live. Therefore, Table 3.27 underestimates the health benefits of full compliance with the AQG level for all locations.

Estimates of the ultimate population-weighted mean concentrations once interim targets or AQG levels have been achieved everywhere are not yet available; thus, the related benefits have not been described here. However, an impact assessment study provided estimates for a scenario in which the new $PM_{2.5}$ interim target 4 (10 μg/m³) had been achieved throughout Switzerland, including at hot spots (Castro et al., 2020). Under this scenario, the population-weighted mean concentration of $PM_{2.5}$ is expected to be only 83% of the interim target 4 value.

4

Good practice statements about other PM types

4.1 Introduction

The GDG decided not to formulate air quality guideline (AQG) levels for the specific types of PM (i.e. BC/EC, SDS and UFP) that were prioritized during the preliminary phase. This decision was made because the GDG considered that the quantitative evidence on independent adverse health effects from these pollutants was still insufficient at the time of deriving the AQG levels. The GDG decided that the best manner for addressing these pollutants in the guideline document was to formulate good practice statements (discussed in section 2.5.3), as outlined in the *WHO handbook for guideline development*, *2nd edition* (WHO, 2014a). That is, when a GDG is confident that a large body of diverse evidence that is hard to synthesize indicates that the desirable effects of a particular course of action far outweigh its undesirable effects (WHO, 2014c).

Section 4.4 (on SDS) is substantially more detailed than sections 4.2 (on BC/EC) and 4.3 (on UFP), and includes several statements on the mitigation measures for population exposure to pollution from SDS. This is intentional, since the mitigation of exposure to pollution from SDS requires different, less standard, approaches than those related to anthropogenic pollution (black carbon and UFP), that focus on source emission reduction.

4.2 Black carbon/elemental carbon

There is concern over the potential impacts on health of black carbon, and a review of the literature by WHO (WHO Regional Office for Europe, 2013a) concluded that evidence links black carbon particles with cardiovascular health effects and premature mortality, for both short- (24-hour) and long-term (annual) exposures. In studies that take black carbon and $PM_{2.5}$ into account simultaneously, associations remained robust for black carbon (WHO Regional Office for Europe, 2013a). Even when black carbon may not be the causal agent, black carbon particles are a valuable additional air quality metric for evaluating the health risks of primary combustion particles from traffic, including organic particles, that are not fully taken into account with $PM_{2.5}$ mass levels. An assessment by US EPA also summarized the evidence of associations between a series of health effects and black carbon concentrations, with conclusions similar to those of the earlier WHO review (US EPA, 2019a).

Black carbon is a measure of airborne soot-like carbon that is determined with optical methods. It is closely related to the mass concentration of elemental carbon (i.e. carbon in various crystalline forms) that is ascertained chemically. BC/EC is typically formed through the incomplete combustion of fossil fuels, biofuel and biomass, and is emitted from both anthropogenic and natural sources.

It consists of pure carbon in several forms, and the relevant particle size fraction can include known carcinogens and other toxic species. Black carbon is a powerful climate-warming agent that acts by absorbing heat in the atmosphere and by reducing albedo (the ability to reflect sunlight) when deposited on snow and ice (Bond et al., 2013).

To address concerns about the health and environmental effects of BC/EC, three good practice statements (Box 4.1) have been formulated. The following sections provide a rationale for each of the statements.

Box 4.1. Good practice statement – BC/EC

Based on insufficient evidence to propose an AQG level, the GDG decided to formulate the following three good practice statements on BC/EC directed to countries and regional authorities.

1. Make systematic measurements of black carbon and/or elemental carbon. Such measurements should not replace or reduce the existing monitoring of pollutants for which guidelines currently exist.
2. Undertake the production of emission inventories, exposure assessments and source apportionment for BC/EC.
3. Take measures to reduce BC/EC emissions from within the relevant jurisdiction and, where considered appropriate, develop standards (or targets) for ambient BC/EC concentrations.

4.2.1 Rationale for statement 1 – measurement of black carbon and/or elemental carbon

Black carbon is a measure of airborne soot-like carbon that is defined operationally by the method used for its measurement, that is, the optical absorption of specific wavelengths by particles collected on a filter. The extent of optical absorption is then converted to black carbon concentrations expressed in units of μg/m³ via a calibration based on a mass measurement of elemental carbon. Continuous measurements of black carbon are often made with aethalometers, which use an optical approach and a standard conversion to mass concentration. Black carbon is a metric similar to elemental carbon, with the latter being a chemical measurement; both are measures of soot-like (graphitic) carbon. Elemental carbon is also defined operationally; it is usually determined by thermo-optical (chemical) techniques, in which the carbonaceous material is driven off the filter at high temperatures in an oxygen-rich environment. There is a close relationship between black carbon and elemental carbon mass measurements, which (to a very good approximation) is linear, but the slope may vary by the specific PM mixture and should be verified locally to reflect local conditions.

There are several measurement methods for black carbon. Hansen (2005) provides a detailed description of a common measurement method. EU Directive 2008/50/EC (European Parliament & Council of the European Union, 2008) requires measurements of elemental carbon, but filter measurements of black carbon or related optical parameters such as absorbance are much simpler and cheaper to make than elemental carbon measurements and, therefore, are much more applicable globally. For example, Jeronimo et al. (2020) describe a low-cost method of measurement(). It should be noted further that black carbon and its optical properties are more relevant to the climate than elemental carbon.

Elemental carbon is required to be measured by EU Directive 2008/50/EC, and the European Committee for Standardization (CEN) has developed a measurement method (CEN, 2017; Brown et al., 2017). As yet, no similar standard exists for black carbon but descriptions of methods of reporting have been given in the EU-funded Aerosol, Clouds and Trace Gases Research Infrastructure (ACTRIS, 2020) and described by the World Meteorological Organization (WMO) (Petzold et al., 2013). Although recommending a standard method for BC/EC monitoring is outside of the scope of WHO air quality guidelines, defining a standard and easy-to-apply method by relevant organizations would facilitate the recommended monitoring.

4.2.2 Rationale for statement 2 – production of emission inventories, exposure assessments and source apportionment for BC/EC

BC/EC emissions arise from incomplete or inefficient combustion and, hence, tend to come from local sources in urban areas and from specific combustion sources such as solid fuel or fuel-oil-fired power plants. Sources include passenger cars, buses, and trucks and other heavy goods vehicles, particularly diesel engines (both on-road and off-road); residential solid fuel use such as wood and coal, as well as liquid fuel such as kerosene; and power plants using heavy fuel oil and coal. Shipping, agricultural waste burning and wildfires are also sources of black BC/EC.

Emission factors for BC/EC are often uncertain, but guidance is available via several guidebooks (EEA, 2019; US EPA, 2019b).

The nature of these local sources means that, in general, exposures to BC/EC are more spatially variable than the total $PM_{2.5}$, so exposure assessments could be more challenging but more informative about the true spatial contrasts in exposures. Assessments could be based on models with fine spatial resolution as well as on measurements. Modelling approaches might involve small-scale urban dispersion models based on Gaussian plume methods, boundary-layer scaling plume models, urban and large-scale 3D chemical transport models, and land-use regression models. Use of well-formulated emission inventories coupled with dispersion air quality models will yield the source apportionment necessary to formulate abatement policies to reduce air pollutants.

4.2.3 Rationale for statement 3 – implementation of measures to reduce BC/EC, including the development of standards where appropriate

Epidemiological studies have already been carried out using black carbon and elemental carbon as exposure metrics (Janssen et al., 2012; US EPA, 2019a). Most studies have been in Europe and North America, and further work in other areas of the world – as well as in Europe and North America – would be valuable, particularly since there now exists recommendations for reporting black carbon measurements, as described above.

There has been considerable discussion in the past over the differential toxicity of the various components of $PM_{2.5}$, but with no clear consensus so far. However, the earlier review of the literature in the WHO REVIHAAP project did state that PM components deriving from combustion were particularly toxic (WHO Regional Office for Europe, 2013a). In addition, much of the consideration of this issue has focused on the question of whether or not there is a better metric than total $PM_{2.5}$ mass to account for the associations demonstrated in the epidemiological studies. It seems unlikely that a clear answer to this question will be forthcoming in the near future and, indeed, in terms of actions to improve public health this may not be the right question to ask.

A more appropriate question to ask may be whether there is an additional metric or component that countries might target for emission reductions next to the total $PM_{2.5}$ mass. For many countries or regions – where the incomplete or inefficient combustion of carbon-containing material is common and where a substantial part of population exposure to PM is due to BC/EC – actions to reduce BC/EC would seem to be an appropriate complementary strategy and a good practice to strengthen clean air policies. BC/EC particles contain known toxic constituents such as carcinogens and are co-emitted with other toxic pollutants that are also products of incomplete combustion, that is, carbon monoxide, polycyclic aromatic hydrocarbons and VOCs. Using total $PM_{2.5}$ as a control metric could mean that targets could be met with no specific pressure to reduce the primary combustion particles and known toxic constituents of BC/EC. Moreover, control of BC/EC requires paying stronger attention to spatial hot spots of primary PM pollution, which are less well captured or identified with $PM_{2.5}$ mass concentrations; thus, compliance with $PM_{2.5}$ standards may not necessarily guarantee low enough levels of elemental carbon for compliance.

In addition, given the carcinogenicity of elemental carbon, the strategy to keep its concentrations as low as possible is in line with the prevailing risk reduction strategy generally pursued for carcinogens. On the other hand, the control of total $PM_{2.5}$ mass in many areas is not totally under the control of a single country or jurisdiction – in many areas long-range transport of secondary PM is a significant contributor of $PM_{2.5}$ mass. Including BC/EC as an indicator of local emission reductions might compensate for the limited ability to influence total $PM_{2.5}$ concentration. Finally, there are sound climatic reasons for reducing black carbon concentrations: along with methane and ozone, black carbon is one of the most important short-lived climate pollutants, the reduction of which could produce rapid improvements in actions to stop climate warming (Bice et al., 2009; Bond et al., 2013; Miller & Jin, 2019).

To illustrate typical ambient levels of black carbon, the results from the United Kingdom Black Carbon Network can be used (Butterfield et al., 2016). Annual mean concentrations of black carbon measured in 2015 were 0.2–0.4 μg/m³ in rural sites, 1.0–2.0 μg/m³ in urban background stations and 1.4–5.1 μg/m³ in roadside locations. Black carbon made up a significant proportion of PM mass concentration at roadside sites, contributing to 12–21% of PM_{10} and 18–32% of $PM_{2.5}$. In an urban background location, these proportions were 5% and 9%, respectively, and in rural background locations were 2–3% of each of the PM fractions.

Black carbon mean concentrations observed in epidemiological studies ranged from 0.65 μg/m³ to 3.9 μg/m³, while for elemental carbon the means generally ranged from 0.47 μg/m³ to 3.5 μg/m³ and reached 7.5–8.8 μg/m³ in individual studies from Asia (Khreis et al., 2017; Luben et al., 2017).

Illustrative annual mean concentrations where statistically significant associations with health outcomes have been found were 1.08–1.15 μg/m³ for black carbon and 0.5–0.8 μg/m³ for elemental carbon (Luben et al., 2017).

Although the evidence base is insufficient to set a certain AQG level to provide a basis for legally binding limit values, adoption of an air quality standard or target (e.g. in the form of a concentration reduction obligation) might be a good instrument to force local actions on BC/EC reduction.

Strategies to control BC/EC emissions should consider local conditions. They may address emissions from biomass and other polluting fuels used for cooking and heating, emissions from diesel vehicles and off-road machinery (World Bank, 2014), and emissions from agricultural (and communal) waste burning and from wildfires.

4.3 Ultrafine particles

UFP are generally considered as particulates with a diameter less than or equal to 0.1 µm, that is, 100 nm (typically based on physical size, thermal diffusivity or electrical mobility). There was already considerable evidence on the toxicological effects of UFP at the time that *Global update 2005* was being prepared, which was acknowledged in the document (WHO Regional Office for Europe, 2006). However, it was stated that the evidence from epidemiology was insufficient to recommend guidelines for UFP. Since then, the body of epidemiological evidence has grown, and two systematic reviews have assessed scientific research papers published from 1997 to 2017 (HEI, 2013; Ohlwein et al., 2019), documenting the rising number of studies being conducted. The studies demonstrated short-term effects of exposure to UFP, including mortality, emergency department visits, hospital admissions, respiratory symptoms, and effects on pulmonary/systemic inflammation, heart rate variability and blood pressure; and long-term effects on mortality (all-cause, cardiovascular, IHD and pulmonary) and several types of morbidity. However, various UFP size ranges and exposure metrics were used, preventing a thorough comparison of results across studies (US EPA, 2019a). Therefore, there was a consensus in the GDG that the body of epidemiological evidence was not yet sufficient to formulate an AQG level.

At the same time, however, there is a large body of evidence from exposure science that is sufficient to formulate good practice advice. The most significant process generating UFP is combustion and, therefore, the main sources of the UFP include vehicles and other forms of transportation (aviation and shipping), industrial and power plants, and residential heating. All of these utilize fossil and biofuels, as well as biomass. Since everyone is exposed to the emissions from these sources, exposure to UFP is of concern.

To address concerns about the health and environmental effects of UFP, four good practice statements (Box 4.2) have been formulated. The following sections provide a rationale for each of the statements.

Box 4.2. Good practice statement – UFP

The GDG decided to formulate the following four good practice statements on UFP to guide national and regional authorities and research towards measures to reduce ambient ultrafine particle concentrations.

1. Quantify ambient UFP in terms of particle number concentration (PNC) for a size range with a lower limit of ≤ 10 nm and no restriction on the upper limit.
2. Expand the common air quality monitoring strategy by integration of UFP monitoring into existing air quality monitoring. Include size-segregated real-time PNC measurements at selected air monitoring stations in addition to, and simultaneously with, other airborne pollutants and characteristics of PM.
3. Distinguish between low and high PNC to guide decisions on the priorities of UFP source emission control. Low PNC can be considered < 1000 particles/cm3 (24-hour mean). High PNC can be considered > 10 000 particles/cm3 (24-hour mean) or 20 000 particles/cm3 (1-hour).
4. Utilize emerging science and technology to advance approaches to the assessment of exposure to UFP for application in epidemiological studies and UFP management.

4.3.1 Rationale for statement 1 – quantification of ambient UFP

PNC is the most common measure used to characterize UFP, and the measurement technologies for this are well established; however, there is no agreed international (or national) standard method on this as yet. The existing instrumental methods for PNC measurement do not provide information on particles in the UFP-specific size range (< 100 nm), and both their lower and upper detection limits vary; the lower limit typically ranges from 2 nm to 20 nm. Therefore, the term quasi-ultrafine refers to particles substantially smaller than 1 µm but larger than 100 nm. In this document, PNC refers to the number concentration of quasi-UFP. The choice of the lower cut-off of measurement is usually critical, since the majority of UFP are often within a smaller size range, particularly in environments affected by fresh combustion emissions; the upper range is less critical. The error (underestimation) for lower size limits up to 10 nm can be calculated and corrected for. The uncertainty in the calibration of instruments measuring PNC is based on a standardized methodology (ISO 27891:2015 (ISO, 2015)) and varies between 30% for lower concentrations (< 1000 particles/cm³) to 10% for typical urban background concentrations (about 10 000 particles/cm³) (Morawska et al., 2008; Thinking Outside the Box team, 2019).

4.3.2 Rationale for statement 2 – expanding UFP monitoring

Whereas the theories underpinning UFP emission and formation processes are generally well developed, local understanding of the origin of UFP (primary/secondary, specific sources) and their chemical composition (solid/liquid, organic carbon/elemental carbon, metals and toxicity) is generally very limited in most parts of the world; UFP and precursor emission inventories and PNC source apportionments hardly exist. Generally, there is very little or no relationship between PNC and mass concentration of larger particles ($PM_{2.5}$), and the existence and degree of relationship between PNC and traffic-emitted gaseous pollutants (carbon monoxide and NO_x) or black carbon varies, depending on location. Therefore, no other pollutant is a good proxy for UFP. However, quantitative knowledge of UFP is needed, since focusing only on $PM_{2.5}$ may result in overlooking the impact of UFP and there is no evidence that mitigating particle mass only (PM_{10}, $PM_{2.5}$), as the existing air quality measures do, will necessarily lead to a reduction in UFP (ANSES, 2019; Thinking Outside the Box team, 2019).

UFP monitoring would provide a good base for evaluation of effects of pollution mitigation and could be used for future epidemiological studies on the health effects of UFP and for distinguishing these effects from the effects of other pollutants. Note that the UFP measurements should not hinder the existing measurements of pollutants for which guidelines currently exist.

4.3.3. Rationale for statement 3 – distinction between low and high PNC

In urban areas, road traffic and other forms of transportation (aviation and shipping) are usually the main sources of UFP. These particles are emitted directly by the sources or formed in the air from gaseous precursors that are usually also emitted by the same sources. In addition, emissions from industrial sources, power plants, residential heating and biomass burning are sources of UFP, contributing to various extents to the UFP concentrations in urban air. Due to the nature of source emissions and particle formation, the spatiotemporal variation of the absolute level of PNC across a single city area is substantially larger than the spatiotemporal variation of larger particles (measured as particle mass concentration), for example $PM_{2.5}$. Based on literature review and expert opinion, there is general agreement that concentrations below 1000 particles/cm³ (24-hour mean), typically observed in environments not affected by anthropogenic emissions, can be considered as low (de Jesus et al., 2019; Thinking Outside the Box team, 2019). It is proposed that 24-hour mean concentrations exceeding the typical levels observed in urban background areas (10 000 particles/cm³) or 1-hour mean concentrations exceeding levels found usually in all urban microenvironments (20 000 particles/cm³) can be considered high.

4.3.4 Rationale for statement 4 – utilization of emerging science and technology to advance population exposure assessment

Estimation of the population exposure to UFP in short- and long-term epidemiological studies (including repeated peak exposures) is significantly more complex than assessment of the exposure to $PM_{2.5}$ and PM_{10}. It would be highly beneficial to develop and utilize standardized measurement procedures that enable meaningful comparison between the results from different studies, which is of particular significance for human exposure and epidemiological studies. Considering the complexity of the measurements, variety of instruments available and difference in the aims of the measurement/monitoring, it is not likely that standard methods to measure UFP will be accepted/established in the foreseeable future. However, scientific progress on many fronts makes personal exposure assessment possible by providing estimates of variation among the different results based on differences in the instruments being used or their settings. Furthermore, there are modelling tools that can allow obtaining the source contributions to UFP concentrations and can increase the robustness of meta-analysis of multicity data for epidemiological studies. Therefore, future long-term studies might consider modelling, increasing the number of monitors or utilizing mobile platforms to collect data across larger urban areas in order to cover the spatial variability in cities (ANSES, 2019; Thinking Outside the Box team, 2019).

4.4 Sand and dust storms

At their first meeting in 2016, the GDG members agreed that SDS needed to be addressed in this update of the WHO air quality guidelines. Dealing with SDS has become a growing priority within the global community, as reflected by the adoption of several resolutions by the UN General Assembly (UN, 2016, 2017, 2018b, 2019b). Improving the implementation of sustainable land management practices, taking measures to prevent and control the main factors of SDS, and improving the development of early warning systems as tools to combat SDS feature among the key priorities for action (UNEP, 2016b).

The discussion and arguments reported here have to take into account the fact that there are countries that are located in desert regions and countries that do not include desert land but are affected by desert dust. SDS events that originated in specific regions can impact various countries owing to the proven long-range transport of dust over countries and, even, continents (Tanaka & Chiba, 2006; UNEP, WMO & UNCCD, 2016; Middleton, 2017). Indeed, a relevant issue to take into consideration is the difference between geographical regions such as the Middle East, the Sahel and northeast Asia, which have considerable SDS events, and others such as eastern Asia, southern Europe, parts of North America, and western Africa, that have experienced various episodes of transported desert dust. Desert dust is usually composed of mineral particles that originate from arid and semi-arid land surfaces, but "sometimes, after having travelled great distances, they may be observed over areas where no dust or sand covers the ground" (WMO, 2020b). SDS are usually prompted by intense winds that elevate large amounts of sand and dust from bare, dry soils into the air (WMO, 2020a). It has to be considered that there is no precise distinction between sand storms and dust storms, since there is a continuum of particle sizes in any storm. Importantly, desert dust events have coincided with substantial increases in measured concentrations of both the PM_{10} and $PM_{2.5}$ size fractions. Furthermore, research from southern Europe suggests an increased accumulation of anthropogenic pollutant concentration during events of transported dust, likely owing to a number of related meteorological phenomena (Querol et al., 2019a).

The WHO-commissioned toxicological review of 67 experimental studies concluded that SDS may be a significant risk factor for inflammatory and allergic lung diseases such as child and adult asthma. Studies, mainly using doses that reflect or at least approach real-world exposures during a dust event, have demonstrated that sand dust particles collected from surface soils (i.e. at the source) and dust-storm particles sampled at remote locations away from the source (and as such, mixed with industrial pollutants and microorganisms) induce inflammatory lung injury and aggravate allergen-induced tissue eosinophilia. No studies were identified that included specific cardiovascular end-points. In vitro findings suggest desert dust surface reactions may enhance the toxicity of aerosols in urban environments (Fussell & Kelly, 2021).

The WHO-commissioned systematic review of adverse health effects from SDS summarized the evidence from 93 studies conducted worldwide. The studies indicate an overall effect of desert dust on cardiovascular mortality and respiratory morbidity, but the evidence is still inconsistent when accounting for sources of PM in different geographical areas (Tobias et al., 2019a, 2019b). In addition, previously published reviews, systematic or not, reported inconsistent results across studies and geographical regions (de Longueville et al., 2013; Hashizume et al., 2010; Karanasiou et al., 2012; Zhang et al., 2016). An existing limitation in the scientific literature is the lack of studies on the long-term health effects of SDS. The health outcomes studied more frequently include (i) daily mortality, natural-cause and cause-specific; (ii) cardiovascular and respiratory morbidity; and (iii) morbidity as documented in hospital admissions and emergency room visits, mainly for cardiovascular and respiratory diseases, including asthma and COPD. Overall, the four reviews (de Longueville et al., 2013; Hashizume et al., 2010; Karanasiou et al., 2012; Zhang et al., 2016) had similar conclusions, suggesting that potential health effects linked to SDS may include increased cardiovascular mortality and respiratory hospital admissions. A range of other health impacts, such as injuries and death from transport accidents due to reduced visibility or the potential implications for disease incidence of meningitis and coccidioidomycosis, have also been reported (Ashley et al., 2015; Baddock et al., 2013; Goudie, 2014). The published studies differed in terms of settings, assessment methods for SDS exposure, lagged exposures examined and epidemiological study designs applied. Moreover, none of the previous reviews attempted to assess the quality of the evidence across the published studies.

The available evidence comes from studies that assessed the health effects of dust events as a binary risk exposure (mainly conducted in eastern Asia), comparing the occurrence of health events during dust and non-dust days, and from studies that considered dust events as an effect modifier for the health effects of any given PM fraction (mainly in southern Europe). Studies considering the effects of desert dust and anthropogenic PM (APM) concentrations independently revealed different effects in eastern Asia (higher association with specific cardiovascular mortality outcomes and ambulance calls related to Asian dust than to suspended PM) and southern Europe (similar health effects for Saharan dust and APM). When the role of APM during dust events was considered, the health effects of APM appeared to be stronger during dust days than during non-dust days. It should be noted that only studies considering short-term exposure have been conducted; there has been no study on the health effects of long-term exposure to sand and desert dust. The populations most susceptible to suffering the short-term effects of suspended particulates are considered to be older persons, individuals with chronic cardiopulmonary disorders, and children (Goudie, 2014).

Based on the available studies, the GDG agreed that formulating an AQG level for SDS was not possible due to insufficient evidence on quantitative and qualitative health risk-related characteristics of SDS. The GDG decided that the best manner for addressing SDS in the guideline document was to formulate qualitative practical recommendations focused on the likely consequences of desert dust and on options for mitigating it. Potential interventions can be part of short- or long-term strategies. Examples of possible short-term options outlined by the GDG in different meetings included: (i) strengthening and/or establishing air quality management programmes; (ii) measuring PM components for the purpose of source apportionment; (iii) conducting research on health impacts and epidemiological studies; and (iv) cleaning up road dust on streets. During the discussions other options were also mentioned: (i) alerting public health authorities and vulnerable populations of increased levels of SDS; (ii) reducing local emissions from anthropogenic sources of dust and other pollutants during dust episodes; (iii) informing the public about personal interventions to reduce outdoor and indoor air pollution sources; and (iv) demonstrating the impact of policies towards lowering anthropogenic pollution (Argyropoulos et al., 2020; Katra & Krasnov, 2020; Querol et al., 2019b).

Long-term mitigation interventions are more complex. A review by Middleton & Kang (2017) classified interventions to mitigate SDS hazards into measures to prevent wind erosion occurring at source and measures to address the atmospheric transport of the particles and their deposition. If wind erosion is reduced, land degradation can be halted and eventually reversed and, in turn, SDS impacts can be mitigated. In agriculture, for example, a number of techniques are available for wind erosion control, including those that minimize the actual risk (e.g. cultivation practices such as minimum tillage) and those that minimize the potential risk (e.g. planting windbreaks) (Middleton & Kang, 2017). In general terms, long-term strategies such as reforestation plans have been implemented at various scales and for many years in different places; these were also meant as climate change mitigation measures (Jindal, Swallow & Kerr, 2008; UNEP, WMO & UNCCD, 2016).

All of the actions that address the impacts of SDS associated with particle transport and deposition include a range of monitoring, early warning, forecasting and communication activities. It is worth emphasizing that there is always a need to understand the context when discussing or implementing the good practices recommended in Box 4.3. Rationales for each of the good practice statements follow Box 4.3.

At the local, national and regional levels, the potential success of the implementation of these good practices is conditioned by actions that address the impacts of SDS with a range of monitoring, early warning, forecasting and communication activities. Other planned short-term actions – in general, relevant and desirable for reducing the overall impact of air pollution – can, if implemented, also decrease the exposure to SDS. These include (i) alerting public health authorities and vulnerable populations of increased levels of air pollution, in particular of SDS; (ii) reducing local emissions from anthropogenic sources of dust and other pollutants, in particular during dust episodes; (iii) informing the public about personal interventions to reduce outdoor and indoor air pollution sources, in particular during SDS episodes, as sheltering during SDS episodes is sometimes the only feasible intervention (indoor air quality should be better than outdoor); and (iv) demonstrating the impact of policies towards lowering anthropogenic pollution. These actions are the mandate of national or local authorities, and international organizations can support policies by providing data, expertise and support.

Box 4.3. Good practice statement – SDS

Considering the available evidence, the GDG decided to formulate the following five good practice statements on SDS for frequently affected areas.

1. Maintain suitable air quality management and dust forecasting programmes. These should include early warning systems and short-term air pollution action plans to alert the population to stay indoors and take personal measures to minimize exposure, and subsequent short-term health effects, during SDS incidents with high levels of PM.
2. Maintain suitable air quality monitoring programmes and reporting procedures, including source apportionment activities to quantify and characterize the PM composition and the percentage contribution of SDS to the overall ambient concentration of PM. This will enable local authorities to target local emissions of PM from anthropogenic and natural sources for reduction.
3. Conduct epidemiological studies, including those addressing long-term effects of SDS, and research activities aimed at better understanding the toxicity of the different types of PM. Such studies are especially recommended for areas where there is a lack of sufficient knowledge and information about the health risk due to frequent exposure to SDS.
4. Implement wind erosion control through the carefully planned expansion of green spaces that considers and is adjusted to the contextual ecosystem conditions. This calls for regional collaboration among countries in the regions affected by SDS to combat desertification and carefully manage green areas.

Box 4.3 contd

5. Clean the streets in those urban areas characterized by a relatively high population density and low rainfall to prevent resuspension by road traffic as a short-term measure after intense SDS episodes with high dust deposition rates. Cleaning can be done by washing and/or sweeping. For the former, non-drinking, underground water from the subway drainage system or treated urban waters should be used (Querol et al., 2019a). This intervention is not feasible in many countries where water is scarce. In such cases, minimizing some of the local urban sources of dust such as construction and demolition activities can be a better alternative intervention. Before planning street cleaning, local authorities should:
    - assess the magnitude of the problem;
    - evaluate rainfall statistics;
    - select the streets that are most critically affected by the dust load situation;
    - ascertain the accumulation rate of sediments; and
    - determine the most effective cleaning method (e.g. frequency, timing and cleaning machine characteristics).

In partnership with other UN agencies, in particular, WMO, research institutes and academic institutions, WHO can ensure expertise and support in relation to dust measurements and their impacts. For example, the WHO Global Ambient Air Quality Database on air pollution, which is updated on a voluntary basis, can strengthen the adoption of good practices by providing a global framework of analysis. This can occur if countries affected by SDS send the WHO Global Database on Air Quality, for a given year, lists of affected zones, cities and agglomerations; information on concentrations and sources; and evidence demonstrating that observed PM concentrations are attributable, at least in part, to SDS episodes. This may provide the basis for different health impact (mortality and morbidity) calculations of air pollution that take into account the SDS contribution. The influence of SDS on air quality management is potentially very significant in orienting decisions, for example on setting national or local standards. Although this process should be based on this update of the WHO air quality guidelines and its AQG levels as the benchmark for setting standards, the rules concerning compliance assessment could be adjusted to accommodate local SDS risks.

4.4.1 Rationale for statement 1 – strengthening and/or establishing air quality management programmes

Preparedness and emergency response procedures in depositional areas need to cover diverse sectors such as public health surveillance, hospital services, air and ground transportation services, and public awareness and resilience. Since emergency response services are generally applied at local level, further subnational-level reviews and planning are needed.

A review by Querol et al. (2019b) suggested that setting up early warning systems for SDS by relevant authorities is an appropriate action to (i) inform exposed and vulnerable populations about behavioural measures that minimize the risks of high dust exposure levels; and (ii) implement special policy and regulatory measures at the local and regional levels to decrease anthropogenic air pollution emissions during dust episodes.

WMO established the Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS) (WMO, 2020c) to improve capabilities for more reliable SDS forecasting, intended for 40 of its Member States, with the Northern Africa-Middle East-Europe Node hosted by Spain, the Asian Node hosted by China, and the Pan-American Node with its Regional Center hosted by the United States and Barbados, respectively. The SDS-WAS mission is to achieve comprehensive, coordinated and sustained observations and modelling capabilities for SDS in order to improve SDS monitoring to increase the understanding of the dust processes and enhance dust prediction capabilities (WMO, 2020c).

Akhlaq, Sheltami & Mouftah (2012) provided an overview of the tools available for SDS prediction and detection, including data requirements and modelling approaches. Technologies include lookout towers, video-surveillance, sensory information, satellite imagery and unmanned aerial vehicles. The authors note that the best approach to use depends on the type of SDS, but that a hybrid approach consisting of wireless sensor networks and satellite imagery is appropriate for detecting and predicting all types of SDS.

The authorities in charge of the warning system should assess the most appropriate means to disseminate alerts to the population. Several means may be considered, such as media coverage, dedicated websites, messaging through social media and dedicated smartphone apps. It is also important to define the target population and identify vulnerable populations that can be particularly affected by SDS, as well as the facilities and other infrastructure that may be needed for such events. The involvement of health professionals and, in particular, of the medical profession should be considered, for example, general practitioners who, knowing the population, can rapidly identify susceptible individuals based on their age, comorbidities, socioeconomic status or social isolation. Although the evidence on adverse health effects from SDS remains preliminary, there is some literature suggesting the effectiveness of public health alerts in promoting behavioural change. Messages that are generally issued by authorities include the following: staying indoors (appropriate in many settings), avoiding exposure, refraining from exercise, following asthma plans (for asthmatic patients), driving with care (for cases of SDS affecting visibility such as dry thunderstorms or haboob), and visiting the doctor if respiratory or cardiovascular symptoms occur (Middleton & Kang, 2017; WHO, 2020a).

Although there is evidence of the cost–effectiveness of early warning systems, especially for those related to weather services, there is no direct evidence for SDS. To be cost–effective, four elements must be present in any early warning system: knowledge of risks, monitoring and alert services, communication, and response capability. Systems are typically cost–effective when the monitored event is relatively frequent, significant harms can occur and there are affordable preventive measures (Rogers & Tsirkunov, 2010; World Bank, 2019). Specifically, it is not just the frequency of events but their intensity that should be considered. However, there is no cut-off, that is, no specific number of episodes per year, to orient decisions. This issue is similar to considering alert systems for wildfires that can affect an area; tools are available to assess the air quality impacts of such events, including their frequency and intensity. If these events are only rare and mild, usually a conventional weather forecast is sufficient to warn the public. These systems and their structure should take into account existing time series of events and evaluate the potential health impacts using epidemiological methods and tools.

Querol et al. (2019b) provided an example of the system established in Portugal and Spain as good practice. The system consists of three modules that allow SDS predicting, detecting SDS when they occur, and quantifying the daily contributions of desert dust to ambient $PM_{2.5}$ and PM_{10} concentrations.

4.4.2 Rationale for statement 2 – strengthening air quality monitoring programmes through identification of dust sources

SDS are usually prompted by intense winds that elevate large amounts of sand and dust from bare, dry soils into the air and transport them for long distances. As a result of this phenomenon, approximately 40% of aerosols in the troposphere are dust particles derived from wind erosion. The main areas from which mineral dust originates are the arid regions of northern Africa, the Arabian Peninsula, and central and eastern Asia (WMO, 2020a). Saharan dust may contribute more than

60% of the total PM_{10} concentration in Mediterranean countries and the Middle East during a strong dust pollution event (Pey et al., 2013; Querol et al., 2009). This may lead to exceedances of the daily average interim target 4 value for PM_{10} of 50 µg/m³. Causes of SDS are affected by direct and indirect drivers in natural ecosystems, direct and indirect drivers in human-dominated ecosystems, and land degradation feedback processes (UNEP, WMO & UNCCD, 2016). In recent centuries, human activities and climate change have aggravated the problem of desert storm generation. The natural composition of desert dust can be affected by several human sources (Mori et al., 2003; Rodríguez et al., 2011). This makes the distinction between natural PM and APM sources and assessment of the health effects of desert dust difficult (Perez & Künzli, 2011; Querol et al., 2019b).

A review commissioned by WHO (Querol et al., 2019b) suggested that acquiring reliable exposure data for source apportionment is a first critical step for epidemiological and health impact assessment studies of SDS. For desert dust, Querol et al. (2019b), based on earlier work by Escudero et al. (2007), recommended the following procedure for source apportionment as a method to quantify desert dust contributions to PM levels for air quality reporting purposes.

- Collect daily $PM_{2.5}$ and PM_{10} data, measured at remote or regional background air quality monitoring stations close to the urban area under evaluation.
- Calculate the 30-day moving 40th percentile PM concentration without taking into account PM levels on the SDS days. The 40th percentile equates to the $RBPM_{10}$ and $RBPM_{2.5}$ levels without the dust contribution.
- Determine the net dust PM (NDPM) levels in PM_{10} and $PM_{2.5}$ ($NDPM_{10}$ and $NDPM_{2.5}$) for the regional background by subtracting $RBPM_{10}$ and $RBPM_{2.5}$ from the bulk PM_{10} and $PM_{2.5}$ levels at the reference regional background-monitoring site.
- At the nearby urban area, $NDPM_{10}$ and $NDPM_{2.5}$ can be considered the net desert dust contribution for the specific area during the specific SDS day. The result of the subtraction of the $NDPM_{10}$ and $NDPM_{2.5}$ values from the urban PM_{10} and $PM_{2.5}$ levels, are the APM loads during the dust days (APM_{10} and $APM_{2.5}$).
- Once the series of NDPM and APM are obtained, the health effects could be evaluated for PM, NDPM and APM.

Source apportionment with receptor modelling, based on sampling and chemical analysis of PM, is also suggested. However, when there are other important sources of non-desert dust (e.g. local soil or urban dust), this approach may be unable to differentiate sources.

A potential solution is implementing the study at a reference rural/remote site. As the review by Querol et al. (2019a) showed, local pollution in areas far away from dust sources can be enhanced under intense SDS (by thinning of the boundary layer and the interaction of mineral dust and gaseous pollutants) and dust can be co-transported with pollutants and microorganisms such as fungi and spores.

Better monitoring systems can support decision-makers to establish to what extent disease outbreaks are the result of transported sand and dust and to assess the contribution that human activities have made to that process. That is, they can help better comprehend the impact of human activities on SDS and how these ultimately impact the environment and social systems.

4.4.3 Rationale for statement 3 – conducting health impacts research and epidemiological studies in areas affected by SDS

WHO has followed a systematic process to review the effects of desert SDS on human health. This has allowed for summarizing quantitatively, using meta-analysis, the effects of dust on several mortality and morbidity outcomes (Tobias et al., 2019b).

Various epidemiological studies on the health effects of dust events have formulated hypotheses in different ways. They have compared health outcomes between days without and with desert dust events, assessed differences in association between total PM and health on days without and with desert dust events, or looked for independent effects of dust-derived PM and APM on health.

The summary of the evidence of the systematic review on desert dust indicated inconsistent results, depending on the way of assessing the effect of dust on health and the geographical region where the studies were conducted. The comparability of short-term estimates of desert dust health effects obtained in different studies could be improved by standardizing the modelling of desert dust exposure, as proposed by Tobías & Stafoggia (2020). Furthermore, studies on long-term effects of SDS are needed.

4.4.4 Rationale for statement 4 – desertification and wind erosion reduction interventions

There is a recognized pathway that links the presence of green spaces and health benefits (Markevych et al., 2017; Rojas-Rueda et al., 2019). Green spaces play an important role that is under intense scrutiny, from both empirical studies and models, in terms of ecosystem services and co-benefits to improve (mental and physical) health, mitigate climate change and provide spaces for physical activities (Egorov et al., 2016).

Various techniques, mainly reforestation plans, have been implemented in different ways in many countries to reduce exposure to desert dust (FAO, 2009, 2021). Most of these techniques were developed to protect cultivated fields from soil loss (Nordstrom & Hotta, 2004), for carbon sequestration projects and to address desertification. Health impacts have rarely been taken into account in most of the projects (Donovan, 2017). Nevertheless, tree and shrub planting should be taken into account to reduce PM in areas heavily affected by desert dusts following careful studies of the environmental conditions of the land and areas where such plans are going to be implemented.

On an international level, there is well-established agreement that

> [t]here is need for an integrated multi-scale approach for effective SDS control. Control measures at the field scale to protect soil and reduce wind speed locally, need to be combined with landscape measures over large areas to reduce wind speed, reduce sand and dust mobilization and increase deposition of sand and dust out of the atmosphere. Measures must simultaneously tackle different components of the landscape, including cropland, rangeland and deserts, as well as other sources, such as building sites, mines, etc. Integrated, landscape level measures are especially critical given the transboundary impacts of SDS.
>
> Control of anthropogenic sources of SDS is synonymous with sustainable land management […] and integrated landscape management […] and requires a long-term vision (UNEP, WMO & UNCCD, 2016).

Such initiatives are successful in the long-term only if they carefully consider existing water resources and utilize well-adapted plant species.

It is worth considering that most of the published studies supporting greening interventions have been carried out in North American (e.g. Nowak & Heisler, 2010), European (Selmi et al., 2016) and some Asian cities (e.g. Yang et al., 2005); some research results are available from areas in desert regions (e.g. Cohen, Potchter & Schnell (2014)). Overall, however, there is a lack of systematic studies in cities and in rural areas heavily affected by desert dust. Most of the studies are mainly urban, although the impacts of desert dust are not negligible for populations living in rural areas. It is worth noting that water resource management can represent a more crucial issue than greening in various countries.

4.4.5 Rationale for statement 5 – urban street cleaning

A review of street cleaning as a measure to mitigate the impact of road dust offers indirect evidence of the benefits of this type of intervention (IDAEA, 2013). The authors found that sweeping alone did not decrease PM levels in the short term, although a reduction could not be excluded in the long term. In contrast, washing – alone or in combination with sweeping – yielded more promising findings, with PM_{10} reductions observed in most reviewed studies. PM_{10} reductions varied within 7–30% of the daily mean PM_{10} concentration depending on the local situation, and were observed in a variety of settings, including Asia, Europe and North America.

In addition, street washing and sweeping can be cost–effective in reducing the health impacts of pollution from road traffic, as indicated in an analysis from the United Kingdom (Ballinger et al., 2016).

The practice of street cleaning should be carefully discussed before adoption due to the use of resources and energy that may not produce the expected overall public health benefits. Additionally, there are no studies that provide direct evidence of the effectiveness of street cleaning for reducing desert dust exposure and/or its adverse health effects after intense episodes with high dust deposition rates.

5

Dissemination of the guidelines

These guidelines will be distributed through multiple communication platforms to reach a wide range of audiences. This includes formal communication lines through WHO offices to relevant national authorities, professional organizations and agencies and nongovernmental organizations; more informal local-scale, on-the-ground platforms; and social media using tools to raise awareness and campaigns to foster engagement. In addition, collaboration platforms with other UN agencies, regional bodies and national partners will be used to facilitate dissemination.

It is important to widely distribute and disseminate the information provided in these updated guidelines, and using effective communication to do so will be key to successful uptake. Although these guidelines are universally applicable, additional and/or different approaches and strategies may be required to disseminate and communicate information about them in low- and middle-income countries, particularly where poverty and inequity could add to the complexity of the distribution and communication process.

The communication strategy for the guidelines aims to address all different types of audiences by modifying the language used to present the guidelines and diversifying the tools and channels used to maximize reach and impact to all relevant users. Communication is based on the provision of strong and clear messages and the establishment of relationships with all relevant stakeholders across sectors to ensure the usefulness, acceptability, understanding and uptake of the final product.

5.1 Tools and approaches to raise awareness of the guidelines

Several tools and approaches will be used, including dedicated WHO webpages, communication materials, awareness-raising campaigns, and specific information dissemination and communication approaches.

The WHO website is the major channel for disseminating information on the air quality guidelines to a range of users and for targeting policy-makers, health-care professionals, governmental agencies, the media, academia and the public. The website provides general information on the project and links to relevant documents and resources.

Lay versions, graphical materials, and materials developed in different official languages for promotion and awareness-raising purposes are available on social media platforms. Other means to communicate the guidelines include answers to frequently asked questions, factsheets and key messages on air pollution and health addressed to policy-makers or health practitioners.

Advocacy and outreach activities in key high-level forums are planned as part of the road map for implementation of this update of the WHO air quality guidelines. A prime example is the joint BreatheLife campaign (led by WHO, the Climate and Clean Air Coalition (CCAC) and UNEP), which aims to mobilize individuals and cities to protect human health and the planet from the adverse effects of air pollution (WHO, CCAC & UNEP, 2018). Another example is the WHO Urban Health Initiative, which promotes the consideration of human health in city development (WHO, 2020c). A specific package to train health-care professionals in air pollution and health will also be launched.

Dissemination of the WHO air quality guidelines is a whole-of-society effort. This means that, while WHO will be targeting several strategic small- and large-scale communication forums, the availability and accessibility of the air quality guidelines will enable their wide distribution among interested parties. This includes civil society organizations, which can further share them through their related initiatives.

In addition, WHO aims to participate in relevant conferences, workshops and stakeholder meetings to introduce the guidelines to audiences globally. These include:

- large, high-profile events with a predominant policy focus;
- smaller workshops or meetings of end-users of the guidelines;
- meetings of professional medical societies;
- events and conferences of the scientific community working on air pollution and health;
- articles, opinions and/or editorials in leading scientific journals;
- meetings, conferences and personal engagements at the local and grass-roots levels, for example at relevant national association events or targeted consultation in affected communities;
- press releases to civil society by local organizations;
- engagement by governments and by WHO regional and country offices; and
- national-level patient groups and networks.

5.2 Risk communication

Effective risk communication enables and empowers people who are facing health risks to make informed decisions that can improve their personal well-being. These people, in turn, can educate others, which can ultimately empower communities to take actions to reduce risks and increase healthy behaviours. The air quality guidelines provide the evidence base from which successful risk communication about air pollution effects on human health can take place. The provision of air quality guideline (AQG) levels, for instance, aims to prompt action to reduce health risks from exposure to air pollutants. By outlining who is most affected by exposure to air pollution, these guidelines are also able to provide direction in terms of to whom risk communication should be targeted in order to be most successful.

It should be noted that risk communication around air pollution is difficult and many factors need to be considered, including understanding how people perceive risk and ensuring that the risks of poor air quality are communicated in a way that empowers rather than disempowers people. In order to do this effectively, using the WHO air quality guidelines as a base, different stakeholders will need to play a role, including governments and civil society. This highlights the importance of dissemination of the guidelines in forms fit for different audiences, particularly for those who are most impacted by poor air quality. Specific information on the principles of risk communication is available in different WHO publications (WHO Regional Office for Europe, 2013b; WHO, 2017, 2020a).

5.3 Advocacy and engagement of stakeholders

The air quality guidelines advocate for services and regulatory frameworks that promote the management and reduction of air pollution to protect the health and well-being of individuals and communities. The successful dissemination and communication of the air quality guidelines aim to ensure the adoption of the guidelines into relevant institutional, community, national and international policies in order to transform existing systems and processes and, ultimately, improve human health.

Any successful advocacy strategy requires collaborative approaches and the effective engagement of relevant stakeholders across sectors. Participatory approaches are deemed valuable, particularly in lower-income contexts. This is because a consultative dialogue is often more successful at tangibly bringing across abstract concepts to communities, for instance, rather than one-way information sessions.

WHO will use its convening power to facilitate effective cooperation and ensure that key stakeholders (not only from different sectors but also from various perspectives, including local and national governments, civil society and academia) can share and benefit from their respective expertise, experience and resources.

6

Implementation of the guidelines

The WHO air quality guidelines set goals for protecting public health on a worldwide scale. They were established through a rigorous process of revision and evaluation of scientific evidence on the health effects of air pollutants and, like other WHO guidelines, are not legally binding recommendations. National standards are developed through a policy-making process by each country, have legal status and are based on the specific conditions of the country itself. Supranational (e.g. EU) and regional standards may also be developed, depending on the political structure of the area. The establishment of adequate legislation for protection of the population from the health effects of air pollutants is an essential step for all countries. The transfer of guidelines into practicable standards is an integral part of public health and environmental protection policy and is a challenge for most countries. The continuous improvement of air quality requires a formidable effort by those countries dedicated to addressing this major environmental health problem in order to progressively reduce the potential health effects, irrespective of the air pollution level at which they start. Abatement measures and air quality improvement should aim to achieve the interim targets and, finally, the air quality guideline (AQG) levels as expeditiously as possible (additional guidance on interim targets can be found in section 2.5.3). Up-to-date knowledge and information on levels of air pollution and guidance on interim targets can increase awareness and provide an incentive for the adoption of measures to reduce the level of pollutants, monitor progress and evaluate results.

This chapter examines that process and provides an overview of the general usefulness of the WHO air quality guidelines, with an emphasis on the careful assessment of national needs, capacity-building and the additional elements that are necessary in the development of national standards. Once standards have been established, there is a need for a proper implementation strategy and management of air quality with monitoring, training and enforcement. Health risk assessment is an essential tool to inform public policy decisions by providing an understanding of pollution-related disease burden and the potential for burden reduction. Collaborations of the health-care sector and many different stakeholders are essential to maintain public health protection.

6.1 Significance of the guidelines: an evidence-informed decision support tool

AQG levels are widely seen as a practical instrument for advancing emission reductions and the design of effective measures and policies. WHO guidelines equip policy-makers and other end-users across a range of different needs with the necessary evidence base to inform their decisions. They serve as a reference for assessing whether, and how much, the exposure of a population (including particular vulnerable and/or susceptible subgroups) is associated with health concerns. For various target audiences and for each stakeholder group, they can function as a critical tool to be used in multiple ways and integrated into their work for years to come.

6.1.1 Use by authorities

Health risk assessments are an important tool for authorities (at international to local levels) when deciding on necessary emission reduction measures because they provide estimates of the health burden/impacts on the population and, therefore, allow a comparison of the consequences among different policy options. These options can include measures to reduce emissions from various sources, measures aimed at reducing concentrations of pollutants in ambient air, measures aimed at reducing exposure of individuals and the population, and/or measures related to urban planning. In principle, the priority should be to prevent emissions of pollutants and reduce them at source.

6.1.2 Use by technical experts and decision-makers

For technical experts and decision-makers, the guidelines are vital in providing information on concentration–response relationships that give insight into the consequences of certain regulations or standards on the associated health effects. They are essential quantitative inputs to quantify the impact of air pollution on health and can be useful at the national and international levels when developing air quality limits or standards as they provide the scientific basis to identify the levels at which air pollution can cause a significant and unacceptable health impact. They provide valuable information used in cost–effectiveness and cost–benefit analyses of various policies and, based on these recommendations, national governments and international organizations can be better informed when introducing air quality standards to ensure the protection of people's health.

6.1.3 Use by civil society, patient and other advocacy groups

They can also be used by civil society, patient and other advocacy groups to raise awareness and encourage actions to protect the population, including susceptible groups such as children, from exposure to air pollution. They can be used to help inform these groups to advocate to policy-makers to improve air quality levels. They are of great value for communicating the health risks and potential cost–effective solutions to reducing air pollution. Organizations responsible for risk communication and general awareness-raising can use these guidelines for promotion campaigns and appropriate risk communication. The guidelines provide scientific evidence on a range of health effects associated with air pollutants and facilitate appropriate risk communication to specific vulnerable and susceptible groups.

Therefore, they need to be promoted broadly to citizens, national and local authorities, and nongovernmental organizations responsible for risk communication.

6.1.4 Use by health/environmental impact assessment practitioners

For health/environmental impact assessment practitioners, these guidelines provide concentration–response relationships that give insight into the expected health effects at observed or expected air pollution levels under various future scenarios. They provide vital input to assist in deriving the health burden or impact of air pollution; in that sense, they can be used when conducting studies to obtain an evaluation of the magnitude of the health problem for a particular situation. The systematic reviews developed in support of these guidelines will support practitioners in raising awareness of the credibility of the issue of air pollution as a public health problem and in applying the recommended concentration–response relationships uniformly so as to justify their use in different countries.

6.1.5 Use by researchers and academics

Researchers and academics will also benefit from the guidelines as they clearly identify critical data gaps that need to be filled in the future through a structured research agenda in order to better protect the population from the harmful effects of air pollution. In addition, the importance of the burden of disease related to air pollution provides an opportunity to justify the inclusion of content related to the guidelines in university curricula for a variety of medical professionals and scientists.

6.2 Assessment of national needs and capacity-building

National needs, including the need for capacity-building, differ greatly among countries. They depend in great part on the existence and level of implementation of national, regional and international policies. In many countries, air pollution is now perceived as a major and growing environmental and public health problem. Nevertheless, significant differences are still evident in multiple areas:

- the existence and operation of air pollution monitoring systems;
- the availability of and public access to data;
- air quality management policies, regulations and standards;
- the availability of trained human resources to understand, assess and monitor health impacts; and
- implementation of universal health coverage and cross-sectoral collaboration.

The existence and operation of air pollution monitoring systems differs by country and city.

Conditions at the country and city levels, specifically for the annual mean $PM_{2.5}$, have been documented as interactive maps as part of the WHO Global Health Observatory (WHO, 2021a). Progress in combining satellite remote sensing, global chemical transport models, land-use regression models, high-resolution dispersion models and surface measurements (including those made using low-cost sensors) has made information on exposure increasingly available, including in some of the most highly polluted and data-poor regions. However, these estimates need to be grounded and evaluated with existing or new ground-based monitoring; further development of these methods depends to a large extent on the availability of surface measurements in all regions of the world.

The availability of and public access to data to assess population exposure to ambient air pollution and quantify the health impacts or burden related to air pollution for past and current scenarios or future projections also differs by country.

Differences also exist between countries in the development and implementation of air quality management policies, regulations and standards that take into consideration the latest research evidence on the health impacts of ambient air pollutants. Policies to reduce emissions of air pollutants, which are clearly preferable and should be the main focus of any air quality management plan, are highly context dependent: what might be effective and contribute to improving public health in one setting might not work in another. Therefore, understanding the particular situation, including the main emissions, sources and nature of the populations exposed, is critical to the development of effective risk management policies and strategies and is important for decision-making. Most critical is to understand the current level of air pollution in relation to the guidelines.

Lastly, there are differences in the implementation and strengthening of universal health coverage and in the level of cooperation of the health sector in decision-making with other sectors. These include the environment, transport, land planning, housing and energy, agriculture, industrial, and building sectors at the national, regional and, in some cases, international levels.

6.3 Moving from guidelines to air quality standards

The primary aims of these guidelines are to provide a uniform basis for the protection of public health from adverse effects of air pollution and to eliminate or reduce exposure to those pollutants known or likely to be hazardous. Based on the extensive scientific evidence available, the guidelines aim to identify the optimal level of air quality to protect public health in different contexts; they provide a pathway to countries to transform the recommended AQG levels into legally enforceable standards. This section discusses ways in which this may be done, drawing from and expanding upon previous documents (WHO Regional Office for Europe, 1987, 1998, 2000b), each of which is a useful resource on this topic. The discussion here is limited to pollutants measured in ambient air and does not include the setting of emission standards.

6.3.1 Air quality standards

Air quality standards are the cornerstone of air quality management. Such standards are adopted and enforced by regulatory authorities to define the acceptable level of air pollution for a country or region. They define the level of an air pollutant, such as a concentration measured in ambient air for a specific averaging time. Unlike the case for a guideline value, several additional elements are usually specified in the definition of a standard. These include the averaging time, the measurement technique and strategy, data handling procedures (including quality assurance/quality control), and the statistics (for example, choice of a particular percentile) and form used to derive the value to be compared with the standard. The definition of a standard may also include a permitted number of exceedances of a certain numerical value in a given period.

Air quality standards may be based solely on scientific evidence and public health considerations. However, other features such as legal aspects, cost–benefit or cost–effectiveness may also be examined. In practice, there are generally several opportunities within a legal framework to address economic issues, as well as issues related to technological feasibility, infrastructural measures and sociopolitical considerations. These can be considered during the standard-setting process or when designing appropriate measures to control emissions. This process may result in the establishment of multiple standards, such as an adverse effect-oriented standard as a long-term goal and less stringent interim standards to be achieved within shorter periods of time.

Standards also depend on political choices about which health and environmental effects should be prevented and the extent to which populations should be protected. They also depend on the country's economic development level, capability in air quality management and other factors. Given that the benefits of clean air policies largely outweigh the cost of managing air pollution (Amann et al., 2017), the political choice for the adoption of rigorous standards may find broad societal support for economic reasons. Some countries have separate standards for the protection of public health and for the environment. Moreover, the stringency of a standard can be influenced by provisions designed to account for individuals or populations who might be more susceptible to the effects of air pollution, such as children, older adults, and individuals with asthma or other pre-existing diseases. Consideration of environmental justice or other equity issues that affect disadvantaged segments of the population may be accounted for when deriving standards. It also might be important to specify whether effects are considered for individual pollutants or for a combined exposure to several pollutants. Air quality standards should be regularly reviewed and revised as new scientific evidence emerges on adverse effects on public health and the environment.

6.3.2 Legal aspects

Within established legal frameworks, and using the WHO air quality guidelines as a starting point, the development of standards involves a consideration of several aspects. These are in part determined by the emission sources, characteristics of populations and physical properties of the environment, and include the following determinations: (i) which pollutants should be regulated; (ii) the adverse health effects against which the population needs to be protected; (iii) which individuals or subpopulations are most at risk for the effects of air pollution; (iv) what level of risk and related costs for society are acceptable to the populations; (v) what uncertainties remain in the evidence base and how they will affect the decision-making process; and (vi) the feasibility of complying with the proposed standards (which includes assessing the costs and benefits of compliance).

Legislation on, as well as the format of, air quality standards varies from country to country but, in general, the following aspects should be considered:

- identification and selection of the pollutants to which the legislative instrument will apply;
- the numerical value of the standards for the various pollutants or the process for making decisions about the appropriate standards, applicable detection methods and monitoring methodology;
- actions to be taken to implement the standard, such as the definition of the time frame needed/allowed for achievement of compliance with the standard, considering emission control measures and necessary abatement strategies; and
- identification of the responsible enforcement authorities.

Depending on their position within a legislative framework, standards may or may not be legally binding. In some countries, the constitution contains provisions regarding the protection of public health and the environment. The development of a legal framework based on constitutional provisions generally comprises two regulatory actions.

The first is the enactment of a formal legal instrument, such as an act, law, ordinance or decree. The second is the development of regulations, by laws, rules and orders.

6.3.3 Factors to be considered in setting standards

The recommendations (Chapter 3) of these WHO air quality guidelines are based on serious health effects (mortality or hospital admissions/emergency room visits) in a general population and are not designed to focus on the protection of sensitive groups. It is notable that epidemiological studies of the general population include sensitive groups, and these sensitive groups contribute, in part, to the reported risk estimates. Furthermore, such studies often do not provide separate CRFs for various subgroups of the population. However, in setting a standard for the control of an environmental pollutant, consideration may be given to additional aspects, including the adverse effects that the standard will address. A hierarchy of effects on health can be identified, ranging from minor and temporary illnesses to acute, severe illness, chronic disease and death. Distinguishing between adverse and non-adverse effects can pose considerable difficulties (Thurston et al., 2017). Of course, more serious effects are generally accepted as adverse. In considering effects that are either temporary and reversible or involve biochemical or functional changes with uncertain clinical significance, judgements must be made as to which of these less serious effects should be considered adverse. With any definition of adversity, a significant degree of subjectivity and uncertainty remains. Judgements as to adversity may differ between countries because of factors including different cultural backgrounds and different levels of health status.

Susceptible populations or groups are defined here as those who are more sensitive because of impairment by concurrent disease or other physiological limitations and specific characteristics that make the health consequences of exposure more significant (e.g. the developmental phase in children and reduction in the physiological reserve capacity of older people). Other vulnerable groups may also be judged to be at special risk owing to their exposure patterns or to having an increased effective dose for a given exposure (e.g. outdoor workers, athletes). These populations may vary across countries owing to differences in the number of people with inadequate medical care; existence of endemic disease; prevailing genetic factors; or prevalence of debilitating diseases, nutritional deficiencies and lifestyle factors. The setting of air quality standards generally takes into account other considerations beyond public health impacts such as economic and technological aspects and, as such, is considered a political decision.

Another factor to be considered in developing standards is information about the concentration–response relationship for the pollutant of concern. Where adequate evidence is available, concentration–response relationships for a number of pollutants are presented in this update of the WHO air quality guidelines.

In developing standards, regulators should consider the degree of uncertainty about concentration–response relationships. Differences in the population structure (age, health status), climate (temperature and humidity) and geography (altitude, different ecosystems) can have an impact on the prevalence, frequency and severity of effects and may modify the concentration–response relationships provided in these guidelines in their application to a particular population.

Important factors to be considered in developing standards are the number of people who are exposed to concentrations of concern and the distribution of exposure among various population groups at current pollution concentrations and at the different concentrations at which standards might be set. As well as monitoring data, the results of exposure modelling can be used at this stage of a risk assessment. The origin of background air pollution, including long-range pollution transport and its contribution to ambient levels, should also be evaluated when considering standards. It is important that guidelines are health based and, therefore, do not consider background values, whereas standards may include considerations of background levels (e.g. in the case of ozone, background increases with a warming climate).

The extent to which ambient air quality estimates from monitoring networks or models correspond to personal exposure in the population should also be considered in standard setting. This will depend on the pollutant in question (e.g. personal exposure to carbon monoxide is poorly characterized by fixed-site monitors) and other local characteristics, including lifestyle, climatic conditions, spatial distribution of pollution sources and local determinants of pollution dispersion.

Other important exposure-related concerns include how much total human exposure is due to ambient, outdoor sources as opposed to indoor sources, and how to apportion the regulatory burden among the different routes of exposure (e.g. PM from outdoor sources versus PM from household cooking with fossil fuels) for pollutants where multiple routes of exposure are important. These may vary substantially between countries. For example, indoor air pollution levels are normally quite substantial in households in countries where fossil and/or biomass fuels in unvented stoves are used for cooking and heating in homes. However, further discussion of the evolving methods of exposure assessment is beyond the scope of these guidelines.

6.3.4 Risk assessment

Generally, the central question in developing air quality standards to protect public health is the degree of protection associated with the different pollution levels at which standards might be established. In the framework of quantitative risk assessment, various proposals for standards can be considered in health or ecological risk models. These models represent a tool that is increasingly used to inform decision-makers about some of the possible consequences of pollution associated with various options for standards (or, alternatively, the reduction in adverse effects associated with moving from current conditions to a particular standard). Regulatory risk assessments are likely to result in different risk estimates across countries owing to differences in exposure patterns and in the size and characteristics of susceptible and vulnerable populations at special risk.

It is important to recognize that there are many uncertainties at each stage of a regulatory risk assessment. The results of sensitivity and uncertainty analyses should be presented to characterize the impact of major uncertainties on the risk estimates. In addition, the methods used to conduct the risk assessments should be clearly described and the limitations and caveats associated with the analysis should be discussed. In addition, the degree of acceptability of risk may vary between countries because of differences in social norms and the degree of adversity and risk perception among the general population and various stakeholders. How the risks associated with air pollution compare with risks from other pollution sources or human activities may also influence risk acceptability (GBD 2019 Risk Factors Collaborators, 2020).

6.4 Air quality management

Risk to health from inhaled pollutants varies with the concentrations of pollutants inhaled and the mechanisms by which they cause adverse effects, which may be acute or chronic. The sources of exposure to airborne contaminants are myriad, even for the pollutants covered by the WHO air quality guidelines, and pollutants are encountered as people move through multiple environments throughout the day. The microenvironmental model is a comprehensive construct for exposures to inhaled agents and for considering risk reduction through air quality management (National Research Council, 2012). A microenvironment is a place where time is spent and that has a particular pollutant concentration profile during the time spent there; for example, a motor vehicle represents a microenvironment during the time spent commuting. A microenvironment with a high concentration of pollution, such as an urban street canyon, could make a substantial contribution to total exposure, even if only a brief period of time were spent there. This model is useful for considering how air quality guidelines and standards can reduce personal exposures and for linking air quality management to benefit public health.

This model is also advantageous for considering the numerous microenvironments relevant to air pollution and associated risks to health, and how characteristics of the environment determine exposures. Table 6.1 lists some key microenvironments in urban environments, the pollution sources within these environments and some of the main pollutants present in them. The residence is particularly important because most people spend the majority of their time at home. In urban areas, the air contaminants in the home include those generated by indoor sources, such as cooking and tobacco smoking, and the indoor penetration of outdoor air pollutants, including PM and carbon monoxide generated by local traffic. Streets, which may have hot spots of air pollution generated by traffic or industrial sources, are another key and distinct microenvironment, and one that can be directly benefited by air quality management. The relative significance of different microenvironments across the world varies by where time is spent, the nature of buildings and housing, the distribution of sources and the stringency of measures taken to manage air quality (Samet, 2010).

Table 6.1. Sources of air pollution in urban microenvironments

Microenvironment	Sources	Pollutants
Home	Cooking, space heating, parked vehicles, hobbies, smoking, household products, pets, rodents, insects	PM, CO, NO_x, VOCs, allergens
Transportation environments	Vehicle and industrial emissions, road dust, background pollution, smoking	PM, including ultrafine PM, CO, NO_x, O_3, VOCs, aeroallergens, carcinogens
Streets	Vehicle emissions, road dust, background pollution	PM, including ultrafine PM, CO, NO_x, O_3, VOCs, carcinogens, lead
Work environments	Industrial processes, smoking, background pollution	PM, CO, VOCs, NO_x, carcinogens
Entertainment environments	Cooking and space heating, background pollution, smoking	PM, VOCs, carcinogens

CO: carbon monoxide; NO_x: nitrogen oxides; O_3: ozone.
Source: reproduced from Samet (2010) with permission from publisher.

The WHO air quality guidelines address air pollution and, hence, cover the many microenvironments where people spend time. At times, the increased breathing rate that results from certain activities may increase the dose of inhaled pollutants at a given concentration. In outdoor environments, there may be high-level exposures, sometimes transient, that may reflect particular industrial sources, traffic hot spots or more general sources, for example wildfires or agricultural burning. Risks for some adverse health effects, such as lung cancer or all-cause mortality, are driven by longer-term and cumulative exposures. Hence, the WHO air quality guidelines include both 24-hour (or even shorter time periods, such as 1 hour for nitrogen dioxide or 10 minutes for sulfur dioxide) and annual averaging times.

In many countries around the world, most time is spent indoors, making indoor microenvironments critical in determining the total exposure to air pollution. Ambient air pollution penetrates indoors, so exposures to pollutants that are covered by the guidelines also occur in homes and other indoor places. Conversely, indoor sources do contribute to outdoor air pollution. An example is the burning of biomass fuels for heating and cooking. The extent of penetration of ambient pollutants into indoor environments varies across pollutants. For PM, the degree of penetration depends on the size distribution of the ambient PM, whereas for gases the reactivity of the pollutant is key (e.g. ozone is highly reactive, which causes concentrations to quickly decay indoors). Also critical are the characteristics of the building, that is, how airtight it is and whether it has an air handling system (and, if so, its characteristics) or an air cleaning system for particles and gases. In higher-income countries, a central air handling system (i.e. a heating, ventilation and air-conditioning system) may be equipped to remove particles.

Modification of time–activity patterns is a widely used governmental and personal strategy to reduce pollution exposure. Air quality indices inform the public when concentrations have reached a level at which health is threatened. Typically, recommendations are tailored to the level reached and the susceptibility of those exposed, for example, people with asthma; avoiding outdoor environments and outdoor exercise is an anchoring strategy. In some locations, particularly those where air pollution is known to reach very high levels, people may use personal protection and air purifiers. These approaches vary in their effectiveness, but neither is a satisfactory alternative to governmental actions to reduce outdoor pollution concentrations.

The development of low-cost monitors for airborne PM allows people to measure one key air pollutant in their specific microenvironments (Lewis, von

Schneidemesser & Peltier, 2018). Although the accuracy of these monitors does not reach the level required for reference monitors used by regulatory agencies, they can provide a useful complement to reports from governmental agencies and can be a valuable resource when central site monitoring of known accuracy is not available. The results can be complementary if aggregated for so-called citizen science purposes, particularly by improving the spatial resolution over that provided by regulatory monitoring networks. People also use the personal monitoring results for guiding their time–activity patterns, particularly those related to time spent outdoors.

Air quality regulation and management include various policy measures to protect population health. Such policy measures need to be informed by previous evidence regarding their efficacy. A specific type of applied research activity, accountability research, assesses whether a certain policy has had an effect on reducing emissions and decreasing concentrations. Such research may also contribute to estimating the burden of disease that might be avoided if certain actions are taken (van Erp et al., 2008).

A proper evaluation of the evidence for effective air quality interventions is under development and a systematic review of the available evidence is accessible from the Cochrane Library (Burns et al., 2019). This document articulates the challenges and limitations of this kind of research. Few existing studies directly examine the effects of these interventions on environmental concentrations of pollutants or the resulting health outcomes. Therefore, the health benefits of interventions must be inferred from the reductions in emissions. In the future, as new policies are introduced, decision-makers should consider a built-in evaluation component, which could facilitate more systematic and comprehensive evaluations.

Specific evidence-informed suggestions for air quality management, according to a hierarchy of interventions, have been proposed (PHE, 2020). In this case, the first priority is preventing, reducing or replacing polluting activities to reduce emissions. The second priority is taking actions to reduce the concentration of air pollution once the polluting activity has occurred and the third is individual avoidance of exposure. The hierarchy for the most effective approaches starts with reducing emissions, followed by reducing concentrations and then reducing exposure. Five areas for potential action have been suggested:

- vehicles and fuels, including for heating
- spatial planning
- industry
- agriculture
- behavioural change.

In addition, high-level interventions have been identified with the potential to benefit health by reducing emissions, concentrations and exposures to the pollutants that cause harm. A report from a WHO consultation in 2019 (WHO, 2020a) provides an overview of the issues related to interventions that are critical for managing air pollution exposure at individual level (e.g. physical activity, use of face masks and air purifiers). A Cochrane review on the topic is also in press; the review protocol has been published (Janjua et al., 2019).

6.5 Methodological guidance for health risk assessment of air pollution

An air pollution health risk assessment estimates the health impact to be expected from measures that affect air quality in different socioeconomic, environmental and policy circumstances. As such, it is an important tool for informing public policy decisions. This section describes in broad terms how the health risks of outdoor air pollution and its sources are estimated and provides an overview of the general principles for the proper conduct of health risk assessment for various scenarios and purposes. This section draws from a previous document (WHO Regional Office for Europe, 2016b) to provide a general understanding of the concepts, scope and principles of health risk assessments.

Health risk assessments aim to estimate the risks of past, current or future exposure to air pollution and of the changes in exposure that may result from planned policies or other modifications of air quality. An air pollution health risk assessment may be quantitative or qualitative; it generally assesses (i) the amount of air pollution present (i.e. pollutant concentrations); (ii) the amount of contact (exposure) of the targeted population; and (iii) how harmful the concentration is to human health (i.e. the resulting health risks to the exposed population). The estimates provided by a health risk assessment are intended to inform the decisions of policy-makers and/or other stakeholders.

As an analytical tool, health risk assessments include a comprehensive assessment of the health impacts of policies, programmes and projects that affect environmental conditions – known as a health impact assessment. Health risk assessments and health impact assessments are different concepts, although the two terms are sometimes used interchangeably. A health impact assessment, which is an extension of the overall risk assessment, is often characterized by a combination of procedures, methods and tools used to judge the effects that a policy, programme or project may have on the health of a population and on the distribution of those effects within the population; it may also identify appropriate actions to manage those effects.

The main purpose of a health risk assessment is to answer policy questions about the likely health impacts of planned policies or modifications of those policies.

Air pollution health risk assessments are often used to answer the following policy questions.

- What is the public health burden associated with current levels of air pollution?
- What are the human health benefits associated with changing an air quality policy or applying a more stringent air quality standard?
- What are the human health impacts of emissions from specific sources or selected economic sectors, and what are the benefits of policies related to these?
- What are the human health impacts of current policy or implemented actions?
- What are the policy implications of the uncertainties of the assessment?

The first step in a health risk assessment is planning. This includes the definition of the policy question to be evaluated, determination of the availability of data and resources, and selection of appropriate methods and tools. Sources of data required for the health risk assessment include, but are not limited to, the level of air pollution, the exposed population and the health effect, and the relationship of risk to exposure (e.g. CRF). During the planning process, selection of the methods to be implemented may depend on data availability or may determine the data requirements. In addition, the identification of different tools that will be useful in the health risk assessment occurs in the planning step.

Estimating population exposure to air pollutants is the next step in the health risk assessment. Data on population exposure to air pollutants generally come from monitoring by local or national institutions. Estimates of population exposure based on measured air pollution data are often limited by the restricted geographical and time coverage of the data. Recently, predicted estimates of pollutant concentrations from statistical models have become more common and can be used to estimate exposure in locations that do not have air quality monitors. Progress in combining satellite remote sensing, global chemical transport modelling, land-use regression models and high-resolution local dispersion models in combination with existing ground-based monitoring has made information on key air pollutant indicators increasingly available, including in some of the most highly polluted and data-poor regions. It may be difficult to harmonize data from different locations, since measurements and model predictions are often made using different procedures and techniques.

When estimating the change in population exposure caused by a hypothetical change in emissions or pollutant concentrations, monitoring data may be used as a baseline level. However, air quality modelling is needed to estimate future concentration changes resulting from policies and technological innovations.

The next step in the health risk assessment is estimating the health risk. To provide useful advice aimed at answering a specific question, a specific health end-point or set of health end-points in a specific population must be identified. The health risk assessment is unlikely to cover the full range of possible adverse health effects in all possible groups of the population but may focus on those health effects that affect the most people or the most susceptible populations. The quantitative risk of air pollution to health in a population is usually represented by a CRF, which is typically based on a risk estimate from epidemiological studies.

Quantifying the health impact is the next step in the health risk assessment. Health risk assessments often report results in terms of the number of attributable deaths or cases of disease, years of life lost or disability adjusted life-years, or to the change in life expectancy attributable to the total exposure to air pollution or to a change in exposure. These metrics aggregate different types of health impact and can be used to highlight different aspects of the health status of a population. It is important to note that these metrics provide expected values for a whole population and cannot be applied to individuals in that population. Tools for health risk assessment calculation are widely available from WHO (AirQ+) or other sources (such as the US EPA BenMAP-CE) (Sacks et al., 2020).

In summary, an air pollution health risk assessment can quantify the health impact of air pollution or of changes in air pollution resulting from different socioeconomic, environmental or policy circumstances. In many countries, health risk assessments are formally required as part of the decision-making process for new programmes, projects, regulations and policies that may affect air quality. Those conducting a health risk assessment need to understand how to do it; know what data are available and needed, and where to find them; and know how to communicate the results. It is a challenging, yet important, task to find a balance between the complexity of information and tools used and the need to produce understandable results for policy-makers and others who do not necessarily have a technical background or expertise in the field.

6.6 Role of the health sector

Health-care professionals are now regularly faced with questions and concerns from patients about the impact that air pollution can have on their health. This holds particularly true for individuals who suffer from chronic conditions, such as asthma, COPD, diabetes, heart failure and IHD. Parents with young children also often have concerns. However, many health-care professionals working in different disease areas and settings are unable or unprepared to advise.

Engagement of the health community as trusted, connected and committed advocates is crucial. The health sector has a role in:

- raising awareness of the impact of air quality on health using evidence provided by the WHO air quality guidelines;
- advising the public and patients about how the impact of air pollutants above WHO air quality guidelines can be mitigated at an individual level; and
- joining advocacy efforts at the national and international levels to ensure that the health arguments for the WHO air quality guidelines are heard in national policy discussions.

Scientific evidence on the impact of air pollution on health is developing rapidly, and these new guidelines provide AQG levels for different pollutants based on a review of the latest evidence. However, the practical implications for patients and the public, specifically in relation to acute air pollution episodes and the impact on chronic conditions, are unclear to many in the health sector. For this reason, in addition to publishing the guidelines, further efforts are needed to promote the understanding, support and engagement of those in the health sector.

For the WHO air quality guidelines to have a significant impact on the lives of people most vulnerable and susceptible to the effects of air pollution, cooperation with professional societies is crucial to raise awareness of and strengthen the messages related to air pollution, as well as to ensure appropriate education and training for health-care workers. Examples include presenting the AQG levels and what they mean for health in a practical and easy-to-understand format, and providing guidance on what actions individuals can take to reduce exposure when the AQG levels are exceeded. Explaining the risk from air pollution to an individual in relation to other risk factors, such as smoking, is also important. There is a clear role for organizations such as medical societies and patient organizations to work with WHO to communicate the WHO air quality guidelines in the most accessible manner and tailored to the needs of different target groups.

6.7 Intersectoral and multistakeholder cooperation

In addition to the increased role that the health sector should play, intersectoral and multistakeholder action is crucial for the successful development and implementation of air quality policies, including achievement of the goals and targets of the 2030 Agenda for Sustainable Development (PHAC & WHO, 2008; WHO Regional Office for Europe, 2018). In many countries, responsibilities for air quality are shared among government institutions, but collaboration is not always optimal. Since air quality is influenced by policies formulated in diverse sectors, whole-system approaches are needed for protecting the public's health.

Key to effective air quality policy is the adoption of a whole-of-government approach. This approach involves downstream and upstream coordination among governance domains and levels, as well as horizontal cooperation across sectors, supported by the appropriate selection of interventions, financing mechanisms and legal instruments (WHO Regional Office for Europe, 2018). Specific models have been available at national level since the 1990s, such as the national environment health action plans (WHO Regional Office for Europe, 1999). An example of this model is the National Air Quality Cooperation Programme in the Netherlands, which fosters cooperation among different levels of government through consensus, legislation and public participation (Joint Task Force on the Health Aspects of Air Pollution, 2018).

In a similar vein, the Health in All Policies approach can help ensure that the health impacts of air pollution are considered in formulating policy outside the health sector (WHO, 2014d). For example, the California Health in All Policies Task Force convened a multisectoral working group to deal with the issues of transit-oriented development, including its impact on air pollution, active transportation and social cohesion (Government of South Australia & WHO, 2017). Among low- and middle-income countries, Thailand provides an example of promoting the Health in All Policies approach. In 2012 Thailand's National Health Assembly brought together all parties and sectors to exchange knowledge and formulate policy proposals on biomass burning from power plants and from forest fires related to agriculture (Government of South Australia & WHO, 2017; Rajan et al., 2017; NHCO, 2019).

Of particular importance is the exchange of knowledge and experiences, not only between government and the scientific community but also through engaging the private sector, civil society, communities and citizens. An inclusive, multistakeholder approach also contributes to building trust and legitimacy in the policy process, and results in more equitable and context-specific policies (WHO Regional Office for Europe, 2018). Moreover, civil society is a key player in raising awareness and promoting action to tackle air pollution challenges in many parts of the world. The private sector, in turn, has an important role in delivering context-relevant technological solutions and services. Therefore, government authorities can nurture a favourable environment by building capacity, promoting partnerships and aligning incentives (Joint Task Force on the Health Aspects of Air Pollution, 2018; Chatterton et al., 2017; CCAC & UNEP, 2019).

To control air pollution regionally, policy instruments are in place to facilitate dialogue, cooperation, and exchange of information and experiences among countries. These include, for example, the United Nations Economic Commission for Europe (UNECE) Convention on Long-Range Transboundary Air Pollution, the Malé Declaration on Control and Prevention of Air Pollution and Its Likely Transboundary Effects for South Asia, the Acid Deposition Monitoring Network in East Asia, the Association of Southeast Asian Nations' Agreement on Transboundary Haze Pollution, and the Eastern Africa Regional Framework Agreement on Air Pollution (CCAC & UNEP, 2019; UNECE, 2011). In particular, the Joint Task Force on the Health Aspects of Air Pollution, established within the UNECE Convention on Long-range Transboundary Air Pollution, is a well-established intersectoral platform for working on air pollution and health and for helping define priorities for action (WHO Regional Office for Europe, 2021b).

On the other hand, the 2030 Agenda for Sustainable Development offers a framework to combat air pollution at global level. Within the framework, connections can be identified between approximately 10 of the SDGs and air pollution, including implicit links at target level. SDG 17 (Partnerships for the Goals) offers targets for intersectoral, multilevel and multistakeholder collaboration to address air pollution that are aligned with the Paris Agreement on climate change (Longhurst et al., 2018).

7

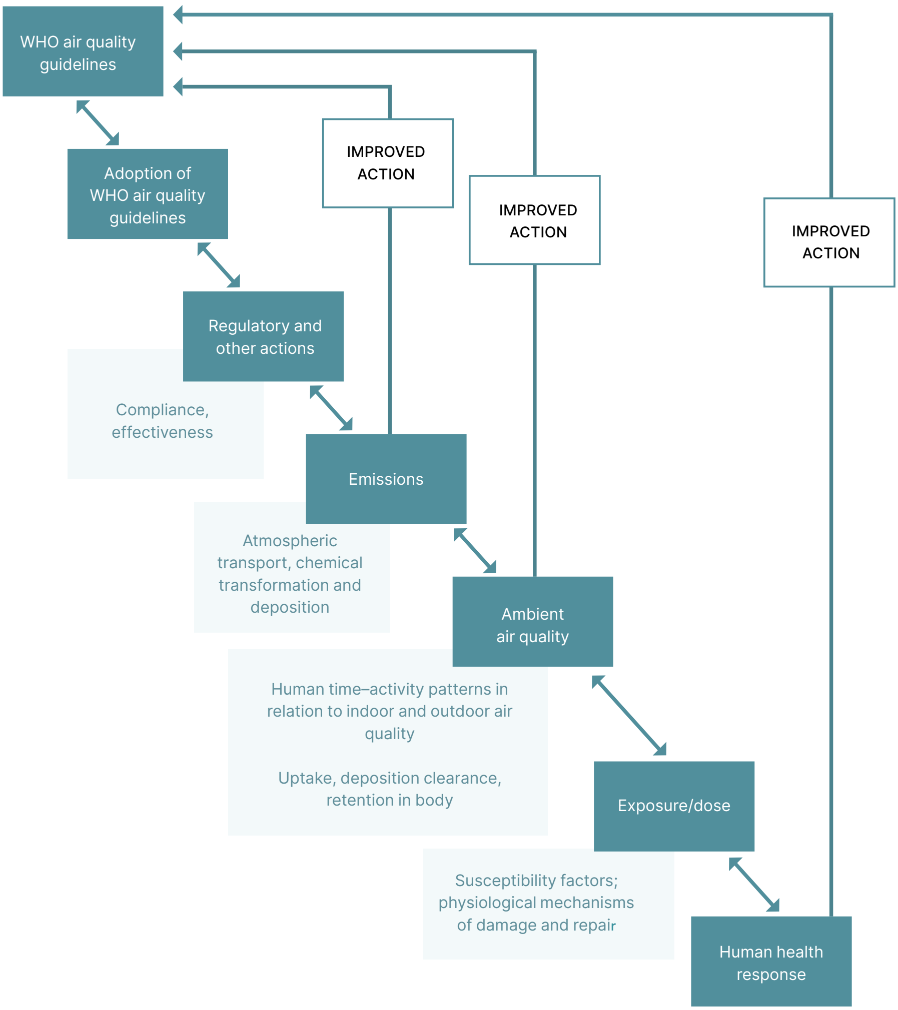
Monitoring and evaluation of the guidelines

The WHO air quality guidelines have the overall purpose of reducing the burden of disease attributable to air pollution globally, aligned with the targets set in the SDGs (UN, 2015) that offer a useful framework for considering gains made in terms of burden reduction. Targets for the SDGs have been set to ensure healthy lives and promote well-being at all ages and to make cities and human settlements inclusive, safe, resilient and sustainable. The WHO air quality guidelines are expected to effectively guide countries towards improving air quality, resulting in a beneficial impact on health risks, and moving closer to meeting several of the SDGs. Monitoring and evaluation of the consequences of implementing the updated guidelines will be key to ensuring their impacts on the reduction of disease burden from air pollution, specifically by:

- evaluating the transfer of the recommendations into local, national, regional and/or international legislation, action plans and other management actions;
- monitoring the achievement of SDG indicators that are directly affected by the recommendations;
- evaluating newly developed or revised air quality standards and other air quality management policies related to ambient air quality that are implemented in countries following publication of the guidelines, in order to determine whether WHO recommendations were used as the basis for their development; and
- surveying different stakeholders to evaluate the quality and usefulness of the guidelines.

An implicit sequence of steps to achieve health targets (such as SDG targets), summarized in Fig. 7.1, follows from promulgation of a guideline or standard. Taking the actual use of the guidelines by national or other regulatory authorities as a starting point, there is a sequence of steps to achieve health benefits, some of which can be tracked (HEI Accountability Working Group, 2003). In considering monitoring and evaluation, the length of time from any action to its health benefits also needs to be acknowledged. This could be a multiyear sequence, particularly for those countries lacking air quality standards and guidelines from the start.

Fig. 7.1. Chain of events within the air pollution accountability framework[a]



[a] HEI defines the air pollution accountability framework as a chain of events that includes the regulation of interest, air quality, exposure/dose and health outcomes, and suggests that accountability research should address the impacts of each of these linkages. Each box represents a link between regulatory action and the human health response to air pollution. Arrows connecting the links indicate possible directions of influence. Text below the arrows identifies general indices of accountability at that stage. At several stages, the knowledge gained from accountability assessments can provide valuable feedback for improving regulatory or other action.

Source: reproduced from the HEI Accountability Working Group (2003), with the permission of the publisher.

7.1 Tracking the implementation of the guidelines

As indicated in Fig. 7.1, the starting point is the actual adoption of the air quality guideline (AQG) levels or interim targets. At this stage of the process, there are steps that can be monitored in a systematic manner. For example, Kutlar Joss et al. (2017) developed a potentially replicable methodology for determining what standards are in place throughout the world. This approach can be followed in maintaining the ongoing tracking of utilization of the WHO air quality guidelines in practice. With the introduction of these updated guidelines, ways to track their dissemination and implementation in countries should be put in place. As a next step, governmental actions need to be taken to incorporate the updated AQG levels or interim targets into regulations or other actions that impact air pollution sources. Such actions can also be tracked by establishing a database (that is periodically updated), as one potential model, which is illustrated in the *WHO report on the global tobacco epidemic 2019* (WHO, 2019b). Based on data compiled by Swiss TPH (Kutlar Joss et al., 2017), WHO developed an interactive tool that provides a snapshot of national air quality standards for classical pollutants for various averaging times. Presented as a map, the tool uses the WHO air quality guidelines and interim targets as references and will be updated regularly (WHO, 2021b).

7.2 Assessing population exposure to ambient pollution

The availability of appropriate population exposure monitoring is critical, as illustrated in Fig. 7.1. Measurement of air pollutant concentrations at fixed-location monitoring sites is the long-standing approach used for air quality management, trend assessment and exposure estimation for epidemiological analyses. However, there is still a lack of air pollution monitoring and inadequate numbers of monitors in rural areas and locations other than major cities in many countries. Thus, monitoring metrics could be the extent of monitoring and the implementation of monitoring to cover gaps. New modelling approaches incorporating satellite and other data may also be useful. In recent decades, in addition to existing air pollution monitoring networks, advanced methods of exposure assessment have become available with the use of satellite observations and various modelling tools to support epidemiological studies, as well as health impact and risk assessment.

Global air pollution concentrations and trends and related estimates of population exposure on priority air pollutant indicators have been compiled in the WHO Global Ambient Air Quality Database, as described in section 1.3.1. Additionally, this update of the WHO air quality guidelines has identified a number of advances in the global development of air pollution monitoring protocols and exposure assessment methods that can be adopted to increase result comparability across studies.

7.3 Health benefits from implementation of the guidelines

The WHO air quality guidelines have the overall purpose of benefiting the health of populations worldwide. The health benefits of the updated WHO air quality guidelines will be realized through reducing population exposures to ambient air pollution via several steps (see Fig. 7.1). Disease burden reflects both the underlying health of populations and the exposures received. Scientific evidence evaluated during the development of this update shows that health risks attributable to air pollution are large and increasing, particularly due to the increases in air pollution exposure in low- and middle-income countries and to ageing of the world population. Major health benefits are expected to be achieved when ambient air pollution levels are reduced widely, following implementation of the guidelines at a global scale. The databases described in section 1.3.1 can be used to inform global estimates of disease and economic burden, and the ongoing estimates of disease burden made by WHO and sister UN agencies within the framework of the SDGs and by the research community will also be useful for tracking progress.

Furthermore, as summarized in Chapter 3, the updated AQG levels and interim targets are derived with improved global CRFs and provide a set of health and exposure indicators for evidence-informed benchmarking of the health impacts of air pollution. These indicators are consistent with SDG targets and can be monitored and evaluated throughout the implementation of the WHO air quality guidelines within and across countries. By adopting the updated guidelines, progress towards achieving the SDG targets can be explicitly monitored and assessed. In particular, this is the case for indicator 3.9.1 on the mortality rate attributed to ambient air pollution and indicator 11.6.2 on the annual mean levels of fine PM, for which WHO is a custodian agency (discussed in section 1.3.7). Such measurements will assist stakeholders to assess their progress in the reduction of disease burden caused by implementation of the WHO air quality guidelines, which will likely result, in parallel, in a further reduction of air pollution.

Countries will need to incorporate the multistep process of air quality management at national level, and stakeholders could be directly and periodically surveyed to evaluate the quality and usefulness of the guidelines towards the goal of reducing disease burden and meeting the applicable SDG targets. Sustained progress in improving air quality is the goal of implementation of the guidelines; monitoring of the guidelines impact on reducing disease burden can provide a strong rationale for potential future updates of the guidelines.

8

Future research needs

There is extensive evidence, which was reviewed to support this update of the WHO air quality guidelines, demonstrating the health effects of exposure to major air pollutants. Evidence from toxicology and epidemiology is sufficient to justify actions to reduce population exposure. Nevertheless, uncertainties and knowledge gaps remain, and future research is needed to reduce these. Suggestions for future research that may help in this regard are listed below. These include further strengthening the policy-relevant scientific base and evidence to support decision-making worldwide, especially in low- and middle-income countries.

- **Set priorities for policy-relevant scientific questions: how, why and for whom do the health effects of air pollution exist?**
  - Assess the shape of the exposure–response relationships at both low and high air pollution concentration levels – the former are now being observed in parts of Europe, North America and Oceania, and the latter are now being observed in parts of Asia and the Eastern Mediterranean Region.
  - Study the toxicity of different sources of air pollution (e.g. tailpipe and non-tailpipe emissions, aviation and shipping emissions, specific industrial sources, wood smoke and desert dust). This includes research into the health effects of technology-driven changes in areas such as primary energy production, where mixtures of coal and biomass replace coal in places.
  - Study the health effects of particle size fractions for which there are limited data.
  - Define sensitive subgroups of the population that need to be protected (e.g. related to socioeconomic status, nutrition, pregnancy, critical windows of development, and young older age) due to the risk of immediate, delayed or lifetime effects.
  - Study multipollutant exposures to determine the relative importance of specific air pollutants (such as nitrogen dioxide, carbon monoxide) and components of PM, with an examination of additive, synergistic or antagonistic effects, including in the presence of pollens or other airborne allergens. This is an area where mechanistic research will likely play an important role.
  - Study the interaction with other environmental and behavioural factors such as traffic noise, green space and allergen exposure; physical activity and diet; and high and low temperatures and other climatic conditions.

- Undertake research into a broader range of health end-points, as the list of organ systems and conditions possibly affected by air pollution is steadily increasing.
  - Study the neurological effects, including the effects on brain morphology in young children and older people, on child development, and on cognitive decline and reduced ability to perform activities of daily life in older people.
  - Study the cardiometabolic effects – emerging evidence links diabetes to air pollution exposure (Yang B-Y et al., 2020), an association in clear need of further corroboration and characterization.
  - Study the effects on various cancer forms (excluding lung cancer, for which a relationship with air pollution has been established).
  - Study the short-term effects of exposure leading to worsening of symptoms for diseases such as allergic, cardiovascular and respiratory conditions and indicated by a wider set of (also subclinical) health status indicators, such as lung function tests or biomarkers.
- Improve the methodology in exposure assessment, study design and evidence synthesis and evaluation.
  - Study exposure assessment – inform this by integrating data form multiple sources (e.g. from large numbers of low-cost sensors) and data fusion (satellite observations, emission sources, dispersion models and ground-based monitoring).
  - Assess multiple sources of exposure in different locations (including home indoor, work indoor and transportation) and time–activity patterns.
  - Assess multiple sources of exposure in populations from different regions, living in different climates, of different socioeconomic status, etc.
  - Improve statistical methods for use in epidemiological studies, such as methods to correct for exposure measurement error in health analyses, multipollutant modelling approaches and methods to correct for confounding.
  - Expand the framework of causal inference by incorporating different study and analysis designs, including novel approaches in epidemiology such as the use of propensity scores, instrumental variables, difference-in-difference analyses and regression discontinuity.
  - Improve methodological aspects related to the evaluation of the quality of individual studies and the synthesis and overall evaluation of the scientific evidence, including determination of the certainty of the body of evidence (e.g. GRADE or other approaches).
- Undertake research into mechanisms of health effects.
  - Study the biological mechanisms explaining epidemiological associations

with all-cause and respiratory mortality of (mixtures represented by) nitrogen dioxide and ozone, especially at low concentration levels.

   - Study the mechanisms of effects of (mixtures represented by) nitrogen dioxide and ozone on the cardiovascular system.
   - Study the effects of mixtures containing particles of different sizes as wells as gaseous pollutants to understand the underlying pathophysiology due to surface interactions between pollutants and molecular or cellular structures (e.g. proteins, lipids, DNA and RNA).

- Continue to develop burden and health impact assessment.

   - Improve methods and input data for health risk assessments, which play a key role in identifying the overall and relative importance of air pollution and its sources for population health. They provide the foundation for identifying priorities and tracking the effectiveness of solutions.
   - Improve the apportionment of population exposure to specific sources or source categories to enable source-specific health risk assessment at the local, national and regional levels.
   - Establish solid mechanisms for the regular review of evidence related to the quantification of CRFs and health burden assessments, including the integrated assessment of burdens from complex mixtures.
   - Integrate air-pollution-related health risk assessment into a comprehensive health impact assessment of actions focused on other determinants of health (such as physical activity, diet and climate).

- Improve assessment of the effectiveness of interventions (accountability research).

   - Evaluate key long-term interventions in all parts of the world, for example local traffic interventions, interventions to reduce emissions from industrial sources, changes in energy use (gas vs electricity), efforts to reduce exposure for at-risk communities and reductions in biomass burning.
   - Evaluate key short-term community (e.g. school closures) and individual (e.g. face masks) interventions during acute episodes, including studies of population exposure, health effects, and societal and economic implications. Evaluation should include conditions critical for successful intervention, for example, sensitivity to socioeconomic conditions; methods of communication; use of adequate exposure indicators; and target group knowledge, attitude and engagement.
   - Develop study methods to assess the effectiveness of interventions and which can provide direct evidence for the attribution of changes in air quality and health to an air quality improvement intervention, as well as to integrate (climate) related co-benefits and dis-benefits.

9

Updating the guidelines

The number of studies of air quality and health has significantly increased since *Global update 2005*, including new studies published after the completion of the systematic reviews conducted for this update. Taken together, the guidelines were informed by a wealth of epidemiological studies that shed light on the risks of exposure to air pollution at both the lower and upper bounds of the concentration–response relationships for the classical air pollutants, including the shapes of such relationships.

WHO will continue monitoring scientific progress in the field to assess the need for future updates. This activity will be facilitated by the Global Air Pollution and Health – Technical Advisory Group, which was established in 2021 (WHO, 2020d), and by annual meetings of the Joint Task Force on the Health Aspects of Air Pollution, established in 1998, within the UNECE Convention on Long-range Transboundary Air Pollution (WHO Regional Office for Europe, 2021b).

Moreover, participation in scientific meetings, follow-up on emerging issues, and close interaction with thematic/technical experts and stakeholders will continue so as to keep abreast of the scientific progress and gauge the need for updating the guidelines. In general, however, the recommendations made in these guidelines are expected to remain valid for a period of up to 10 years.

References

42 U.S.C. § 7409 – US Code – Unannotated Title 42. The Public Health and Welfare § 7409. National primary and secondary ambient air quality standards.

Abbey DE, Nishino N, McDonnell WF, Burchette RJ, Knutsen SF, Beeson WL et al. (1999). Long-term inhalable particles and other air pollutants related to mortality in nonsmokers. Am J Respir Crit Care Med. 159(2):373–82. doi: 10.1164/ajrccm.159.2.9806020.

Achakulwisut P, Brauer M, Hystad P, Anenberg SC (2019). Global, national, and urban burdens of paediatric asthma incidence attributable to ambient NO_2 pollution: estimates from global datasets. Lancet Planet Health. 3(4):e166–78. doi: 10.1016/S2542-5196(19)30046-4.

ACTRIS (2020). Standard operating procedures and measurement guidelines for ACTRIS in situ aerosol particle variables. Kjeller: ACTRIS Data Centre (https://actris.nilu.noContent/?pageid=13d5615569b04814a6483f13bea96986, accessed 7 August 2020).

Akhlaq M, Sheltami TR, Mouftah HT (2012). A review of techniques and technologies for sand and dust storm detection. Rev Environ Sci Biotechnol. 11:305–22. doi: https://doi.org/10.1007/s11157-012-9282-y.

Amann M, Holland M, Maas R, Vandyck T, Saveyn B (2017). Costs, benefits and economic impacts of the EU clean air strategy and their implications on innovation and competitiveness. Laxenburg: International Institute for Applied Systems Analysis (https://ec.europa.eu/environment/air/pdf/clean_air_outlook_economic_impact_report.pdf, accessed 2 December 2020).

ANSES (2019). Particulate matter in ambient air. Health effects according to components, sources and particle size. Impact on air pollution of the technologies and composition of the motor vehicle fleet operating in France. Paris: Agence nationale de sécurité sanitaire de l'alimentation, de l'environnement et du travail [French Agency for Food, Environmental and Occupational Health & Safety] (https://www.anses.fr/fr/system/files/AIR2014SA0156RaEN.pdf, accessed 7 August 2020).

Argyropoulos CD, Hassan H, Kumar P, Kakosimos KE (2020). Measurements and modelling of particulate matter building ingress during a severe dust storm event. Build Environ. 167:106441. doi: https://doi.org/10.1016/j.buildenv.2019.106441.

Ashley WS, Strader S, Dziubla DC, Haberlie A (2015). Driving blind: weather-related vision hazards and fatal motor vehicle crashes. Bull Am Meteorol Soc. 96(5):755–78. doi: https://doi.org/10.1175/BAMS-D-14-00026.1

Badaloni C, Cesaroni G, Cerza F, Davoli M, Brunekreef B, Forastiere F (2017). Effects of long-term exposure to particulate matter and metal components on mortality in the Rome longitudinal study. Environ Int. 109:146–54. doi: 10.1016/j.envint.2017.09.005.

Baddock MC, Strong CL, Murray PS, McTainsh GH (2013). Aeolian dust as a transport hazard. Atmos Environ. 71:7–14. doi: 10.1016/j.atmosenv.2013.01.042.

Ballinger A, Chowdhury T, Sherrington C, Cole G (2016). Air pollution: economic analysis. Main report. Bristol: Eunomia Research & Consulting (https://www.nice.org.uk/guidance/ng70/evidence/economic-report-pdf-4595574493, accessed 8 August 2020).

Beelen R, Hoek G, van den Brandt PA, Goldbohm RA, Fischer P, Schouten LJ et al. (2008). Long-term effects of traffic-related air pollution on mortality in a Dutch cohort (NLCS-AIR study). Environ Health Perspect. 116(2):196–202. doi: 10.1289/ehp.10767.

Beelen R, Raaschou-Nielsen O, Stafoggia M, Andersen ZJ, Weinmayr G, Hoffmann B et al. (2014). Effects of long-term exposure to air pollution on natural-cause mortality: an analysis of 22 European cohorts within the multicentre ESCAPE project. Lancet. 383(9919):785–95. doi: 10.1016/S0140-6736(13)62158-3.

Bell ML, Peng RD, Dominici F, Samet JM (2009). Emergency hospital admissions for cardiovascular diseases and ambient levels of carbon monoxide: results for 126 United States urban counties, 1999–2005. Circulation. 120(11):949–55. doi: 10.1161/CIRCULATIONAHA.109.851113.

Benmarhnia T, Rey L, Cartier Y, Clary CM, Deguen S, Brousselle A (2014). Addressing equity in interventions to reduce air pollution in urban areas: a systematic review. Int J Public Health. 59(6):933–44. doi: 10.1007/s00038-014-0608-0.

Bentayeb M, Wagner V, Stempfelet M, Zins M, Goldberg M, Pascal M et al. (2015). Association between long-term exposure to air pollution and mortality in France: a 25-year follow-up study. Environ Int. 85:5–14. doi: 10.1016/j.envint.2015.08.006.

Bice K, Eil A, Habib B, Heijmans P, Kopp R, Nogues J et al. (2009). Black carbon: a review and policy recommendations. Princeton (NJ): Woodrow Wilson School of Public & International Affairs, Princeton University.

Blair A, Burg J, Foran J, Gibb H, Greenland S, Morris R et al. (1995). Guidelines for application of meta-analysis in environmental epidemiology. ISLI Risk Science Institute. Regul Toxicol Pharmacol. 22(2):189–97. doi: 10.1006/rtph.1995.1084.

Bond TC, Doherty SJ, Fahey DW, Forster PM, Berntsen T, DeAngelo BJ et al. (2013). Bounding the role of black carbon in the climate system: a scientific assessment. J Geophys Res Atmos. 118(11):5380–552. doi: https://doi.org/10.1002/jgrd.50171.

Boogaard H, van Erp AM, Walker KD, Shaikh R (2017). Accountability studies on air pollution and health: the HEI experience. Curr Environ Health Rep. 4(4):514–22. doi: 10.1007/s40572-017-0161-0.

Bowe B, Xie Y, Li T, Yan Y, Xian H, Al-Aly Z (2018). The 2016 global and national burden of diabetes mellitus attributable to $PM_{2.5}$ air pollution. Lancet Planet Health. 2(7):e301–12. doi: 10.1016/S2542-5196(18)30140-2.

Brauer M, Amann M, Burnett RT, Cohen A, Dentener F, Ezzati M et al. (2012). Exposure assessment for estimation of the global burden of disease attributable to outdoor air pollution. Environ Sci Technol. 46(2):652–60. doi: 10.1021/es2025752.

Brauer M, Freedman G, Frostad J, van Donkelaar A, Martin RV, Dentener F et al. (2016). Ambient air pollution exposure estimation for the global burden of disease 2013. Environ Sci Technol. 50(1):79–88. doi: 10.1021/acs.est.5b03709.

Brauer M, Brook JR, Christidis T, Chu Y, Crouse DL, Erickson A et al. (2019). Mortality-Air Pollution Associations in Low-Exposure Environments (MAPLE): phase 1. Res Rep Health Eff Inst. (203):1–87. PMID: 31909580.

Brown RJC, Beccaceci S, Butterfield DM, Quincey PG, Harris PM, Maggos T et al. (2017). Standardisation of a European measurement method for organic carbon and elemental carbon in ambient air: results of the field trial campaign and the determination of a measurement uncertainty and working range. Environ Sci Process Impacts. 19(10):1249–59. doi: 10.1039/c7em00261k.

Brunekreef B, Beelen R, Hoek G, Schouten L, Bausch-Goldbohm S, Fischer P et al. (2009). Effects of long-term exposure to traffic-related air pollution on respiratory and cardiovascular mortality in the Netherlands: the NLCS-AIR study. Res Rep Health Eff Inst. (139):5–71. PMID: 19554969.

Burnett RT, Pope CA III, Ezzati M, Olives C, Lim SS, Mehta S et al. (2014). An integrated risk function for estimating the global burden of disease attributable to ambient fine particulate matter exposure. Environ Health Perspect. 122(4):397–403. doi: 10.1289/ehp.1307049.

Burnett R, Chen H, Szyszkowicz M, Fann N, Hubbell B, Pope CA III et al. (2018). Global estimates of mortality associated with long-term exposure to outdoor fine particulate matter. Proc Natl Acad Sci U S A. 115(38m):9592–7. doi: 10.1073/pnas.1803222115. License: CC BY-NC-ND.

Burns J, Boogaard H, Polus S, Pfadenhauer LM, Rohwer AC, van Erp AM et al. (2019). Interventions to reduce ambient particulate matter air pollution and their effect on health. Cochrane Database Syst Rev. 5(5):CD010919. doi: 10.1002/14651858.CD010919.pub2.

Butterfield D, Beccaceci S, Quincey P, Sweeney B, Lilley A, Bradshaw C et al. (2016). 2015 Annual Report for the UK Black Carbon Network. National Physical Laboratory (NPL Report ENV 7; http://eprintspublications.npl.co.uk/7276/1/ENV7.pdf, accessed 17 August 2020).

Cakmak S, Hebbern C, Pinault L, Lavigne E, Vanos J, Crouse DL et al. (2018). Associations between long-term $PM_{2.5}$ and ozone exposure and mortality in the Canadian Census Health and Environment Cohort (CANCHEC), by spatial synoptic classification zone. Environ Int. 111:200–11. doi: 10.1016/j.envint.2017.11.030.

Carey IM, Atkinson RW, Kent AJ, van Staa T, Cook DG, Anderson HR (2013). Mortality associations with long-term exposure to outdoor air pollution in a national English cohort. Am J Respir Crit Care Med. 187(11):1226–33. doi: 10.1164/rccm.201210-1758OC.

Castro A, Götschi T, Achermann B, Baltensperger U, Buchmann B, Dietrich DF et al. (2020). Comparing the lung cancer burden of ambient particulate matter using scenarios of air quality standards versus acceptable risk levels. Int J Public Health. 65(2):139–48. doi: 10.1007/s00038-019-01324-y.

CCAC, UNEP (2019). Air pollution in Asia and the Pacific: science-based solutions. Nairobi: United Nations Environment Programme (https://ccacoalition.org/en/resources/air-pollution-asia-and-pacific-science-based-solutions-summary-full-report, accessed 9 December 2020).

CEN (2017). Ambient air: measurement of elemental carbon (EC) and organic carbon (OC) collected on filters. Brussels: Comite Europeen de Normalisation [European Committee for Standardization] (BS EN 16909:2017).

Cesaroni G, Badaloni C, Gariazzo C, Stafoggia M, Sozzi R, Davoli M et al. (2013). Long-term exposure to urban air pollution and mortality in a cohort of more than a million adults in Rome. Environ Health Perspect. 121(3):324–31. doi: 10.1289/ehp.1205862.

Chang K-L, Cooper O, West JJ, Serre M, Schultz M, Lin M et al. (2019). A new method (M 3 Fusion-v1) for combining observations and multiple model output for an improved estimate of the global surface ozone distribution. Geosci Model Dev. 12(3):955–78. doi: https://doi.org/10.5194/gmd-12-955-2019.

Chatterton T, de Vito L, Csobod E, Szuppinger P, Heves G (2017). D3.1. Review of social science in air quality and carbon management. Final Revised April 2018. Geneva: Zenodo. doi: 10.5281/zenodo.3972106.

Chen J, Hoek G (2020). Long-term exposure to PM and all-cause and cause-specific mortality: a systematic review and meta-analysis. Environ Int. 143:105974. doi: 10.1016/j.envint.2020.105974. License: CC BY-NC-ND.

Chen K, Breitner S, Wolf K, Stafoggia M, Sera F, Vicedo-Cabrera AM et al. (2021). Ambient carbon monoxide and daily mortality: a global time-series study in 337 cities. Lancet Planet Health. 5(4):e191–9. doi: 10.1016/S2542-5196(21)00026-7.

Chen R, Yin P, Meng X, Liu C, Wang L, Xu X et al. (2017). Fine particulate air pollution and daily mortality. A nationwide analysis in 272 Chinese cities. Am J Respir Crit Care Med. 196(1):73–81. doi: 10.1164/rccm.201609-1862OC.

Chen X, Zhang LW, Huang JJ, Song FJ, Zhang LP, Qian ZM et al. (2016). Long-term exposure to urban air pollution and lung cancer mortality: a 12-year cohort study in Northern China. Sci Total Environ. 571:855–61. doi: 10.1016/j.scitotenv.2016.07.064.

Cheng MF, Tsai SS, Yang CY (2009). Air pollution and hospital admissions for myocardial infarction in a tropical city: Kaohsiung, Taiwan. J Toxicol Environ Health A. 72(19):1135–40. doi: 10.1080/15287390903091756.

Clancy L, Goodman P, Sinclair H, Dockery DW (2002). Effect of air-pollution control on death rates in Dublin, Ireland: an intervention study. Lancet. 360(9341):1210–14. doi: 10.1016/S0140-6736(02)11281-5.

Cohen AJ, Brauer M, Burnett R, Anderson HR, Frostad J, Estep K et al. (2017). Estimates and 25-year trends of the global burden of disease attributable to ambient air pollution: an analysis of data from the Global Burden of Diseases Study 2015. Lancet. 389(10082):1907–18. doi: 10.1016/S0140-6736(17)30505-6.

Cohen P, Potchter O, Schnell I (2014). The impact of an urban park on air pollution and noise levels in the Mediterranean city of Tel-Aviv, Israel. Environ Pollut. 195:73–83. doi: 10.1016/j.envpol.2014.08.015.

Collaboration for Environmental Evidence (2013). Guidelines for systematic review and evidence synthesis in environmental management. Version 4.2. Environ Evid. (http://www.environmentalevidence.org/Documents/Guidelines/Guidelines4.2.pdf, accessed 5 December 2020).

Crouse DL, Peters PA, Hystad P, Brook JR, van Donkelaar A, Martin RV et al. (2015). Ambient $PM_{2.5}$, O_3, and NO_2 exposures and associations with mortality over 16 years of follow-up in the Canadian Census Health and Environment Cohort (CanCHEC). Environ Health Perspect. 123(11):1180–6. doi: 10.1289/ehp.1409276.

de Hoogh K, Gulliver J, van Donkelaar A, Martin RV, Marshall JD, Bechle MJ et al. (2016). Development of West-European $PM_{2.5}$and NO_2 land use regression models incorporating satellite-derived and chemical transport modelling data. Environ Res. 151:1–10. doi: 10.1016/j.envres.2016.07.005.

de Hoogh K, Chen J, Gulliver J, Hoffmann B, Hertel O, Ketzel M et al. (2018). Spatial $PM_{2.5}$, NO_2, O_3 and BC models for Western Europe: evaluation of spatiotemporal stability. Environ Int. 120:81–92. doi: 10.1016/j.envint.2018.07.036.

de Jesus AL, Rahman MM, Mazaheri M, Thompson H, Knibbs LD, Jeong C et al. (2019). Ultrafine particles and $PM_{2.5}$ in the air of cities around the world: are they representative of each other? Environ Int. 129:118–35. doi: 10.1016/j.envint.2019.05.021.

de Longueville F, Ozer P, Doumbia S, Henry S (2013). Desert dust impacts on human health: an alarming worldwide reality and a need for studies in West Africa. Int J Biometeorol. 57(1):1–19. doi: 10.1007/s00484-012-0541-y.

Dehbi HM, Blangiardo M, Gulliver J, Fecht D, de Hoogh K, Al-Kanaani Z et al. (2017). Air pollution and cardiovascular mortality with over 25 years follow-up: a combined analysis of two British cohorts. Environ Int. 99:275–81. doi: 10.1016/j.envint.2016.12.004.

Desikan A, Crichton S, Hoang U, Barratt B, Beevers SD, Kelly FJ et al. (2016). Effect of exhaust- and nonexhaust-related components of particulate matter on long-term survival after stroke. Stroke. 47(12):2916–22. doi: 10.1161/STROKEAHA.116.014242.

Di Q, Wang Y, Zanobetti A, Wang Y, Koutrakis P, Choirat C et al. (2017a). Air pollution and mortality in the Medicare population. N Engl J Med. 376:2513–22. doi: 10.1056/NEJMoa1702747. Copyright © 2017 Massachusetts Medical Society.

Di Q, Dai L, Wang Y, Zanobetti A, Choirat C, Schwartz JD et al. (2017b). Association of short-term exposure to air pollution with mortality in older adults. JAMA. 318(24):2446–56. doi: 10.1001/jama.2017.17923.

Dimakopoulou K, Samoli E, Beelen R, Stafoggia M, Andersen ZJ, Hoffmann B et al. (2014). Air pollution and nonmalignant respiratory mortality in 16 cohorts within the ESCAPE project. Am J Respir Crit Care Med. 189(6):684–96. doi: 10.1164/rccm.201310-1777OC.

Dirgawati M, Hinwood A, Nedkoff L, Hankey GJ, Yeap BB, Flicker L et al. (2019). Long-term exposure to low air pollutant concentrations and the relationship with all-cause mortality and stroke in older men. Epidemiology. 30(suppl 1):S82–9. doi: 10.1097/EDE.0000000000001034.

Dockery DW, Pope CA III, Xu X, Spengler JD, Ware JH, Fay ME et al. (1993). An association between air pollution and mortality in six US cities. N Engl J Med. 329(24):1753–9. doi: 10.1056/NEJM199312093292401.

Dockery DW, Rich DQ, Goodman PG, Clancy L, Ohman-Strickland P, George P et al. (2013). Effect of air pollution control on mortality and hospital admissions in Ireland. Res Rep Health Eff Inst. (176):3–109. PMID: 24024358.

Dominici F, Schwartz J, Di Q, Braun D, Choirat C, Zanobetti A (2019). Assessing adverse health effects of long-term exposure to low levels of ambient air pollution: phase 1. Res Rep Health Eff Inst. (200):1–51. PMID: 31909579.

Donovan GH (2017). Including public-health benefits of trees in urban-forestry decision making. Urban For Urban Green. 22:120–3. doi: https://doi.org/10.1016/j.ufug.2017.02.010.

EEA (2019). EMEP/EEA air pollutant emission inventory guidebook 2019. Technical guidance to prepare national emission inventories 1994–2019. Copenhagen: European Environment Agency (EEA Report No. 13/2019; https://www.eea.europa.eu/publications/emep-eea-guidebook-2019, accessed 7 August 2020).

EEA (2020). Air quality in Europe – 2020 report. Copenhagen: European Environment Agency (EEA Report No. 09/2020; https://www.eea.europa.eu/publications/air-quality-in-europe-2020-report, accessed 18 February 2021).

Egorov AI, Mudu P, Braubach M, Martuzzi M (2016). Urban green spaces and health. Copenhagen: World Health Organization Regional Office for Europe (https://www.euro.who.int/__data/assets/pdf_file/0005/321971/Urban-green-spaces-and-health-review-evidence.pdf, accessed 8 August 2020).

Enstrom JE (2005). Fine particulate air pollution and total mortality among elderly Californians, 1973–2002. Inhal Toxicol. 17(14):803–16. doi: 10.1080/08958370500240413.

Escudero M, Querol X, Pey J, Alastuey A, Pérez N, Ferreira F et al. (2007). A methodology for the quantification of the net African dust load in air quality monitoring networks. Atmos Environ. 41:5516–24. doi: https://doi.org/10.1016/j.atmosenv.2007.04.047.

Eum KD, Kazemiparkouhi F, Wang B, Manjourides J, Pun V, Pavlu V et al. (2019). Long-term NO_2 exposures and cause-specific mortality in American older adults. Environ Int. 124:10–15. doi: 10.1016/j.envint.2018.12.060.

European Parliament, Council of the European Union (2008). Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe. OJ. L152/1 (https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32008L0050&from=en, accessed 17 November 2020).

Evangelopoulos D, Perez-Velasco R, Walton H, Gumy S, Williams M, Kelly F et al. (2020). The role of burden of disease assessment in tracking progress towards achieving WHO global air quality guidelines. Int J Public Health. 65:1455–65. doi: 10.1007/s00038-020-01479-z.

FAO (2009). Guidelines for good forestry and range practices in arid and semi-arid zones of the Near East. Cairo: FAO Regional Office for the Near East (Working paper RNEO 1-09; http://www.fao.org/3/al040e/al040e00.pdf, accessed 13 July 2021).

FAO (2021). Action Against Desertification [website]. Rome: Food and Agriculture Organization of the United Nations (http://www.fao.org/in-action/action-against-desertification/overview/en/, accessed 2 March 2021).

Faustini A, Rapp R, Forastiere F (2014). Nitrogen dioxide and mortality: review and meta-analysis of long-term studies. Eur Respir J. 44(3):744–53. doi: 10.1183/09031936.00114713.

Filleul L, Rondeau V, Vandentorren S, Le Moual N, Cantagrel A, Annesi-Maesano I et al. (2005). Twenty five year mortality and air pollution: results from the French PAARC survey. Occup Environ Med. 62(7):453–60. doi: 10.1136/oem.2004.014746.

Fischer PH, Marra M, Ameling CB, Hoek G, Beelen R, De Hoogh K et al. (2015). Air pollution and mortality in seven million adults: the Dutch Environmental Longitudinal Study (DUELS). Environ Health Perspect. 123(7):697–704. doi: http://dx.doi.org/10.1289/ehp.1408254.

Fischer PH, Marra M, Ameling CB, Velders GJM, Hoogerbrugge R, de Vries W et al. (2020). Particulate air pollution from different sources and mortality in 7.5 million adults: the Dutch Environmental Longitudinal Study (DUELS). Sci Total Environ. 705:135778. doi: 10.1016/j.scitotenv.2019.135778.

Frampton MW, Balmes JR, Bromberg PA, Stark P, Arjomandi M, Hazucha MJ et al. (2017). Multicenter Ozone Study in oldEr Subjects (MOSES): part 1. Effects of exposure to low concentrations of ozone on respiratory and cardiovascular outcomes. Boston (MA): Health Effects Institute (Research Report 192 Part 1; https://www.healtheffects.org/publication/multicenter-ozone-study-older-subjects-moses-part-1-effects-exposure-low-concentrations, accessed 21 February 2021).

Fussell JC, Kelly FJ. (2021). Mechanisms underlying the health effects of desert sand dust. Environ Int. 157:106790. doi: 10.1016/j.envint.2021.106790.

GBD 2016 Risk Factors Collaborators (2017). Global, regional, and national comparative risk assessment of 84 behavioural, environmental and occupational, and metabolic risks or clusters of risks, 1990–2016: a systematic analysis for the Global Burden of Disease Study 2016. Lancet. 390(10100):1345–422. doi: 10.1016/S0140-6736(17)32366-8.

GBD 2019 Risk Factors Collaborators (2020). Global burden of 87 risk factors in 204 countries and territories, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019. Lancet. 396(10258):1223–49. doi: 10.1016/S0140-6736(20)30752-2.

Geddes JA, Martin RV, Boys BL, van Donkelaar A (2016). Long-term trends worldwide in ambient NO_2 concentrations inferred from satellite observations. Environ Health Perspect. 124(3):281–9. doi: 10.1289/ehp.1409567.

Goudie AS (2014). Desert dust and human health disorders. Environ Int. 63:101–13. doi: 10.1016/j.envint.2013.10.011.

Government of South Australia, WHO (2017). Progressing the Sustainable Development Goals through Health in All Policies: case studies from around the world. Adelaide: Government of South Australia (https://www.who.int/social_determinants/publications/progressing-sdg-case-studies-2017.pdf?ua=1, accessed 17 November 2020).

Gryparis A, Forsberg B, Katsouyanni K, Analitis A, Touloumi G, Schwartz J et al. (2004). Acute effects of ozone on mortality from the “air pollution and health: a European approach” project. Am J Respir Crit Care Med. 170(10):1080–7. doi: 10.1164/rccm.200403-333OC.

Hammer MS, van Donkelaar A, Li C, Lyapustin A, Sayer AM, Hsu NC et al. (2020). Global estimates and long-term trends of fine particulate matter concentrations (1998–2018). Environ Sci Technol. 54(13):7879–90. doi: 10.1021/acs.est.0c01764.

Hanigan IC, Rolfe MI, Knibbs LD, Salimi F, Cowie CT, Heyworth J et al. (2019). All-cause mortality and long-term exposure to low level air pollution in the “45 and up study” cohort, Sydney, Australia, 2006–2015. Environ Int. 126:762–70. doi: 10.1016/j.envint.2019.02.044.

Hansell A, Ghosh RE, Blangiardo M, Perkins C, Vienneau D, Goffe K et al. (2016). Historic air pollution exposure and long-term mortality risks in England and Wales: prospective longitudinal cohort study. Thorax. 71(4):330–8. doi: 10.1136/thoraxjnl-2015-207111.

Hansen ADA (2005). The Aethalometer. Berkeley (CA): Magee Scientific Company (https://www.psi.ch/sites/default/files/import/lac/ProjectAddonCatcosOperationsEN/Aethalometer_book_2005.07.02.pdf, accessed 6 August 2020).

Hart JE, Garshick E, Dockery DW, Smith TJ, Ryan L, Laden F (2011). Long-term ambient multipollutant exposures and mortality. Am J Respir Crit Care Med. 183(1):73–8. doi: 10.1164/rccm.200912-1903OC.

Hart JE, Rimm EB, Rexrode KM, Laden F (2013). Changes in traffic exposure and the risk of incident myocardial infarction and all-cause mortality. Epidemiology. 24(5):734–42. doi: 10.1097/EDE.0b013e31829d5dae.

Hart JE, Liao X, Hong B, Puett RC, Yanosky JD, Suh H et al. (2015). The association of long-term exposure to $PM_{2.5}$ on all-cause mortality in the Nurses’ Health Study and the impact of measurement-error correction. Environ Health. 14:38. doi: 10.1186/s12940-015-0027-6.

Hartiala J, Breton CV, Tang WHW, Lurmann F, Hazen SL, Gilliland FD et al. (2016). Ambient air pollution is associated with the severity of coronary atherosclerosis and incident myocardial infarction in patients undergoing elective cardiac evaluation. J Am Heart Assoc. 5(8):e003947. doi: 10.1161/JAHA.116.003947.

Hashizume M, Ueda K, Nishiwaki Y, Michikawa T, Onozuka D (2010). Health effects of Asian dust events: a review of the literature. Nihon Eiseigaku Zasshi. 65(3):413–21 (in Japanese). doi: 10.1265/jjh.65.413.

Health Canada (2010). Residential indoor air quality guideline: carbon monoxide. Ottawa: Health Canada (https://www.canada.ca/en/health-canada/services/publications/healthy-living/residential-indoor-air-quality-guideline-carbon-monoxide.html, accessed 25 June 2021).

Health Canada (2013). Canadian smog science assessment. Volume 2: health effects. Ottawa: Health Canada (https://publications.gc.ca/site/eng/447367/publication.html, accessed 12 July 2021).

Health Canada (2016a). Human health risk assessment for ambient nitrogen dioxide. Ottawa: Health Canada (https://www.canada.ca/en/health-canada/services/publications/healthy-living/human-health-risk-assessment-ambient-nitrogen-dioxide.html, accessed 12 July 2021).

Health Canada (2016b). Human health risk assessment for sulphur dioxide – analysis of ambient exposure to and health effects of sulphur dioxide in the Canadian population. Ottawa: Health Canada (https://publications.gc.ca/collections/collection_2016/sc-hc/H144-29-2016-eng.pdf, accessed 12 July 2021).

HEI (2013). Understanding the health effects of ambient ultrafine particles. HEI Review Panel on Ultrafine Particles. Boston (MA): Health Effects Institute (HEI Perspectives 3; https://www.healtheffects.org/system/files/Perspectives3.pdf, accessed 7 August 2020).

HEI (2021). Mortality and morbidity effects of long-term exposure to low-level $PM_{2.5}$, black carbon, NO_2 and O_3: an analysis of European cohorts. In: Ongoing research [website]. Boston (MA): Health Effects Institute (https://www.healtheffects.org/research/ongoing-research/mortality-and-morbidity-effects-long-term-exposure-low-level-pm25-black, accessed 6 July 2021).

HEI Accountability Working Group (2003). Assessing health impact of air quality regulations: concepts and methods for accountability research. Boston (MA): Health Effects Institute (Communication 11; https://www.healtheffects.org/system/files/Comm11.pdf, accessed 15 March 2021).

Heinrich J, Thiering E, Rzehak P, Krämer U, Hochadel M, Rauchfuss KM et al. (2013). Long-term exposure to NO_2 and PM_{10} and all-cause and cause-specific mortality in a prospective cohort of women. Occup Environ Med. 70(3):179–86. doi: 10.1136/oemed-2012-100876.

Higgins JPT, Green S, editors (2011). Cochrane handbook for systematic reviews of interventions. Version 5.1.0 (updated March 2011). The Cochrane Collaboration (https://training.cochrane.org/handbook/archive/v5.1/, accessed 6 December 2020).

Hoek G, Beelen R, de Hoogh K, Vienneau D, Gulliver J, Fischer P et al. (2008). A review of land-use regression models to assess spatial variation of outdoor air pollution. Atmos Environ. 42(33):7561–78. doi: https://doi.org/10.1016/j.atmosenv.2008.05.057.

Hsieh YL, Yang YH, Wu TN, Yang CY (2010). Air pollution and hospital admissions for myocardial infarction in a subtropical city: Taipei, Taiwan. J Toxicol Environ Health A. 73(11):757–65. doi: 10.1080/15287391003684789.

Huangfu P, Atkinson R (2020). Long-term exposure to NO_2 and O_3 and all-cause and respiratory mortality: a systematic review and meta-analysis. Environ Int. 144:105998. doi: 10.1016/j.envint.2020.105998. License: CC BY-NC-ND.

Hultcrantz M, Rind D, Akl EA, Treweek S, Mustafa RA, Iorio A et al. (2017). The GRADE working group clarifies the construct of certainty of evidence. J Clin Epidemiol. 87:4–13. doi: 10.1016/j.jclinepi.2017.05.006.

Hvidtfeldt UA, Sorensen M, Geels C, Ketzel M, Khan J, Tjonneland A et al. (2019). Long-term residential exposure to $PM_{2.5}$, PM_{10}, black carbon, NO_2, and ozone and mortality in a Danish cohort. Environ Int. 123:265–72. doi: 10.1016/j.envint.2018.12.010.

Hystad P, Setton E, Cervantes A, Poplawski K, Deschenes S, Brauer M et al. (2011). Creating national air pollution models for population exposure assessment in Canada. Environ Health Perspect. 119(8):1123–9. doi: 10.1289/ehp.1002976.

IDAEA (2013). The scientific basis of street cleaning activities as road dust mitigation measure. Barcelona: Institute of Environmental Assessment and Water Research (http://airuse.eu/wp-content/uploads/2013/11/B7-3-ES_road-cleaning.pdf, accessed 2 December 2020).

International Programme on Chemical Safety (1997). Nitrogen oxides, 2nd edition. Environmental Health Criteria 188. Geneva: United Nations Environment Programme, International Labour Organization, World Health Organization (http://www.inchem.org/documents/ehc/ehc/ehc188.htm, accessed 17 June 2021).

IntHout J, Ioannidis JP, Rovers MM, Goeman JJ (2016). Plea for routinely presenting prediction intervals in meta-analysis. BMJ Open. 6(7):e010247. doi: 10.1136/bmjopen-2015-010247.

ISO (2015). ISO 27891:2015. Aerosol particle number concentration: calibration of condensation particle counters. ISO/TC 24/SC 4. Geneva: International Organization for Standardization (https://www.iso.org/standard/44414.html, accessed 7 August 2020).

Janjua S, Powell P, Atkinson R, Stovold E, Fortescue R (2019). Individual-level interventions to reduce personal exposure to outdoor air pollution and their effects on long-term respiratory conditions. Cochrane Database of Syst. Rev. (10):CD013441. doi: 10.1002/14651858.CD013441.

Janssen NAH, Gerlofs-Nijland ME, Lanki T, Salonen RO, Cassee F, Hoek G et al. (2012). Health effects of black carbon. Copenhagen: WHO Regional Office for Europe (https://www.euro.who.int/__data/assets/pdf_file/0004/162535/e96541.pdf, accessed 7 August 2020).

Jeronimo M, Stewart Q, Weakley AT, Giacomo J, Zhang X, Hyslop N et al. (2020). Analysis of black carbon on filters by image-based reflectance. Atmos Environ. 223:117300. doi: 10.1016/j.atmosenv.2020.117300.

Jerrett M, Finkelstein MM, Brook JR, Arain MA, Kanaroglou P, Stieb DM et al. (2009). A cohort study of traffic-related air pollution and mortality in Toronto, Ontario, Canada. Environ Health Perspect. 117(5):772–7. doi: 10.1289/ehp.11533.

Jindal R, Swallow B, Kerr J (2008). Forestry-based carbon sequestration projects in Africa: potential benefits and challenges. Natural Resources Forum. 32(2):116–30. doi: https://doi.org/10.1111/j.1477-8947.2008.00176.x.

Joint Task Force on the Health Aspects of Air Pollution (2018). Effects of air pollution on health. Report of the Joint Task Force on the Health Aspects of Air Pollution on its twenty-first meeting. Geneva: United Nations Economic Commission for Europe (https://unece.org/fileadmin/DAM/env/documents/2018/Air/EMEP/ECE_EB.AIR_GE.1_2018_17-1811946E.pdf, accessed 15 March 2021).

Karanasiou A, Moreno N, Moreno T, Viana M, De Leeuw F, Querol X (2012). Health effects from Sahara dust episodes in Europe: literature review and research gaps. Environ Int. 47:107–14. doi: 10.1016/j.envint.2012.06.012.

Karner AA, Eisinger DS, Niemeier DA (2010). Near-roadway air quality: synthesizing the findings from real-world data. Environ Sci Technol. 44(14):5334–44. doi: 10.1021/es100008x.

Katanoda K, Sobue T, Satoh H, Tajima K, Suzuki T, Nakatsuka H et al. (2011). An association between long-term exposure to ambient air pollution and mortality from lung cancer and respiratory diseases in Japan. J Epidemiol. 21(2):132–43. doi: 10.2188/jea.je20100098.

Katra I, Krasnov H (2020). Exposure assessment of indoor PM levels during extreme dust episodes. Int J Environ Res Public Health. 17(5):1625. doi: 10.3390/ijerph17051625.

Kazemiparkouhi F, Eum KD, Wang B, Manjourides J, Suh HH (2020). Long-term ozone exposures and cause-specific mortality in a US Medicare cohort. J Expo Sci Environ Epidemiol. 30(4):650–8. doi: 10.1038/s41370-019-0135-4.

Khreis H, Kelly C, Tate J, Parslow R, Lucas K, Nieuwenhuijsen M (2017). Exposure to traffic-related air pollution and risk of development of childhood asthma: a systematic review and meta-analysis. Environ Int. 100:1–31. doi: 10.1016/j.envint.2016.11.012.

Kim O-J, Kim S-Y, Kim H (2017). Association between long-term exposure to particulate matter air pollution and mortality in a South Korean national cohort: comparison across different exposure assessment approaches. Int J Environ Res Public Health. 14(10):1103. doi: 10.3390/ijerph14101103.

Klompmaker JO, Hoek G, Bloemsma LD, Marra M, Wijga AH, van den Brink C et al. (2020). Surrounding green, air pollution, traffic noise exposure and non-accidental and cause-specific mortality. Environ Int. 134:105341. doi: 10.1016/j.envint.2019.105341.

Knibbs LD, Hewson MG, Bechle MJ, Marshall JD, Barnett AG (2014). A national satellite-based land-use regression model for air pollution exposure assessment in Australia. Environ Res. 135:204–11. doi: 10.1016/j.envres.2014.09.011.

Krewski D, Burnett RT, Goldberg MS, Hoover BK, Siemiatycki J, Jerrett M et al. (2003). Overview of the reanalysis of the Harvard Six Cities Study and American Cancer Society study of particulate air pollution and mortality. J Toxicol Environ Health A. 66(16–19):1507–51. doi: 10.1080/15287390306424.

Kutlar Joss M, Eeftens M, Gintowt E, Kappeler R, Künzli N (2017). Time to harmonize national ambient air quality standards. Int J Public Health. 62(4):453–62. doi: 10.1007/s00038-017-0952-y. License: CC BY 4.0.

Laden F, Schwartz J, Speizer FE, Dockery DW (2006). Reduction in fine particulate air pollution and mortality: extended follow-up of the Harvard Six Cities Study. Am J Respir Crit Care Med. 173(6):667–72. doi: 10.1164/rccm.200503-443OC.

Larkin A, Geddes JA, Martin RV, Xiao Q, Liu Y, Marshall JD et al. (2017). Global land use regression model for nitrogen dioxide air pollution. Environ Sci Technol. 51(12):6957–64. doi: 10.1021/acs.est.7b01148.

Lee KK, Spath N, Miller MR, Mills NL, Shah ASV (2020). Short-term exposure to carbon monoxide and myocardial infarction: a systematic review and meta-analysis. Environ Int. 143:105901. doi: 10.1016/j.envint.2020.105901. License: CC BY-NC-ND.

Lefler JS, Higbee JD, Burnett RT, Ezzati M, Coleman NC, Mann DD et al. (2019). Air pollution and mortality in a large, representative US cohort: multiple-pollutant analyses, and spatial and temporal decompositions. Environ Health. 18(1):101. doi: 10.1186/s12940-019-0544-9.

Lepeule J, Laden F, Dockery D, Schwartz J (2012). Chronic exposure to fine particles and mortality: an extended follow-up of the Harvard Six Cities Study from 1974 to 2009. Environ Health Perspect. 120(7):965–70. doi: 10.1289/ehp.1104660.

Lewis AC, von Schneidemesser E, Peltier RE (2018). Low-cost sensors for the measurement of atmospheric composition: overview of topic and future applications. Geneva: World Meteorological Organization (https://www.ccacoalition.org/en/resources/low-cost-sensors-measurement-atmospheric-composition-overview-topic-and-future, accessed 2 December 2020).

Lim CC, Hayes RB, Ahn J, Shao Y, Silverman DT, Jones RR et al. (2019). Long-term exposure to ozone and cause-specific mortality risk in the United States. Am J Respir Crit Care Med. 200(8):1022–31. doi: 10.1164/rccm.201806-1161OC. Copyright © 2019 American Thoracic Society. All rights reserved.

Lim SS, Vos T, Flaxman AD, Danaei G, Shibuya K, Adair-Rohani H et al. (2012). A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010. Lancet. 380(9859):2224–60. doi: 10.1016/S0140-6736(12)61766-8.

Lipfert FW, Wyzga RE, Baty JD, Miller JP (2006). Traffic density as a surrogate measure of environmental exposures in studies of air pollution health effects: long-term mortality in a cohort of US veterans. Atmos Environ. 40:154–69. doi: https://doi.org/10.1016/j.atmosenv.2005.09.027.

Lippmann M, Chen LC, Gordon T, Ito K, Thurston GD (2013). National Particle Component Toxicity (NPACT) Initiative: integrated epidemiologic and toxicologic studies of the health effects of particulate matter components. Res Rep Health Eff Inst. (177):5–13. PMID: 24377209.

Lipsett MJ, Ostro BD, Reynolds P, Goldberg D, Hertz A, Jerrett M et al. (2011). Long-term exposure to air pollution and cardiorespiratory disease in the California Teachers Study cohort. Am J Respir Crit Care Med. 184(7):828–35. doi: 10.1164/rccm.201012-2082OC.

Liu C, Chen R, Sera F, Vicedo-Cabrera AM, Guo Y, Tong S et al. (2019). Ambient particulate air pollution and daily mortality in 652 cities. N Engl J Med. 381(8):705–15. doi: 10.1056/NEJMoa1817364. Copyright © 2019 Massachusetts Medical Society.

Longhurst J, Barnes J, Chatterton T, de Vito L, Everard M, Hayes E et al. (2018). Analysing air pollution and its management through the lens of the UN Sustainable Development Goals: a review and assessment. WIT Trans Ecol Environ. 230(1):3–14. doi: 10.2495/AIR180011.

Luben TJ, Nichols JL, Dutton SJ, Kirrane E, Owens EO, Datko-Williams L et al. (2017). A systematic review of cardiovascular emergency department visits, hospital admissions and mortality associated with ambient black carbon. Environ Int. 107:154–62. doi: https://doi.org/10.1016/j.envint.2017.07.005.

Markevych I, Schoierer J, Hartig T, Chudnovsky A, Hystad P, Dzhambov AM et al. (2017). Exploring pathways linking greenspace to health: theoretical and methodological guidance. Environ Res. 158:301–17. doi: 10.1016/j.envres.2017.06.028.

Mathur MB, VanderWeele TJ (2020). Sensitivity analysis for unmeasured confounding in meta-analyses. J Am Stat Assoc. 115(529):163–72. doi: 10.1080/01621459.2018.1529598.

McDonnell WF, Nishino-Ishikawa N, Petersen FF, Chen LH, Abbey DE (2000). Relationships of mortality with the fine and coarse fractions of long-term ambient PM_{10} concentrations in nonsmokers. J Expo Anal Environ Epidemiol. 10(5):427–36. doi: 10.1038/sj.jea.7500095.

Meng X, Liu C, Chen R, Sera F, Vicedo-Cabrera AM, Milojevic A et al. (2021). Short term associations of ambient nitrogen dioxide with daily total, cardiovascular, and respiratory mortality: multilocation analysis in 398 cities. BMJ. 372:n534. doi: 10.1136/bmj.n534.

Middleton N, Kang U (2017). Sand and dust storms: impact mitigation. Sustainability. 9(6):1053. doi: https://doi.org/10.3390/su9061053.

Middleton NJ (2017). Desert dust hazards: a global review. Aeolian Res. 24:53–63. doi: https://doi.org/10.1016/j.aeolia.2016.12.001.

Miller J, Jin L (2019). Global progress toward soot-free diesel vehicles in 2019. Washington (DC): International Council on Clean Transportation (https://theicct.org/publications/global-progress-toward-soot-free-diesel-vehicles-2019, accessed 7 August 2020).

Mills IC, Atkinson RW, Anderson HR, Maynard RL, Strachan DP (2016). Distinguishing the associations between daily mortality and hospital admissions and nitrogen dioxide from those of particulate matter: a systematic review and meta-analysis. BMJ Open. 6(7):e010751. doi: 10.1136/bmjopen-2015-010751.

Morawska L, Ristovski ZD, Jayaratne ER, Keogh D, Ling X (2008). Ambient nano and ultrafine particles from motor vehicle emissions: characteristics, ambient processing and implications on human exposure. Atmos Environ. 42(35):8113–38. doi: https://doi.org/10.1016/j.atmosenv.2008.07.050.

Morgan RL, Thayer KA, Bero L, Bruce N, Falck-Ytter Y, Ghersi D et al. (2016). GRADE: assessing the quality of evidence in environmental and occupational health. Environ Int. 92–93:611–16. doi: 10.1016/j.envint.2016.01.004.

Morgan RL, Thayer KA, Santesso N, Holloway AC, Blain R, Eftim SE et al. (2019). A risk of bias instrument for non-randomized studies of exposures: a users' guide to its application in the context of GRADE. Environ Int. 122:168–84. doi: 10.1016/j.envint.2018.11.004.

Mori I, Nishikawa M, Tanimura T, Quan H (2003). Change in size distribution and chemical composition of kosa (Asian dust) aerosol during long-range transport. Atmos Environ. 37(30):4253–63. doi: https://doi.org/10.1016/S1352-2310(03)00535-1.

Moshammer H, Poteser M, Kundi M, Lemmerer K, Weitensfelder L, Wallner P et al. (2020). Nitrogen-dioxide remains a valid air quality indicator. Int J Environ Res Public Health. 17(10):3733. doi: 10.3390/ijerph17103733. License: CC BY.

National Research Council (2012). Exposure science in the 21st century: a vision and a strategy. Washington (DC): The National Academies Press.

National Research Council (2014). Review of EPA's Integrated Risk Information System (IRIS) process. Washington (DC): The National Academies Press.

NHCO (2019). National Health Assembly [website]. Nonthaburi: National Health Commission Office (https://en.nationalhealth.or.th/nha/, accessed 17 November 2020).

NIHR (2021). PROSPERO. International prospective register of systematic reviews [database]. York: National Institute for Health Research (https://www.crd.york.ac.uk/PROSPERO/, accessed 7 July 2021).

Nordstrom KF, Hotta S (2004). Wind erosion from crop–land in the USA: a review of problems, solutions, and prospects. Geoderma. 121(3–4):157–67. doi: https://doi.org/10.1016/j.geoderma.2003.11.012.

Novotny EV, Bechle MJ, Millet DB, Marshall JD (2011). National satellite-based land-use regression: NO_2 in the United States. Environ Sci Technol. 45(10):4407–14. doi: 10.1021/es103578x.

Nowak DJ, Heisler GM (2010). Air quality effects of urban trees and parks. Ashburn (VA): National Recreation and Parks Association Research (https://www.fs.fed.us/nrs/pubs/jrnl/2010/nrs_2010_nowak_002.pdf, accessed 8 August 2020).

Ohlwein S, Kappeler R, Kutlar Joss M, Künzli N, Hoffmann B (2019). Health effects of ultrafine particles: a systematic literature review update of epidemiological evidence. Int J Public Health. 64(4):547–59. doi: 10.1007/s00038-019-01202-7.

OpenAQ (2021). OpenAQ [online database]. Washington (DC): OpenAQ (https://openaq.org, accessed 17 February 2021).

Orellano P, Reynoso J, Quaranta N (2021). Short-term exposure to sulphur dioxide (SO_2) and all-cause and respiratory mortality: a systematic review and meta-analysis. Environ Int. 150:106434. doi: 10.1016/j.envint.2021.106434. License: CC BY-NC-ND.

Orellano P, Reynoso J, Quaranta N, Bardach A, Ciapponi A (2020). Short-term exposure to particulate matter (PM_{10} and $PM_{2.5}$), nitrogen dioxide (NO_2), and ozone (O_3) and all-cause and cause-specific mortality: systematic review and meta-analysis. Environ Int. 142:105876. doi: 10.1016/j.envint.2020.105876. License: CC BY-NC-ND.

Ostro B, Hu J, Goldberg D, Reynolds P, Hertz A, Bernstein L et al. (2015). Associations of mortality with long-term exposures to fine and ultrafine particles, species and sources: results from the California Teachers Study cohort. Environ Health Perspect. 123(6):549–56. doi: 10.1289/ehp.1408565.

Owens EO, Patel MM, Kirrane E, Long TC, Brown J, Cote I et al. (2017). Framework for assessing causality of air pollution-related health effects for reviews of the national ambient air quality standards. Regul Toxicol Pharmacol. 88:332–7. doi: 10.1016/j.yrtph.2017.05.014.

Pappin AJ, Christidis T, Pinault LL, Crouse DL, Brook JR, Erickson A et al. (2019). Examining the shape of the association between low levels of fine particulate matter and mortality across three cycles of the Canadian Census Health and Environment Cohort. Environ Health Perspect. 127(10):107008. doi: 10.1289/EHP5204.

Parker JD, Kravets N, Vaidyanathan A (2018). Particulate matter air pollution exposure and heart disease mortality risks by race and ethnicity in the United States: 1997 to 2009 National Health Interview Survey with mortality follow-up through 2011. Circulation. 137(16):1688–97. doi: 10.1161/CIRCULATIONAHA.117.029376.

Paul KC, Haan M, Mayeda ER, Ritz BR (2019). Ambient air pollution, noise, and late-life cognitive decline and dementia risk. Annu Rev Public Health. 40:203–20. doi: 10.1146/annurev-publhealth-040218-044058.

Perez L, Künzli N (2011). Saharan dust: no reason to exempt from science or policy. Occup Environ Med. 68(6):389–90. doi: 10.1136/oem.2010.063990.

Peters R, Ee N, Peters J, Booth A, Mudway I, Anstey KJ (2019). Air pollution and dementia: a systematic review. J Alzheimers Dis. 70:S145–63. doi: 10.3233/JAD-180631.

Petzold A, Ogren JA, Fiebig M, Laj P, Li SM, Baltensperger U et al. (2013). Recommendations for reporting "black carbon" measurements. Atmos Chem Phys. 13:8365–79. doi: https://doi.org/10.5194/acp-13-8365-2013, 2013.

Pey J, Querol X, Alastuey A, Forastiere F, Stafoggia M (2013). African dust outbreaks over the Mediterranean Basin during 2001–2011: PM_{10} concentrations, phenomenology and trends, and its relation with synoptic and mesoscale meteorology. Atmos Chem Phys. 13:1395–410. doi: https://doi.org/10.5194/acp-13-1395-2013.

PHAC, WHO (2008). Health equity through intersectoral action: an analysis of 18 country case studies. Ottawa: Public Health Agency of Canada (https://www.who.int/social_determinants/resources/health_equity_isa_2008_en.pdf?ua=1, accessed 17 November 2020).

PHE (2018). Associations of long-term average concentrations of nitrogen dioxide with mortality: a report by the Committee on the Medical Effects of Air Pollutants. London: Public Health England (https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/734799/COMEAP_NO2_Report.pdf, accessed 21 February 2021).

PHE (2020). Review of interventions to improve outdoor air quality and public health: principal interventions for local authorities. London: Public Health England (https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/795185/Review_of_interventions_to_improve_air_quality.pdf, accessed 5 December 2020).

Pinault L, Tjepkema M, Crouse DL, Weichenthal S, van Donkelaar A, Martin RV et al. (2016). Risk estimates of mortality attributed to low concentrations of ambient fine particulate matter in the Canadian Community Health Survey cohort. Environ Health. 15:18. doi: 10.1186/s12940-016-0111-6. License: CC BY 4.0.

Pinault LL, Weichenthal S, Crouse DL, Brauer M, Erickson A, Donkelaar AV et al. (2017). Associations between fine particulate matter and mortality in the 2001 Canadian Census Health and Environment Cohort. Environ Res. 159:406–15. doi: 10.1016/j.envres.2017.08.037.

Pope CA III, Ezzati M, Dockery DW (2009). Fine-particulate air pollution and life expectancy in the United States. N Engl J Med. 360(4):376–86. doi: 10.1056/NEJMsa0805646.

Pope CA III, Burnett RT, Thun MJ, Calle EE, Krewski D, Ito K et al. (2002). Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution. JAMA. 287(9):1132–41. doi: 10.1001/jama.287.9.1132.

Puett RC, Schwartz J, Hart JE, Yanosky JD, Speizer FE, Suh H et al. (2008). Chronic particulate exposure, mortality, and coronary heart disease in the nurses' health study. Am J Epidemiol. 168(10):1161–8. doi: 10.1093/aje/kwn232.

Puett RC, Hart JE, Suh H, Mittleman M, Laden F (2011). Particulate matter exposures, mortality, and cardiovascular disease in the health professionals follow-up study. Environ Health Perspect. 119(8):1130–5. doi: 10.1289/ehp.1002921.

Querol X, Pey J, Pandolfi M, Alastuey A, Cusack M, Perez N et al. (2009). African dust contributions to mean ambient PM_{10} levels across the Mediterranean Basin. Atmos Environ. 43(28):4266–77. doi: https://doi.org/10.1016/j.atmosenv.2009.06.013.

Querol X, Perez N, Reche C, Ealo M, Ripoll A, Tur J et al. (2019a). African dust and air quality over Spain: is it only dust that matters? Sci Total Environ. 686:737–52. doi: 10.1016/j.scitotenv.2019.05.349.

Querol X, Tobías A, Pérez N, Karanasiou A, Amato F, Stafoggia M et al. (2019b). Monitoring the impact of desert dust outbreaks for air quality for health studies. Environ Int. 130:104867. doi: 10.1016/j.envint.2019.05.061.

Rajan D, Mathurapote N, Putthasri W, Posayanonda T, Pinprateep P, de Courcelles S et al. (2017). The triangle that moves the mountain: nine years of Thailand's National Health Assembly (2008–2016). Geneva: World Health Organization (https://apps.who.int/iris/handle/10665/260464, accessed 7 December 2020).

Rich DQ, Frampton MW, Balmes JR, Bromberg PA, Arjomandi M, Hazucha MJ et al. (2020). Multicenter Ozone Study in oldEr Subjects (MOSES): part 2. Effects of personal and ambient concentrations of ozone and other pollutants on cardiovascular and pulmonary function. Boston (MA): Health Effects Institute (Research report 192, Part 2; https://www.healtheffects.org/system/files/moses-rr-192-pt2_0.pdf, accessed 12 July 2021).

Rodríguez S, Alastuey A, Alonso-Pérez S, Querol X, Cuevas E, Abreu-Afonso J et al. (2011). Transport of desert dust mixed with North African industrial pollutants in the subtropical Saharan Air Layer. Atmos Chem Phys. 11(13):6663–85. doi: https://doi.org/10.5194/acp-11-6663-2011.

Rogers D, Tsirkunov V (2010). Global assessment report on disaster risk reduction. Global assessment report on disaster risk reduction: costs and benefits of early warning systems. Washington (DC): International Strategy for Disaster Reduction and the World Bank (https://documents1.worldbank.org/curated/en/609951468330279598/pdf/693580ESW0P1230aster0Risk0Reduction.pdf, accessed 12 July 2020).

Rojas-Rueda D, Nieuwenhuijsen MJ, Gascon M, Perez-Leon D, Mudu P (2019). Green spaces and mortality: a systematic review and meta-analysis of cohort studies. Lancet Planet Health. 3(11):e469–77. doi: 10.1016/S2542-5196(19)30215-3.

Romieu I, Gouveia N, Cifuentes LA, de Leon AP, Junger W, Vera J et al. (2012). Multicity study of air pollution and mortality in Latin America (the ESCALA study). Res Rep Health Eff Inst. (171):5–86. PMID: 23311234.

Rosenlund M, Picciotto S, Forastiere F, Stafoggia M, Perucci CA (2008). Traffic-related air pollution in relation to incidence and prognosis of coronary heart disease. Epidemiology. 19(1):121–8. doi: 10.1097/EDE.0b013e31815c1921.

Rothman KJ, Greenland S (2018). Planning study size based on precision rather than power. Epidemiology. 29(5):599–603. doi: 10.1097/EDE.0000000000000876.

Sacks JD, Fann N, Gumy S, Kim I, Ruggeri G, Mudu P (2020). Quantifying the public health benefits of reducing air pollution: critically assessing the features and capabilities of WHO's AirQ+ and US EPA's Environmental Benefits Mapping and Analysis Program–community edition (BenMAP-CE). Atmosphere (Basel). 11(5):1–15. doi: 10.3390/atmos11050516.

Samet JM (2010). Urban air quality. In: Vlahov D, Boufford JI, Pearson CE, Norris L, editors. Urban health: global perspectives. Hoboken (NJ): John Wiley & Sons: 317–38.

Samoli E, Peng R, Ramsay T, Pipikou M, Touloumi G, Dominici F et al. (2008). Acute effects of ambient particulate matter on mortality in Europe and North America: results from the APHENA study. Environ Health Perspect. 116(11):1480–6. doi: 10.1289/ehp.11345.

Saracci R (2017). The hazards of hazard identification in environmental epidemiology. Environ Health. 16(1):85. doi: 10.1186/s12940-017-0296-3.

Schneider A, Cyrys J, Breitner S, Kraus U, Peters A (2018). Quantifizierung von umweltbedingten Krankheitslasten aufgrund der Stickstoffdioxid-Exposition in Deutschland [Quantification of environmental burdens of disease due to nitrogen dioxide exposure in Germany]. Dessau-Roßlau: Umweltbundesamt [German Environment Agency] (https://www.umweltbundesamt.de/sites/default/files/medien/421/publikationen/abschlussbericht_no2_krankheitslast_final_2018_03_05.pdf, accessed 15 March 2021).

Schünemann H, Brożek J, Guyatt G, Oxman A, editors (2013). Handbook for grading the quality of evidence and the strength of recommendations using the GRADE approach (updated October 2013). Hamilton: GRADE Working Group (gdt.guidelinedevelopment.org/app/handbook/handbook.html, accessed 4 November 2020).

Selmi W, Weber C, Rivière E, Blond N, Mehdi L, Nowak D (2016). Air pollution removal by trees in public green spaces in Strasbourg city, France. Urban For Urban Green. 17:192–201. doi: https://doi.org/10.1016/j.ufug.2016.04.010.

Shaddick G, Thomas ML, Amini H, Broday D, Cohen A, Frostad J et al. (2018). Data integration for the assessment of population exposure to ambient air pollution for global burden of disease assessment. Environ Sci Technol. 52(16):9069–78. doi: 10.1021/acs.est.8b02864.

Sheehan MC, Lam J, Navas-Acien A, Chang HH (2016). Ambient air pollution epidemiology systematic review and meta-analysis: a review of reporting and methods practice. Environ Int. 92–93:647–56. doi: 10.1016/j.envint.2016.02.016.

Steenland K, Schubauer-Berigan MK, Vermeulen R, Lunn RM, Straif K, Zahm S et al. (2020). Risk of bias assessments and evidence syntheses for observational epidemiologic studies of environmental and occupational exposures: strengths and limitations. Environ Health Perspect. 128(9):095002. doi: 10.1289/EHP6980.

Straif K, Cohen A, Samet J, editors (2013). Air pollution and cancer. Lyon: International Agency for Research on Cancer (IARC Scientific Publications; 161; https://publications.iarc.fr/Book-And-Report-Series/Iarc-Scientific-Publications/Air-Pollution-And-Cancer-2013, accessed July).

Tanaka TY, Chiba M (2006). A numerical study of the contributions of dust source regions to the global dust budget. Glob Planet Change. 52(1–4):88–104. doi: https://doi.org/10.1016/j.gloplacha.2006.02.002.

Thinking Outside the Box team (2019). Ambient ultrafine particles: evidence for policy makers. Pfinztal: European Federation of Clean Air and Environmental Protection Associations (White paper; https://efca.net/files/WHITE%20PAPER-UFP%20evidence%20for%20policy%20makers%20(25%20OCT).pdf, accessed 7 August 2020).

Thurston GD, Ahn J, Cromar KR, Shao Y, Reynolds HR, Jerrett M et al. (2016a). Ambient particulate matter air pollution exposure and mortality in the NIH-AARP diet and health cohort. Environ Health Perspect. 124(4):484–90. doi: 10.1289/ehp.1509676.

Thurston GD, Burnett RT, Turner MC, Shi Y, Krewski D, Lall R et al. (2016b). Ischemic heart disease mortality and long-term exposure to source-related components of US fine particle air pollution. Environ Health Perspect. 124(6):785–94. doi: 10.1289/ehp.1509777.

Thurston GD, Kipen H, Annesi-Maesano I, Balmes J, Brook RD, Cromar K et al. (2017). A joint ERS/ATS policy statement: what constitutes an adverse health effect of air pollution? An analytical framework. Eur Respir J. 49(1):1600419. doi: 10.1183/13993003.00419-2016.

Tobías A, Stafoggia M (2020). Modeling desert dust exposures in epidemiologic short-term health effects studies. Epidemiology. 31:788–95. doi: 10.1097/EDE.0000000000001255.

Tobias A, Karanasiou A, Amato F, Roqué M, Querol X (2019a). Health effects of desert dust and sand storms: a systematic review and meta-analysis protocol. BMJ Open. 9(7):e029876. doi: 10.1136/bmjopen-2019-029876.

Tobias A, Karanasiou A, Amato F, Querol X (2019b). Health effects of desert dust and sand storms: a systematic review and meta-analysis. Environ Epidemiol. 3:396. doi: 10.1097/01.EE9.0000610424.75648.58.

Tonne C, Wilkinson P (2013). Long-term exposure to air pollution is associated with survival following acute coronary syndrome. Eur Heart J. 34(17):1306–11. doi: 10.1093/eurheartj/ehs480.

Tsai SS, Chen PS, Yang YH, Liou SH, Wu TN, Sung FC et al. (2012). Air pollution and hospital admissions for myocardial infarction: are there potentially sensitive groups? J Toxicol Environ Health A. 75(4):242–51. doi: 10.1080/15287394.2012.641202.

Tseng E, Ho WC, Lin MH, Cheng TJ, Chen PC, Lin HH (2015). Chronic exposure to particulate matter and risk of cardiovascular mortality: cohort study from Taiwan. BMC Public Health. 15:936. doi: 10.1186/s12889-015-2272-6.

Turner MC, Cohen A, Jerrett M, Gapstur SM, Diver WR, Pope CA III et al. (2014). Interactions between cigarette smoking and fine particulate matter in the risk of lung cancer mortality in Cancer Prevention Study II. Am J Epidemiol. 180(12):1145–9. doi: 10.1093/aje/kwu275.

Turner MC, Jerrett M, Pope CA III, Krewski D, Gapstur SM, Diver WR et al. (2016). Long-term ozone exposure and mortality in a large prospective study. Am J Respir Crit Care Med. 193(10):1134–42. doi: 10.1164/rccm.201508-1633OC.

Ueda K, Nagasawa S-Y, Nitta H, Miura K, Ueshima H (2012). Exposure to particulate matter and long-term risk of cardiovascular mortality in Japan: NIPPON DATA80. J Atheroscler Thromb. 19(3):246–54. doi: 10.5551/jat.9506.

UN (1948). Universal declaration of human rights. New York (NY): United Nations (https://www.un.org/en/about-us/universal-declaration-of-human-rights, accessed 9 December 2020).

UN (2015). Draft outcome document of the United Nations summit for the adoption of the post-2015 development agenda. New York (NY): United Nations (United Nations General Assembly draft resolution A/69/L.85; https://digitallibrary.un.org/record/800852, accessed 9 December 2020).

UN (2016). Combating sand and dust storms. New York (NY): United Nations (United Nations General Assembly resolution A/RES/70/195; https://undocs.org/en/A/RES/70/195, accessed 9 December 2020).

UN (2017). Combating sand and dust storms. New York (NY): United Nations (United Nations General Assembly resolution A/RES/71/219 https://undocs.org/pdf?symbol=en/a/res/71/219, accessed 9 December 2020).

UN (2018a). Political declaration of the third high-level meeting of the General Assembly on the prevention and control of non-communicable diseases. New York (NY): United Nations (United Nations General Assembly resolution A/RES/73/2; https://www.un.org/en/ga/search/view_doc.asp?symbol=A/RES/73/2, accessed 10 July 2021).

UN (2018b). Combating sand and dust storms. New York (NY): United Nations (United Nations General Assembly resolution A/RES/72/225; https://undocs.org/pdf?symbol=en/A/RES/72/225, accessed 9 December 2020).

UN (2019a) Issue of human rights obligations relating to the enjoyment of a safe, clean, healthy and sustainable environment. New York (NY): United Nations (A/HRC/40/55; https://undocs.org/en/A/HRC/40/55, accessed 20 February 2021).

UN (2019b). Combating sand and dust storms. New York (NY): United Nations (United Nations General Assembly resolution A/RES/73/237; https://undocs.org/en/A/RES/73/237, accessed 9 December 2020).

UN Statistics Division (2020). Global indicator framework for the Sustainable Development Goals and targets of the 2030 Agenda for Sustainable Development. New York (NY): UN Statistics Division; 2020 (A/RES/71/313, E/CN.3/2018/2, E/CN.3/2019/2, E/CN.3/2020/2; https://unstats.un.org/sdgs/indicators/Global%20Indicator%20Framework%20after%202020%20review_Eng.pdf, accessed 12 July 2021).

UNECE (2011). Strengthening cooperation with regional air pollution networks and initiatives outside the convention. Geneva: United Nations Economic Commission for Europe (Informal document No. 12; https://www.unece.org/fileadmin/DAM/env/documents/2011/eb/eb/n_12.pdf, accessed 9 December 2020).

UNEP (2014). Strengthening the role of the United Nations Environment Programme in promoting air quality. Nairobi: United Nations Environment Programme (United Nations Environment Assembly resolution 1/7; https://www.informea.org/en/decision/strengthening-role-united-nations-environment-programme-promoting-air-quality, accessed 9 December 2020).

UNEP (2016a). Sand and dust storms. Nairobi: United Nations Environment Programme (United Nations Environment Assembly resolution UNEP/EA.2/Res.21; https://wedocs.unep.org/handle/20.500.11822/11194?show=full, accessed 9 December 2020).

UNEP (2016b). Sand and dust storms. Nairobi: United Nations Environment Programme (UNEA-2 Factsheet; https://wedocs.unep.org/bitstream/handle/20.500.11822/7608/sand.pdf?sequence=3&amp%3BisAllowed=, accessed 9 December 2020).

UNEP (2018). Preventing and reducing air pollution to improve air quality globally. Nairobi: United Nations Environment Programme (United Nations Environment Assembly resolution UNEP/EA.3/Res.8; https://wedocs.unep.org/handle/20.500.11822/31023, accessed 9 December 2020).

UNEP (2020). Used vehicles and the environment. A global overview of used light duty vehicles: flow, scale and regulation. Nairobi: United Nations Environment Programme (https://www.unep.org/resources/report/global-trade-used-vehicles-report, accessed 18 November 2020).

UNEP, WMO, UNCCD (2016). Global assessment of sand and dust storms. Nairobi: United Nation Environment Programme (https://uneplive.unep.org/redesign/media/docs/assessments/global_assessment_of_sand_and_dust_storms.pdf, accessed 9 December 2020).

US EPA (1993). Air quality criteria for oxides of nitrogen. Research Triangle Park (NC): United States Environmental Protection Agency (EPA/600/8-91/049aF-cF. 3v).

US EPA (1995). Air quality criteria for ozone and related photochemical oxidants. Research Triangle Park (NC): United States Environmental Protection Agency (EPA/600/P-93/004aF-cF.3v).

US EPA (2009). Integrated Science Assessment (ISA) for particulate matter (final report, Dec 2009). Washington (DC): United States Environmental Protection Agency (EPA/600/R-08/139F; https://cfpub.epa.gov/ncea/isa/recordisplay.cfm?deid=216546, accessed 9 December 2020).

US EPA (2010). Integrated Science Assessment (ISA) for carbon monoxide. Washington (DC): United States Environmental Protection Agency (EPA/600/R-09/019F; https://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=218686, accessed 5 December 2020).

US EPA (2013). Integrated Science Assessment (ISA) for ozone and related photochemical oxidants (final report, February 2013). Washington (DC): United States Environmental Protection Agency (EPA/600/R-10/076F; https://cfpub.epa.gov/ncea/isa/recordisplay.cfm?deid=247492, accessed 9 December 2020).

US EPA (2015). Integrated Science Assessment (ISA) for sulfur oxides – health criteria (first external review draft, November 2015). Washington (DC): United States Environmental Protection Agency (EPA/600/R-15/066; https://cfpub.epa.gov/ncea/isa/recordisplay.cfm?deid=310044, accessed 9 December 2020)

US EPA (2016). Integrated Science Assessment (ISA) for oxides of nitrogen – health criteria (final report, January 2016). Washington (DC): United States Environmental Protection Agency (EPA/600/R-15/068; https://cfpub.epa.gov/ncea/isa/recordisplay.cfm?deid=310879, accessed 9 December 2020).

US EPA (2017). Integrated Science Assessment (ISA) for sulfur oxides – health criteria. Washington (DC): United States Environmental Protection Agency (EPA/600/R-17/451; https://cfpub.epa.gov/ncea/isa/recordisplay.cfm?deid=338596, accessed 5 December 2020).

US EPA (2019a). Integrated Science Assessment (ISA) for particulate matter (final report, December 2019). Washington (DC): United States Environment Protection Agency (EPA/600/R-19/188; https://www.epa.gov/isa/integrated-science-assessment-isa-particulate-matter, accessed 21 February 2021).

US EPA (2019b). AP-42: Compilation of air emissions factors. In: Air emissions factors and quantification [website]. Washington (DC): United States Environment Protection Agency (https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-compilation-air-emissions-factors, accessed 7 August 2020).

US EPA (2020). Integrated Science Assessment (ISA) for ozone and related photochemical oxidants. Washington (DC): United States Environmental Protection Agency (https://www.epa.gov/isa/integrated-science-assessment-isa-ozone-and-related-photochemical-oxidants, accessed 28 October 2020).

US EPA (2021). Environmental Benefits Mapping and Analysis Program – Community Edition (BenMAP-CE) [website]. Washington (DC): United States Environmental Protection Agency (https://www.epa.gov/benmap, accessed 20 February 2021).

Vahlsing C, Smith KR (2012). Global review of national ambient air quality standards for PM(10) and SO(2) (24 h). Air Qual Atmos Health. 5(4):393–9. doi: 10.1007/s11869-010-0131-2.

van Erp AM, O'Keefe R, Cohen AJ, Warren J (2008). Evaluating the effectiveness of air quality interventions. J of Toxicol Environ Health. Part A. 71(9–10):583–7. doi: 10.1080/15287390801997708.

Vedal S, Campen MJ, McDonald JD, Larson TV, Sampson PD, Sheppard L et al. (2013). National Particle Component Toxicity (NPACT) initiative report on cardiovascular effects. Res Rep Health Eff Inst. (178):5–8. PMID: 24377210.

Vicedo-Cabrera AM, Sera F, Liu C, Armstrong B, Milojevic A, Guo Y et al. (2020). Short term association between ozone and mortality: global two stage time series study in 406 locations in 20 countries. BMJ. 368:m108. doi: 10.1136/bmj.m108. License: CC BY 4.0.

Villeneuve PJ, Weichenthal SA, Crouse D, Miller AB, To T, Martin RV et al. (2015). Long-term exposure to fine particulate matter air pollution and mortality among Canadian women. Epidemiology. 26(4):536–45. doi: 10.1097/EDE.0000000000000294. Copyright © 2015 Wolters Kluwer Health, Inc. All rights reserved (https://journals.lww.com/epidem/Fulltext/2015/07000/Long_term_Exposure_to_Fine_Particulate_Matter_Air.14.aspx, accessed 11 July 2021).

Vohra K, Vodonos A, Schwartz J, Marais EA, Sulprizio MP, Mickley LJ (2021). Global mortality from outdoor fine particle pollution generated by fossil fuel combustion: results from GEOS-Chem. Environ Res. 195:110754. doi: 10.1016/j.envres.2021.110754.

Vrijheid M, Fossati S, Maitre L, Marquez S, Roumeliotaki T, Agier L et al. (2020). Early-life environmental exposures and childhood obesity: an exposome-wide approach. Environ Health Perspect. 128(6):67009. doi: 10.1289/EHP5975.

Weichenthal S, Pinault LL, Burnett RT (2017). Impact of oxidant gases on the relationship between outdoor fine particulate air pollution and nonaccidental, cardiovascular, and respiratory mortality. Sci Rep. 7(1):16401. doi: 10.1038/s41598-017-16770-y.

Weichenthal S, Villeneuve PJ, Burnett RT, van Donkelaar A, Martin RV, Jones RR et al. (2014). Long-term exposure to fine particulate matter: association with nonaccidental and cardiovascular mortality in the agricultural health study cohort. Environ Health Perspect. 122(6):609–15. doi: 10.1289/ehp.1307277.

Whaley P, Nieuwenhuijsen M, Burns J, editors (2021). Update of the WHO global air quality guidelines: systematic reviews. Environ Int. 142(Special issue) (https://www.sciencedirect.com/journal/environment-international/special-issue/10MTC4W8FXJ, accessed 17 June 2021).

WHO (2014a). WHO handbook for guideline development, 2nd edition. Geneva: World Health Organization (https://apps.who.int/iris/handle/10665/145714, accessed 4 November 2020).

WHO (2014b). WHO guidelines for indoor air quality: household fuel combustion. Geneva: World Health Organization (https://apps.who.int/iris/handle/10665/141496, accessed 9 December 2020).

WHO (2014c). Strong recommendations when the evidence is low quality. In: WHO handbook for guideline development, 2nd edition. Geneva: World Health Organization:169–82 (https://apps.who.int/iris/bitstream/handle/10665/145714/9789241548960_chap14_eng.pdf?sequence=5&isAllowed=y, accessed 6 August 2020).

WHO (2014d). Health in All Policies: Helsinki statement. Framework for country action. Geneva: World Health Organization; 2014 (https://apps.who.int/iris/handle/10665/112636, accessed 5 March 2021).

WHO (2015). Resolution WHA68.8. Health and the environment: addressing the health impact of air pollution. Geneva: World Health Organization (https://apps.who.int/iris/handle/10665/253237, accessed 19 November 2020).

WHO (2016a). Health and the environment: road map for an enhanced global response to the adverse health effects of air pollution. In: Sixty-ninth World Health Assembly, Geneva, 23–28 May 2016. Resolutions and decisions, annexes. Geneva: World Health Organization (https://apps.who.int/iris/handle/10665/259134, accessed 6 March 2021).

WHO (2016b). International Statistical Classification of Diseases and Related Health Problems, tenth revision, 2016 version [website]. Geneva: World Health Organization; 2016 (https://icd.who.int/browse10/2016/en, accessed 7 March 2021).

WHO (2017). Communicating risk in public health emergencies: a WHO guideline for emergency risk communication (ERC) policy and practice. Geneva: World Health Organization (https://apps.who.int/iris/handle/10665/259807, accessed 3 March 2021).

WHO (2018). Burden of disease from ambient air pollution for 2016, version 2. April 2018. Geneva: World Health Organization (https://www.who.int/airpollution/data/AAP_BoD_results_May2018_final.pdf?ua=1, accessed 17 March 2021).

WHO (2019a). Compendium of WHO malaria guidance: prevention, diagnosis, treatment, surveillance and elimination. Geneva: World Health Organization (https://apps.who.int/iris/handle/10665/312082, accessed 10 December 2020).

WHO (2019b). WHO report on the global tobacco epidemic 2019: offer help to quit tobacco use. Geneva: World Health Organization (https://apps.who.int/iris/handle/10665/326043, accessed 17 November 2020).

WHO (2020a). Personal interventions and risk communication on air pollution. Geneva: World Health Organization (https://apps.who.int/iris/handle/10665/333781, accessed 21 June 2021).

WHO (2020b). Health equity. In: Social determinants of health [website]. Geneva: World Health Organization (https://www.who.int/health-topics/social-determinants-of-health#tab=tab_3, accessed 17 June 2021).

WHO (2020c). Urban Health Initiative [website]. Geneva: World Health Organization; 2020 (https://www.who.int/initiatives/urban-health-initiative, accessed 28 June 2021).

WHO (2020d). Call for experts: Global Air Pollution and Health – Technical Advisory Group [website]. Geneva: World Health Organization (https://www.who.int/news-room/articles-detail/call-for-experts-global-air-pollution-and-health-technical-advisory-group, accessed 11 July 2021).

WHO (2021a). WHO Global Ambient Air Quality Database [online database]. Geneva: World Health Organization (https://www.who.int/data/gho/data/themes/air-pollution/who-air-quality-database, accessed 10 September 2021).

WHO (2021b). National air quality standards [website]. Geneva: World Health Organization (https://www.who.int/tools/air-quality-standards, accessed 10 July 2021).

WHO, CCAC, UNEP (2018). Breathelife campaign [website]. Geneva: World Health Organization (https://breathelife2030.org/, accessed 27 June 2021).

WHO Global Air Quality Guidelines Working Group on Certainty of Evidence Assessment (2020). Approach to assessing the certainty of evidence from systematic reviews informing WHO global air quality guidelines. Amsterdam: Elsevier (https://ars.els-cdn.com/content/image/1-s2.0-S0160412020318316-mmc4.pdf, accessed 21 July 2020).

WHO Regional Office for Europe (1987). Air quality guidelines for Europe. Copenhagen: WHO Regional Office for Europe (https://apps.who.int/iris/handle/10665/107364, accessed 25 June 2021).

WHO Regional Office for Europe (1998). Guidance for setting air quality standards. Report on a WHO Working Group. Copenhagen: WHO Regional Office for Europe (EUR/ICP/EHPM 02 01 02; https://apps.who.int/iris/handle/10665/108084, accessed 24 June 2021).

WHO Regional Office for Europe (1999). Implementing national environmental health action plans in partnership: Third Ministerial Conference on Environment and Health, London, 16–18 June 1999. Copenhagen: WHO Regional Office for Europe (https://apps.who.int/iris/handle/10665/108214, accessed 7 December 2020).

WHO Regional Office for Europe (2000a). Air quality guidelines for Europe, 2nd edition. Copenhagen: WHO Regional Office for Europe (https://apps.who.int/iris/handle/10665/107335, accessed 24 June 2021).

WHO Regional Office for Europe (2000b). Use of the guidelines in protecting public health. In: Air quality guidelines, 2nd edition. Copenhagen: WHO Regional Office for Europe:41–55. (https://apps.who.int/iris/handle/10665/107335, accessed 9 December 2020).

WHO Regional Office for Europe (2006). Air quality guidelines – global update 2005. Particulate matter, ozone, nitrogen dioxide and sulfur dioxide. Copenhagen: WHO Regional Office for Europe (https://apps.who.int/iris/handle/10665/107823, accessed 9 December 2020).

WHO Regional Office for Europe (2009). WHO guidelines for indoor air quality: dampness and mould. Copenhagen: WHO Regional Office for Europe (https://apps.who.int/iris/handle/10665/164348, accessed 17 June 2021).

WHO Regional Office for Europe (2010). WHO guidelines for indoor air quality: selected pollutants. Copenhagen: WHO Regional Office for Europe (https://apps.who.int/iris/handle/10665/260127, accessed 24 June 2021).

WHO Regional Office for Europe (2013a). Review of evidence on health aspects of air pollution – REVIHAAP project. Copenhagen: WHO Regional Office for Europe (Technical report; https://apps.who.int/iris/handle/10665/341712, accessed 17 June 2021).

WHO Regional Office for Europe (2013b). Health and environment: communicating the risks. Copenhagen: WHO Regional Office for Europe (https://apps.who.int/iris/handle/10665/108629, accessed 18 February 2021).

WHO Regional Office for Europe (2016a). WHO expert consultation: available evidence for the future update of the WHO global air quality guidelines (AQGs). Copenhagen: WHO Regional Office for Europe (https://apps.who.int/iris/handle/10665/341714, accessed 17 June 2021).

WHO Regional Office for Europe (2016b). Health risk assessment of air pollution: general principles. Copenhagen: WHO Regional Office for Europe (https://apps.who.int/iris/handle/10665/329677, accessed 9 December 2020).

WHO Regional Office for Europe (2017). Evolution of WHO air quality guidelines: past, present and future. Copenhagen: WHO Regional Office for Europe (https://apps.who.int/iris/handle/10665/341912, accessed 10 July 2021).

WHO Regional Office for Europe (2018). Multisectoral and intersectoral action for improved health and well-being for all: mapping of the WHO European Region. Governance for a sustainable future: improving health and well-being for all. Final report. Copenhagen: WHO Regional Office for Europe (https://apps.who.int/iris/handle/10665/341715, accessed 17 June 2021).

WHO Regional Office for Europe (2020). Risk of bias assessment instrument for systematic reviews informing WHO global air quality guidelines. Copenhagen: WHO Regional Office for Europe (https://apps.who.int/iris/handle/10665/341717, accessed 17 June 2021).

WHO Regional Office for Europe (2021a). AirQ+: software tool for health risk assessment of air pollution [website]. Copenhagen: WHO Regional Office for Europe (https://www.euro.who.int/en/health-topics/environment-and-health/air-quality/activities/airq-software-tool-for-health-risk-assessment-of-air-pollution, accessed 20 February 2021).

WHO Regional Office for Europe (2021b). Health aspects of long-range transboundary air pollution [website]. Copenhagen: WHO Regional Office for Europe (https://www.euro.who.int/en/health-topics/environment-and-health/air-quality/activities/health-aspects-of-long-range-transboundary-air-pollution, accessed 10 July 2021).

WMO (2020a). Sand and dust storms [website]. Geneva: World Meteorological Organization (https://public.wmo.int/en/our-mandate/focus-areas/environment/SDS, accessed 10 December 2020).

WMO (2020b). Dust storm or sandstorm [website]. Geneva: World Meteorological Organization (https://cloudatlas.wmo.int/en/dust-storm-or-sandstorm.html, accessed 10 December 2020).

WMO (2020c). WMO Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS) [website]. Geneva: World Meteorological Organization (https://community.wmo.int/wwrp-gaw-sds, accessed 10 December 2020).

Wong CM, Vichit-Vadakan N, Kan H, Qian Z (2008). Public Health and Air Pollution in Asia (PAPA): a multicity study of short-term effects of air pollution on mortality. Environ Health Perspect. 116(9):1195–202. doi: 10.1289/ehp.11257.

Woodruff TJ, Sutton P (2011). An evidence-based medicine methodology to bridge the gap between clinical and environmental health sciences. Health Aff (Millwood). 30(5):931–7. doi: 10.1377/hlthaff.2010.1219.

World Bank (2014). Reducing black carbon emissions from diesel vehicles: impacts, control strategies, and cost benefit analysis. Washington (DC): World Bank (http://documents1.worldbank.org/curated/en/329901468151500078/pdf/864850WP00PUBL0l0report002April2014.pdf, accessed 18 February 2021).

World Bank (2016). The cost of air pollution: strengthening the economic case for action. Washington (DC): World Bank (https://documents.worldbank.org/en/publication/documents-reports/documentdetail/781521473177013155/the-cost-of-air-pollution-strengthening-the-economic-case-for-action, accessed 17 March 2021).

World Bank (2019). Sand and dust storms in the Middle East and North Africa Region: sources, costs, and solutions. Washington (DC): World Bank (http://documents1.worldbank.org/curated/en/483941576489819272/pdf/Sand-and-Dust-Storms-in-the-Middle-East-and-North-Africa-MENA-Region-Sources-Costs-and-Solutions.pdf, accessed 13 March 2021).

World Bank (2021). The world by income and region [website]. Washington (DC): World Bank (https://datatopics.worldbank.org/world-development-indicators/the-world-by-income-and-region.html, accessed 7 July 2021).

Yang B-Y, Fan S, Thiering E, Seissler J, Nowak D, Dong G-H et al. (2020). Ambient air pollution and diabetes: a systematic review and meta-analysis. Environ Res. 180:108817. doi: 10.1016/j.envres.2019.108817.

Yang J, McBride J, Zhou J, Sun Z (2005). The urban forest in Beijing and its role in air pollution reduction. Urban For Urban Green. 3(2):65–78. doi: https://doi.org/10.1016/j.ufug.2004.09.001.

Yang J, Zhou M, Li M, Yin P, Hu J, Zhang C et al. (2020). Fine particulate matter constituents and cause-specific mortality in China: a nationwide modelling study. Environ Int. 143:105927. doi: 10.1016/j.envint.2020.105927.

Yang X, Liang F, Li J, Chen J, Liu F, Huang K et al. (2020). Associations of long-term exposure to ambient $PM_{2.5}$ with mortality in Chinese adults: a pooled analysis of cohorts in the China-PAR project. Environ Int. 138:105589. doi: 10.1016/j.envint.2020.105589.

Yang Y, Tang R, Qiu H, Lai P-C, Wong P, Thach T-Q et al. (2018). Long term exposure to air pollution and mortality in an elderly cohort in Hong Kong. Environ Int. 117:99–106. doi: 10.1016/j.envint.2018.04.034.

Yin P, Brauer M, Cohen A, Burnett RT, Liu J, Liu Y et al. (2017). Long-term fine particulate matter exposure and nonaccidental and cause-specific mortality in a large national cohort of Chinese men. Environ Health Perspect. 125(11):117002. doi: 10.1289/EHP1673.

Yorifuji T, Kashima S, Tsuda T, Ishikawa-Takata K, Ohta T, Tsuruta K et al. (2013). Long-term exposure to traffic-related air pollution and the risk of death from hemorrhagic stroke and lung cancer in Shizuoka, Japan. Sci Total Environ. 443:397–402. doi: 10.1016/j.scitotenv.2012.10.088.

Zhang Q, Jiang X, Tong D, Davis SJ, Zhao H, Geng G et al. (2017). Transboundary health impacts of transported global air pollution and international trade. Nature. 543(7647):705–9. doi: 10.1038/nature21712.

Zhang X, Zhao L, Tong DQ, Wu G, Dan M, Teng B (2016). A systematic review of global desert dust and associated human health effects. Atmosphere. 7(12):158. doi: https://doi.org/10.3390/atmos7120158.

Zheng X-y, Orellano P, Lin H-l, Jiang M, Guan W-j (2021). Short-term exposure to ozone, nitrogen dioxide, and sulphur dioxide and emergency room visits and hospital admissions due to asthma: a systematic review and meta-analysis. Environ Int. 150:106435. doi: 10.1016/j.envint.2021.106435. License: CC BY-NC-ND.

Zhou M, Liu Y, Wang L, Kuang X, Xu X, Kan H (2014). Particulate air pollution and mortality in a cohort of Chinese men. Environ Pollut. 186:1–6. doi: 10.1016/j.envpol.2013.11.010.

Annex 1. Groups engaged during the development of the guidelines

Tables A1.1–A1.7 give details of the various teams involved in the development of the guidelines at various stages.

Table A1.1. WHO steering group

Name (membership period)	Position	Department
Heather Adair-Rohani (2016–2021)	Technical Officer	WHO headquarters, Geneva, Switzerland
Magaran Monzon Bagayoko (2016–2019)	Scientist, Protection of the Human Environment	WHO Regional Office for Africa, Brazzaville, Congo
Carlos Dora (2016–2017)	Coordinator, Interventions for Healthy Environments	WHO headquarters, Geneva, Switzerland
Sophie Gumy (2016–2021)	Technical Officer	WHO headquarters, Geneva, Switzerland
Mohd Nasir Hassan (2016–2017)	Team Leader, Environmental Health	WHO Regional Office for the Western Pacific, Manila, Philippines
Marie-Eve Héroux (2016–2017)	Technical Officer, Air Quality And Noise	WHO Regional Office for Europe, European Centre for Environment and Health, Bonn, Germany
Dorota Jarosińska (2016–2021)	Programme Manager, Living and Working Environments	WHO Regional Office for Europe, European Centre for Environment and Health, Bonn, Germany
Rok Ho Kim (2017–2020)	Coordinator, Health and the Environment	WHO Regional Office for the Western Pacific, Manila, Philippines
Dana Loomis (2016–2017)	Head, Monographs Group	International Agency for Research on Cancer, Lyon, France

Table A1.1 contd

Name (membership period)	Position	Department
Mazen Malkawi (2016–2021)	Regional Adviser, Environmental Health Exposures	WHO Regional Office for the Eastern Mediterranean, Regional Centre for Environmental Health Action, Amman, Jordan
Guy Mbayo (2020–2021)	Technical Officer, Climate Change, Health and Environment	WHO Regional Office for Africa, Brazzaville, Congo
Pierpaolo Mudu (2016–2021)	Technical Officer	WHO Regional Office for Europe, European Centre for Environment and Health, Bonn, Germany
Lesley Jayne Onyon (2016–2021)	Regional Adviser, Occupational and Environmental Epidemiology	WHO Regional Office for South-East Asia, New Delhi, India
Elizabet Paunović (2016–2018)	Head of Office	WHO Regional Office for Europe, European Centre for Environment and Health, Bonn, Germany
Román Pérez Velasco (2017–2021)	Technical Officer, Environment and Health	WHO Regional Office for Europe, European Centre for Environment and Health, Bonn, Germany
Genandrialine Peralta (2020–2021)	Coordinator, Health and the Environment	WHO Regional Office for the Western Pacific, Manila, Philippines
Nathalie Röbbel (2019–2021)	Unit Head, Air Quality and Health	WHO headquarters, Geneva, Switzerland
Agnes Soares da Silva (2016–2021)	Adviser, Environmental Epidemiology	WHO Regional Office for the Americas, Washington, DC, the United States
Nadia Vilahur Chiaraviglio (2016; 2018)	Consultant; Scientist	WHO Regional Office for Europe, European Centre for Environment and Health, Bonn, Germany (2016); International Agency for Research on Cancer, Lyon, France (2018)
Hanna Yang (2017–2020)	Technical Officer, Air Quality	WHO Regional Office for Europe, European Centre for Environment and Health, Bonn, Germany

Table A1.2. Guideline development group

Name (membership period)	Position and affiliation	Sex	Area of expertise specifically sought for guidelines[a]
Marwan Al-Dimashki (2016–2021)	Chief Environmental Consultant, Kuwait Environment Public Authority, Safat, Kuwait	M	3, 6
Emmanuel K.-E. Appoh (2016–2021)	Head, Environmental Quality Department, Environmental Protection Agency, Accra, Ghana	M	5, 6
Kalpana Balakrishnan (2016–2021)	Associate Dean (Research) and Director, WHO Collaborating Centre for Occupational and Environmental Health, Sri Ramachandra University, Chennai, India	F	5, 6
Michael Brauer (2016–2021)	Professor, School of Population and Public Health, University of British Columbia, Vancouver, BC, Canada	M	1, 3
Bert Brunekreef (2016–2021)	Professor Emeritus, Institute for Risk Assessment Sciences, Utrecht University, Utrecht, the Netherlands	M	1, 7
Aaron J. Cohen (2016–2021)	Consulting Principal Scientist, Health Effects Institute, Boston, MA, the United States	M	1, 7
Francesco Forastiere (2016–2021)	Senior Researcher, Institute for Biomedical Research and Innovation, National Research Council (CNR–IRIB), Palermo, Italy	M	1, 2
Lu Fu (2017–2021)	China Director, Clean Air Asia, Beijing, China	F	4–6
Sarath K. Guttikunda (2016–2021)	Director, Urban Emissions, Goa, India	M	1, 3
Mohammad Sadegh Hassanvand (2016–2021)	Associate Professor, Institute for Environment Research, Tehran University of Medical Sciences, Tehran, Iran	M	1, 3
Marie-Eve Héroux (2017–2021)	Head, Air Quality Assessment Section, Health Canada, Ottawa, ON, Canada	F	1, 6, 7
Wei Huang (2016–2021)	Professor, School of Public Health, Peking University, Beijing, China	F	2, 6

Table A1.2 contd

Name (membership period)	Position and affiliation	Sex	Area of expertise specifically sought for guidelines[a]
Haidong Kan (2016–2021)	Professor and Director, School of Public Health, Fudan University, Shanghai, China	M	1, 5
Nguyen Thi Kim Oanh (2016–2021)	Professor, Environmental Engineering and Management, Asian Institute of Technology, Pathumthani, Thailand	F	3
Michał Krzyżanowski (2016–2021)	Visiting Professor, School of Public Health, Imperial College London, London, England, the United Kingdom	M	1, 6, 7
Nino Künzli (2016–2021)	Professor and Unit Head, Education and Training, Swiss Tropical and Public Health Institute (Swiss TPH) and University of Basel, Basel, Switzerland	M	1
Thomas J. Luben (2016–2021)	Senior Epidemiologist, United States Environmental Protection Agency, Research Triangle Park, NC, the United States	M	1, 7
Lidia Morawska (2016–2021)	Distinguished Professor and Director, International Laboratory for Air Quality and Health, Queensland University of Technology, Brisbane, QLD, Australia	F	3, 7
Kaye Patdu (2016–2017)	Head of Programs, Clean Air Asia, Manila, Philippines	F	5, 6
Pippa Powell (2016–2021)	Director, European Lung Foundation, Sheffield, England, the United Kingdom	F	5
Horacio Riojas-Rodríguez (2016–2021)	Environmental Health Director, National Institute of Public Health (INSP), Cuernavaca, Mexico	M	1, 3–5
Jonathan Samet (2016–2021)	Dean and Professor, Colorado School of Public Health, Aurora, CO, the United States	M	1, 6
Martin Williams[b] (2016–2020)	Professor, School of Public Health, Imperial College London, London, England, the United Kingdom	M	3, 6
Caradee Y. Wright (2016–2021)	Senior Specialist Scientist, Environment and Health Research Unit, South African Medical Research Council (SAMRC), Pretoria, South Africa	F	3

Table A1.2 contd

Name (membership period)	Position and affiliation	Sex	Area of expertise specifically sought for guidelines[a]
Xia Wan (2016–2021)	Professor, Peking Union Medical College, School of Basic Medicine, Beijing, China	F	1
André Zuber (2016–2017)	Policy Officer, Industrial Emissions, Air Quality & Noise Unit, Directorate-General for Environment, European Commission, Brussels, Belgium	M	6

[a] Area of expertise/interest: 1. Health effects of air pollution – epidemiological evidence and/or risk assessment; 2. Health effects of air pollution – toxicological and clinical evidence; 3. Air pollution emissions and atmospheric chemistry/exposure assessment; 4. Best practices, interventions and/or health economics; 5. Vulnerable groups, equity, human rights, gender and/or developing country perspective; 6. End-user perspective, policy implications, implementation of the guidelines; 7. Methodology and guideline development.
[b] Deceased 21 September 2020.

Table A1.3. Systematic review team[a]

Systematic review topic	Experts involved	Affiliation
Long-term exposure to $PM_{2.5}$ and PM_{10} All-cause and cause-specific mortality	Jie Chen	Institute for Risk Assessment Sciences, Utrecht University, Utrecht, the Netherlands
	Gerard Hoek	Institute for Risk Assessment Sciences, Utrecht University, Utrecht, the Netherlands
Long-term exposure to O_3 and NO_2 All-cause and respiratory mortality	Richard Atkinson	Population Health Research Institute, St George's, University of London, London, England, the United Kingdom
	Peijue Huangfu	Population Health Research Institute, St George's, University of London, London, England, the United Kingdom
Short-term exposure to $PM_{2.5}$, PM_{10}, O_3 and NO_2 All-cause and cause-specific mortality	Ariel Bardach	Institute for Clinical Effectiveness and Health Policy (IECS-CONICET), Buenos Aires, Argentina
	Agustín Ciapponi	Institute for Clinical Effectiveness and Health Policy (IECS-CONICET), Buenos Aires, Argentina
	Pablo Orellano	Centre for Research and Technology Transfer San Nicolás, National Technology University (UTN-CONICET), San Nicolás, Argentina
	Nancy Quaranta	San Nicolás Regional Faculty, National Technology University (UTN), San Nicolás, Argentina Scientific Research Commission of the Province of Buenos Aires, La Plata, Argentina
	Julieta Reynoso	San Felipe General Hospital, San Nicolás, Argentina
Short-term exposure to SO_2 All-cause and respiratory mortality	Pablo Orellano	Centre for Research and Technology Transfer San Nicolás, National Technology University (UTN-CONICET), San Nicolás, Argentina
	Nancy Quaranta	San Nicolás Regional Faculty, National Technology University (UTN), San Nicolás, Argentina Scientific Research Commission of the Province of Buenos Aires, La Plata, Argentina
	Julieta Reynoso	San Felipe General Hospital, San Nicolás, Argentina

Table A1.3 contd

Systematic review topic	Experts involved	**Affiliation**
Short-term exposure to O_3, NO_2 and SO_2 Emergency department visits and hospital admissions due to asthma	Wei-jie Guan	State Key Laboratory of Respiratory Disease, National Clinical Research Center for Respiratory Disease, Guangzhou Institute of Respiratory Health, First Affiliated Hospital of Guangzhou Medical University, Guangzhou Medical University, Guangzhou, China
	Mei Jiang	State Key Laboratory of Respiratory Disease, National Clinical Research Center for Respiratory Disease, Guangzhou Institute of Respiratory Health, First Affiliated Hospital of Guangzhou Medical University, Guangzhou Medical University, Guangzhou, China
	Hua-liang Lin	Sun Yat-sen University, Guangzhou, China
	Pablo Orellano	Centre for Research and Technology Transfer San Nicolás, National Technology University (UTN-CONICET), San Nicolás, Argentina
	Xue-yan Zheng	Institute of Non-communicable Disease Control and Prevention, Guangdong Provincial Center for Disease Control And Prevention, Guangdong, China
Short-term exposure to CO Myocardial infarction	Kuan Ken Lee	British Heart Foundation Centre for Cardiovascular Science, University of Edinburgh, Edinburgh, Scotland, the United Kingdom
	Mark R. Miller	British Heart Foundation Centre for Cardiovascular Science, University of Edinburgh, Edinburgh, Scotland, the United Kingdom
	Nicholas L. Mills	British Heart Foundation Centre for Cardiovascular Science and the Usher Institute of Population Health Sciences and Informatics, University of Edinburgh, Edinburgh, Scotland, the United Kingdom
	Anoop S.V. Shah	British Heart Foundation Centre for Cardiovascular Science and Usher Institute of Population Health Sciences and Informatics, University of Edinburgh, Edinburgh, Scotland, the United Kingdom
	Nicholas Spath	British Heart Foundation Centre for Cardiovascular Science, University of Edinburgh, Edinburgh, Scotland, the United Kingdom

[a] Specific contributions are reported in the articles published in the special issue of *Environment International*: *Update of the WHO global air quality guidelines: systematic reviews* (Whaley et al., 2021; see main reference list).

Table A1.4. External methodologists

Methodological topic	**Methodologist (period of service)**	**Affiliation**
Systematic review and guideline development (guideline methodology)	Jos Verbeek (2016–2020)	Coordinating Editor, Cochrane Work Review Group, Kuopio, Finland
RoB assessment	Rebecca Morgan (2017–2019)	Assistant Professor, McMaster University, Hamilton, ON, Canada

Table A1.5. External review group – individual experts

Name	**Affiliation**	**Sex**	**Area of expertise specifically sought for guidelines**[a]
Samir Afandiyev	Public Health and Reforms Centre, Baku, Azerbaijan	M	2, 3, 6
Mohammad Alolayan	College of Life Sciences, Kuwait University, Kuwait City, Kuwait	M	3, 6
Richard Ballaman	Federal Office of the Environment, Bern, Switzerland	M	6
Jill Baumgartner	Institute for Health and Social Policy, McGill University, Montreal, QC, Canada	F	1, 5
Hanna Boogaard	Health Effects Institute, Boston, MA, the United States	F	1, 3
David M. Broday	Faculty of Civil and Environmental Engineering, Technion – Israel Institute of Technology, Haifa, Israel	M	3
Richard T. Burnett	Population Studies Division, Health Canada, Ottawa, ON, Canada	M	1, 6
Jacob Burns	Institute for Medical Informatics, Biometry and Epidemiology, Pettenkofer School of Public Health, Ludwig-Maximilians-University, Munich, Germany	M	7
Flemming Cassee	National Institute for Public Health and the Environment (RIVM), Bilthoven, the Netherlands	M	2

Table A1.5 contd

Name	Affiliation	Sex	Area of expertise specifically sought for guidelines[a]
Evan Coffman	United States Environmental Protection Agency, Research Triangle Park, NC, the United States	M	1, 7
Séverine Deguen	School of Public Health (EHESP), Rennes, France	F	1, 5
Sagnik Dey	Centre for Atmospheric Sciences, Indian Institute of Technology, New Delhi, India	M	3, 5, 6
Dimitris Evangelopoulos	School of Public Health, Imperial College London, London, England, the United Kingdom	M	1
Mamadou Fall	Faculty of Medicine, Pharmacy and Dentistry, Cheikh Anta Diop University (UCAD), Dakar, Senegal	M	1–3
Neal Fann	United States Environmental Protection Agency, Research Triangle Park, NC, the United States	M	1, 4
Daniela Fecht	School of Public Health, Imperial College London, London, England, the United Kingdom	F	3, 5
Julia Fussell	School of Public Health, Imperial College London, London, England, the United Kingdom	F	2
Davina Ghersi	National Health and Medical Research Council, Canberra, ACT, Australia	F	6, 7
Otto Hänninen	Finnish Institute for Health and Welfare (THL), Helsinki, Finland	M	1, 2, 6
Barbara Hoffmann	Institute for Occupational, Social and Environmental Medicine, Heinrich Heine University of Düsseldorf, Düsseldorf, Germany	F	1, 2
Michael Holland	Ecometrics Research and Consulting, Reading, England, the United Kingdom	M	4, 6
Yun-Chul Hong	Institute of Environmental Medicine, College of Medicine, Seoul National University, Seoul, Republic of Korea	M	1, 2, 6
Bin Jalaludin	School of Public Health and Community Medicine, University of New South Wales, Kensington, NSW, Australia	M	1, 5

Table A1.5 contd

Name	Affiliation	Sex	Area of expertise specifically sought for guidelines[a]
Meltem Kutlar Joss	Swiss TPH, University of Basel, Basel, Switzerland	F	1, 6
Juleen Lam	Department of Health Sciences, California State University, East Bay, Hayward, CA, the United States	F	1, 7
Kin Bong Hubert Lam	Nuffield Department of Population Health, University of Oxford, Oxford, England, the United Kingdom	M	1, 4
Puji Lestari	Institute of Technology Bandung, Bandung, Indonesia	F	3, 6
Morton Lippmann	NYU School of Medicine, New York University, New York, NY, the United States	M	1–3
Sylvia Medina	Public Health France, Saint-Maurice, France	F	1, 6
Rajen Naidoo	School of Nursing and Public Health, University of Kwazulu Natal, Durban, South Africa	M	1, 5, 6
Mark J. Nieuwenhuijsen	Barcelona Institute for Global Health (ISGlobal), Barcelona, Spain	M	1, 3
Jeongim Park	Department of Environmental Health Science, Soonchunhyang University, Asan, Republic of Korea	F	1, 3
Rita Pavasini	Cardiology Centre, University of Ferrara, Ferrara, Italy	F	2
Annette Peters	Helmholtz Zentrum München – German Research Center for Environmental Health, Institute of Epidemiology II, Neuherberg, Germany	F	1, 2
Vincent-Henri Peuch	Copernicus Atmosphere Monitoring Service, European Centre for Medium-Range Weather Forecasts, Reading, England, the United Kingdom	M	3, 6
C. Arden Pope III	College of Family, Home, and Social Sciences, Brigham Young University, Provo, UT, the United States	M	1, 4
Reginald Quansah	School of Public Health, College of Health Sciences, University of Ghana, Legon, Ghana	M	5–7

Table A1.5 contd

Name	Affiliation	Sex	Area of expertise specifically sought for guidelines[a]
Xavier Querol Carceller	Institute of Environmental Assessment and Water Research (IDAEA), Spanish National Research Council (CSIC), Barcelona, Spain	M	3, 4
Matteo Redaelli	Agency for Food, Environmental and Occupational Health & Safety (ANSES), Maisons-Alfort, France	M	1, 7
Eva Rehfuess	Institute for Medical Informatics, Biometry and Epidemiology, Pettenkofer School of Public Health, Ludwig-Maximilians-University Munich, Munich, Germany	F	6, 7
Alexander Romanov	Scientific Research Institute for Atmospheric Air Protection (SRI Atmosphere), Saint Petersburg, Russian Federation	M	3, 6
Anumita Roychowdhury	Centre for Science and Environment (CSE), New Delhi, India	F	4–6
Jason Sacks	United States Environmental Protection Agency, Research Triangle Park, NC, the United States	M	1, 7
Paulo Saldiva	Faculty of Medicine, University of São Paulo, São Paulo, Brazil	M	2
Najat Saliba	Faculty of Arts and Science, American University of Beirut, Beirut, Lebanon	F	3
Andreia C. Santos	London School of Hygiene and Tropical Medicine, University of London, London, England, the United Kingdom	F	4
Jeremy Sarnat	Rollins School of Public Health, Emory University, Atlanta, GA, the United States	M	1, 3
Paul T.J. Scheepers	Radboud Institute for Health Sciences, Nijmegen, the Netherlands	M	2, 7
Srijan Lal Shrestha	Central Department of Statistics, Tribhuvan University, Kirtipur, Kathmandu, Nepal	M	1, 3, 5

Table A1.5 contd

Name	Affiliation	Sex	Area of expertise specifically sought for guidelines[a]
Mónica Silva González	Proklima International, Latin America and the Caribbean, German Corporation for International Cooperation (GIZ), Eschborn, Germany	F	5, 6
Kirk R. Smith[b]	School of Public Health, University of California Berkeley, Berkeley, CA, the United States	M	1, 4, 5
Massimo Stafoggia	Department of Epidemiology, Lazio Region Health Service, Rome, Italy	M	1, 4
David M. Stieb	Air Quality Health Effects Research Section, Health Canada, Vancouver BC, Canada	M	1, 2, 7
Jordi Sunyer	Barcelona Institute for Global Health (ISGlobal), Barcelona, Spain	M	1
Duncan C. Thomas	Keck School of Medicine, University of Southern California, Los Angeles, CA, the United States	M	1, 7
George D. Thurston	NYU School of Medicine, New York University, New York, NY, the United States	M	1
Linwei Tian	School of Public Health, The University of Hong Kong, China, Hong Kong SAR	M	1, 2
Aurelio Tobías Garces	Institute of Environmental Assessment and Water Research (IDAEA), Spanish National Research Council (CSIC), Barcelona, Spain	M	1, 4, 7
Rita Van Dingenen	European Commission Joint Research Centre, Ispra, Italy	F	3
Sotiris Vardoulakis	National Centre for Epidemiology and Population Health, Australian National University, Canberra ACT, Australia	M	1, 4
Giovanni Viegi	Institute of Biomedicine and Molecular Immunology "Alberto Monroy", National Research Council (CNR-IBIM), Palermo, Italy	M	1, 2

Table A1.5 contd

Name	Affiliation	Sex	Area of expertise specifically sought for guidelines[a]
Kuku Voyi	School of Health Systems and Public Health, University of Pretoria, Hatfield, South Africa	F	1, 2, 5
Heather Walton	School of Public Health, Imperial College London, London, England, the United Kingdom	F	1, 6
Paul Whaley	Lancaster Environment Centre, Lancaster University, Lancaster, England, the United Kingdom	M	7
Takashi Yorifuji	Graduate School of Environmental and Life Science, Okayama University, Okayama, Japan	M	1, 2

[a] Area of expertise/interest: 1. Health effects of air pollution – epidemiological evidence and/or risk assessment; 2. Health effects of air pollution – toxicological and clinical evidence; 3. Air pollution emissions and atmospheric chemistry/exposure assessment; 4. Best practices, interventions and/or health economics; 5. Vulnerable groups, equity, human rights, gender and/or developing country perspective; 6. End-user perspective, policy implications, implementation of the guidelines; 7. Methodology and guideline development.
[b] Deceased 15 June 2020.

Table A1.6. External review group – stakeholder organizations

Organization	Location	Area of expertise specifically sought for guidelines[a]
Abu Dhabi Global Environmental Data Initiative (AGEDI)	Abu Dhabi, United Arab Emirates	2, 3
African Centre for Clean Air (ACCA)	Kampala, Uganda	1, 4
Association for Emissions Control by Catalyst (AECC)	Schaerbeek, Belgium	1, 2, 5
Clean Air Asia (CAA)	Manila, the Philippines	1, 2
ClientEarth	London, England, the United Kingdom	3
Concawe	Brussels, Belgium	2, 4, 6

Table A1.6 contd

Organization	Location	Area of expertise specifically sought for guidelines[a]
European Environment Agency (EEA)	Copenhagen, Denmark	3
European Environmental Bureau (EEB)	Brussels, Belgium	3
European Federation of Allergy and Airways Diseases Patients' Associations (EFA)	Brussels, Belgium	4
European Respiratory Society (ERS)	Lausanne, Switzerland	4
Health and Environment Alliance (HEAL)	Brussels, Belgium	3, 4
International Society for Environmental Epidemiology (ISEE)	Herndon, VA, the United States	3, 4
International Transport Forum (ITF)	Paris, France	5
South Asia Co-operative Environment Programme (SACEP)	Colombo, Sri Lanka	3

[a] Area of expertise/interest: 1. Air quality; 2. Climate change; 3. Environment in general; 4. Health; 5. Transport; 6. Energy.

Table A1.7. Working groups[a]

Working group title	Experts involved	Group membership in the process
Risk of Bias Assessment	Bert Brunekreef	Guideline development group
	Aaron J. Cohen	Guideline development group
	Francesco Forastiere	Guideline development group
	Rebecca Morgan	External methodologists
	Jos Verbeek	External methodologists
Working group title	**Experts involved**	**Group membership in the process**
Certainty of Evidence Assessment	Bert Brunekreef	Guideline development group
	Aaron J. Cohen	Guideline development group
	Francesco Forastiere	Guideline development group
	Nino Künzli	Guideline development group
	Rebecca Morgan	External methodologists
	Jos Verbeek	External methodologists
Derivation of Air Quality Guideline Levels and Interim Targets	Bert Brunekreef	Guideline development group
	Aaron J. Cohen	Guideline development group
	Francesco Forastiere	Guideline development group
	Gerard Hoek[b]	Systematic review team
	Nino Künzli	Guideline development group
	Michał Krzyżanowski	Guideline development group
	Jonathan Samet	Guideline development group
	Jos Verbeek (until 2020)	External methodologists
	Martin Williams[c]	Guideline development group
	Caradee Y. Wright	Guideline development group

Table A1.7 contd

Working group title	Experts involved	Group membership in the process
Good Practice Statements	Francesco Forastiere	Guideline development group
	Michał Krzyżanowski	Guideline development group
	Lidia Morawska	Guideline development group
	Martin Williams[c]	Guideline development group
	Xavier Querol Carceller	External review group
	Massimo Stafoggia	External review group
	Aurelio Tobías Garces	External review group

[a] The working groups were coordinated by the members of the WHO Secretariat, Román Pérez Velasco and Dorota Jarosińska, with general assistance from Hanna Yang and specific support from Pierpaolo Mudu on the good practice statements related to SDS. The work produced by the working groups was reviewed by the GDG and by members of the systematic review team and the ERG, where needed.
[b] Technical consultant who supported the work conducted by the working group.
[c] Deceased 21 September 2020.

Annex 2. Assessment of conflict of interest

All external contributors to the guidelines, including members of the GDG, systematic review team, external methodologists and ERG, completed WHO declaration of interest forms in accordance with WHO's policy for experts. Further, WHO technical staff reviewed curricula vitae of candidates for the groups. At the beginning of the GDG meetings, participants declared or updated their competing interests (Table A2.1).

The conflict-of-interest assessment was done according to WHO procedures. If a conflict was declared, an initial review was undertaken by the WHO Secretariat to assess its relevance and significance. A declared conflict of interest is insignificant or minimal if it is unlikely to affect or to be reasonably perceived to affect the expert's judgement. Insignificant or minimal interests are those unrelated or only tangentially related to the subject of the activity or work and its outcome; nominal in amount or inconsequential in importance; or expired and unlikely to affect current behaviour.

The WHO Secretariat reviewed and assessed the declarations, which were cleared through the Office of Compliance, Risk Management and Ethics when required. WHO was of the opinion that these declarations did not constitute conflicts of interest and that the considered experts could participate in the process subject to disclosure of their interests.

The relevant declared interests of members of the GDG are summarized below. Other participants in the process, such as the systematic review team (see the special issue of *Environment International*: *Update of the WHO global air quality guidelines: systematic reviews* (Whaley et al., 2021; see main reference list)) and external methodologists, did not declare relevant interests. Some individual members of the large ERG declared non-significant, relevant interests. However, these interests – as well as those of the stakeholder organizations – were carefully considered in assessing their inputs and comments.

Table A2.1. Summary of relevant interests declared by members of the GDG

Name	Details of interests
Marwan Al-Dimashki	Employed by the Environment Public Authority of Kuwait
Michael Brauer	Consultant for HEI and the British Columbia Lung Association; research support from HEI; travel expenses to meetings of the European Respiratory Society; expert opinions for the Ministry of Justice, Province of Ontario, for the Greater Vancouver Regional District and, on behalf of EcoJustice, on a lawsuit against the Province of Ontario; chair of the Air Pollution Expert Group of the World Heart Federation (2019–present); honorarium paid for by the Electric Power Research Institute to present at its annual meeting regarding the International Agency for Research on Cancer's air pollution monograph
Bert Brunekreef	Research support from the HEI; Chairman of the European Respiratory Society Environment and Health Committee (2014–2017)
Aaron J. Cohen	Formerly employed by HEI; consulting for HEI and Vital Strategies
Francesco Forastiere	Consultant for HEI, Health Canada, World Bank and WHO; member of the European Respiratory Society Environment and Health Committee
Lu Fu	Employed by Clean Air Asia
Mohammad Sadegh Hassanvand	Research support from the Tehran University of Medical Sciences
Marie-Eve Héroux	Employed by Health Canada and formerly employed by WHO (until 2017)
Wei Huang	Consultant for WHO
Michał Krzyżanowski	Consultant for the Frank Bold Society, Health and Environment Alliance, Health Canada, UN Environment, Vital Strategies and WHO; chair of the Policy Committee at the International Society for Environmental Epidemiology (until 2018); member of the Board of the International Joint Policy Committee of the Societies of Epidemiology (until 2018)

Table A2.1 contd

Name	Details of interests
Nino Künzli	President of the Swiss Federal Commission on Air Hygiene; member of the European Respiratory Society Environment and Health Committee (until 2018)
Thomas J. Luben	Travel expenses to meeting paid for by the American Petroleum Institute; expert opinion for the United States Department of Justice on the lawsuit *United States vs Mountain State Carbon, LLC*
Lidia Morawska	Consultant for WHO (March–July 2019)
Kaye Patdu	Employed by Clean Air Asia (until 2017); expert opinion on behalf of Clean Air Asia in the development of $PM_{2.5}$ standards in the Philippines (2013)
Pippa Powell	Employed by the European Lung Foundation
Jonathan Samet	Chair of the Oversight Committee of Long-Term Epidemiological Studies of Air Pollution, HEI
Martin Williams[a]	Consultant for the World Bank; research support from the European Commission
Caradee Y. Wright	Employed by South African Medical Research Council; research support from National Department of Environmental Affairs of South Africa; vice-President of the National Association for Clean Air (until 2018); founder of the Environmental Health Research Network; member of the Public Health Association of South Africa
André Zuber	Employed by the European Commission (until 2017)

[a] Deceased 21 September 2020.

Annex 3. Summaries of systematic reviews of evidence informing the air quality guideline levels

This annex contains the abstracts and certainty of evidence tables from the systematic reviews published in the special issue of *Environment International*: *Update of the WHO global air quality guidelines: systematic reviews* (Whaley et al., 2021; see main reference list), where additional information can be found. The abstracts and tables are provided in this annex courtesy of *Environment International*.

A3.1 Long-term exposure to PM and all-cause and cause-specific mortality: a systematic review and meta-analysis (Chen & Hoek, 2020)

Abstract

As new scientific evidence on health effects of air pollution is generated, air quality guidelines need to be periodically updated. The objective of this review is to support the derivation of updated guidelines by the World Health Organization (WHO) by performing a systematic review of evidence of associations between long-term exposure to particulate matter with diameter under 2.5 µm ($PM_{2.5}$) and particulate matter with diameter under 10 µm (PM_{10}), in relation to all-cause and cause-specific mortality. As there is especially uncertainty about the relationship at the low and high end of the exposure range, the review needed to provide an indication of the shape of the concentration-response function (CRF).

We systematically searched MEDLINE and EMBASE from database inception to 9 October 2018. Articles were checked for eligibility by two reviewers. We included cohort and case-control studies on outdoor air pollution in human populations using individual level data. In addition to natural-cause mortality, we evaluated mortality from circulatory diseases (ischemic heart disease (IHD) and cerebrovascular disease (stroke) also specifically), respiratory diseases (Chronic Obstructive Pulmonary Disease (COPD) and acute lower respiratory

illness (ALRI) also specifically) and lung cancer. A random-effect meta-analysis was performed when at least three studies were available for a specific exposure-outcome pair. Risk of bias was assessed for all included articles using a specifically developed tool coordinated by WHO. Additional analyses were performed to assess consistency across geographic region, explain heterogeneity and explore the shape of the CRF. A GRADE (Grading of Recommendations Assessment, Development and Evaluation) assessment of the body of evidence was made using a specifically developed tool coordinated by WHO.

A large number (N=107) of predominantly cohort studies (N=104) were included after screening more than 3000 abstracts. Studies were conducted globally with the majority of studies from North America (N=62) and Europe (N=25). More studies used $PM_{2.5}$ (N=71) as the exposure metric than PM_{10} (N=42). $PM_{2.5}$ was significantly associated with all causes of death evaluated. The combined Risk Ratio (RR) for $PM_{2.5}$ and natural-cause mortality was 1.08 (95%CI 1.06, 1.09) per 10 μg/m³. Meta analyses of studies conducted at the low mean $PM_{2.5}$ levels (<25, 20, 15, 12, 10 μg/m³) yielded RRs that were similar or higher compared to the overall RR, consistent with the finding of generally linear or supralinear CRFs in individual studies. Pooled RRs were almost identical for studies conducted in North America, Europe and Western Pacific region. PM_{10} was significantly associated with natural cause and most but not all causes of death. Application of the risk of bias tool showed that few studies were at a high risk of bias in any domain. Application of the GRADE tool resulted in an assessment of “high certainty of evidence” for $PM_{2.5}$ with all assessed endpoints except for respiratory mortality (moderate). The evidence was rated as less certain for PM_{10} and cause-specific mortality (“moderate” for circulatory, IHD, COPD and “low” for stroke mortality).

Compared to the previous global WHO evaluation, the evidence base has increased substantially. However studies conducted in low and middle income countries (LMICs) are still limited. There is clear evidence that both $PM_{2.5}$ and PM_{10} were associated with increased mortality from all causes, cardiovascular disease, respiratory disease and lung cancer. Associations remained below the current WHO guideline value of 10 μg/m³ for $PM_{2.5}$.

Systematic review registration number (PROSPERO ID): CRD42018082577.

Table A3.1. Certainty of evidence profile for each exposure–outcome combination

	Reasons for downgrading										Reasons for upgrading						Overall	Final certainty assessment
	A1	Rationale	A2	Rationale	A3	Rationale	A4	Rationale	A5	Rationale	B1	Rationale	B2	Rationale	B3	Rationale		
$PM_{2.5}$ and natural cause	0	Little influence on the overall effect	0	No evidence of indirectness	0	Prediction interval does not include unity	0	Sample size large enough to assess RR with sufficient precision	0	No evidence of publication bias	0	Insufficient basis for upgrading	0	Confounders would shift the RR in both directions	+1	Evidence of increase in risk with increasing exposure	+1	High
PM_{10} and natural cause	0	Little influence on the overall effect	0	No evidence of indirectness	0	Prediction interval does not include unity	0	Sample size large enough to assess RR with sufficient precision	0	No evidence of publication bias	0	Insufficient basis for upgrading	0	Confounders would shift the RR in both directions	+1	Evidence of increase in risk with increasing exposure	+1	High
$PM_{2.5}$ and circulatory	0	Little influence on the overall effect	0	No evidence of indirectness	0	Prediction interval does not include unity	0	Sample size large enough to assess RR with sufficient precision	0	No evidence of publication bias	0	Insufficient basis for upgrading	0	Confounders would shift the RR in both directions	+1	Evidence of increase in risk with increasing exposure	+1	High
PM_{10} and circulatory	0	Little influence on the overall effect	0	No evidence of indirectness	-1	Prediction interval includes unity and larger than twice the CI	0	Sample size large enough to assess RR with sufficient precision	0	No evidence of publication bias	0	Insufficient basis for upgrading	0	Confounders would shift the RR in both directions	+1	Evidence of increase in risk with increasing exposure	0	Moderate

A1 = limitations in studies (risk of bias); A2 = indirectness; A3 = inconsistency; A4 = imprecision; A5 = publication bias.
B1 = large RR; B2 = all confounding decreases observed RR; B3 = concentration–response gradient.
Note: +" indicates an increase in the confidence level; "–" indicates a decrease in the confidence level; "0" indicates no change in the confidence level.

A3.2 Long-term exposure to NO_2 and O_3 and all-cause and respiratory mortality: a systematic review and meta-analysis (Huangfu & Atkinson, 2020)

Abstract

Background: WHO has published several volumes of Global Air Quality Guidelines to provide guidance on the health risks associated with exposure to outdoor air pollution. As new scientific evidence is generated, air quality guidelines need to be periodically revised and, where necessary, updated.

Objectives: The aims of the study were 1) to summarise the available evidence on the effect of long-term exposure to ozone (O_3) and nitrogen dioxide (NO_2) on mortality; 2) and to assess concentration response functions (CRF), their shape and the minimum level of exposures measured in studies to support WHO's update of the air quality guidelines.

Data sources: We conducted a systematic literature search of the Medline, Embase and Web of Science databases following a protocol proposed by WHO and applied Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) guidelines for reporting our results.

Study eligibility criteria: Cohort studies in human populations (including sub-groups at risk) exposed to long-term concentrations of NO_2 and O_3. Outcomes assessed were all-cause, respiratory, Chronic Obstructive Pulmonary Disease (COPD) and Acute Lower Respiratory Infection (ALRI) mortality.

Study appraisal and synthesis methods: Studies included in the meta-analyses were assessed using a new risk of bias instrument developed by a group of experts convened by WHO. Study results are presented in forest plots and quantitative meta-analyses were conducted using random effects models. The certainty of evidence was assessed using a newly developed adaptation of GRADE.

Results: The review identified 2068 studies of which 95 were subject to review with 45 meeting the inclusion criteria. An update in September 2018 identified 159 studies with 1 meeting the inclusion criteria. Of the 46 included studies, 41 reported results for NO_2 and 20 for O_3. The majority of studies were from the USA and Europe with the remainder from Canada, China and Japan. Forty-two studies reported results for all-cause mortality and 22 for respiratory mortality.

Associations for NO_2 and mortality were positive; random-effects summary relative risks (RR) were 1.02 (95% CI: 1.01, 1.04), 1.03 (1.00, 1.05), 1.03 (1.01, 1.04) and 1.06 (1.02, 1.10) per 10 μg/m³ for all-cause (24 cohorts), respiratory (15 cohorts), COPD (9 cohorts) and ALRI (5 cohorts) mortality respectively. The review identified high levels of heterogeneity for all causes of death except COPD. A small number of studies investigated the shape of the concentration–response relationship and generally found little evidence to reject the assumption of linearity across the concentration range.

Studies of O_3 using annual metrics showed the associations with all-cause and respiratory mortality were 0.97 (0.93, 1.02) and 0.99 (0.89, 1.11) per 10 μg/m³ respectively. For studies using peak O_3 metrics, the association with all-cause mortality was 1.01 (1.00, 1.02) and for respiratory mortality 1.02 (0.99, 1.05), each per 10 μg/m³. The review identified high levels of heterogeneity. Few studies investigated the shape of the concentration–response relationship.

Certainty in the associations (adapted GRADE) with mortality was rated low to moderate for each exposure-outcome pair, except for NO_2 and COPD mortality which was rated high.

Limitations: The substantial heterogeneity for most outcomes in the review requires explanation. The evidence base is limited in terms of the geographical spread of the study populations and, for some outcomes, the small number of independent cohorts for meta-analysis precludes meaningful meta-regression to explore causes of heterogeneity. Relatively few studies assessed specifically the shape of the CRF or multi-pollutant models.

Conclusions: The short-comings in the existing literature base makes determining the precise nature (magnitude and linearity) of the associations challenging. Grade assessments were moderate or low for both NO_2 and O_3 for all causes of mortality except for NO_2 and COPD mortality where the certainty of the evidence was judged as high.

Table A3.2. Certainty of evidence profile for NO_2 and all-cause mortality

Domain	Judgement	Down/up grade
Limitations in studies	Twenty-four included studies. Risk of bias moderate because although not all studies adjusted for all confounders, exclusion of high risk of bias studies did not reduce the summary RR	No downgrading
Indirectness	All studies included the desired population, exposures and outcomes	No downgrading
Inconsistency	The 80% prediction interval included 1 & > twice CI. High level of heterogeneity in general population studies. Studies controlling for individual measures of BMI, smoking, SES gave slightly higher, less precise summary RR. Exclusion of patient cohorts (6) did not change summary RR & CI	Downgrade one level
Imprecision	The number of person years in the included studies was greater than 940 000	No downgrading
Publication bias	According to the funnel plot and Egger's test (P<0.1), there were sign of publication bias/funnel plot asymmetry	No downgrading
Large effect size	Summary RR = 1.02. Precision reduced for cohorts with all individual confounder adjustment but not summary estimate. Insufficient information on unmeasured potential confounders available	No upgrading
Plausible confounding towards null	Confounding direction unknown but precision may be affected	No upgrading
Dose–response relation	A linear dose–response relationship was assumed in all studies. 5 studies investigated the shape of the dose–response relationship with no evidence to suggest non-linear. 95% CI for linear RR excluded 1	Upgrade one level
GRADE conclusion	Downgrade one level and upgrade one level	MODERATE CERTAINTY EVIDENCE MEAN RR UNADJUSTED FOR CO-POLLUTANTS EQUALS 1.02 PER 10 μg/m³

Table A3.3. Certainty of evidence profile for NO_2 and respiratory mortality

Domain	Judgement	Down/up grade
Limitations in studies	Fifteen included studies. Risk of bias moderate because although not all studies adjusted for all confounders, exclusion of high risk of bias studies did not alter summary RR	No downgrading
Indirectness	All studies included the desired population, exposures and outcomes	No downgrading
Inconsistency	The 80% prediction interval included 1; PI = 2 x CI. Studies controlling for individual measures of BMI, smoking, SES gave lower summary RR and CI included 1. Exclusion of single patient cohort did not change summary RR & CI. High level of heterogeneity in general population studies	Downgrade one level
Imprecision	The number of person years in the included studies was greater than 940 000	No downgrading
Publication bias	According to the funnel plot little evidence of publication bias	No downgrading
Large effect size	Summary RR = 1.03. Insufficient information on unmeasured potential confounders available	No upgrading
Plausible confounding towards null	Confounding direction unknown but precision may be affected	No upgrading
Dose–response relation	A linear dose–response relationship was assumed in all studies, 95% CI for linear RR excluded 1. No evidence to confirm shape of the dose–response relationship	Upgrade one level
GRADE conclusion	No downgrade and no upgrade	MODERATE CERTAINTY EVIDENCE MEAN RR UNADJUSTED FOR CO-POLLUTANTS EQUALS 1.03 PER 10 $\mu g/m^3$

Table A3.4. Certainty of evidence profile for NO_2 and COPD mortality

Domain	Judgement	Down/up grade
Limitations in studies	Nine included studies. Risk of bias moderate because although not all studies adjusted for all confounders, exclusion of 2 high risk of bias studies did not alter summary RR	No downgrading
Indirectness	All studies included the desired population, exposures and outcomes	No downgrading
Inconsistency	The 80% prediction interval did not include 1	No downgrading
Imprecision	The number of person years in the included studies was greater than 940 000	No downgrading
Publication bias	No analysis of publication bias – too few studies (n=9)	No downgrading
Large effect size	Summary RR = 1.02. Insufficient information on unmeasured potential confounders available	No upgrading
Plausible confounding towards null	Confounding direction unknown but precision may be affected	No upgrading
Dose–response relation	A linear dose–response relationship was assumed in all studies, 95% CI for linear RR excluded 1. 2 studies investigated the shape of the dose–response relationship with no evidence to suggest non-linear	Upgrade one level
GRADE conclusion	No downgrade and upgrade one level	HIGH CERTAINTY EVIDENCE MEAN RR UNADJUSTED FOR CO-POLLUTANTS EQUALS 1.03 PER 10 $\mu g/m^3$

Table A3.5. Certainty of evidence profile for NO_2 and ALRI mortality

Domain	Judgement	Down/up grade
Limitations in studies	Five included studies. Risk of bias moderate for all studies, not all studies adjusted for all confounders	No downgrading
Indirectness	All studies included the desired population, exposures and outcomes	No downgrading
Inconsistency	The 80% prediction interval included 1 but the PI was not > 2 x CI. Substantial heterogeneity amongst small number of studies	Downgrade one level
Imprecision	The number of person years in the included studies was greater than 940 000	No downgrading
Publication bias	No analysis of publication bias – too few studies	No downgrading
Large effect size	Summary RR = 1.02. Insufficient information on unmeasured potential confounders available	No upgrading
Plausible confounding towards null	Confounding direction unknown but precision may be affected	No upgrading
Dose–response relation	No information on shape. 95% CI for linear RR excluded 1	Upgrade one level
GRADE conclusion	No downgrade and no upgrade	MODERATE CERTAINTY EVIDENCE MEAN RR UNADJUSTED FOR CO-POLLUTANTS EQUALS 1.06 PER 10 μg/m³

Table A3.6. Certainty of evidence profile for O_3 annual exposure and all-cause mortality

Domain	Judgement	Down/up grade
Limitations in studies	Nine included studies. Three studies with a total weight of 28% in the meta-analysis had high risk of bias. Excluding these studies did not change significantly the summary RR	No downgrading
Indirectness	One study with study sample of stroke patients based in London. However, it was a small study and only carried 1% weight	No downgrading
Inconsistency	The 80% prediction interval included 1 & PI > 2 x CI	Downgrade one level
Imprecision	The number of person years in the included studies was greater than 940 000	No downgrading
Publication bias	No analysis of publication bias – too few studies (n=9)	No downgrading
Large effect size	Summary RR=0.97	No upgrading
Plausible confounding towards null	Confounding direction unknown but precision may be affected	No upgrading
Dose–response relation	A linear dose–response relationship was assumed in all studies. 95% CI for linear RR included 1. None of the studies reported the dose–response relationship	No upgrading
GRADE conclusion	Downgrade one level and no upgrade	LOW CERTAINTY EVIDENCE MEAN RR UNADJUSTED FOR CO-POLLUTANTS EQUALS 0.97 PER 10 μg/m³

Table A3.7. Certainty of evidence profile for O_3 annual exposure and respiratory mortality

Domain	Judgement	Down/up grade
Limitations in studies	Only 4 studies; all rated low or moderate risk of bias	No downgrading
Indirectness	All studies included the desired population, exposures and outcomes	No downgrading
Inconsistency	The 80% prediction interval included 1 & PI > 2 x CI. Substantial heterogeneity amongst small number of studies	Downgrade one level
Imprecision	The number of person years in the included studies was greater than 940 000	No downgrading
Publication bias	No analysis of publication bias – too few studies (n=4)	No downgrading
Large effect size	Summary RR=0.99	No upgrading
Plausible confounding towards null	Confounding direction unknown but precision may be affected	No upgrading
Dose–response relation	A linear dose–response relationship was assumed in all studies. 95% CI for linear RR included 1. None of the studies reported dose–response relationship	No upgrading
GRADE conclusion	Downgrade one level and no upgrade	LOW CERTAINTY EVIDENCE MEAN RR UNADJUSTED FOR CO-POLLUTANTS EQUALS 0.99 PER 10 μg/m³

Table A3.8. Certainty of evidence profile for O_3 peak exposure and all-cause mortality

Domain	Judgement	Down/up grade
Limitations in studies	Seven included studies. One study with high risk of bias – exclusion did not change summary RR	No downgrading
Indirectness	One study might have introduced some selection bias due to the volunteering sample chosen. However, it was only weighted at less than 2% among all studies	No downgrading
Inconsistency	The 80% prediction interval included 1; PI = 2 x CI	No downgrading
Imprecision	The number of person years in the included studies was greater than 940 000	No downgrading
Publication bias	No analysis of publication bias – too few studies (*n*=6)	No downgrading
Large effect size	Summary RR = 1.01. All critical confounders were adjusted for. Insufficient information on unmeasured potential confounders available	No upgrading
Plausible confounding towards null	Confounding direction unknown but precision may be affected	No upgrading
Dose–response relation	A linear dose–response relationship was assumed in all studies. 95% CI for linear RR included 1. One study investigated the shape of the dose–response relationship with no evidence to suggest non-linear	No upgrading
GRADE conclusion	No downgrade and no upgrade	MODERATE CERTAINTY EVIDENCE MEAN RR UNADJUSTED FOR CO-POLLUTANTS EQUALS 1.01 PER 10 μg/m³

Table A3.9. Certainty of evidence profile for O_3 peak exposure and respiratory mortality

Domain	Judgement	Down/up grade
Limitations in studies	Four included studies. One study high risk of bias. Exclusion did not alter significantly the RR and CI	No downgrading
Indirectness	All studies included the desired population, exposures and outcomes	No downgrading
Inconsistency	The 80% prediction interval included 1; PI = 2 x CI. Substantial heterogeneity amongst small number of studies	Downgrade one level
Imprecision	The number of person years in the included studies was greater than 940 000	No downgrading
Publication bias	No analysis of publication bias – too few studies (n=3)	No downgrading
Large effect size	Summary RR = 1.02. Insufficient information on unmeasured potential confounders available	No upgrading
Plausible confounding towards null	Confounding direction unknown but precision may be affected	No upgrading
Dose–response relation	A linear dose–response relationship was assumed in all studies. 95% CI for linear RR included 1. One study investigated the dose–response relationship. No evidence to confirm shape of the dose–response relationship for ozone exposure	No upgrading
GRADE conclusion	No downgrade and no upgrade	LOW CERTAINTY EVIDENCE MEAN RR UNADJUSTED FOR CO-POLLUTANTS EQUALS 1.02 PER 10 μg/m³

A3.3 Short-term exposure to particulate matter (PM_{10} and $PM_{2.5}$), nitrogen dioxide (NO_2), and ozone (O_3) and all-cause and cause-specific mortality: systematic review and meta-analysis (Orellano et al., 2020)

Abstract

Background: Air pollution is a leading cause of mortality and morbidity worldwide. Short-term exposure (from one hour to days) to selected air pollutants has been associated with human mortality. This systematic review was conducted to analyse the evidence on the effects of short-term exposure to particulate matter with aerodynamic diameters less or equal than 10 and 2.5 μm (PM_{10}, $PM_{2.5}$), nitrogen dioxide (NO_2), and ozone (O_3), on all-cause mortality, and PM_{10} and $PM_{2.5}$ on cardiovascular, respiratory, and cerebrovascular mortality.

Methods: We included studies on human populations exposed to outdoor air pollution from any source, excluding occupational exposures. Relative risks (RRs) per 10 μg/m^3 increase in air pollutants concentrations were used as the effect estimates. Heterogeneity between studies was assessed using 80% prediction intervals. Risk of bias (RoB) in individual studies was analysed using a new domain-based assessment tool, developed by a working group convened by the World Health Organization and designed specifically to evaluate RoB within eligible air pollution studies included in systematic reviews. We conducted subgroup and sensitivity analyses by age, sex, continent, study design, single or multicity studies, time lag, and RoB. The certainty of evidence was assessed for each exposure-outcome combination. The protocol for this review was registered with PROSPERO (CRD42018087749).

Results: We included 196 articles in quantitative analysis. All combinations of pollutants and all-cause and cause-specific mortality were positively associated in the main analysis, and in a wide range of sensitivity analyses. The only exception was NO_2, but when considering a 1-hour maximum exposure. We found positive associations between pollutants and all-cause mortality for PM_{10} (RR: 1.0041; 95% CI: 1.0034-1.0049), $PM_{2.5}$ (RR: 1.0065; 95% CI: 1.0044-1.0086), NO_2 (24-hour average) (RR: 1.0072; 95% CI: 1.0059-1.0085), and O_3 (RR: 1.0043; 95% CI: 1.0034-1.0052). PM_{10} and $PM_{2.5}$ were also positively associated with cardiovascular, respiratory, and cerebrovascular mortality. We found some degree of heterogeneity between studies in three exposure-outcome combinations, and this heterogeneity could not be explained after subgroup analysis. RoB was low or moderate in the majority of articles.

The certainty of evidence was judged as high in 10 out of 11 combinations, and moderate in one combination.

Conclusions: This study found evidence of a positive association between short-term exposure to PM_{10}, $PM_{2.5}$, NO_2, and O_3 and all-cause mortality, and between PM_{10} and $PM_{2.5}$ and cardiovascular, respiratory and cerebrovascular mortality. These results were robust through several sensitivity analyses. In general, the level of evidence was high, meaning that we can be confident in the associations found in this study.

Table A3.10 Certainty of evidence profile for each exposure–outcome combination

Exposure – outcome	Downgrade					Upgrade			Certainty of evidence
	Limitations in studies	Indirectness	Inconsistency	Imprecision	Publication bias	Large effect size	Confounding	Concentration-response gradient	
PM_{10} – all-cause mortality	(0) No differences between studies with low/ moderate versus high RoB	(0) The research question in the studies reflects the original question.	(0) 80% prediction interval did not include unity.	(0) Number of mortality cases higher than 100,000.	(0) Publication bias detected, but no difference between multicity and single-city studies was observed.	(+1) Unmeasured confounding would not suffice to explain away the effect estimate.	(0) Several potential confounders that would shift the RR in both directions.	(+1) Significant positive association detected in the main analysis.	**High** ⊠⊠⊠⊠
PM_{10} – cardiovascular mortality	(0) No differences between studies with low/ moderate versus high RoB	(0) The research question in the studies reflects the original question.	(0) 80% prediction interval did not include unity.	(0) Number of mortality cases higher than 100,000.	(0) Publication bias detected, but no difference between multicity and single-city studies was observed.	(+1) Unmeasured confounding would not suffice to explain away the effect estimate.	(0) Several potential confounders that would shift the RR in both directions.	(+1) Significant positive association detected in the main analysis.	**High** ⊠⊠⊠⊠
PM_{10} – respiratory mortality	(0) No differences between studies with low/ moderate versus high RoB	(0) The research question in the studies reflects the original question.	(0) 80% prediction interval did not include unity.	(0) Number of mortality cases higher than 100,000.	(0) Publication bias was not detected.	(+1) Unmeasured confounding would not suffice to explain away the effect estimate.	(0) Several potential confounders that would shift the RR in both directions.	(+1) Significant positive association detected in the main analysis.	**High** ⊠⊠⊠⊠

Certainty of evidence, starting from moderate certainty (⊠⊠⊠); CRFs, concentration–response functions; (), between brackets is the downgrading of levels in that domain; RoB, risk of bias in individual studies; RR, relative risk.

Table A3.10 contd

Exposure – outcome	Limitations in studies	Indirectness	Inconsistency	Imprecision	Publication bias	Large effect size	Confounding	Concentration-response gradient	Certainty of evidence
	Downgrade					Upgrade			
PM_{10} – cerebrovascular mortality	(0) No differences between studies with low/ moderate and high RoB	(0) The research question in the studies reflects the original question.	(0) 80% prediction interval did not include unity.	(0) Number of mortality cases higher than 100,000.	(0) Publication bias detected, but no difference between multicity and single-city studies was observed.	(+1) Unmeasured confounding would not suffice to explain away the effect estimate.	(0) Several potential confounders that would shift the RR in both directions.	(+1) Significant positive association detected in the main analysis.	⊠⊠⊠⊠ **High**
$PM_{2.5}$ – all-cause mortality	(0) Statistical differences between studies with low/ moderate versus high RoB, but studies showing high RoB had small weight on the results	(0) The research question in the studies reflects the original question.	(0) 80% prediction interval did not include unity.	(0) Number of mortality cases higher than 100,000.	(0) Publication bias detected, but no difference between multicity and single-city studies was observed.	(+1) Unmeasured confounding would not suffice to explain away the effect estimate.	(0) Several potential confounders that would shift the RR in both directions.	(+1) Significant positive association detected in the main analysis.	⊠⊠⊠⊠ **High**
$PM_{2.5}$ – cardiovascular mortality	(0) No differences between studies with low/ moderate versus high RoB	(0) The research question in the studies reflects the original question.	(0) 80% prediction interval did not include unity.	(0) Number of mortality cases higher than 100,000.	(0) Publication bias was not detected.	(+1) Unmeasured confounding would not suffice to explain away the effect estimate.	(0) Several potential confounders that would shift the RR in both directions.	(+1) Significant positive association detected in the main analysis.	⊠⊠⊠⊠ **High**

Certainty of evidence, starting from moderate certainty (⊠⊠⊠); CRFs, concentration–response functions; (), between brackets is the downgrading of levels in that domain; RoB, risk of bias in individual studies; RR, relative risk.

Table A3.10 contd

Exposure – outcome	Limitations in studies in studies	Indirectness	Inconsistency	Imprecision	Publication bias	Large effect size	Confounding	Concentration-response gradient	Certainty of evidence
	Downgrade					Upgrade			
$PM_{2.5}$ – respiratory mortality	(0) No differences between studies with low/moderate versus high RoB	(0) The research question in the studies reflects the original question.	(0) 80% prediction interval included unity, but is not twice the confidence interval.	(0) Number of mortality cases higher than 100,000.	(0) Publication bias was not detected.	(0) Unmeasured confounding could influence the effect estimate.	(0) Several potential confounders that would shift the RR in both directions.	(+1) Significant positive association detected in the main analysis.	**High** ⊠⊠⊠⊠
$PM_{2.5}$ – cerebrovascular mortality	(-1) Statistical differences between studies with low/moderate versus high RoB	(0) The research question in the studies reflects the original question.	(0) 80% prediction interval included unity, but is not twice the confidence interval.	(0) Number of mortality cases higher than 100,000.	(0) Publication bias was not detected.	(+1) Unmeasured confounding would not suffice to explain away the effect estimate	(0) Several potential confounders that would shift the RR in both directions.	(+1) Significant positive association detected in the main analysis.	**High** ⊠⊠⊠⊠
NO_2 (24-hour average) – all-cause mortality	(-1) Statistical differences between studies with low/moderate versus high RoB	(0) The research question in the studies reflects the original question.	(0) 80% prediction interval did not include unity.	(0) Number of mortality cases higher than 100,000.	(0) Publication bias detected, but no difference between multicity and single-city studies was observed.	(+1) Unmeasured confounding would not suffice to explain away the effect estimate.	(0) Several potential confounders that would shift the RR in both directions.	(+1) Significant positive association detected in the main analysis.	**High** ⊠⊠⊠⊠

Certainty of evidence, starting from moderate certainty (⊠⊠⊠); CRFs, concentration–response functions; (), between brackets is the downgrading of levels in that domain; RoB, risk of bias in individual studies; RR, relative risk.

Table A3.10 contd

Exposure – outcome	Limitations in studies	Indirectness	Inconsistency	Imprecision	Publication bias	Large effect size	Confounding	Concentration-response gradient	Certainty of evidence
	Downgrade					**Upgrade**			
NO_2 – (1-hour max.) – all-cause mortality	(0) No differences between studies with low/ moderate versus high RoB	(0) The research question in the studies reflects the original question.	(0) 80% prediction interval did not include unity.	(0) Number of mortality cases higher than 100,000.	(0) Publication bias was not detected.	(0) Unmeasured confounding could influence the effect estimate.	(0) Several potential confounders that would shift the RR in both directions.	(0) No significant association detected in the main analysis.	**Moderate** ⊠⊠⊠□
O_3 – all-cause mortality	(0) No differences between studies with low/ moderate versus high RoB	(0) The research question in the studies reflects the original question.	(0) 80% prediction interval did not include unity.	(0) Number of mortality cases higher than 100,000.	(0) Publication bias detected, but no difference between multicity and single-city studies was observed.	(+1) Unmeasured confounding would not suffice to explain away the effect estimate.	(0) Several potential confounders that would shift the RR in both directions.	(+1) Significant positive association detected in the main analysis.	**High** ⊠⊠⊠⊠

Certainty of evidence, starting from moderate certainty (⊠⊠⊠); CRFs, concentration–response functions; (), between brackets is the downgrading of levels in that domain; RoB, risk of bias in individual studies; RR, relative risk.

A3.4 Short-term exposure to sulfur dioxide (SO_2) and all-cause and respiratory mortality: a systematic review and meta-analysis (Orellano, Reynoso & Quaranta, 2021)

Abstract

Background: Many studies have assessed the harmful effects of ambient air pollution on human mortality, but the evidence needs further exploration, analysis, and refinement, given the large number of studies that have been published in recent years. The objective of this study was to evaluate all the available evidence of the effect of short-term exposure to ambient sulphur dioxide (SO_2) on all-cause and respiratory mortality.

Methods: Articles reporting observational epidemiological studies were included, comprising time-series and case-crossover designs. A broad search and wide inclusion criteria were considered, encompassing international and regional databases, with no geographical or language restrictions. A random effect meta-analysis was conducted, and pooled relative risk for an increment of 10 μg/m³ in SO_2 concentrations were calculated for each outcome. We analysed the risk of bias (RoB) in individual studies for specific domains using a new domain-based RoB assessment tool, and the certainty of evidence across studies with an adaptation of the Grading of Recommendations Assessment, Development and Evaluation approach. The certainty of evidence was judged separately for each exposure-outcome combination. A number of subgroup and sensitivity analyses were carried out, as well as assessments of heterogeneity and potential publication bias. The protocol for this review was registered with PROSPERO (CRD42019120738).

Results: Our search retrieved 1,128 articles, from which 67 were included in quantitative analysis. The RoB was low or moderate in the majority of articles and domains. An increment of 10 μg/m³ in SO_2 (24-hour average) was associated with all-cause mortality (RR: 1.0059; 95% CI: 1.0046–1.0071; p-value: <0.01), and respiratory mortality (RR: 1.0067; 95% CI: 1.0025–1.0109; p-value: <0.01), while the same increment in SO_2 (1-hour max.) was associated with respiratory mortality (RR:1.0052; 95% CI: 1.0013–1.0091; p-value: 0.03). Similarly, the association was positive but non-significant for SO_2 (1-hour max.) and all-cause mortality (RR: 1.0016; 95% CI: 0.9930–1.0102; p-value: 0.60). These associations were still significant after the adjustment for particulate matter, but not for other pollutants, according to the results from 13 articles that evaluated co-pollutant models. In general, linear concentration-response functions with no thresholds were found for the two outcomes, although this was only evaluated in a small number of studies. We found signs of heterogeneity for SO_2 (24-hour average) – respiratory mortality and SO_2 (1-hour max.) – all-cause mortality, and funnel plot asymmetry

for SO_2 (24-hour average) – all-cause mortality. The certainty of evidence was high in two combinations, i.e. SO_2 (24-hour average) – all-cause mortality and SO_2 (1-hour max.) – respiratory mortality, moderate in one combination, i.e. SO_2 (24-hour average) – respiratory mortality, and low in the remaining one combination.

Conclusions: Positive associations were found between short-term exposure to ambient SO_2 and all-cause and respiratory mortality. These associations were robust against several sensitivity analyses, and were judged to be of moderate or high certainty in three of the four exposure-outcome combinations.

Table A3.11. Certainty of evidence profile for each exposure–outcome combination

Exposure–outcome	Limitations in studies in studies	Indirectness	Inconsistency	Imprecision	Publication bias	Large effect size	Confounding	Concentration-response gradient	Certainty of evidence
	Downgrade					Upgrade			
SO_2 (24-hour average) – all-cause mortality	(0) No differences between studies with low/ moderate versus high RoB	(0) The research question in the studies reflects the PECO question.	(0) 80% prediction interval did not include unity.	(0) At least one multicity study showed a clinically meaningful association.	(0) Publication bias possibly detected, but a positive significant association was estimated when using multicity studies only.	(+1) Unmeasured confounding would not suffice to explain away the effect estimate.	(0) Several potential confounders that would shift the RR in both directions.	(+1) Significant association detected in the main analysis.	**High** ⊠⊠⊠⊠
SO_2 (24-hour average) – respiratory mortality	(0) No differences between studies with low/ moderate versus high RoB	(0) The research question in the studies reflects the PECO question.	(-1) 80% prediction interval included unity, and was twice the size of the 95% CI.	(0) At least one multicity study showed a clinically meaningful association.	(0) Publication bias was not detected.	(0) According to the analysis of the E-value, the presence of unmeasured confounders is plausible.	(0) Several potential confounders that would shift the RR in both directions.	(+1) Significant association detected in the main analysis.	**Moderate** ⊠⊠⊠☐

Certainty of evidence, starting from moderate certainty (⊠⊠⊠); (), between brackets is the downgrading of levels in that domain; RoB, risk of bias in individual studies; RR, relative risk; CI, 95% confidence interval; PECO, population, exposure, comparator, and outcomes.

Table A3.11 contd

Exposure – outcome	Limitations in studies in studies	Indirectness	Inconsistency	Imprecision	Publication bias	Large effect size	Confounding	Concentration-response gradient	Certainty of evidence
	Downgrade					Upgrade			
SO_2 (1-hour max.) – all-cause mortality	(0) Not enough studies to detect differences in the RoB.	(0) The research question in the studies reflects the PECO question..	(-1) 80% prediction interval included unity, and was twice the size of the 95% CI	(0) At least one multicity study showed a clinically meaningful association.	(0) Not enough studies to analyse publication bias.	(0) Unmeasured confounding was not analysed, because the association was not significant.	(0) Several potential confounders that would shift the RR in both directions.	(0) The association was not significant.	**Low** ⊠⊠☐☐
SO_2 (1-hour max.) – respiratory mortality	(0) Not enough studies to detect differences in the RoB.	(0) The research question in the studies reflects the PECO question.	(0) 80% prediction interval did not include unity.	(0) At least one multicity study showed a clinically meaningful association..	(0) Not enough studies to analyse publication bias.	(0) According to the analysis of the E-value, the presence of unmeasured confounders is plausible.	(0) Several potential confounders that would shift the RR in both directions.	(+1) Significant association detected in the main analysis.	**High** ⊠⊠⊠⊠

Certainty of evidence, starting from moderate certainty (⊠⊠⊠); (), between brackets is the downgrading of levels in that domain; RoB, risk of bias in individual studies; RR, relative risk; CI, 95% confidence interval; PECO, population, exposure, comparator, and outcomes.

A3.5 Short-term exposure to ozone, nitrogen dioxide, and sulphur dioxide and emergency department visits and hospital admissions due to asthma: a systematic review and meta-analysis (Zheng et al., 2021)

Abstract

Background: Air pollution is a major environmental hazard to human health and a leading cause of morbidity for asthma worldwide.

Objectives: To assess the current evidence on short-term effects (from several hours to 7 days) of exposure to ozone (O_3), nitrogen dioxide (NO_2), and sulphur dioxide (SO_2) on asthma exacerbations, defined as emergency room visits (ERVs) and hospital admissions (HAs).

Methods: We searched PubMed/MEDLINE, EMBASE and other electronic databases to retrieve studies that investigated the risk of asthma-related ERVs and HAs associated with short-term exposure to O_3, NO_2, or SO_2. We evaluated the risks of bias (RoB) for individual studies and the certainty of evidence for each pollutant in the overall analysis. A subgroup analysis was performed, stratified by sex, age, and type of asthma exacerbation. We conducted sensitivity analysis by excluding the studies with high RoB and based on the E-value. Publication bias was examined with the Egger's test and with funnel plots.

Results: Our literature search retrieved 9,059 articles, and finally 67 studies were included, from which 48 studies included the data on children, 21 on adults, 14 on the elderly, and 31 on the general population. Forty-three studies included data on asthma ERVs, and 25 on asthma HAs. The pooled relative risk (RR) per 10 μg/m^3 increase of ambient concentrations was 1.008 (95%CI: 1.005, 1.011) for maximum 8-hour daily or average 24-hour O_3, 1.014 (95%CI: 1.008, 1.020) for average 24-hour NO_2, 1.010 (95%CI: 1.001, 1.020) for 24-hour SO_2, 1.017 (95%CI: 0.973, 1.063) for maximum 1-hour daily O_3, 0.999 (95%CI: 0.966, 1.033) for 1-hour NO_2, and 1.003 (95%CI: 0.992, 1.014) for 1-hour SO_2. Heterogeneity was observed in all pollutants except for 8-hour or 24-hour O_3 and 24-hour NO_2. In general, we found no significant differences between subgroups that can explain this heterogeneity. Sensitivity analysis based on the RoB showed certain differences in NO_2 and SO_2 when considering the outcome or confounding domains, but the analysis using the E-value showed that no unmeasured confounders were expected. There was no major evidence of publication bias.

Based on the adaptation of the Grading of Recommendations Assessment, Development and Evaluation, the certainty of evidence was high for 8-hour or 24-hour O_3 and 24-hour NO_2, moderate for 24-hour SO_2, 1-hour O_3, and 1-hour SO_2, and low for 1-hour NO_2.

Conclusion: Short-term exposure to daily O_3, NO_2, and SO_2 was associated with an increased risk of asthma exacerbation in terms of asthma-associated ERVs and HAs.

Table A3.12. Certainty of evidence profile for each exposure–outcome combination

Exposure – outcome	Limitations in studies	Indirectness	Inconsistency	Imprecision	Publication bias	Large effect size	Confounding	Concentration-response gradient	Certainty of evidence
	Downgrade					**Upgrade**			
O_3 (8-h or 24-h) – ERV or HA	(0) Statistical differences between studies with low/moderate versus high RoB, but the pooled effect in low/moderate RoB articles is significant	(0) The research question in the studies reflects the original question	(0) 80% prediction interval did not include unity	(0) Number of asthma exacerbations higher than 150,000.	(0) Publication bias was not detected	(+1) Unmeasured confounding would not suffice to explain away the effect estimate	(0) Several potential confounders that would shift the RR in both directions.	(+1) Significant positive association detected in the main analysis.	**High** ⊠⊠⊠⊠
NO_2 (24-h) – ERV or HA	(0) Statistical differences between studies with low/moderate versus high RoB, but the pooled effect in low/moderate RoB articles is significant	(0) The research question in the studies reflects the original question	(0) 80% prediction interval did not include unity	(0) Number of asthma exacerbations higher than 150,000.	(0) Publication bias was not detected	(+1) Unmeasured confounding would not suffice to explain away the effect estimate	(0) Several potential confounders that would shift the RR in both directions.	(+1) Significant positive association detected in the main analysis.	**High** ⊠⊠⊠⊠
SO_2 (24-h) z– ERV or HA	(-1) Statistical differences between studies with low/ moderate versus high RoBt	(0) The research question in the studies reflects the original question	(-1) 80% prediction interval included unity, and was twice the width of the 95%CI	(0) Number of asthma exacerbations higher than 150,000.	(0) Publication bias was not detected	(+1) Unmeasured confounding would not suffice to explain away the effect estimate	(0) Several potential confounders that would shift the RR in both directions.	(+1) Significant positive association detected in the main analysis.	**Moderate** ⊠⊠⊠☐

Certainty of evidence, starting from moderate certainty (⊠⊠⊠); (), between brackets is the downgrading of levels in that domain; RoB, risk of bias in individual studies; RR, relative risk.

Table A3.12 contd

Exposure – outcome	Limitations in studies	Indirectness	Inconsistency	Imprecision	Publication bias	Large effect size	Confounding	Concentration-response gradient	Certainty of evidence
	Downgrade					Upgrade			
O_3 (1-h) – ERV or HA	(0) Differences between studies with low/moderate versus high RoB were not evaluated.	(0) The research question in the studies reflects the original question	(0) 80% prediction interval included unity, but is not twice the 95%CI	(0) Number of asthma exacerbations higher than 150,000.	(0) Publication bias was not evaluated	(0) E-value was not calculated, because the pooled RR is not significant.	(0) Several potential confounders that would shift the RR in both directions.	(0) No significant association detected in the main analysis.	**Moderate** ⊠⊠⊠☐
NO_2 (1-h) – ERV or HA	(0) No differences between studies with low/moderate versus high RoB.	(0) The research question in the studies reflects the original question	(0) 80% prediction interval included unity, but is not twice the 95%CI	(-1) Number of asthma exacerbations lower than 150,000.	(0) Publication bias was not evaluated	(0) E-value was not calculated, because the pooled RR is not significant.	(0) Several potential confounders that would shift the RR in both directions.	(0) No significant association detected in the main analysis.	**Low** ⊠⊠☐☐
SO_2 (1-h) – ERV or HA	(0) Differences between studies with low/moderate versus high RoB were not evaluated.	(0) The research question in the studies reflects the original question	(0) 80% prediction interval included unity, but is not twice the 95%CI	(0) Number of asthma exacerbations higher than 150,000.	(0) Publication bias was not evaluated	(0) E-value was not calculated, because the pooled RR is not significant.	(0) Several potential confounders that would shift the RR in both directions.	(0) No significant association detected in the main analysis.	**Moderate** ⊠⊠⊠☐

Certainty of evidence, starting from moderate certainty (⊠⊠⊠); (), between brackets is the downgrading of levels in that domain; RoB, risk of bias in individual studies; RR, relative risk.

A3.6 Short-term exposure to carbon monoxide and myocardial infarction: a systematic review and meta-analysis (Lee et al., 2020)

Abstract

Background: Previous studies suggest an association between short-term exposure to carbon monoxide and myocardial infarction. We performed a systematic review and meta-analysis to assess current evidence on this association to support the update of the World Health Organization (WHO) Global Air Quality Guidelines.

Methods: We searched Medline, Embase and Cochrane Central Register of Controlled Trials to update the evidence published in a previous systematic review up to 30th September 2018 for studies investigating the association between short-term exposure to ambient carbon monoxide (up to lag of seven days) and emergency department visits or hospital admissions and mortality due to myocardial infarction. Two reviewers assessed potentially eligible studies and performed data extraction independently. Random-effects meta-analysis was used to derive the pooled risk estimate per 1mg/m³ increase in ambient carbon monoxide concentration. Risk of bias in individual studies was assessed using a domain-based assessment tool. The overall certainty of the body of evidence was evaluated using an adapted certainty of evidence assessment framework.

Results: We evaluated 1,038 articles from the previous review and our updated literature search, of which, 26 satisfied our inclusion criteria. Overall, myocardial infarction was associated with exposure to ambient carbon monoxide concentration (risk ratio of 1.052, 95% confidence interval 1.017 – 1.089 per 1mg/m³ increase). A third of studies were assessed to be at high risk of bias (RoB) due to inadequate adjustment for confounding. Using an adaptation of the Grading of Recommendations Assessment, Development and Evaluation (GRADE) framework, the overall evidence was assessed to be of moderate certainty.

Conclusions: This review demonstrated that the pooled risk ratio for myocardial infarction was 1.052 (95% CI 1.017–1.089) per 1mg/m³ increase in ambient carbon monoxide concentration. However, very few studies originated from low- and middle-income countries.

Table A3.13. Certainty of evidence profile for CO and myocardial infarction

Domain	Judgement	Down/up grade
Limitations in studies	Ten studies were assessed to be high risk of bias due to inadequate adjustment for confounding. Subgroup analysis did not demonstrate a statistically significant difference in risk estimates between studies at low/moderate risk of bias versus those at high risk of bias	No downgrading
Indirectness	All included studies were consistent with the prespecified PECOS	No downgrading
Inconsistency	The 80% prediction interval was 0.871–1.271. However, most of this is driven by 3 studies that reported outlying results. Sensitivity analysis excluding these studies had a 80% prediction interval of 1.002–1.030	No downgrading
Imprecision	Although the number of participants included in the review (1.5 million) was significantly lower than the estimated sample size required (12.1 million), risk estimates reported by the studies are sufficiently precise	No downgrading
Publication bias	Visual inspection of the funnel plot does not indicate significant asymmetry	No downgrading
Large effect size	Overall relative risk was 1.052. Based on this, an E-value of 1.29 was calculated. However there is insufficient information to determine strength of unmeasured confounders	No upgrading
Plausible confounding towards null	Direction of effect of other confounding is unknown	No upgrading
Dose–response relation	None of the studies reported the dose–response relationship	No upgrading
GRADE conclusion		MODERATE CERTAINTY OF EVIDENCE

The main objective of these updated global guidelines is to offer health-based air quality guideline levels, expressed as long- or short-term concentrations, for six key air pollutants: $PM_{2.5}$, PM_{10}, ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. In addition, the guidelines provide interim targets to guide reduction efforts for these pollutants, as well as good practice statements for the management of certain types of PM (i.e. black carbon/elemental carbon, ultrafine particles, and particles originating from sand and dust storms). These guidelines are not legally binding standards; however, they provide WHO Member States with an evidence-informed tool they can use to inform legislation and policy. Ultimately, the goal of these guidelines is to help reduce levels of air pollutants in order to decrease the enormous health burden resulting from exposure to air pollution worldwide.

Compared with previous WHO guidelines, these guidelines:

- use new methods for evidence synthesis and guideline development;
- reinforce previous evidence on the adverse health effects of air pollution; and
- provide evidence of adverse health effects from air pollution at lower levels than previously known.

The guidelines are a critical tool for the following three main groups of users:

- policy-makers, lawmakers and technical experts at the local, national and international levels who are responsible for developing and implementing regulations and standards for air quality, air pollution control, urban planning and other policy areas;
- national and local authorities and nongovernmental organizations, civil society organizations and advocacy groups such as patients, citizen groups, industrial stakeholders and environmental organizations; and
- academics, health and environmental impact assessment practitioners, and researchers in the broad field of air pollution.

WHO European Centre for Environment and Health
Platz der Vereinten Nationen 1
D-53113 Bonn, Germany

Tel.: +49 228 815 0400
Fax: +49 228 815 0440
E-mail: euroeceh@who.int / aqh_who@who.int
Website: www.euro.who.int

9789240034228

APP/EPR/603

ENVIRONMENTAL PERMITTING (ENGLAND AND WALES) REGULATIONS 2016, REGULATION 31, PARAGRAPH 15 OF SCHEDULE 5, SCHEDULE 6 AND SCHEDULE 13

APPEAL BY CALDER VALLEY SKIP HIRE LIMITED AGAINST THE REFUSAL OF CALDERDALE METROPOLITAN BOROUGH COUNCIL TO GRANT AN ENVIRONMENTAL PERMIT FOR THE OPERATION OF A SMALL WASTE INCINERATION PLANT

LAND AT BELMONT INDUSTRIAL ESTATE, ROCHDALE ROAD, SOWERBY BRIDGE, WEST YORKSHIRE, HX6 3LL

LOCAL AUTHORITY REFS: S13/005 AND MAU/31215

STATEMENT OF CASE OF METROPOLITAN BOROUGH COUNCIL OF CALDERDALE

Introduction

1. The application for an environmental permit under Schedule 13 to the Environmental Permitting (England and Wales) Regulations 2016 (“EPR”) is dated 6 August 2020. In the application Calder Valley Skip Hire Limited (“CVSH”) applied to Calderdale Metropolitan Borough Council (“the Council”) for an environmental permit in order to operate a small waste incineration plant (“SWIP”) within a building located on the Belmont Industrial Estate, Rochdale Road, Sowerby Bridge, West Yorkshire, HX6 3LL. The waste to be incinerated is approximately 10,000 tonnes pa of combustible refuse derived fuel.

2. For the reasons set out in this Statement of Case the Council does not seek to resist the grant of an environmental permit that is the subject of this appeal.

Factual Background

3. CVSH currently operate an established waste facility at the Belmont Industrial Estate. It has an Environmental Permit for waste activities under a Waste Management Licence (“WML”). The WML was regulated and monitored by the Environment Agency under the terms of the WML 65545. The WML had a condition preventing the burning of materials on site. On 21 April 2021 WML 65545 was superseded by permit EPR/SP3196ZQ.

4. The specific proposal in these proceedings relates to an application to operate a SWIP in an existing building at the site. A SWIP is defined within the EPR as all incineration and co-incineration plants below the limits specified in Chapter 2 of the Industrial Emissions Directive. A Permit to operate a SWIP is required to be issued by a Local Authority in line with Schedule 13 of EPR and reflect Article 44 of the Industrial Emissions Directive. Furthermore, the SWIP is required to operate in accordance with Chapter IV of the Industrial Emissions Directive and not exceed the emissions limits set within Article VI Part 3 and 4 of the same.

5. The Local Authority is the regulator for Schedule 13 SWIPs. There is no published guidance for the determination of a Schedule 13 SWIP as it does not constitute a Part A or Part B permit for the purposes of the Permitting Regulations. However, in the absence of a specific guidance document, the Environmental Permitting Core Guidance directs Local Authorities to the GGM ‘General Guidance Manual on Policy and Procedures for A2 and B installations’.

6. Planning permission for the construction and operation of a SWIP (together with mechanical drying of soils) was granted on appeal by a Decision Letter dated 4th February 2020.

7. In that appeal decision, Inspector [redacted] identified one of the main issues in the determination of the planning appeal was the effect on living conditions in the local area with particular reference to air quality (paragraphs 10 and 11).

8. Both parties to the planning appeal called and tested expert evidence in relation to air quality monitoring and impact. White Young Green (“WYG”) (now “Tetra Tech”) gave evidence in support of the Council’s case.

9. The existence of the Calderdale Air Quality Management Area ("AQMA") at Sowerby Bridge was noted. The AQMA at its nearest point was approximately 700 metres from the proposed SWIP.

10. Air quality assessments had been submitted in evidence including assessments of air quality within the study area without the proposed development - the baseline - as well as the likely cumulative impacts of development in combination with others.

11. The Council's concern related to Nitrogen Dioxide (NO_2).

12. The Inspector, consistent with both parties' case, referred to the air quality limits in England in respect of NO_2 being set by regulations transposing the provisions of EU Directives and EU Limit Values with the aim of protecting human health in the environment. The air quality objectives ("AQOs") are:

- 40 $\mu g/m^3$ as an annual mean
- 200 $\mu g/m^3$ measured as a 1-hour mean not to be exceeded more than 18 times per calendar year.

13. The evidence demonstrated that within the existing AQMA there was no reason to consider that the one-hour mean AQO for NO_2 would be likely to be exceeded. However, there had been a history of exceedance of the annual mean AQO of 40 $\mu g/m^3$. This was attributable to traffic related pollution.

14. Inspector [redacted] made an assessment of the output of the computer models predicting the levels of pollution concentrations within and close to the existing AQMA. He concluded[1] that for sensitive receptors in the vicinity of R8 (a particular monitoring point) the CVSH experts' predicted annual mean for NO_2 baseline contribution of 35.5 $\mu g/m^3$ was likely to be reasonably reliable.

---

[1] Paragraph 37.

15. Inspector [redacted] then went on to consider the contribution to the existing pollution load the SWIP would contribute. He observed that the highest predicted annual mean NO_2 contribution from the point source at R8 would be 0.19 $\mu g/m^3$ in the Environmental Statement Addendum. In respect of other locations, the contribution from the SWIP would be: "even lower at other locations in the AQMA." The Land Use Planning & Development Control: Planning for Air Quality ("LPDC")[2] stated that a contribution of less than 0.5% of the AQO could be regarded as a change of 0% and described the same as "negligible"[3].

16. Inspector [redacted] recognised that there was a parallel system of control under EPR that would have to be applied to the operation of the SWIP. This was dealt with at Paragraph 43 of the Decision Letter. He referenced the Environmental Statement Addendum ("ESA") assuming that emissions would be at their maximum levels allowed for within the current Industrial Emissions Directive[4] that was described as a conservative approach. The rationale for considering, for the purposes of the determination of the planning appeal, that the approach was conservative was that the control of the proposed incinerator process and emissions would be regulated under the terms of the Environmental Permit.

17. In respect of this issue at Paragraph 52 Inspector [redacted] concluded:

> *"I consider overall, that it would be reasonable to regard the ESA predicted stack emissions contributions as likely to be conservative, such that the actual contributions would be unlikely to be higher."*

18. He added at Paragraph 53:

> *"Insofar as there are parts of the AQMA where the AQO is being exceeded, in my judgment, the proposal would be unlikely to make a material contribution to the unacceptable levels of NO_2 there."*

19. At Paragraph 57:

---

[2] Guidance published by Environmental Protection UK and the Institute of Air Quality Management.
[3] Paragraph 39 of the DL.
[4] 2010/75/EU.

"I conclude that, with respect to its effect on air quality within the AQMA, the scheme would not materially harm the health and safety of users of the AQMA or the quality and enjoyment of the environment there. Furthermore, it would be possible to ensure that this remains the case through a combination of the imposition of planning conditions, which I deal with below, and the regulatory controls likely to be associated with the required Environmental Permit."

20. In respect of air quality outside the existing AQMA, at Paragraph 61 the Inspector concludes that the scheme would not materially harm the health and safety of users of the site or surroundings. He considered that a combination of the planning conditions and the regulatory controls required to be complied with in accordance with any environmental permit would secure that position.

21. Inspector [redacted] allowed the appeals and granted planning permission for the development.

22. CVSH applied for an environmental permit for the SWIP in August 2020. As noted previously the Council is the appropriate body responsible for the regulation of the operation and emissions from the SWIP rather than the Environment Agency.

23. In order to address the issues arising from the application, the Council commissioned a report on the application from WYG – an international engineering company with environmental expertise. The report is dated 22nd December 2020.

24. On 18th September 2020 the Council made a request for further information under paragraph 4(1) of Schedule 5, EPR 2016. The Appellant responded on the 16th October 2020.

25. On the 25th January 2021 the Council provided a draft permit to the Appellant and invited its comments. The Appellant's comments were provided on 28th January 2021.

Grant of the environmental permit and judicial review claim

26. The Council referred the determination of the permit application to its Cabinet.

27. The application was recommended for approval and the Cabinet accepted the recommendation and resolved to approve the permit application on the 8th February 2021.

28. The Council issued the environmental permit to the Appellant on 10th February 2021.

29. On 9 April 2021 an application was made to the High Court for permission to bring a judicial review claim. The claim advanced four grounds seeking to quash the grant of the environmental permit. The application was opposed both by the Council and the Appellant. However, the High Court granted permission to proceed with the judicial review on 23rd July 2021. The Council decided to concede on the first of the grounds of the judicial review claim. Thus, the Council agreed to concede that a procedural error of law had occurred in that it had believed that if the application had not been determined on 8th February 2021 it would be deemed to be refused.

30. The Appellant joined with the Council in consenting to an order being made that the grant of the permit be quashed. A Quashing Order was made by the High Court by consent on 14th September 2021.

The redetermination process

31. Following the Quashing Order the status of the permit application reverted to that of being undetermined.

32. On the 30th September the Council's solicitor informed the Appellant's solicitor that it had instructed environmental consultants, Tetra Tech to clarify the content of its earlier report (issued by WYG in December 2020) and that the further report be the subject of a brief round of consultation seeking scientific responses to its content.

33. In November 2021 the Appellant's environmental consultants RPS carried out a Permit Decision Review and supplied a copy of it to the Council to assist the Council in its redetermination of the permit application.

34. On 21 April 2022 a Pollution Control Officer on behalf of the Council requested further information "*regarding the assessment of 1-hour mean NO2 concentrations and a sensitivity test regarding uncertainty within the air quality assessments".*

35. On 3 May 2022 the Council disclosed the report from Tetra Tech dated 1 April 2022 and a note dated 17 March 2022 which provided comments on the information volunteered to the Council by the Appellant on 16 March 2022.

Non-determination

36. On 23 May 2022 the Appellant served notice on the Council pursuant to paragraph 15(1) of Schedule 5 to EPR 2016. As a consequence, the permit application was deemed to have been refused.

37. The Environmental Statement submitted with the planning application and the Environmental Statement Addendum dealt with air quality and air quality assessment. The refusal of the planning application was on the basis of the Council considering the that the impact of the proposal would cause an unacceptable deterioration of air quality. The effect of the proposed incinerator development on air quality was the principal issue at the subsequent planning appeal.

38. The Inspector allowed the planning appeal and granted planning permission for the development of the incinerator.

39. Paragraph 188 of the National Planning Policy Framework, 2021 explains the different roles played respectively by the planning regime and the environmental permitting regime. It states:

> *"The focus of planning policies and decisions should be on whether proposed development is an acceptable use of land, rather than the control of processes*

> *or emissions (where these are subject to separate pollution control regimes). Planning decisions should assume that these regimes will operate effectively. Equally, where a planning decision has been made on a particular development, the planning issues should not be revisited through the permitting regimes operated by pollution control authorities."*

40. in short, the planning system decides whether the development is an acceptable use of land taking into account air quality impacts. It does so by assuming that the environmental permitting regime will operate effectively. In this case, at paragraphs 57 and 61 of the Decision Letter (set out above) the Inspector provided his conclusions on the land use aspects of the proposal. Specifically, Inspector [redacted] concluded that the SWIP and its operation would not materially harm the health and safety of those within the nearby Air Quality Management Area (AQMA2); the site and its surroundings and the quality and enjoyment of the environment. He stated that it would be possible to ensure that position would remain so through a combination of the planning conditions and the regulatory controls associated with the environmental permit.

41. It is the permitting regime that is concerned with the control of processes and emissions.

44. The Council has sought and obtained legal advice on the issues surrounding the request for further information in April 2022. The request sought information on:

(a) short-term NO_2 concentrations; and,

(b) uncertainty.

Concentration of NO_2

45. The Environmental Statement Addendum ("ESA"), July 2019 and evidence presented to the Inquiry addressed this subject. Predicted short-term NO_2 impacts at receptor locations were set out in Table 3.14 of Chapter 7 Air Quality (within section 3) of the ESA and in Table 5.2 of the Additional Air Quality Assessment (AQA). The normal operation of the plant will

require its operation to be within the long-term emission limits in order to meet the daily average emission limit. The Inspector observed at paragraph 56:

> *"There is no dispute that the proposal would not risk compliance with the 1-hour mean AQO for NO_2 with predicted levels, taking account of the baseline and process contribution, predicted to remain well below the AQO. As regards the impact of the process contribution, LPDC assessment framework is only designed to be used with annual mean concentrations. The LPDC indicates that for short-term concentrations less than 10% of the AQAL can be regarded as being insignificant and in the range 11%-20% the impact can be described as slight. At R8 the ESA predicts a process contribution far less than 10% of the 1-hour mean AQO for NO_2; insignificant".*

Uncertainty

46. Section 3 of the ESA addressed uncertainty at paragraphs 3.82 to 3.90. The additional AQA within the ESA addressed uncertainty in paragraphs 3.48 to 3.57 and at Appendix F: ADMS Model Sensitivity Testing.

47. During the course of the Planning Inquiry the issue of uncertainty was a controversial issue and was addressed in evidence prepared by consultants, RPS, for the Appellant and WYG for the Council.

48. The Inspector addressed the subject of uncertainty and made his findings in paragraphs 41 to 52. At paragraph 52 Inspector [redacted] stated:

> *"In contrast to the approach to uncertainty advocated by RPS, at the Inquiry WYG advocated the application of a +/- 20% error bar to modelling results to account for uncertainties. Applying the +/- 20% suggested by WYG to the 0.19 µg/m3 result would give a range of 0.15-0.23 µg/m3. The upper end of the range would be marginally greater than 0.5% of the AQO. Nonetheless, even if that were rounded to a 1% change, the impact, with reference to the LPDC assessment framework, would remain negligible."*

49. At paragraph 59 of the Appeal Decisions the conclusion was stated to be:

> *"The ESA predicts a maximum annual mean NO2 process contribution at R5 of up to 1%.43 Taken together with the baseline, the predicted annual mean concentration at R5 would equate to around 82% of the AQO. With reference to the LPDC assessment framework, this would be a negligible impact. The*

> *outcome would be the same even if the process contribution were to be increased to reflect the upper end of the range that would result from the application of the +/- 20% error bar suggested by WYG. However, for the reasons set out above in relation to the AQMA2, I consider that this would not be appropriate and the RPS approach to uncertainty is to be preferred".*

50. The Council is advised that the issues raised in the planning appeal concerning the principle of the proposed use in land use terms cannot be revisited in the permit determination process. This is consistent with the advice in paragraph 188 of NPPF set out above. The request for a "sensitivity test" in the request for further information in April 2022 is addressing uncertainty.

51. The Council accepts that emissions from the SWIP will be controlled by the permit conditions and limited by continuous pollutant monitoring that will be undertaken within the stack or at the point of exit in order to record full emission concentrations prior to dispersion and pollution.

The Council's Position

52. The Council is advised that following the grant of planning permission for the SWIP and subject to ensuring that the relevant provisions of the Industrial Emissions Directive set out in Schedule 13 to EPR 2016 are satisfied and controlled by permit conditions, the Appellant is entitled to the grant of an environmental permit for the operation of the SWIP and associated plant at the Appeal Site.

53. The conclusion reached by the Council in determining to granting the permit in February 2021 was correct. No further evidence has been provided to undermine the assessment made.

54. The Council has concluded that there are no legitimate grounds or basis to resist the grant of a permit subject to appropriate conditions.

55. In those circumstances, the Council invites the Secretary of State to allow the appeal and direct the Council to grant an environmental permit to the Appellant for the operation of the SWIP and associated plant at the Appeal Site subject to necessary and appropriate conditions.

Notice reference [redacted]

Calderdale Metropolitan Borough Council

Environmental Permitting (England and Wales) Regulations 2016 (as amended)

paragraph 17 to Part 1 of Schedule 5: Notice of Refusal

Permit application reference S13/004

To [redacted]
Calder Valley Skip Hire Ltd
Rochdale Road
Sowerby Bridge
Halifax
HX6 3LL

Calderdale Metropolitan Borough Council ("the Council"), in the exercise of the powers conferred upon it by regulation 13 of the Environmental Permitting (England and Wales) Regulations 2016 ("the 2016 Regulations") hereby gives you notice as follows:

The Council has decided to refuse the application S13/004 for an environmental permit to operate a small waste incineration plant at Mearclough Road, Sowerby Bridge HX6 3LF.

The statement of reasons for refusal of the permit is set out in Schedule 1 to this notice.

Your attention is drawn to the rights of appeal against the refusal to grant an environmental permit under regulation 31, and to matters relating to the exercise of those rights in paragraphs 2 and 3 of Schedule 6 of the 2016 Regulations.

Signed on behalf of the Council

[redacted]

… ……… Date…20 June 2018……………..

[redacted]
An authorised officer of the Council

Notice reference [redacted]

Schedule 1 Statement of Reasons

The principal aim of the Environmental Permitting regime is to protect the environment and human health.

In refusing the application it was concluded that that could not be achieved through the application of conditions.

There is a clear conflict between the permit terms for the SWIP applied for and the terms of the existing Environment Agency permit for the site which includes a condition (52) that prohibits the burning of materials within the site boundary. It cannot be made a condition of the SWIP that the applicant amend condition 52 should the SWIP be approved and therefore, if a permit is approved, there are no powers to ensure that this is done.

Related to that is the concern about enforceability and any related conditions in a situation where operations on the site are governed by two separate permits; the SWIP, and the broader EA permit. Having considered both legal advice and information from Defra, it is concluded that there is insufficient certainty about the ability of the council to enforce permit conditions.

These conditions are particularly important taking account of two aspects of the application:-

First, the air modelling is not considered to be adequate and the proposed chimney is not sufficient to achieve safe dispersal of potential pollutants. The proposal depends on theoretical modelling and further changes may be required in the light of actual operation. It is therefore critical that the council would be able to enforce such changes if required, or to require operation to cease.

Second, it is accepted that there is no safe level of NOx levels and it is accepted that the SWIP site could impact on an AQMA. The application does not provide reasonable grounds to believe that it will not lead to an increase in NOx levels within the locality, but again there is no certainty that action could be taken in the event of a breach.

For the above reasons the permit should is refused.

End of Schedule 1

Signed on behalf of the Council

[redacted] ……   Date……20 June 2018………………..

[redacted]

An authorised officer of the Council

Appeal notes

You have the right to appeal against this decision. Your attention is drawn to 'Environmental Permitting (England and Wales) Regulations 2016 - Environmental Permits - The Appeal Procedure – Guidance' [February 2017] as issued by the Planning Inspectorate.

Appeals against the refusal to grant an application must be made not later than six months after the date of the decision.

ENVIRONMENTAL PERMITTING REGULATIONS 2016

BELMONT INDUSTRIAL ESTATE, SOWERBY BRIDGE, HALIFAX

CLOSING ON BEHALF OF CALDERDALE COUNCIL

1.1 The application involves an incinerator [a 'small waste incineration plant'] to be housed in an existing building at the Belmont Trading Estate, Rochdale Road, Sowerby Bridge. The proposal is defined in regulation 2 of the Environmental Permitting (England and Wales) Regulations 2016 as a waste incineration plant or waste co-incineration plant with a capacity less than or equal to 10 tonnes per day for hazardous waste or no more than 3 tonnes per hour for non-hazardous waste.

1.2 The waste to be incinerated is approximately 10,000 tonnes pa of 'refuse derived fuel' waste code 19 12 10. Wastes under code 19 12 10 are generally non-hazardous.

1.3 Currently the Council regulates a number of installations by way of an Environmental Permit. There are other permitted installations in the Borough regulated by the Environment Agency.

1.4 Planning permission to incorporate this incinerator at the application site was allowed upon appeal after a lengthy public inquiry and decision by the Secretary of State. Although the planning regime and the environmental permitting regime are separate regimes those findings serve as a useful background to some of the matters now considered.

1.5 Determination of an application for a permit is under the EPR 2016 and Statutory guidance - 'Environmental Permitting General Guidance Manual on Policy and Procedures for A2 and B installations' [Defra, 2012].

1.6 Determination of an environmental permit application is an objective and technical consideration and entirely separate to planning permission. The environmental permitting regime has 4 aims:

a) to protect the environment and human health,
b) to deliver permitting and compliance effectively and efficiently in a way that provides increased clarity and minimises the administrative burden on both the regulator and the operators of facilities,
c) to encourage regulators to promote best practice in the operation of regulated facilities, and
d) to continue to fully implement European legislation. As a starting point, and in the case of waste incineration, Directive 2006/12/EC of the European Parliament and of the Council of 5 April 2006 on Waste, and Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on Industrial Emissions (Integrated Pollution Prevention and Control) are both statutes which seek to protect human health and the environment through the requirements they impose.

Matters considered in the administration of the application

1.7 The matters to be considered in arriving at a decision are set out in the application documents, in the legislation, and in statutory guidance.

1.8 Part 1 to Schedule 9 of the EPR applies certain articles of the EU Waste Framework Directive ('WFD') to every environmental permit for a waste operation. These are articles 4, 13, 18(2)(b) and (c), the second paragraph of 23(1) and (3) and (4) and 35(1).

1.9 Paragraph 4 of Schedule 13 of the EPR sets out the matters to be considered to determine the application for the SWIP. These are articles 5(1) and (3), 7, 8(2), 9, 42(1), 43, 45(1) (2) and (4), 46, 47, 48(1) to (4), 49, 50, 51(1) to (3), 52, 53, 54, 55 and 82(5) and (6) of the EU Industrial Emissions Directive ('IED').

1.10 Compliance with the requirements of the WFD and IED are normally taken to fulfil the aims of the environmental permitting regime unless there is clear evidence that serious harm would still result despite that compliance. The requirements have been taken into consideration in determining this application and in drafting permit conditions. Conditions also reflect the principle of Best Available Techniques ('BAT') that in simple terms is a balance between the costs of compliance to the operator and the benefits to the environment.

1.11 In addition to technical matters specific issues have been considered:

(a) Whether or not the applicant is competent to hold a permit. The applicant's competence to hold a permit was questioned by the public. The requirement of the GGM is to consider convictions of relevant offences. Refusal of an application for a permit would be appropriate for offences that demonstrated a deliberate disregard for the environment or for environmental regulation. Neither the Environment Agency or Calderdale Planning Services, being the two principal organisations regulating the applicant's current operations raised this concern.

(b) Whether there is conflict with environmental permit EAWML 65545 issued and enforced by the Environment Agency for the waste management operation at the Belmont site. That permit was varied to exclude the area of the current application site from within the boundary of land covered by that permit. In this way there will be no conflict between conditions attaching to each permit.

Options considered

1.12 The requirement of the EPR is to determine the application. The options are that the application for an environmental permit

a) be granted, subject to conditions, or

b) be refused, in which case the applicant can appeal against refusal, or

c) not be determined, in which case the applicant can appeal against deemed refusal.

1.13 It is necessary to attach clear, relevant, enforceable and workable conditions to a permit to deliver the aims of the environmental permitting regime.

1.14 Schedule 13 of the EPR 2016 requires that: "*The regulator must exercise its relevant functions so as to ensure compliance with the [listed] provisions of the Industrial Emissions Directive".* It does not explicitly rule out the inclusion of other conditions in a permit but the legal basis for the inclusion of any additional conditions would need to be clearly established.

1.15 Finally, I want to address some emerging themes:

(a) There is not a choice of Regulator. Parliament through the legislation has determined it is the Council.

(b) The availability (or otherwise) of the Regulator's resources is irrelevant. It is for the Council to meet its statutory responsibilities.

(c) Likewise, the issues of the competence (or lack thereof) of the Regulator's officers is an irrelevance. The Council is obliged to apply the law and how it does that is a matter for them.

(d) The exercise is concerned with an objective and technical consideration of the application so as to determine whether it is compliant with the EPR and especially whether it can be operated without harm to the environment and human health.

(e) In doing so no consideration is required as to the specification or suitability of the precise pieces of plant that are proposed to be operated. The object of the Hearing is to determine the specification of the resultant emissions that have to be achieved - it is a result driven exercise. If the plant acquired is not fit for purpose and is incapable of meeting the emission level set that is Operator's concern and is incapable of substantiating a justification for some other and lower level.

(f) The motivation of the Operator is not relevant. There is no rational basis for disputing their competence – they have been operationing a site monitored by the EA for many years. As this Hearing has demonstrated they have available to them the appropriate level of environmental expertise to bring the project to fruition.

(g) The basis of so many of the objections relates to concerns over the lack of confidence in or availability of resources of the Council. That much is clear from the case put in Closing that there could be, in the place of the Council, an independent body to oversee the operation of the SWIP. In truth, this is an acknowledgement that, in principle, the plant can be controlled and operated to an appropriate level such that residual concerns over any risk to human health or the environment is removed.

Conclusion

1.16 There is no proper basis to conclude that the proposed incinerator cannot be operated in a manner consistent with the EPR.

1.17 The detail of the conditions that would be appropriate to be imposed on the Permit have been addressed fully in the Hearing. They provide a robust suite of conditions to control the activities and are consistent with the EPR, WFD and IED.

[redacted]

Counsel for Calderdale Council

31st May 2023.

The Planning Inspectorate

Appeal Decisions

Inquiry sat on 9-12, 24 April & 26-28 November 2019

Accompanied site visit made on 23 April 2019

by [redacted]

an Inspector appointed by the Secretary of State for Housing, Communities and Local Government

Decision date: 4th February 2020

Appeal A Ref: APP/A4710/W/18/3205776
Belmont Industrial Estate, Rochdale Road, Sowerby Bridge, West Yorkshire, HX6 3BL

- The appeal is made under section 78 of the Town and Country Planning Act 1990 against a refusal to grant planning permission.
- The appeal is made by Calder Valley Skip Hire Ltd against the decision of Calderdale Metropolitan Borough Council.
- The application Ref 17/00113/WAM, dated 1 February 2017, was refused by notice dated 2 January 2018.
- The proposed development is described as construction of external flue, and change of use of existing building from recycling use (B2) to heat and energy recovery process (sui generis) and introduction of mechanical drying of inert soils and aggregates (B2) adjacent to the existing recycling shed together with the installation in underground ducts of pipes connecting the energy recovery plant in the said building to the dryer.

Appeal B Ref: APP/A4710/W/18/3205783
Belmont Industrial Estate, Rochdale Road, Sowerby Bridge, West Yorkshire, HX6 3BL

- The appeal is made under section 78 of the Town and Country Planning Act 1990 against a refusal to grant planning permission under section 73 of the Town and Country Planning Act 1990 for the development of land without complying with conditions subject to which a previous planning permission was granted.
- The appeal is made by Calder Valley Skip Hire Ltd against the decision of Calderdale Metropolitan Borough Council.
- The application Ref 17/00114/VAR, dated 1 February 2017, was refused by notice dated 2 January 2018.
- The application sought planning permission for a Recycling centre with indoor sorting shed and widening of access from Rochdale Road (as amended) without complying with conditions attached to planning permission Ref. 04/02712/FUL, dated 29 June 2006.
- The conditions in dispute are Nos. 5 and 12 which state that:
  - No. 5-Unless otherwise agreed in writing by the Local Planning Authority, the use of the premises shall be restricted to the hours from 07:00 to 18:00 Mondays to Fridays and from 08:00 to 14:00 on Saturdays, and the premises shall not be used at any time on Sundays and Bank or Statutory Holidays.
  - No. 12-There shall be no burning at any time on the site.
- The reasons given for the conditions are:
  - No. 5-In the interests of the amenity of occupiers of nearby properties.
  - No. 12-In the interests of the amenity of the occupiers of nearby properties and to ensure compliance with Policy N91 of the *Calderdale Unitary Development Plan*.

Decisions

1. Appeal A (APP/A4710/W/18/3205776) is allowed and planning permission is granted for construction of external flue, and change of use of existing building from recycling use (B2) to heat and energy recovery process (sui generis) and introduction of mechanical drying of inert soils and aggregates (B2) adjacent to the existing recycling shed together with the installation in underground ducts of pipes connecting the energy recovery plant in the said building to the dryer at Belmont Industrial Estate, Rochdale Road, Sowerby Bridge, West Yorkshire, HX6 3BL in accordance with the terms of the application, Ref. 17/00113/WAM, dated 1 February 2017, subject to the schedule of conditions set out in Appendix 3 at the end of this document.

2. Appeal B (Ref. APP/A4710/W/18/3205783) is allowed and planning permission is granted for a Recycling centre with indoor sorting shed and widening of access from Rochdale Road (as amended) at Belmont Industrial Estate, Rochdale Road, Sowerby Bridge, West Yorkshire, HX6 3BL in accordance with the application Ref. 17/00114/VAR, dated 1 February 2017, without compliance with the conditions previously imposed on planning permission Ref. 04/02712/FUL, dated 29 June 2006, and subject to the schedule of conditions set out in Appendix 4 at the end of this document.

Procedural matters

3. Whilst the planning application the subject of appeal A was with the Council for determination the plans were amended to remove a previously proposed extension to an existing building and the description of development was modified to reflect this change. I have taken this into account and determined the appeal on the basis of the modified scheme, as did the Council. The modified description is reflected in the summary information and formal decision set out above.

4. Regulation 76 of *The Town and Country Planning (Environmental Impact Assessment) Regulations 2017* (2017 EIA Regulations) sets out the circumstances under which *The Town and Country Planning (Environmental Impact Assessment) Regulations 2011* (2011 EIA Regulations) continue to apply. These include where '*an applicant, appellant or qualifying body, as the case may be, has submitted an Environmental Statement or requested a scoping opinion*' prior to the commencement of the 2017 EIA Regulations. In the case of the subject appeals, the 2011 EIA Regulations continue to apply. An Environmental Statement[1] (ES) was submitted in support of the proposals.

5. Topographical survey results attached to the appellant's email to the Planning Inspectorate, dated 17 April 2019, indicated that the ground floor level of the appeal building, which had been used in the ES and formed the basis of a number of the assessments, was incorrect. The actual floor level was around 9 metres lower. In response, on the 18 April 2019, the Planning Inspectorate issued a request on my behalf, pursuant to Regulation 22 of the *Town and Country Planning (Environmental Impact Assessment) Regulations 2011 (as amended)*, that the appellant provide Further Information for the purposes of the Inquiry, reflecting the correct site levels.

[1] CD10 and addenda related to traffic and habitats, submitted on 8 February 2019 to the Council and the Planning Inspectorate.

6. At the Inquiry on 24 April 2019, the appellant confirmed its intention to comply with the request and asked for the Inquiry to be adjourned to allow time for it to prepare and submit the Further Information. I agreed to the request, so that my decisions could be based on the updated Environmental Statement in the interests of all parties. Furthermore, the resumption date for the Inquiry of 26 November 2019 was announced.

7. The Inquiry resumed on 26 November 2019, following the submission of an Environmental Statement Addendum, July 2019[2] (ESA) (and technical appendices) taking account of the corrected site level data as well as an associated update of the Non-Technical Summary. Other information, such as proofs of evidence, were submitted for the purposes of the Inquiry. In reaching my conclusions, I have taken account of the environmental information, which I consider to be sufficient to assess the likely environmental impacts of the applications.

8. Reference documents submitted by the appellant prior to the Inquiry, nos. 1-53, are referred to as core documents (CD) in the footnotes below. Documents submitted following the opening of the Inquiry are listed in Appendix 2 and are given Inquiry Document numbers (ID).

Main Issues

9. The Council cited a single reason for the refusal of the planning applications the subject of appeals A and B, which related to air quality. However, I have also had regard to other relevant planning concerns raised by interested parties.[3]

10. In relation to appeal A, I consider that the main issues are: whether the proposal would be inappropriate development in the Green Belt, having regard to any relevant local and national policies; the effect on the openness of the Green Belt; the effect on living conditions in the local area, with particular reference to air quality as well as noise and disturbance; the effect on flood risk; the effect on the safety and convenience of the users of public footpath Sowerby Bridge 94a; and, whether the proposal would be consistent with the aims of local and national policy as regards moving the management of waste up the Waste Hierarchy.

11. In relation to appeal B, I consider that the main issue is the effect on living conditions in the local area, with particular reference to air quality as well as noise and disturbance.

Reasons

Background

12. The appeal site is currently used as a waste recycling and recovery centre, a use for which planning permission was originally granted in 2006[4]. The proposed small waste incinerator plant (SWIP) would be housed in an existing building (SWIP building/appeal building) situated at the northeastern end of the site. Whilst that building was formerly used for vehicle maintenance, at present it is being used to store some of the proposed plant. The proposed mechanical dryer would be situated alongside the southwestern elevation of the

[2] Inquiry Document 75 (ID75).
[3] ID69 para 2.2.
[4] Planning permission Ref. 04/02712/FUL.

large waste recycling building (WRB), which is situated towards the middle of the site. Between the WRB and the SWIP building there is an office building as well as a weighbridge and associated small office. Much of the remainder of the site is surfaced in concrete. The site is accessed using a short accessway off the A58, Rochdale Road.

Appeal A

Inappropriate development in the Green Belt

13. The proposal would include the addition of an incinerator flue stack (proposed stack) to the SWIP building. RUDP Policy NE3 indicates that proposals for limited extension and/or alteration to buildings other than dwellings will be refused unless very special circumstances to justify inappropriate development are demonstrated. However, the *National Planning Policy Framework, February 2019* (the Framework) indicates that the construction of new buildings should be regarded as inappropriate in the Green Belt, with certain exceptions. The exceptions include the extension or alteration of a building provided it does not result in disproportionate additions over and above the size of the original building[5]. I consider therefore, that RUDP Policy NE3 is inconsistent with the provisions of the Framework and unduly restrictive. For those reasons, whilst under the terms of RUDP Policy NE3 the appeal scheme would amount to inappropriate development in the Green Belt, I give that matter little weight.

14. I also give little weight to the unsupported assertion made by the appellant at the Inquiry that the SWIP building may have formed part of a large mill building which previously occupied a similar position on site. I attribute greater weight to the first-hand account of a former local resident[6], who stated that the mill building had been removed in its entirety in the 1970s. I consider it appears most likely that the SWIP building, which was the subject of planning application Ref. 06/01246/FUL seeking *an extension to the servicing garage*, was the building as built; the original building for the purposes of Green Belt policy. Based on the estimates agreed by the Council and appellant, it appears to me that the extension approved by planning permission Ref. 06/01246/FUL is likely to have resulted in a small increase in the footprint of the building and an increase of around 46% in its volume. The proposed stack would have an external diameter of some 0.6 metres and would project above the ridgeline of the taller section of the existing building by around 4.6 metres[7]. The increase in the volume of the building resulting from the appeal proposal would be small. In my judgement, having regard to the cumulative effect of extensions, the proposed extension of the SWIP building would not result in disproportionate additions over and above the size of the original building.

15. The form, bulk and general design of the SWIP building is in keeping with its surroundings, which include a number of buildings such as the larger WRB. The SWIP building is of permanent and substantial construction and is capable of conversion without major or complete reconstruction. The Framework indicates that the re-use of such buildings is not inappropriate providing the

[5] Framework definition-Building as it existed on 1 July 1948 or, if constructed after 1 July 1948, as it was built originally.
[6] A Watson.
[7] Environmental Statement Addendum Appendix 2.2 Survey Levels Comparison Table.

development preserves openness and does not conflict with the purposes[8] of including land within the Green Belt.

16. The appellant has estimated that the transportation of waste between the WRB and the SWIP building would be likely to involve around 5 vehicle movements per hour during a normal working day. However, it appears to me that vehicles able to access the SWIP building would be likely to be much smaller than the Heavy Goods Vehicles (HGVs) that already move around the site on a frequent basis. The number of vehicle movements associated with the transportation of SWIP ash off site would be limited. Under these circumstances, I consider that the vehicle movements associated with the proposed change of use would be unlikely to have a material detrimental effect on the openness of the Green Belt. My view is reinforced by the potential fallback use of the SWIP building. The appellant has indicated that in the event of planning permission being refused in this case, it is likely that the SWIP building would be put to another use within the scope of existing permissions and that some 2-way traffic flows would be associated with that use. Whilst I have no reason to believe that the number of vehicle movements would be as high as likely to be associated with the appeal scheme, I consider that some weight is attributable to the fallback position. Although incinerator ash would be stored in skips within the existing yard area, prior to removal from site, the quantities involved would be likely to be relatively small and skip storage is a feature of the existing use.

17. In summary, the proposed change of use would result in an increase in the size of the SWIP Building, albeit limited, additional vehicular activity between on-site buildings, and additional skip storage in the yard area. However, the existing site is characterised by a number of buildings that are bulkier than the SWIP building, frequent movements of large vehicles and the external storage of skips. Furthermore, whilst the buildings and associated operational activity would be clearly visible from the public footpath that runs through the site, surrounding woodland limits visibility from vantage points in the wider area. The proposed stack would not extend above the top of the neighbouring woodland canopy. I consider overall that the proposal would preserve the openness of the Green Belt.[9] Furthermore, in my judgement, the re-use of the building within an existing waste management site would not conflict with the purposes of including land within the Green Belt. Therefore, the re-use of the proposed SWIP building would not amount to inappropriate development in the Green Belt.

18. The proposed mechanical dryer would be sited in the yard area alongside the southwestern elevation of the WRB. The appellant has indicated that it would be a free-standing piece of plant, not fixed to the concrete surface, and this has not been disputed. Under these circumstances, I consider that it would not amount to operational development. Furthermore, it would not result in a material change of use, as it would be used to process inert soils and aggregates as part of an industrial process (Class B2) and the site is already in Class B2 use. Therefore, it would not constitute inappropriate development in the Green Belt. If in the alternative, the proposed mechanical dryer were to amount to operational development in the form of an extension to the WRB, as

[8] Framework-purpose: to check the unrestricted sprawl of large built-up areas; to prevent neighbouring towns merging into one another; to assist in safeguarding the countryside from encroachment; to preserve the setting and special character of historic towns; and, to assist in urban regeneration, by encouraging the recycling of derelict and other urban land.
[9] ID70 section 4 and proof of evidence of Andrew Stevenson Appendix 2..

argued by the Council, this would not alter my conclusion. Relative to the large scale of the original WRB, the mechanical dryer would add little in terms of either footprint or volume. Having regard to the cumulative effect of previously approved extensions, the proposed mechanical dryer would not result in disproportionate additions over and above the size of the original WRB. In those circumstances, it would not constitute inappropriate development in the Green Belt either.

19. The proposed installation of pipes to connect the SWIP to the mechanical dryer would amount to an engineering operation which would not affect the openness of the Green Belt, as the pipes would be situated below the surface of the site. Furthermore, the pipework installation beneath the concreted yard area of the site would not conflict with the purposes of including land within the Green belt set out in the Framework. It would not constitute inappropriate development in the Green Belt.

20. I conclude that whilst the scheme would amount to inappropriate development under the terms of RUDP Policy NE3, that Policy is not consistent with the Framework and, in that context, is unduly restrictive, and so I give that matter little weight. I conclude overall, that the appeal proposals would not amount to inappropriate development in the Green Belt, with particular reference to the terms of the Framework. This is also the view of the Council. It follows that the Framework requirement to demonstrate very special circumstances in order to justify inappropriate development in the Green Belt does not apply in this case.

Openness of the Green Belt

21. I consider, for the reasons set out above, that the proposal would preserve the openness of the Green Belt.[10]

Living conditions-air quality

22. Policy EP 1 of the *Calderdale Replacement Unitary Development Plan, 2006* (RUDP) indicates that development which might cause air pollution will only be permitted if: i) it would not harm the health and safety of users of the site and surrounding area; and, ii) it would not harm the quality and enjoyment of the environment. Furthermore, where permission is granted, appropriate conditions and/or planning obligations will be attached to ensure that the air quality is maintained. Reading the Policy as a whole, it appears to me that the latter requirement seeks to maintain the air quality expected to result from the development, which has been found to meet criteria i) and ii). It does not seek to ensure that air quality is maintained at a pre-existing level. If that were the case, it seems to me that criteria i) and ii) would be redundant.

23. RUDP Policy WM 9 identifies that proposals for incinerators will only be permitted where they meet a number of criteria. They include, amongst other things, that: the development creates no unacceptable environmental or amenity problems; and, appropriate provision is made for the control of emissions to the air. Furthermore, it requires incinerators to be located in an area appropriate to their development (such as an industrial area) away from major concentrations of population. The reasoned justification for the Policy indicates that the reasons for this requirement include the impact of airborne emissions.

[10] ID70 section 4 and proof of evidence of Andrew Stevenson Appendix 2..

24. These Policies are consistent with the aims of the Framework, which seeks to ensure, amongst other things, that new development is appropriate to its location taking into account the likely effects (including cumulative effects) of pollution on health, living conditions and the natural environment, as well as the potential sensitivity of the site or the wider area to impacts that could arise from the development.

25. The appeal site comprises an existing waste management site at the bottom of a steep sided valley and, in the vicinity of the site, the valley bottom is generally characterised by commercial and industrial land uses. Rochdale Road runs along the valley side to the northwest of the site and whilst the area beyond is predominantly in residential use, it includes some other uses such as schools. In comparison, the southeastern side of the valley thereabouts is generally characterised by a lower density, scattered pattern of residential development, with grassland and some livestock in evidence. I share the view set out in the Council's Report to the Planning Committee that the nearby residential areas do not amount to a major concentration of population.[11] The Calderdale Air Quality Management Area No. 2 (AQMA2), which encompasses parts of Sowerby Bridge, is situated approximately 700 metres to the northeast of the proposed SWIP, at the closest point.

26. *Land-Use Planning & Development Control: Planning for Air Quality* (LPDC) is guidance published by Environmental Protection UK and the Institute of Air Quality Management. Although it is non-statutory guidance, there is no dispute either: that it is widely used to guide the assessment of the air quality implications of development proposals; and, that it is a material consideration in this case. It indicates that in the majority of cases, the impacts from an individual development will be insufficiently large to result in measurable changes in health outcomes that could be regarded as significant by health care professionals. In reality, therefore, it is the impact on local air quality that is used as a proxy for assessing effects on health. Furthermore, it identifies an assessment framework for describing impacts which can be used as a starting point to make a judgement on significance of effect. The LPDC indicates that judgement of the overall significance of effect of a development should be made by a competent professional who is suitably qualified and will need to take account of factors such as: the existing and future air quality in the absence of the development; the extent of current and future population exposure to the impacts; and, the influence and validity of any assumptions adopted when undertaking the prediction of impacts. Furthermore, the presence of an AQMA that may be affected by a proposed development will increase the sensitivity of the application and any accompanying assessment. The LPDC assessment framework impacts descriptor table acknowledges this.[12]

27. The air quality assessments submitted in evidence include assessments of air quality within the study area without the proposed development (baseline) as well as the likely cumulative impact of the development. The ESA indicates that, when consulted, the Council's Pollution Control Officer confirmed that there were no significant committed sources of emissions which should additionally be taken into account. I have not been provided with any compelling evidence to the contrary and note that a permit application

[11] CD21.
[12] LPDC para 7.1-7.12

Ref. S13/004 for the operation of a SWIP at the appellant's Mearclough Road site in Sowerby Bridge has been refused[13].

28. The Council has confirmed that the concerns upon which its reason for refusal is based relate to Nitrogen Dioxide (NO_2) and not to any of the other potential emissions to air from the scheme. With reference to those other potential emissions, including PM_{10}, $PM_{2.5}$ and hexavalent chromium (Cr VI), the ESA confirms that the predicted process contributions would not be significant and I have not been provided with any compelling evidence to the contrary.[14] I turn then to consider NO_2.

29. As identified in the '*ClientEarth judgements*' referred to by the Council and others, *exposure to nitrogen dioxide in the air carries with it a significant risk to human health. A recent analysis from Department for the Environment, Food and Rural Affairs (Defra) estimates that the effects of exposure to nitrogen dioxide has "an effect on mortality equivalent to 23,500 deaths annually in the UK"…Recognising those risks, EU law seeks to control that exposure by imposing limits on ambient nitrogen dioxide in the territories of Member States and, when limits are exceeded, requiring the publication of Air Quality Plans (AQPs) aimed at reducing that exposure.* Emphasis was placed on '*achieving compliance in the shortest possible time*'.[15] Air quality limits in England in respect of NO_2 are set by Regulations transposing the provisions of EU Directives and EU Limit values, with the aim of protecting human health and the environment.[16] The associated air quality objectives (AQOs) are: 40 $\mu g/m^3$ measured as an annual mean; and, 200 $\mu g/m^3$ measured as a 1-hour mean not to be exceeded more than 18 times per calendar year.

Effect within Calderdale Air Quality Management Area No. 2

30. The Council's Environmental Health Officer (EHO) has indicated that the designation of AQMA2 is due to levels of NO_2 and whilst there is no reason to believe that the 1-hour mean AQO for NO_2 is likely to be exceeded in AQMA2, there is a history of exceedance of the annual mean AQO of 40 $\mu g/m^3$. It is believed the associated levels of NO_2 are largely due to traffic-related pollution supplementing the background levels. Furthermore, the EHO indicates that problematic characteristics of AQMA2 include: built development along West Street and Wharf Street which create street canyons restricting the dissipation of fumes; as well as, standing traffic and parts of the highway where vehicles are acting under load, e.g. accelerating away from traffic lights and climbing Bolton Brow. The main focus of the Council's *Air Quality Action Plan*[17] as well as the *West Yorkshire Low Emission Strategy* is on road transport interventions and modal shift.[18]

31. The Council's *2019 Air Quality Annual Status Report, June 2019* (ASR) indicates that Sowerby Bridge was affected by roadworks in 2018 and although there have been some increases in annual mean concentrations between 2017 and 2018 at a number of the AQMA2 monitoring locations, the associated concentrations in those years are characterised by the ASR as being similar. In my view, this is a reasonable finding, in light of the limited differences

[13] ID70 Appendix 13.
[14] ESA page 3-35.
[15] ID115 paras 12-18.
[16] ID46 page 7 refers.
[17] CD38 and the emerging plan CD49.
[18] CD32 para 10, ID13, Environmental Statement Addendum Appendix 3 para 4.4.

[redacted]

between them. Although the ASR confirms that the AQMA2 continues to be affected by concentrations above the annual mean objective at some of the monitored sites, it identifies that there has clearly been a fall over the period 2012 to 2018 and I consider that the existence of a downward trend is supported by the trend analysis submitted by the appellant.[19] Against that background, I give little weight to the assertion of the Council's air quality witness (WYG) that there is no clear trend, which appears to be based in part on incomplete 2017 data for diffusion tubes SB18 and SB21.[20]

32. The Council accepts that the proposal would not result in increased traffic levels to/from the site relative to the levels which have already been approved under previous permissions. Continuation of those restrictions could be ensured in this case through the imposition of a suitable condition. I consider therefore, that the proposal would not conflict with the actions set out in the Council's *Air Quality Action Plan* or the *West Yorkshire Low Emission Strategy* the main focus of which is to address traffic pollution. Whilst the appellant anticipates that the proposal would reduce the need to transport residual waste from the site to landfill, no allowance for such a reduction has been made in the air quality assessments undertaken on its behalf.

33. I deal first with the air quality baseline, before turning to the impact of the proposed incinerator. A number of different approaches have been used in the air quality assessments submitted in evidence to establish the baseline NO_2 contribution at Receptor 8 (R8), which is located at the southwestern boundary of the AQMA2. In my judgement, of those, the approach taken by RPS in the ESA assessment is the more reliable. In the ES the baseline at R8 was simply assumed to be 95% of the AQO, with reference to exceedances of the AQO at some but not all of the monitoring locations within the AQMA2. In contrast, in its initial evidence to the Inquiry, RPS assumed a figure of 42 $\mu g/m^3$, the average of the values recorded during the period 2012-2016 at the Council's automatic continuous monitoring point AQS4. However, given the variation in monitored levels throughout the AQMA2 and that AQS4 is some distance away from R8, in my view, it is not self-evident that this is either representative or conservative.

34. In its evidence to the Inquiry, WYG used an ADMS-Roads model verified using its own diffusion tube monitoring results to predict baseline NO_2 concentrations. A similar approach was taken by RPS in the ESA, using the Council's own monitoring results to verify the model. Model verification, which involves a comparison of the predicted versus measured concentrations, allows an adjustment to be made for systematic errors. Such errors may include uncertainties in traffic flow, vehicle emissions factors and estimated background concentrations, as well as limitations of the model to represent dispersion in settings where air flow is affected by features such as roadside buildings and trees[21]. Both models have been adjusted and found to be performing well, with reference to the monitored results. However, there is a significant difference between the WYG and RPS baseline predictions for R8: WYG predicting 49.14 $\mu g/m^3$; and, RPS predicting 35.5 $\mu g/m^3$.[22]

[19] ID84.
[20] ID82 and CD46 page 37 table and footnote 'tubes SB18, SB20 and SB21 were discontinued during 2017 and no annualization has been carried out'.
[21] CD41 page 23 para f.
[22] Proof of evidence of Mr Mann, March 2019 Appendix B page 42 Table B4 .

35. The ESA confirms that originally, and unusually, the location of R8 was within the road space, rather than at the façade of a building occupied by sensitive receptors. It appears that initially, in the ES assessment, this was unimportant as R8 was being used to judge the impact of the maximum process contribution from the SWIP on the AQMA2 in the context of an assumed baseline figure which was not specific to the R8 location. I agree with RPS that that is not a suitable location for a modelling exercise which seeks to predict levels at sensitive receptor locations.

36. For the ESA, RPS has adjusted the position of R8, moving it from a location within the road to a position that better represents the facades of nearby properties at the boundary of the AQMA2. It is not self-evident that this adjustment has been made by WYG, and RPS has indicated that this may explain WYG's surprisingly high baseline prediction for R8. In my view, there are also a number of other reasons to give greater weight to the RPS baseline prediction. The WYG predicted baseline level of 49.14 $\mu g/m^3$ is far higher than the value of around 38 $\mu g/m^3$ measured at its nearest diffusion tube survey location point 12 (DT12), whereas, given the location of DT12 next to a bus stop and closer to a traffic light controlled junction than R8, it would be reasonable to expect the value at facades neighbouring R8 (set back from the road) to be lower. My view in this regard is reinforced by the contour map provided by WYG, which suggests that as you move from DT12 towards R8 the concentration could be expected to fall to somewhere in the range 39-36 $\mu g/m^3$.[23] Furthermore, at the Inquiry WYG acknowledged that the numerical assessment set out in its proofs of evidence contained a number of errors and whilst it sought to correct these at the Inquiry[24], I consider that this casts doubt over the reliability of its other analysis.

37. For the reasons set out above, and given that its model verification check showed the model to be performing well, I consider that, for sensitive receptors in the vicinity of R8, the RPS predicted annual mean NO_2 baseline contribution of 35.5 $\mu g/m^3$ is likely to be reasonably reliable. Furthermore, I am satisfied that it is not necessary to apply an error bar to the result in light of the model verification results.

38. I turn now to consider the impact of the proposed development.
The assessments submitted in evidence of the likely impact of pollutants dispersed from the proposed incinerator stack point source have made use of the ADMS and/or AERMOD dispersion models. They are formally validated steady state Gaussian models and are widely used for undertaking air quality assessments of industrial pollution sources. The Council and appellant agree that they are suitable models with which to assess the likely impact of the discharge from the proposed stack and that they have been used appropriately[25].

39. However, only the point source dispersion modelling reported in the ESA was based on the correct discharge height for the stack, the earlier assessments[26] being based on an incorrect level, as set out at the start of this decision. Therefore, I give greater weight to the ESA assessments. The highest predicted

[23] ID82 figure 3.2.
[24] ID84 pages 7 and 8, ID111-amongst other things, the value for monitoring point 12 is reduced from 44.78 to 37.97 $\mu g/m^3$.
[25] CD44 para 8.
[26] Modelling undertaken by: Entran for the original Environmental Statement; RPS for the original proof of evidence of Mr Smyth; and, WYG for the original proof of Mr Mann.

annual mean NO_2 contribution from the point source at R8 is 0.19 µg/m^3 in the ESA.[27] Having regard to the baseline and process contributions, the predicted environmental concentration would not exceed the AQO.[28] As I have already indicated, R8 is located at the southwestern boundary of the AQMA2 and, based on the contour plots provided by WYG and RPS, it appears likely that the contribution of the point source would be even lower at other locations in the AQMA2, further from the site.[29] 0.19 µg/m^3 represents 0.46% of the AQO. The footnotes to the LPDC assessment framework indicate that the user is encouraged to treat the numbers with recognition of their likely accuracy and not to assume a false level of precision. In this context it indicates that a contribution of less than 0.5% of the AQO can be regarded as a change of 0% and described as negligible.

40. The LPDC indicates that whilst model verification will normally be expected for modelling of road traffic emissions, it is not practicable to undertake model verification on point source models. However, the LPDC indicates it is desirable that air quality assessments include a comment on the sensitivity of the results to input choices, so that a view may be taken of the uncertainties.

41. RPS takes the view that it is not appropriate to attempt to quantify the uncertainty of the modelled results, not least due to practical difficulties identified by CERC, the ADMS software authors, involved in attempting to compare modelled and observed annual average concentrations. Instead it relies on a qualitative analysis of uncertainty, with reference to the software models and the inputs used.

42. As regards the inputs to the models, RPS identifies the main components of uncertainty in the predicted concentrations as being associated with the stack emissions, meteorological data and receptor assumptions. Furthermore, it argues that, as a result of the conservative approach it has taken to the inputs, the model outputs are likely to be towards the top of the uncertainty range, tending towards a worst case rather than a central estimate.

43. Dealing first with stack emissions assumptions, the ESA assumes for the most part, including in relation to Nitrogen Oxides, that emissions would be at the maximum levels allowed by the current Industrial Emissions Directive (2010/75/EU) (IED). I consider this to be a conservative approach for a number of reasons. Control of the proposed incinerator process and emissions from it would be regulated under the terms of an Environmental Permit (EP). There is no dispute that it would be open to the Regulator to set limits in accordance with the IED and I have no reason to believe that higher levels would be permitted in this particular case. I give little weight to the example of an EP provided by interested parties, which permitted a higher emission level, as it appears to relate to a wood fuelled boiler in a relatively isolated, exposed location in a moorland setting.[30] The nature and location of development is not directly comparable to that before me. I also consider it would be reasonable to expect that, in practice, operators of the regulated incinerator proposed at the appeal site would aim to operate at a level some way below EP requirements in order to ensure compliance. The appellant has indicated that this would be

[27] ESA Appendix 3 table 5.1.
[28] ID 86-Air emissions risk assessment for your Environmental Permit, page 7 of 12, further action would not be required, ID100.
[29] ESA Figure 2 and Proof of evidence of Mr Mann, March 2019 Figure 4.2.
[30] ID70 Appendix 12.

likely to be the case and that the proposed incinerator would be capable of achieving emission levels for oxides of nitrogen well below the maximum level allowed by the IED. I give no weight to the concern raised by a number of interested parties that EP emissions requirements may not be enforced, as the Framework confirms that planning decisions should assume that separate pollution control regimes operate effectively.

44. Turning to meteorological data, Defra's *Local Air Quality Management Technical Guidance (TG16)* indicates that for point sources, multiple years of meteorological data (three years or more) should be used. This is to ensure that the potential effects of fluctuating wind directions in different years are taken into account when defining exceedance areas. Although results for all meteorological years should be reported, it confirms that any decision should be based upon the worst-case result. The ESA follows this approach with simulations performed using 5 years of data from Leeds-Bradford Airport Weather Station. Whilst using the worst-case result, in this instance 0.19 $\mu g/m^3$, indicates a level of conservatism, in my view it is not significant, given the limited range across the 5 years, 0.14-0.19 $\mu g/m^3$.[31]

45. I have had regard to the concerns raised by a number of local residents that as the airport is on higher ground and around 25 Km to the northeast of the location of the appeal site, which is in the bottom of a steep sided valley, the data used is unlikely to be representative of the area under study. However, the data used has been modified by the models to take account of local topography, surface roughness effects, such as the neighbouring woodland, and building effects. Furthermore, sensitivity tests have been undertaken, using data from Bingley Weather Station, which is closer to the site, and different modelling assumptions, which indicate that the ESA approach is robust. In addition, air quality witnesses for the Council and appellant have indicated that the modelling accounts to some extent for the effects of temperature inversions, which local residents have indicated are not uncommon in this locality.

46. Under the circumstances, I am content that the meteorological data and the manner in which it is used is likely to be reasonably representative of the area under study, as required by TG16. I have no compelling reason in this case to depart from the view of RPS that this approach is preferable to the use of Numerical Weather Prediction model data, which provides forecast data rather than measured; a matter which is not disputed by WYG.[32]

47. Turning to receptors, the ESA results focus for the most part on discrete receptor locations. With reference to the modelled contour plots showing the predicted geographical extent of impacts[33], I am content that the discrete receptor locations are representative of the likely impact at locations where people are likely to be exposed, having regard to existing patterns of development and the possibility of further development in the future on land to the north of Rochdale Road.

48. As regards the software models themselves, there is no dispute that some uncertainty is likely to be associated with the software models used, being simplified versions of the real situation. However, as I have indicated, they:

[31] ID94.
[32] ID94, ID93.
[33] ESA Figures 2 and 3.

have been formally validated; are widely used for regulatory purposes; and, the Council and appellant agree that they are suitable to assess the likely dispersion of emissions from the proposed stack.

49. At a late stage in the Inquiry, it was suggested by WYG that Computational Fluid Dynamics Modelling (CFDM) could be used to assess the likely impact of calm conditions on dispersion. However, RPS explained that it would be impracticable to use it to make an assessment against the NO_2 AQOs, due to the quantity of data that would need to be processed. I have not been provided with any compelling evidence to the contrary. Furthermore, as part of the sensitivity testing undertaken for the ESA, ADMS was run using a 'calms' option, enabling calm conditions down to wind speeds of 0.3 m/s to be modelled. It found that the NO_2 impacts remain negligible. Furthermore, the appellant's analysis of the meteorological data indicates that lower wind speeds occur only 1% of the time. Under the circumstances, I agree with RPS that CFDM would not be justified in this case.[34]

50. Overall, in my view, RPS's approach to the consideration of likely uncertainty is reasonably robust.

51. In contrast to the approach to uncertainty advocated by RPS, at the Inquiry WYG advocated the application of a +/- 20% error bar to modelling results to account for uncertainties. Applying the +/- 20% suggested by WYG to the 0.19 $\mu g/m^3$ result would give a range of 0.15-0.23 $\mu g/m^3$. The upper end of the range would be marginally greater than 0.5% of the AQO. Nonetheless, even if that were rounded to a 1% change, the impact, with reference to the LPDC assessment framework, would remain negligible[35]. However, this +/- 20% error bar suggested by WYG was not reflected in its previous written submissions and appears to be based on little more than a case specific judgement of the individual WYG witness, whose written proofs of evidence submitted to the Inquiry were acknowledged to contain a number of errors. Against this background, I consider that little weight is attributable to the suggested WYG approach[36]; and the reasoned RPS approach is to be preferred.

52. I consider overall, that it would be reasonable to regard the ESA predicted stack emissions contributions as likely to be conservative, such that the actual contributions would be unlikely to be higher.

53. As I have already indicated, R8 is located at the southwestern boundary of the AQMA2 and, based on the contour plots provided by WYG and RPS, it appears likely that the contribution of the point source would be even lower at other locations in the AQMA2, further from the site.[37] Insofar as there are parts of the AQMA2 where the AQO is being exceeded, in my judgement, the proposal would be unlikely to make a material contribution to the unacceptable levels of NO_2 there. In this respect it would accord with paragraph 170 e) of the Framework which seeks to prevent new development from contributing to unacceptable levels of air pollution.

[34] ID82 and ID84.
[35] Long-term average concentration at receptor in assessment year= ((35.5+0.23)/40)x100=89%, % change in concentration relative to Air Quality Assessment Level taken as 1%.
[36] ID116 para 10b.- 'Mr Mann reproduced an extract from Coleville et al and suggested that this supported his error bar of +/-20%. But it does not-Coleville et al found that ADMS Urban…over predicts annual mean nitrogen dioxide by between 0 and 12%.'
[37] ESA Figure 2 and Proof of evidence of Mr Mann, March 2019 Figure 4.2.

54. Against this background, I agree with the professional judgement of RPS that the impact of the proposal in terms of the annual mean level of NO_2 would be negligible and it would be unlikely to have a significant effect on human health. Furthermore, in my view, it would be unlikely to materially delay progress towards compliance with the AQO within the AQMA2.[38]

55. Paragraph 181 of the Framework indicates that decisions should contribute towards compliance with relevant limit values or national objectives for pollutants, taking into account the presence of Air Quality Management Areas. Insofar as this indicates that schemes should result in a reduction in existing pollution levels in areas where limit values are being exceeded, the appeal scheme would not do so. However, given the negligible impact of the proposal, it would not materially worsen compliance in the AQMA2. Furthermore, it would not conflict with the actions set out in the Council's *Air Quality Action Plan*, which focus on transport initiatives, and would be unlikely to materially delay progress towards compliance. Under these circumstances, I consider that this conflict with the Framework should, in this instance, be accorded only limited weight.[39]

56. There is no dispute that the proposal would not risk compliance with the 1-hour mean AQO for NO_2, with predicted levels, taking account of the baseline and process contribution, predicted to remain well below the AQO. As regards the impact of the process contribution, LPDC assessment framework is only designed to be used with annual mean concentrations[40]. The LPDC indicates that for short-term concentrations less than 10% of the AQAL can be regarded as being insignificant and in the range 11%-20% the impact can be described as slight[41]. At R8 the ESA predicts a process contribution far less than 10% of the 1-hour mean AQO for NO_2; insignificant.

57. I conclude that, with respect to its effect on air quality within the AQMA2, the scheme would not materially harm the health and safety of users of the AQMA2 or the quality and enjoyment of the environment there. Furthermore, it would be possible to ensure that this remains the case through a combination of the imposition of planning conditions, which I deal with below, and the regulatory controls likely to the associated with the required Environmental Permit.
I conclude that the effect on the AQMA2 would not conflict with the aims of RUDP Policies EP 1 or WM 9. Nor would it conflict with the Framework insofar as it seeks to ensure that new development is appropriate to its location taking into account the likely effects (including cumulative effects) of pollution on health, living conditions and the natural environment, as well as the potential sensitivity of the site or the wider area to impacts that could arise from the development.

Effect outside Calderdale Air Quality Management Area No. 2

58. WYG has undertaken a survey of baseline air quality within the area surrounding the development site using diffusion tubes mounted close to roadsides. The fullest set of results were reported in ID82. I give little weight to

[38] These circumstances are materially different from those in the case of Gladman Developments Ltd v SSCLG & CPRE (Kent)[2019]EWCA Civ 1543, (ID78), which makes reference to '*moderate adverse*' impacts being '*almost certain*'.
[39] Ms Seymour's rebuttal proof Appendix 1-APP/A4710/W/17/3185542. The approach taken in the 'Hipperholme' appeal decision is of little assistance, as it was determined in the context of an earlier version of the Framework, which differs on this matter.
[40] Table 6.3 footnote 3.
[41] LPDC paras 6.36-6.39.

the previous partial reports. At the resumed Inquiry WYG acknowledged that the numerical analysis set out in ID82 contained a number of errors and it provided corrected data tables in ID111. Of the locations surveyed outside the AQMA2, the highest annual average level reported was 32.29 µg/m^3 (around 81% of the AQO) at a point along Rochdale Road, approximately opposite the appeal site entrance and on the roadside in front of No. 84, Receptor 5. Based on the evidence provided[42], I consider that it would be reasonable to expect the level at the façade of No. 84, which is set back from the highway to be lower. Nonetheless, I have assumed that the reported value is indicative of the baseline at R5 for the purposes of the assessment below.

59. The ESA predicts a maximum annual mean NO_2 process contribution at R5 of up to 1%.[43] Taken together with the baseline, the predicted annual mean concentration at R5 would equate to around 82% of the AQO. With reference to the LPDC assessment framework, this would be a negligible impact. The outcome would be the same even if the process contribution were to be increased to reflect the upper end of the range that would result from the application of the +/- 20% error bar suggested by WYG. However, for the reasons set out above in relation to the AQMA2, I consider that this would not be appropriate and the RPS approach to uncertainty is to be preferred. A significantly lower figure would be obtained if the ESA roads modelling results are used (predicted environmental contribution of approximately 31 µg/m^3, equivalent to around 78% of the AQO), rather than the WYG baseline air quality survey results. The ESA indicates that the maximum annual mean NO_2 predicted environmental contributions at the other identified residential receptors outside of the AQMA2 are likely to be lower than at R5. Unlike those residential receptors, R7 represents Spring Bank Industrial Estate, a work place, where the annual-mean AQO does not apply[44]. Nonetheless, the maximum annual mean NO_2 predicted environmental contribution there is also expected to fall well below the AQO.

60. There is no dispute that outside the AQMA2 the proposal would not risk compliance with the 1-hour mean AQO for NO_2, with predicted environmental contributions, taking account of the baseline and process contributions, remaining well below the AQO at all the identified receptors. Furthermore, with reference to the LPDC guidelines for short-term concentrations, the ESA predicts process contributions far less than 10% of the 1-hour mean AQO for NO_2; insignificant, at all receptors. In WYG's original analysis the predicted short-term concentrations fell below 10% of the 1-hour mean AQO for NO_2 at all but 2 receptors, levels at R1 and R8 predicted to be around 11%; slight impact. However, as already identified, that analysis was based on an incorrect stack height and so I give it less weight than the ESA analysis.

61. I conclude that, with respect to its effect on air quality outside the AQMA2, the scheme would not materially harm the health and safety of users of the site or surroundings or the quality and enjoyment of the environment there. Furthermore, it would be possible to ensure that this remains the case through a combination of the imposition of planning conditions, which I deal with below, and the regulatory controls likely to be associated with the required Environmental Permit. I conclude that the effect on air quality outside of the

[42] Mr Smyth's proof of evidence pages 45 and 89-117.
[43] ESA Appendix 3 Table 5.1.
[44] ESA page 33 Table 5.1 footnote.

AQMA2 would not conflict with either RUDP Policies EP 1 or WM 9 or the Framework.

Other matters

62. I have had regard to the concern raised by a large number of interested parties that the effect of the proposal on air quality would harm the health of local residents, who include, amongst others, children, elderly people and some people with breathing difficulties. In no small part, this concern has been prompted by relatively recent experience of the impact on air quality caused by a serious waste fire at the site, which damaged the WRB. However, that event is not directly comparable to the appeal proposal, in relation to which I have concluded the evidence does not support such a finding of harm. There were no objections to the scheme on the grounds of its impact on air quality from either the Council's Environmental Health Officer, the Environment Agency or Public Health England. This adds further weight to my conclusion. Furthermore, in my judgement, there is no compelling evidence before me to show that the perception of harm would be likely to have any significant land use consequences in the local area. Under these circumstances, I give little weight to the perception of harm.

63. I have found appeal decision Ref. APP/J4423/A/10/2143547, drawn to my attention by the Council, to be of little assistance in my consideration of the proposal before me, as the circumstances were materially different. The previous appeal related to a proposed food store extension in Sheffield. Furthermore, it was determined with reference to: a different Policy and guidance framework; and, the risk that the related scheme would itself result in a breach of the annual mean AQO.

Conclusions-air quality

64. I conclude overall, that the effect of the proposal on living conditions in the local area, with particular reference to air quality, would be acceptable and, in relation to this matter, it would not conflict with the requirements of RUDP Policies WM 9 or EP 1 or the aims of the Framework, with particular reference to location relative to concentrations of population as well as environmental and amenity impacts.

Living conditions-noise and disturbance

65. The effect of the scheme on living conditions in the local area with reference to noise and disturbance has not been given as a reason for refusal by the Council, who considers that adequate safeguards could be put in place through the imposition of conditions.[45] However, it has been raised by a number of local residents, who are concerned to ensure that the proposal does not result in increased noise from the site, which they regard as already being unacceptable from time to time.[46]

66. No increase in traffic beyond the limits already approved by the Council is proposed in this case. Furthermore, it does not automatically follow from the nature of the scheme that noise events associated with HGV's waiting on Rochdale Road for the site to open would increase. Relative to the existing position, traffic associated with the export of residual waste would be likely to

[45] ID77.
[46] ID70 section 5.

decrease to some extent. Nonetheless, the scheme would introduce new activity to the site.

67. Consistent with the requirements of RUDP Policy WM 9, RUDP Policy EP 8 indicates that where development proposals could lead to the juxtaposition of incompatible land uses, they will only be permitted if they do not lead to an unacceptable loss of amenity caused by factors such as noise. Where development is permitted appropriate planning conditions will be added as necessary to provide mitigation measures. These Policies are consistent with the aims of the Framework, which seeks to safeguard against development that would contribute to unacceptable levels of noise pollution, including cumulative effects, and to mitigate and reduce to a minimum potential adverse impacts from noise from new developments.

68. The ESA noise assessment considers existing ambient noise levels, the existing operations on the appeal site as well as noise likely to be associated with the proposed SWIP, using the BS 4142:2014 (+A1:2019) *Methods for rating and assessing industrial and commercial sound*. Existing operations have been modelled as part of the ESA noise assessment, in contrast to the ES approach in which existing operations were treated as part of the baseline studies. The assessment of noise likely to be associated with the proposed SWIP operation has included detailed consideration of activities associated with the SWIP building, transportation of refuse derived fuel across the yard and use of the proposed dryer.

69. In common with the findings of the ES noise assessment, the ESA noise assessment concludes that the scheme would have negligible noise effects. I have not been provided with any compelling evidence to the contrary. Whilst the Council indicated that, based on its own measurements, the actual nigh-time background noise level on Rochdale Road may be significantly lower than the 46 $L_{A90,T}$ dB(A) identified by the ESA, the background to the Council's 33 dB(A) value was not fully evidenced and this limits the weight attributable to it. Nonetheless, in any event, as identified by authors of the ESA noise assessment, this would not alter the outcome considered against the significance framework set out in the ESA.[47] It would remain negligible.

70. The ESA noise assessment takes account of a number of proposed measures which would limit noise arising from the site. It would be necessary to secure those measures by condition. It takes account of the proposed operation of the SWIP for 24 hours per day on only 5 days of the week (Monday-Friday). The ESA indicates that there would be a single vent in the southwestern façade of the building to allow adequate ventilation and it is anticipated that during the daytime the entrance door to the SWIP building would only be open for relatively short periods of time to allow the movement of mobile plant involved in moving refuse derived fuel. However, for the purposes of the ESA noise assessment, it was conservatively assumed that the door would be open throughout the daytime assessment period. It is also assumed that mobile plant movements to and from the SWIP building would only occur during the daytime and the doors to the building would remain closed at night. To my mind, the identified mitigation measures could be secured by suitable conditions.

[47] ID79 Appendix 9 page 2, ESA page 4-6.

71. In submissions to the Inquiry, a number of interested parties expressed the concern that, based on past experience, noise arising from within the site would not be adequately regulated. For its part, the Council has indicated that whilst its Environmental Health team has received a number of complaints concerning noise arising from existing activities at the appeal site, it has determined that they did not constitute a statutory nuisance and enforcement action was not justified.[48]

72. Condition no. 4 of planning permission Ref. 04/02712/FUL sets the noise level limit at the site boundary for the existing operation. The Council's Report to the Planning Committee concerning planning application Ref. 17/00113/WAM confirms that verification of sound levels at the boundary presents challenges, not least as part of the boundary follows the River Ryburn. Due to the challenges involved, the Council and appellant agreed at the Inquiry that it is impracticable to undertake the monitoring required to assess compliance with condition no. 4. An alternative condition was proposed, based on assessment in accordance with the BS 4142:2014 (+A1:2019) methodology at residential receptor points which are considered to be representative[49], together with a condition requiring the implementation of a noise management plan. Having had regard to the comments made during the open discussion of the proposed alternative conditions at the Inquiry, whilst minor amendments would be required, I agree that the proposed alternative approach would be necessary: in the interests of enforceability; and, for the purpose of safeguarding living conditions in the local area, not least as over time the particular equipment used on site may differ from that considered in the ES/ESA assessments.

73. I conclude that, subject to conditions, the effect of the proposal on living conditions in the local area, with particular reference to noise and disturbance, would be acceptable. In this respect it would accord with the aims of RUDP Policies EP 8 and WM 9 as well as the Framework.

Safety and convenience of the users of Footpath Sowerby Bridge 94a

74. Public footpath Sowerby Bridge 94a connects Rochdale Road to the west of the appeal site, to a route along a former railway line through woodland on its eastern side. I understand that the former railway line may form part of a future greenway route being promoted by the community through the Sowerby Bridge Masterplan.[50] The section of the route of the public footpath through the site, which is clearly marked, runs along the side of the access road and across the yard area alongside the weighbridge. As a result, HGVs routinely run alongside and cross the footpath when entering, leaving and manoeuvring within the site[51].

75. Traffic associated with the transfer of waste between the WRB and SWIP building would be likely to increase the frequency with which vehicles cross the footpath. In particular the section between the weighbridge office and the main office building. However, from what I saw, I consider it likely that intervisibility between pedestrians using the footpath and vehicles approaching from the WRB or SWIP building would be sufficiently good to ensure that pedestrians

[48] CD43 and ID103.
[49] ID85.
[50] ID26. ID50-The Council states that it has not been through any formal planning process and would not attract significant weight in development management decisions.
[51] ID55.

and approaching vehicles would be unlikely to come into conflict with one another.

76. I conclude that the appeal scheme would be unlikely to harm the safety or convenience of the users of Footpath Sowerby Bridge 94a, nor would it conflict with the aims of RUDP Policies EP 15 or T11, or the Framework insofar as they seek to protect public rights of way and access.

Flood risk

77. The appeal SWIP building is located alongside the River Ryburn.
The Environment Agency's Fluvial Flood Risk Maps indicate that the site of the SWIP building is predominantly located within Flood Zones 2 and 3, with a medium to high sensitivity to fluvial flooding. With reference to the national *Planning Practice Guidance* (PPG), the proposed development is classified as a land use that is 'less vulnerable' to flooding, which is appropriate within Flood Zones 1 and 2. Furthermore, as the scheme comprises a change of use of that building, it is not subject to sequential and exception tests. A site-specific Flood Risk Assessment (FRA) is required and has been provided as part of the ES, with an addendum as part of the ESA.

78. The FRA indicates that detailed hydraulic modelling of the River Ryburn is considered to be beyond the scope of the assessment, given the limited scale of development. Instead a conservative flood level has been derived using the Flood Zone 2 extent as a proxy for Flood Zone 3 with climate change. Having had regard to the supporting technical paper[52] and the absence of any objection from the Environment Agency, I consider this approach to be acceptable. On this basis the FRA identifies a design flood level of 84.35 metres above Ordnance Datum (AOD), which is around 150 mm above the floor level of the appeal building.

79. The FRA identifies a number of measures to safeguard the building and its contents from flooding/flood damage, including the installation of flood gates and raising sensitive equipment above the estimated flood level by at least 300 mm. In my view, these measures are reasonable and implementation could be ensured through the imposition of a suitable condition.
Furthermore, the existing internal staircase gives access to higher ground outside the building, providing a safe and dry access/egress route. In addition, the FRA indicates that stockpiles of SWIP fuel stored in the WRB, which would be subject to similar risks, would also be raised above flood level.
I am satisfied that these measures would be unlikely to materially reduce flood storage capacity, as the existing appeal building is already enclosed for the most part and floor space within the WRB may well be occupied by waste stockpiles, if not used for the storage of SWIP fuel. The proposed drying plant, which would be located to the southwest of the WRB, would be mounted on legs to minimise flood risk and to ensure that the floodwater displacement potential would be negligible. Incinerator bottom ash would be stored in a small number of skips in the yard area, thereby in my view ensuring containment, minimising flood risk and representing a negligible impact in terms of potential floodwater displacement.

80. The Environment Agency's Surface Water Flood Risk Maps indicate that the site of the appeal building has a low to medium risk of flooding from that source.

[52] ID79 Appendix 2.

I have had regard to the concerns raised by interested parties with respect to the adequacy of the existing site drainage system and evidence showing that parts of the site, including the area around the appeal building, have been the subject of surface water flooding in recent years.[53] Nevertheless, having had regard to that evidence, it appears to me that the mitigation measures referred to above, such as flood gating and elevating sensitive equipment, would also be likely to be sufficient to adequately safeguard the scheme from surface water flood risk.

81. I conclude overall that, subject to condition, the effect of the appeal scheme with respect to flood risk would be acceptable. It would not conflict with RUDP Policies EP 20 and EP 17, which are consistent with the Framework insofar as it seeks to ensure, amongst other things, that: flood risk is not increased elsewhere; development is appropriately flood resistant and resilient; any residual risk can be safely managed; and safe access/egress routes are included. Neither the Council nor the Environment Agency object to the scheme on the basis of flood risk and this adds further weight to my finding.[54]

Waste Hierarchy

82. RUDP Policy WM 1 identifies that proposals for waste management facilities will be assessed against a number of criteria, which include that there is a demonstrated need for the facility. The reasoned justification for the Policy confirms that the aims of the Council's waste management strategy include reducing the amount of waste sent to landfill. The Framework promotes the prudent use of natural resources and indicates that it should be read in conjunction with the Government's planning policy for waste. The *National Planning Policy for Waste, October 2014* (NPPW) confirms the country's waste ambitions include the delivery of sustainable development and resource efficiency by driving waste up the Waste Hierarchy. Disposal, which includes landfill and is the lowest tier of the Waste Hierarchy, is the least desirable option. Other recovery, which includes *R1-use principally as a fuel or other means to generate electricity*, is the next tier in the Hierarchy followed by recycling.

83. The ES (January 2017) indicates that the proposed SWIP would process around 8,000 to 10,000 tonnes/annum of residual non-recyclable waste arising from the existing waste management and recycling operations carried out on site. It indicated that this tonnage of materials was being disposed of to landfill, the lowest tier in the Waste Hierarchy. In my view, this is likely to have been the case, with reference to the 2016 Waste Return sent to the Environment Agency, which details the destinations of waste removed from the site, and other supporting information provided, which identifies the likely levels of recyclable/non-recyclable waste (ID66). I am satisfied that the likely fuel source for the proposed SWIP would be waste otherwise destined for landfill and not recycling.

84. That is not the end of the matter. If the proposal would be an incineration facility dedicated to the processing of municipal solid waste, it must comply with the R1 energy efficiency index in order to be classed as 'other recovery', as opposed to 'disposal'. Guidelines on the R1 energy efficiency formula in Annex II of the Directive 2008/98/EC indicate that '*Waste incinerators*

[53] ID70 section 5.
[54] ID76-Environment Agency response to the ESA.

dedicated to the incineration of municipal waste are waste incinerators which have the permit and are technically designed in a way so that they are capable to incinerate mixed municipal solid waste… The R1 formula does not apply to co-incineration plants and facilities dedicated to the incineration of hazardous waste, hospital waste, sewage sludge or industrial waste.'

85. The appellant has confirmed that the proposed SWIP would be capable of incinerating mixed municipal waste. However, the ES indicated that the existing waste stream giving rise to residual non-recyclable waste was primarily from commercial sources and although some municipal waste is received, it indicated that it is not the main source and the SWIP would not be dedicated to the treatment of municipal waste.

86. However, the available records, ID66, indicate that the majority of the waste received by the site in 2016 was mixed municipal waste (EWC code 20 03 01), as was all of the landfilled waste referred to above. With reference to the 2017 Waste Return (17WR), whilst the waste identified by the appellant as being sent to landfill was also coded as mixed municipal waste, the 17WR indicated that the source of that waste was not municipal. At the Inquiry, the appellant was reported as suggesting that it had coded the waste incorrectly on that Waste Return. I give this suggestion little weight, not least as the appellant has not sought to correct any such reporting error in the records it has submitted to the Environment Agency. Furthermore, to my mind, on the face of the records, it does not automatically follow that there was an error in the coding, given that EWC code 20 03 01 may comprise not only household waste, but also similar commercial, industrial and institutional wastes.

87. The 2019 Waste Return records completed by the appellant following the adjournment of the Inquiry in April 2019 indicate that the profile of waste received and removed from the site has changed somewhat. I give limited weight to this change, not least as the appellant has indicated that the waste types received at the site are likely to fluctuate from time to time and, as identified by the appellant, it still includes a significant amount of mixed municipal waste.

88. Based on the evidence presented, I consider that the source of non-recyclable waste available for use as fuel for the SWIP may well be mixed municipal waste and, as a result, it may be that the proposal could be regarded as being dedicated to the processing of municipal waste. Whilst I note that the appellant's contract with the Council for the management of street cleaning waste was not renewed in 2019, I understand that that waste stream was recycled and would not have contributed to the proposed feedstock for the SWIP.[55] Therefore, this matter does not alter my findings.

89. I have had regard to the appellant's argument that the SWIP may not be classed as an 'installation' to which the R1 efficiency index would apply. However, given: the appellant's acknowledgement that some SWIPs, such as those incinerating waste wood, are classed as 'installations'; and, uncertainty with respect to the character of the fuel, I consider that little weight is attributable to that argument.[56]

[55] ID96.
[56] ID97.

90. Under the circumstances set out above, I consider that in order to be sure that the proposal can be regarded as other recovery, thereby driving the management of the associated waste up the Waste Hierarchy, it would be necessary to ensure that it would meet the requirements of the R1 energy efficiency index. The appellant has stated that it would be able to do so[57] and to my mind this could be secured by condition. In my judgement, subject to condition, it is more likely than not that the SWIP would operate as an R1 facility.

91. The SWIP would produce ash as a by-product of the energy from waste process. Whilst it is the appellant's hope that it can be recycled in the production of aggregates, there is no guarantee that this will be the case and so I give such a benefit no weight in this case.

92. I conclude, with reference to RUDP Policy WM 1, the NPPW and the Framework, that the scheme would be consistent with the aims of local and national policy as regards moving the management of waste up the Waste Hierarchy. I consider that this weighs heavily in favour of the scheme. The scheme would also accord with: Policy WA1 of the *emerging Calderdale Local Plan* (eCLP), which seeks to ensure, amongst other things, that development supports the Waste Hierarchy; and, eCLP Policy CC1 insofar as it seeks to minimise waste going to landfill. I understand that these emerging Policies, which are consistent with the Framework, are not the subject of objections and having had regard to the stage of preparation of the plan, I give them limited weight.

93. Furthermore, the proposal would provide the opportunity for waste arising within Calderdale, as evidenced by the Waste Returns, to be managed in Calderdale, rather than being transported to other areas for management. This would be consistent with: the proximity principle advocated by the NPPW, the aim of which is to ensure communities and businesses are engaged with and take more responsibility for their own waste; and, RUDP Policy WM 1 insofar as it seeks to ensure consideration is given to the location of proposals in relation to the main sources of waste. This also weighs in favour of the scheme.

Other matters

94. The Council and appellant agree that the proposal would not have an adverse impact on sensitive ecological receptors including protected species, habitats and wildlife corridors, and would not harm the adjacent woodland, in keeping with the aims of RUDP Policies NE 15, NE 16 and NE 20 as well as section 15 of the Framework. [58] Furthermore, the proposals would be unlikely to have an adverse effect on the setting of designated heritage assets in the area, having had regard to the appeal site's existing industrial character and appearance, the intervening distances, topography and development as well as the dense woodland enveloping the site and restricting views. In addition, the appeal site makes no contribution to the significance of any heritage asset. In these respects, the proposal would comply with the aims of RUDP Policy BE 15 and section 16 of the Framework.[59] I have not been provided with any compelling evidence to the contrary.

[57] CD15.
[58] CD43 paras 42-43.
[59] CD 43 para 44.

95. Consistent with the Framework, eCLP Policy CC5 gives encouragement to the transition to a low carbon future in a changing climate by, amongst other things, supporting renewable and low carbon energy and associated infrastructure. I understand that this emerging Policy is not the subject of objections and having had regard to the stage of preparation of the plan, I give it limited weight.

96. There is no dispute that emissions resulting from the combustion of waste at the site would include CO_2.[60] However, the Department for Environment, Food and Rural Affairs' (Defra) document entitled *Energy from waste-A guide to the debate, February 2014 (revised edition)* (EFWG) indicates that, in carbon terms, energy from waste is generally a better management route than landfill for residual waste. The EFWG identifies that key factors include the renewable (biodegradable) content of the waste and the energy efficiency of the plant. The appellant has indicated that the residual waste can be expected to include some biodegradable waste and this is supported by the Waste Returns. Furthermore, as I have already indicated, it would be possible to ensure that the proposed facility would comply with the R1 energy efficiency index through the imposition of a suitable condition. The EFWG indicates that the more efficient the energy from waste plant is at turning waste into energy, the greater the carbon offset from conventional power generation and the lower net emissions from energy from waste. I am also conscious that in this particular case, the residual waste used as fuel would no longer be transported to landfill, avoiding trips with which emissions are also associated. Having regard to factors such as these, it appears to me that the proposal would be likely to have a lower greenhouse gas impact (carbon dioxide equivalents) than the existing landfill route, a view shared by the Council.[61] Whilst I note that a number of interested parties have expressed contrary views with reference to work by 'United Kingdom without Incineration Network', the analysis referred to is based on a much larger electricity-only incinerator scenario, not directly comparable to the appeal proposal.[62]

97. I consider on balance that the scheme would accord with eCLP Policy CC5, although in the absence of evidence to show the scale of any associated benefits in terms of greenhouse gas emissions relative to landfill, this particular factor does not add significantly to the weight in favour of the scheme.

98. I note that the Council, acting as the Environmental Permitting Authority, has refused a permit application Ref. S13/004 for the operation of a SWIP at the appellant's Mearclough Road site in Sowerby Bridge[63]. However, whilst I do not know the full circumstances of that scheme, it appears to me that it is not directly comparable to the case before me, not least in terms of its location relative to Sowerby Bridge, and in relation to which I have found that the impact on air quality would be acceptable. Under these circumstances, it is not self-evident that the application for the Environmental Permit which would be required to operate the appeal SWIP, when it is made, would be refused.[64] Each case must be considered primarily on its own merits.

[60] ID70 section 3.4, Appendix 9 National Policy Statement for Renewable Energy Infrastructure (EN-3) para 2.5.38.
[61] ID16 paras 35-46, CD43 para 30.
[62] ID70 section 3.4 and Appendix 11.
[63] ID70 Appendix 13.
[64] ID70 page 9 and Appendix 4.

99. The appeal site comprises previously developed land, well related to the road network and a short distance from an urban area. In my judgement, it can be regarded as a sustainable location, in terms of limiting travel demand and protecting the countryside, and would not conflict with the aims of RUDP Policy GP 2.

100. With reference to my conclusions on the main issues and these other matters, I consider that the proposal would not conflict with the aims of RUDP Policy NE4, which requires schemes involving the re-use of buildings in the Green Belt to meet certain criteria. I note that the requirements of this Policy go beyond those of the Framework as regards the re-use of buildings in the Green Belt.

***Conditions*[65]**

101. The Council has provided a list of suggested conditions, which it considers should be imposed in the event of the appeal being allowed and planning permission granted. The list was discussed at the Inquiry, together with other conditions suggested by interested parties. I have had regard to those views, when compiling the list of conditions set out in Appendix 3 to these decisions, which departs from the Council's list where I consider it necessary in order to accord with the tests of conditions set out in the Framework.

102. In addition to the normal commencement condition (1), conditions would be necessary to ensure that the works would be carried out in accordance with the approved plans (2) and that the scale and nature of the SWIP would be as applied for; a small waste incineration plant fuelled by residual non-recyclable non-hazardous waste arising from on-site waste management operations, with a capacity to take up to 2 tonnes per hour (3-5). This would be necessary in the interests of certainty as well as to ensure that the development is generally in accordance with the scheme which was the subject of the ES/ESA. It would not be reasonable to prohibit the burning of all municipal solid waste, as proposed by the Council, not least as the residual non-recyclable waste arising from site operations is likely to include such waste.

103. In order to ensure that the management of waste would be moved up the Waste Hierarchy, conditions would be necessary requiring that: the infrastructure would be installed and would remain available to enable the use of electricity and heat derived from the SWIP to be used; and, the efficiency of the SWIP energy generation process meets or exceeds the requirements of the R1 energy efficiency index[66] (6-8).

104. In the interests of safeguarding living conditions in the local area, conditions would be necessary to: control the environmental impact of construction activities through a Construction Environmental Management Plan; limit noise levels arising from within the site; restrict operating hours; control dust arising from activity associated with the appeal scheme and control the height of soils stockpiles; control artificial lighting; and, prohibit burning within the site, except in the proposed SWIP (9-17). In my judgement, it is not necessary to make general provision for the appellant to set aside the proposed restrictions on operating hours during emergencies; this would be a

[65] The numbers in brackets ( ) relate to the conditions set out in Appendix 3.
[66] CD15-Annexe 6 to the ES.

matter for discussion with the Local Planning Authority on a case by case basis.

105. In order to manage flood risk and protect the environment from contamination, conditions would be necessary to: ensure the implementation of mitigation measures set out in the Flood Risk Assessment; and, ensure that ground levels within the yard areas of the site are not raised (18-19).

106. The Council, through the grant of planning permission Ref. 06/01777/VAR, approved a relaxation of the restriction imposed by condition no. 27 attached to planning permission Ref. 04/02712/FUL, which seeks to restrict the number of vehicle movements associated with the appeal site. The appellant has confirmed that the appeal A scheme will not lead to vehicle movements exceeding the current restriction and there is no guarantee that it would result in lower levels of vehicle movements, below the level approved by the Council. Whilst I note the desire of a number of interested parties that the approved vehicle movement allowance be reduced, it is not justified by the evidence before me and is not supported by the Council. However, in the interests of certainty and enforcement, in my judgement, a condition would be necessary setting out the existing restriction imposed by condition no. 1 of planning permission Ref. 06/01777/VAR and ensuring records are kept (20).

107. In addition, I consider that the establishment of a liaison group would be likely to help mitigate the concerns expressed by local residents with respect to the proposed use of the site[67]. In light of the significant level of public interest expressed in the appeal proposal, a condition requiring the establishment of such a group would be reasonable and necessary, in the interests of safeguarding living conditions in the local area (21). Furthermore, as the site includes previously developed land which has been filled in parts, it would be necessary to impose a condition seeking to control the risk that excavation would disturb contaminated land, in the interests of safeguarding living conditions in the local area (22).

108. The proposed SWIP would be subject to a separate pollution control regime concerned with the control of processes and emissions, necessitating an Environmental Permit. The Framework indicates that planning decisions should assume that these regimes will operate effectively. Under these circumstances and in light of my findings with respect to the likely impact on air quality, I consider that it would not be necessary to impose a planning condition seeking to control or require monitoring of emissions from the process. Furthermore, the national *Planning Practice Guidance* indicates that blanket removal of freedoms to carry out small scale alterations that would otherwise not require planning permission are unlikely to meet the tests of reasonableness and necessity. Whilst permitted development rights applicable to waste management facilities are constrained by a number of factors, they do not include the Green Belt. In my judgement, I have not been provided with evidence to show that there would be clear justification in this case to remove permitted development rights and under the circumstances, such a condition would not be reasonable or necessary.

109. I have had regard to the concerns raised by a number of interested parties that conditions associated with planning permission Ref. 04/02712/FUL have

[67] Membership to include representatives of the site operator and the local planning authority as well as representatives of local residents, should they wish to be represented.

not been adequately enforced by the Council in the past.[68] Nonetheless, in my judgement, the conditions set out in Appendix 3 to this document meet the tests of conditions, including that they would be practical to enforce. The allocation of resources to such activities is a matter for the Council and not for me.

Conclusions

110. Whilst I have found that the proposal would amount to inappropriate development under the terms of RUDP Policy NE3, I give this matter little weight as the Policy's requirements are not consistent with the terms of the more recent Framework. Under the terms of the Framework, I have found that the scheme would not be inappropriate development in the Green Belt, a view shared by the Council. Against this background, I consider that although RUDP Policy NE3 is out of date, this does not trigger the application of the 'tilted balance', as it is not one of the policies which are most important for determining the appeal.

111. It is clear from the written submissions made and the views expressed by a large number of local people, including some elected officials and objectors who appeared at the Inquiry, that there is a significant level of public opposition to the appeal scheme. However, although the views of those people are important, they must be balanced against the other aspects of the evidence.

112. It has been suggested, with reference to air quality, that allowing the appeal would result in a breach of Human Rights, in particular Schedule 1, Part I Article 2 of the *Human Rights Act 1998*; the right to life. I do not consider this argument to be well founded, as I have found that the scheme would not materially harm human health. In my judgement, having had regard to my conclusions on the main issues and other matters raised, allowing the appeal would not result in interference with or violation of any Human Rights, with reference to the *Human Rights Act 1998*.

113. I conclude on balance that the benefits of the scheme would outweigh any adverse impacts likely to be associated with it and the appeal scheme would accord with the Development Plan taken as a whole. Furthermore, it would amount to sustainable development under the terms of the Framework taken as a whole. For the reasons given above, I conclude that appeal A should be allowed.

Appeal B

114. The planning application subject of Appeal B sought planning permission for a *Recycling centre with indoor sorting shed and widening of access from Rochdale Road (as amended)* without complying with conditions attached to planning permission Ref. 04/02712/FUL. The conditions in dispute were condition nos. 5 and 12. In the event that the appeal were to be allowed, a new planning permission would be created; the original planning permission Ref. 04/02712/FUL remaining unaltered.

115. The application sought a relaxation of the terms of: condition no. 5, which restricts the hours of use of the premises; and, condition no. 12, which prohibits burning on site. The aim was to enable the proposed small waste

[68] For example, ID25.

incinerator plant within the appeal building to burn residual non-recyclable waste and to operate 24 hrs/day Monday to Friday inclusive. I have already taken those matters into account when considering the likely impact of the scheme the subject of appeal A.

Living conditions-air quality

116. For the reasons set out above in relation to appeal A, I consider that, with respect to its effect on air quality, the scheme would not materially harm the health and safety of users of the site or surroundings or the quality and enjoyment of the environment there. I conclude that the effect of the proposed modifications of condition nos. 5 and 12 on living conditions in the local area, with particular reference to air quality would be acceptable, and it would not conflict with the requirements of RUDP Policies WM 9 or EP 1 or the aims of the Framework. Furthermore, in that context the existing restrictions imposed by condition nos. 5 and 12 would not be reasonable and necessary.

Living conditions-noise and disturbance

117. For the reasons set out above in relation to appeal A, I conclude that, subject to the imposition of conditions, the effect of the proposed modifications of condition nos. 5 and 12 on living conditions in the local area, with particular reference to noise and disturbance, would be acceptable and it would not conflict with the requirements of RUDP Policies EP 8 and WM 9 or the Framework. In support of that outcome, it would also be necessary to modify the terms of condition no. 4 attached to planning permission Ref. 04/02712/FUL, which deals with noise monitoring.

Conditions

118. As I have indicated, in the event that appeal B were to be allowed, a new planning permission would be created. The guidance in the national *Planning Practice Guidance* makes clear that decision notices for the grant of planning permission under section 73 should also repeat other relevant conditions from the original planning permission, unless they have already been discharged. The Council has provided a list of suggested conditions, which whilst based on the original planning permission Ref. 04/02712/FUL, includes minor modifications (other than in relation to original condition nos. 4, 5 and 12) to reflect the current status of the previously imposed conditions. The list was discussed at the Inquiry, together with other conditions suggested by interested parties. I have had regard to those views, when compiling the list of conditions set out in Appendix 4 to these decisions, which departs from the Council's list where I consider it necessary in order to accord with the tests of conditions set out in the Framework.

119. The Council's suggested list of conditions did not include condition nos. 21-25 attached to the original planning permission. As the status of those original conditions is unclear, I consider that it would be necessary to re-impose them. In the event that some have in fact been discharged, that is a matter which can be addressed by the parties. The Council, through the grant of planning permission Ref. 06/01777/VAR, approved a relaxation of the restriction imposed by condition no. 27 attached to planning permission Ref. 04/02712/FUL, which seeks to restrict the number of vehicle movements associated with the appeal site. In the interests of consistency, it would be necessary to impose the more recent restriction.

120. In my judgement, the modified conditions proposed would not alter the nature of the previously approved recycling centre development Ref. 04/02712/FUL and would fall within the scope of section 73 of the *Town and Country Planning Act 1990.*

Conclusions

121. I conclude on balance that the benefits of the scheme would outweigh any adverse impacts likely to be associated with it and the appeal scheme would accord with the Development Plan taken as a whole. Furthermore, it would amount to sustainable development under the terms of the Framework taken as a whole.

122. For the reasons given above, I conclude that appeal B should succeed. I will grant a new planning permission without condition nos. 4, 5, 12 and 27 attached to planning permission Ref. 04/02712/FUL but substituting others and restating, with minor modifications, those other undisputed conditions that are/maybe still subsisting and capable of taking effect.

[redacted]

INSPECTOR

APPENDIX 1-APPEARANCES

FOR THE LOCAL PLANNING AUTHORITY:		
[redacted] Of Counsel		
	He called	
	[redacted]	WYG Environmental Planning Transport
	[redacted]	Calderdale Metropolitan Borough Council
	[redacted] (conditions only)	Calderdale Metropolitan Borough Council

FOR THE APPELLANT:		
[redacted] Of Counsel		
	He called	
	[redacted]	RPS Group
	[redacted]	RPS Group
	[redacted]	RPS Group
	[redacted] (conditions only)	Entran Ltd
	[redacted] (conditions only)	Gunnercooke LLP

INTERESTED PERSONS:	
[redacted]	Councillor
[redacted]	Councillor
[redacted]	Councillor
[redacted]	Councillor
[redacted]	Local resident
[redacted]	Local resident
[redacted]	Local resident
[redacted]	Local resident
[redacted]	Local resident
[redacted]	Local resident
[redacted]	Local resident
[redacted]	Local resident

APPENDIX 2-INQUIRY DOCUMENTS

1	Council's letters notifying interested parties of the appeals and the Inquiry arrangements
2	Correspondence from interested parties in response to the appeal notifications
3	WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulphur dioxide-Global update 2005
4	16/00297/WVARS (withdrawn) red lined plan
5	15/01072/WAM (withdrawn) Plans
6	10/00270/FUL Extension to recycling building planning permission and plans
7	06/01777/VAR Variation of condition 27-Vehicle movements planning permission
8	06/01246/FUL Extension of servicing garage planning permission
9	04/02712/FUL Recycling centre planning permission
10	04/00893/FUL Recycle centre refused
11	17/00114 Red lined plan
12	17/00113 red lined and 'to scale' plans
13	CD32-Revised-Planning interim consultation response 17/00113/WAM Environmental Health October 2017
14	SOL response to CD32
15	Official copy of register of title including red lined plan
16	Defra's Energy from waste-A guide to the debate, February 2014 (revised edition)
17	INCENER8 Operation, maintenance and installation handbook
18	Photos of proposed SWIP installation
19	Waste descriptors applicable to the EWC codes in Table 5.2 of the Planning Statement
20	Stronga Flowdrya FD1WS specification
21	Site survey drawing 9677/12/01 Mar'12
22	Opening statement on behalf of the Council
23	Opening statement on behalf of the appellant
24	Gov.UK Waste incinerator plant: apply for R1 status
25	Complaints regarding planning and EA Permit breaches at CVSH
26	[redacted]- proof of evidence
27	[redacted]- proof of evidence
28	[redacted]- proof of evidence
29	[redacted]- proof of evidence
30	WYG Air quality modelling uncertainty notes
31	ADMS5 user guide and table showing the % of windspeeds at Bingley and Leeds-Bradford ≤0.75 m/s
32	Plan showing road spot levels close to the site
33	Plan showing locations of the site, Mearclough and a school in Sowerby Bridge
34	[redacted]- proof of evidence
35	[redacted]- reference documents
36	Appeal site Waste Returns 2017
37	Appeal site EA compliance band rating
38	Appellant's Old House Lane ownership note
39	Entran note-Points of clarification-noise

40	Drawing 9677/19/28B Stronga Flowdrya FD17
41	Defra's NO_2 diffusion tubes for LAQM: Guidance note for local authorities, March 2006
42	Directive 2010/75/EU on industrial emissions
43	Directive 2008/98/EC on waste and repealing certain Directives
44	Defra's Local Air Quality Management Technical Guidance (TG16)-extract
45	[redacted]-reference documents 'Child health experts warn air pollution is damaging children's health'
46	[redacted]-reference documents UNICEF 'Healthy air for every child: a call for national action'
47	[redacted] photos of the site 16 March 2019
48	[redacted] photo view of appeal site from 80 Rochdale Road
49	Council's draft suggested conditions
50	Council's note on the status of the Sowerby Bridge Masterplan
51	Council's Clarification note R1
52	Council's Clarification note on its position regarding applications impacting on air quality
53	Appellant's note on the R1 energy efficiency formula
54	RPS' note on Uncertainty
55	Appellant's Note concerning the footpath, vehicle movements and associated topics
56	[redacted]-proof of evidence
57	Appellant's Note on Residual Waste Quantities and the Waste Returns
58	Appellant's note Thermal Processing Building Storage
59	Ordnance survey map extracts for the vicinity of the appeal site
60	WYG Air quality note
61	Gov. UK Planning Policy Guidance: Air quality
62	Email from the appellant to the Planning Inspectorate, dated 17 April 2019, Topographical survey
63	Email from the Planning Inspectorate to the Council and appellant, dated 18 April 2019-Inspector's questions
64	Letter from the Planning Inspectorate to the appellant, dated 18 April 2019, Regulation 22 request for Further Information
65	Letter from the Planning Inspectorate to the appellant, dated 23 April 2019, clarifying the Further Information is requested for the purposes of the Inquiry
66	Email from the appellant to the Planning Inspectorate, dated 23 April 2019, documentation requested by the Inspector.
67	Council's draft suggested conditions (updated)
68	Appellant's Further Note on Residual Waste and Waste Returns
69	WYG Air quality note
70	Closing Statement on behalf of the Community Objectors
	Documents submitted during the adjournment
71	Inspector's Inquiry Note-actions for the adjournment and resumption of the Inquiry (latest v4)
72	Email from the appellant to the Planning Inspectorate, dated 7 June 2019, MSW and the R1 energy efficiency formula

73	Letter from the Council to the Planning Inspectorate, dated 17 June 2019, R1.
74	Email from the appellant to the Planning Inspectorate, dated 5 July 2019, RPS' response to WYG's note dated 23 April 2019
75	Environmental Statement Addendum
76	Consultation responses relating to the Environmental Statement Addendum
77	Bundle of correspondence between the Council and appellant with respect to noise measurements
78	Email from Triangle Village to the Planning Inspectorate, dated 23 September 2019, Court of Appeal decision Gladman Developments Ltd
79	Appellant's response (tabs 1-9) to the Regulation 22 consultation correspondence from interested parties.
80	Statement of Common Ground agreed between the Council and appellant, dated 26 September 2019
81	Council's draft suggested conditions and objector's comments
82	[redacted] proof of evidence, October 2019
83	Email from the Planning Inspectorate to the appellant, dated 21 November 2019, Inspector's clarification/some further questions
84	[redacted] rebuttal proof of evidence
85	Email from the appellant to the Planning Inspectorate, dated 22 November 2019, Agreed note on the proposed noise condition[69]
	Documents submitted following the resumption of the Inquiry
86	Gov.UK Environmental Management-guidance, Air emissions risk assessment for your environmental permit
87	Gov.Uk Environmental permitting: air dispersion modelling reports
88	Defra's Local Air Quality Management Technical Guidance (TG16)-full copy
89	Gov.UK PPG: Air quality
90	Email from the Planning Inspectorate to the Council/appellant, dated 25 November 2019, Inspector's questions
91	Council's note on 'Planning Matters'
92	Council plan showing the extent of the designated Green Belt local to the appeal site
93	WYG-Planning Inspectorate Air Quality Modelling Queries
94	RPS-Response to Inspector's written questions on air quality modelling and uncertainty
95	RPS-Response to Inspector's written questions on R1 and CO_2
96	Gunnercooke-Response to SWIP feedstock questions
97	Gunnercooke-Municipal solid waste and the R1 energy efficiency formula
98	[redacted]-proof of evidence
99	[redacted]-proof of evidence
100	WYG-Air quality note on Environment Agency 'Air emissions risk assessment for your environmental permit'
101	RPS-Environmental Statement Addendum-Appendix F: ADMS Model Sensitivity Testing, tables to 2 decimal places.

[69] Circulated (22/11/19) to interested parties (via contact person agreed at the Inquiry) prior to the resumption of the Inquiry.

102	Council's draft suggested conditions upon which the 'triangle village' comments were based (Inquiry document 81)
103	Email between the Council's [redacted], dated 30 October 2019, with respect to noise complaint investigation
104	Council's-Updated note on Green Belt
105	[redacted]
106	Plan and photos for 06/01246/FUL Extension of servicing garage planning permission
107	Council's letter notifying interested parties of the Inquiry resumption details (previously announced at the Inquiry)
108	T Sulich-proof of evidence
109	[redacted]
110	Appeal site historic plan and photo ([redacted])
111	WYG-Amended tables 3.2 and 5.3 of [redacted] evidence and tables showing the potential impact of lowering the emissions limit from 200 mg/m^3 to 120 mg/m^3
112	RPS-Response to Inspector's questions on air quality modelling inputs in the ESA
113	Council/appellant agreed calculation of current/original building volumes
114	Council/appellant agreed suggested condition related to the R1 energy efficiency index
115	Council's closing statement
116	Appellant's closing statement

APPENDIX 3-APPEAL A-SCHEDULE OF CONDITIONS

1) The development hereby permitted shall begin not later than 3 years from the date of this decision.

2) The development hereby permitted shall be carried out in accordance with the following approved plans except to the extent that variation of the plans is required by another condition of this planning permission:

   9677/27/02A- Site Plan & Location Plan;

   9677/19/33- Building to accommodate energy recovery plant for renewable energy (excluding the illustrative internal plant layout), dated June 19.

   9677/17/03A- Illustrative Drawing and Location of New Stronga Flowdrya;

   9677/19/28C- Stronga Flowdrya FD17, dated 15/04/19; and,

   UAM3183_B- Topographical survey sheets 1-4, dated June 2019.

3) No Hazardous Waste shall be used to fuel the small waste incineration plant (SWIP) hereby approved.

4) Only non-recyclable waste derived from the onsite operations shall be used to fuel the SWIP hereby approved. No material shall be brought into the site at any time for incineration for the sole purpose of disposal.

5) The throughput of the SWIP hereby approved shall be no greater than 2 tonnes per hour.

6) Before the first operation of the SWIP hereby approved details of the Drying Plant and the connections to it from the SWIP shall be submitted to and approved in writing by the Local Planning Authority. The Drying Plant and the connections to it shall be completed in accordance with the approved details before the first operation of the SWIP and shall be maintained as installed. The SWIP shall not be operated in the event that the Drying Plant is not available for use.

7) Before the first operation of the SWIP, a scheme for its connection to the National Grid for the export of electricity shall be submitted to and approved in writing by the Local Planning Authority. The connection shall be completed in accordance with the approved details before the first operation of the SWIP and shall be maintained as installed. The SWIP shall not be operated in the event that the connection to the National Grid for the export of electricity is not available for use.

8) Before the first operation of the SWIP hereby approved a scheme shall be submitted to and approved in writing by the Local Planning Authority to demonstrate that electrical generation and/or heat recovery systems have been installed with the capability to meet equivalent energy outputs per unit of waste derived fuel input that meets or exceeds the equivalent of the R1 energy efficiency index. The SWIP shall be operated and maintained in accordance with the approved scheme to ensure that it continues to meet this R1 energy efficiency index and maintains Recovery status.

9) No trenching or other construction activities associated with the scheme hereby approved shall take place until a Construction Environmental Management Plan (CEMP) has been submitted to and approved in writing by the Local Planning Authority. The CEMP shall include methods of contractor liaison with the general public, hours of work and timescales of implementation, management practices to control dust, traffic, access, waste and water resources. All trenching and other construction activities shall thereafter take place in accordance with the approved CEMP.

10) The rating level (as defined in BS4142:2014+A1:2019 'Method for rating and assessing industrial and commercial sound’) of noise emitted from the site shall not exceed the background noise levels by more than 5 dB during the day (07:00-23:00 hours) or night (23:00-07:00 hours). The rating level shall be determined in accordance with the procedure set out in BS4142:2014+A1:2019 for the residential properties located at [redacted] Sowerby Bridge. The assessment period shall be one hour during the day and fifteen minutes at night.

11) Before the first operation of the SWIP hereby approved a site specific Noise Management Plan (NMP) with the objective of limiting, so far as practicable, noise arising from activities at the site, shall be submitted to and approved in writing by the Local Planning Authority. The NMP shall include details of the arrangements for: movement of materials in the yard; loading of the drying plant; loading and unloading of skips; noise from reversing alarms; the investigation of noise complaints and remedial action. The NMP shall be implemented before the first operation of the SWIP and shall be adhered to thereafter.

12) No audible warning alarm for operations within the SWIP building shall be audible outside the boundary of the site.

13) (a) Except as provided by (b) - (c) below no vehicular movements, waste movements, movement of skips, recycling operations or operation of the drying plant authorised or required by this permission or by permission 17/00114/VAR shall be carried out on the site except between the following times: 07:00 hrs to 18:00 hrs Mondays to Fridays; and, 08:00 to 14:00 on Saturdays.

(b) The SWIP hereby approved shall only operate for 24 hours a day on Monday to Friday. On those days during the hours between 00:00 hrs to 07:00 hrs and between 18:00 hrs to 00:00 hrs the SWIP shall only operate when all of the roller shutter doors in the building which contains the SWIP are closed. The SWIP shall not operate on Saturdays, Sundays, or on Bank/Public Holidays.

(c) The above time restrictions shall not apply to environmental monitoring.

(d) Save for environmental monitoring there shall be no other working on Sundays or on Bank/Public Holidays.

14) Before the first operation of the SWIP hereby approved a dust management scheme for the operation of the SWIP and Drying Plant shall be submitted to and approved in writing by the Local Planning Authority. The scheme shall include management of dust arising from: Loading of the SWIP; Removal of Bottom Ash from the SWIP; Transportation of Bottom Ash from the site; as well as, loading and unloading of the Drying Plant and storage of the associated dried material. The approved dust management plan shall thereafter be implemented in full throughout the operation of the SWIP and Drying Plant.

15) The height of the soils stockpiles in the drying area shall be restricted to no more than 3 metres in height.

16) Before any external artificial lighting is installed for the purpose of illuminating activities or areas associated with the SWIP and/or Drying Plant operations, details of a scheme to adequately control any glare and obtrusive light produced by the artificial external lighting shall be submitted to and approved in writing by the Local Planning Authority. The lighting installation shall comply with the recommendations of the Institution of Lighting Professionals (ILP) "Guidance Notes for the Reduction of Obtrusive Light" reference GN01: 2011 for environmental zone E2. The artificial lighting shall be installed in accordance with the scheme so approved and retained thereafter. The scheme should include the following information:

    a) The proposed level of maintained illuminance, measured horizontally at ground level;

    b) The maintenance factor;

    c) The predicted maximum vertical illuminance that will be caused by the lighting when measured at windows of any residential properties in the vicinity;

d) The proposals to minimise or eliminate glare from the use of the lighting installation when viewed from windows of properties in the vicinity;

e) The proposed type of luminaires to be installed showing for each unit, the location, height, orientation, light source type and power;

f) The proposed hours of operation of the lighting.

Furthermore, there shall also be submitted to the Local Planning Authority upon completion of the approved lighting a statement of a suitably qualified contractor that the light emitted by any lighting installation to which this condition applies is fully compliant with the ILP guidance for the relevant environmental zone.

17) Except for the operation of the SWIP hereby approved in accordance with the conditions attached to this permission, there shall be no open burning on the site at any time.

18) The development hereby approved shall be carried out in accordance with the Flood Risk Assessment Addendum Report (FRA) by RMA Environmental Ltd, referenced RMA/LC1984_1 - Calder Valley Skip Hire FRA and dated 26 July 2019, and the mitigation measures detailed within the FRA: Flood resilience/resistance measures shall be set at a minimum of 300 mm above finished floor level. These requirements shall be fully implemented prior to the SWIP and/or Drying Plant first being brought into use.

19) There shall be no raising of ground levels within the yard areas of the site at any time.

20) The maximum total number of movements by vehicles with a gross plated weight of more than 3.5 tonnes into and out of the whole site (including but not limited to those associated with the waste recycling activities and associated with the development subject of planning permission Ref. 17/00113/WAM) shall not exceed 120 (i.e. 60 movements into the site and 60 movements out) per day. A log of vehicle movements shall be kept and made available to the Local Planning Authority upon request.

21) Before the first operation of the SWIP hereby approved a scheme detailing the establishment of a liaison group shall be submitted to and approved in writing by the Local Planning Authority. The scheme shall include details of the liaison group objectives, membership, frequency and location of meetings and arrangements for the publication of the minutes of the meetings as well as a timetable for implementation of the scheme. Liaison group meetings shall be held in accordance with the approved scheme.

22) No excavation work associated with the development hereby approved shall commence until an assessment of the risks posed by any contamination, carried out in accordance with British Standard BS 10175: Investigation of potentially contaminated sites - Code of Practice and the Environment Agency's Model Procedures for the Management of Land Contamination (CLR 11) (or equivalent British Standard and Model Procedures if replaced), shall have been submitted to and approved in writing by the Local Planning Authority. If any contamination is found, a report specifying the measures to be taken, including the timescale, to

remediate the site to render it suitable for the approved development shall be submitted to and approved in writing by the Local Planning Authority. The site shall be remediated in accordance with the approved measures and timescale and a verification report shall be submitted to and approved in writing by the Local Planning Authority. If, during the course of development, any contamination is found which has not been previously identified, work shall be suspended and additional measures for its remediation shall be submitted to and approved in writing by the Local Planning Authority. The remediation of the site shall incorporate the approved additional measures and a verification report for all the remediation works shall be submitted to the Local Planning Authority within 30 days of the report being completed and approved in writing by the Local Planning Authority.

APPENDIX 4-APPEAL B-SCHEDULE OF CONDITIONS

1) The development hereby permitted shall be carried out in accordance with the following approved plans except to the extent that variation of the plans is required by any other condition of this planning permission:

   CV28 Existing road layout and proposed improvements;

   CV29 Road gradients;

   CV30 Road cross sections;

   NA1 dated 21 September 2005 Location Plan;

   NA2 dated 21 September 2005 New Building Design;

   NA7 dated 21 September 2005 New Storage Bay Design;

   NA9 dated 21 September 2005 Road Details; and,

   NA10 dated 21 September 2005 Site Garage.

2) The facing materials approved under condition 2 of planning permission 04/02712/FUL on 26/4/2007 shall be retained in their approved form.

3) The roofing materials approved under condition 3 of planning permission 04/02712/FUL on 26/4/2007 shall be retained in their approved form.

4) The rating level (as defined in BS4142:2014+A1:2019 'Method for rating and assessing industrial and commercial sound') of noise emitted from the site shall not exceed the background noise levels by more than 5 dB during the day (07:00-23:00 hours) or night (23:00-07:00 hours). The rating level shall be determined in accordance with the procedure set out in BS4142:2014+A1:2019 for the residential properties located at 28, 44, 46, 80 and 90 Rochdale Road, Sowerby Bridge and 'Bank House' and 'Bank Cottage', Long Lane, Norland, Sowerby Bridge. The assessment period shall be one hour during the day and fifteen minutes at night.

5) Before the first operation of the Small Waste Incineration Plant (SWIP) approved by planning permission Ref. 17/00113/WAM a site specific Noise Management Plan (NMP) with the objective of limiting, so far as

practicable, noise arising from activities at the site, shall be submitted to and approved in writing by the Local Planning Authority. The NMP shall include details of the arrangements for: movement of materials in the yard; loading of the drying plant; loading and unloading of skips; noise from reversing alarms; the investigation of noise complaints and remedial action. The NMP shall be implemented before the first operation of the SWIP and shall be adhered to thereafter.

6) (a) Except as provided by (b) - (c) below no vehicular movements, waste movements, movement of skips, recycling operations or operation required by this permission or by permission 17/00113/WAM shall be carried out on the site except between the following times: 07:00 hrs to 18:00 hrs Mondays to Fridays; and, 08:00 to 14:00 on Saturdays.

(b) The SWIP approved by planning permission Ref. 17/00113/WAM shall only operate for 24 hours a day on Monday to Friday. On those days during the hours between 00:00 hrs to 07:00 hrs and between 18:00 hrs to 00:00 hrs the SWIP shall only operate when all of the roller shutter doors in the building which contains the SWIP are closed. The SWIP shall not operate on Saturdays, Sundays, or on Bank/Public Holidays.

(c) The above time restrictions shall not apply to environmental monitoring.

(d) Save for environmental monitoring there shall be no other working on Sundays or on Bank/Public Holidays.

7) All vehicles used by the operator of the site for the use of conveying skips to and from the site shall be fitted with a device in order to attenuate the impact noise generated from the moving of chains on the vehicles in accordance with the scheme submitted under condition 6 of planning permission 04/02712/FUL and approved in writing on 28/10/2008.

8) On the date of this decision and thereafter suppression of dust on access roads, circulation areas, storage of materials in stockpiles and the loading to and from stockpiles shall be carried out in accordance with the details submitted under condition 7 of planning permission 04/02712/FUL and approved in writing on 28/10/2008. Immediate preventative action, including suspension of operations if necessary, shall be taken if dust generated on the site becomes airborne and can be seen to be carried by the wind beyond the site boundaries.

9) On the date of this decision and thereafter prevention of the deposit of mud and waste material on the public highway caused by the operations hereby approved shall be carried out in accordance with the scheme submitted under condition 8 of planning permission 04/02712/FUL and approved in writing on 28/10/2008.

10) On the date of this decision and thereafter prevention of materials from becoming airborne shall be carried out in accordance with the control measures submitted under condition 9 of planning permission 04/02712/FUL and approved in writing on 28/10/2008.

11) Artificial lighting implemented in accordance with the details submitted under condition 10 of planning permission 04/02712/FUL and approved in writing on 1/3/2018 shall be retained in its approved form.

12) Mill House shall only be used as offices, occupied or used in connection with and ancillary to the occupation or use of the existing premises and replacement buildings permitted by planning permission 04/02712/FUL and at no time be severed and occupied as a separate independent unit.

13) Except for the operation of the SWIP in accordance with the conditions attached to this planning permission and planning permission Ref. 17/00113/WAM, there shall be no open burning on the site at any time.

14) No crushing or screening of material shall take place outside the replacement building permitted by planning permission 04/02712/FUL.

15) Materials, goods, plant and/or equipment shall not be stacked or deposited externally to a height exceeding 3 metres above the level of the concrete yard.

16) The parking areas/vehicle manoeuvring areas shown on the approved plan (amended 21 September 2005) no. NA1 shall be retained in their approved form for that purpose for the occupiers of and visitors to the development.

17) The access improvements shown on the approved plans nos. CV28, CV29 and CV30 shall be retained in their entirety for the lifetime of the development.

18) There shall be no obstructions above 900 mm in height at any time within the visibility splays shown on the approved plan no. NA1 (amended 21 September 2005).

19) Public footpath Sowerby Bridge 94a running through the site shall not be closed, stopped up, diverted or obstructed over either the whole or part of its length at any time.

20) Any proposed liquid storage (fuel oil, process chemicals, etc) tanks shall be located and retained within a bund having a capacity of not less than 110% of the largest tank. If the tanks are connected by pipework in such a way as to allow equalization of the level of the contents, then the bund capacity shall be 110% of the highest combined volume. Floor and walls of the bund shall at all times be impervious to oil and water (and resistant to any stored chemicals). Inlet/outlet/vent pipes and gauges shall at all times be within the bunded area. Before any such bunds are first brought into use, details of the arrangements for the proper disposal of contaminated surface water from within the bund (there must be no uncontrolled discharge to any drain or sewer) shall have been submitted to and approved in writing by the Local Planning Authority. Disposal shall thereafter be carried out only in accordance with the approved details.

21) Prior to being discharged into any watercourses, surface water sewer or soakaway system, all surface water drainage from parking areas and hardstandings shall be passed through an oil interceptor installed in accordance with a scheme previously submitted to and approved in writing by the Local Planning Authority. Roof water shall not be required to pass through the interceptor.

22) The development shall not begin, until a scheme for the provision of surface water drainage works has been submitted to and approved in writing by the Local Planning Authority. The drainage works shall be

completed in accordance with the approved details and timetable agreed, and shall be so retained thereafter.

23) No works or storage shall commence on the site until all trees/shrubs/hedgerows which are to be retained have been protected by the erection of a strong durable 1.5 metre high barrier fence in accordance with BS 5837. This shall be positioned so as to enclose their perimeter crown spreads, or as may be agreed in writing by the Local Planning Authority. The protective fencing shall be properly maintained for the duration of the development and shall not be removed during this period without the written approval of the Local Planning Authority.
The positions of all trees/shrubs to be retained and the protective fencing shall be clearly marked on a plan(s) which shall have been submitted for the prior written approval of the Local Planning Authority before the commencement of the development.

24) With the exception of trees (but excluding trees T5 and T8) specifically shown on the permitted plan to be felled, or as otherwise agreed in writing by the Local Planning Authority, no trees on the site shall be lopped, topped, uprooted, felled, wilfully damaged or destroyed. Any trees so damaged, felled or destroyed without such approval within 5 years of the completion of the development shall be replaced before the end of the following planting season with trees of a size and species in a position approved in writing by the Local Planning Authority which shall be so retained thereafter.

25) The development shall not begin until a scheme for the long-term management of the woodland area and for protected species has been submitted to and approved in writing by the Local Planning Authority. This shall include a programme for the implementation of the management plans and they shall thereafter be implemented in accordance with the details so approved.

26) The recommendations contained in the submitted Bat Report (September 2005) shall be fully implemented in accordance with the timescales set out in the Report.

27) All loaded lorries leaving the site shall be securely and effectively sheeted before they leave the site.

28) The maximum total number of movements by vehicles with a gross plated weight of more than 3.5 tonnes into and out of the whole site (including but not limited to those associated with the waste recycling activities hereby approved and associated with the development subject of planning permission Ref. 17/00113/WAM) shall not exceed 120 (i.e. 60 movements into the site and 60 movements out) per day. A log of vehicle movements shall be kept by the site operator and made available to the Local Planning Authority upon request.

STATEMENT OF OBJECTION TO ENVIRONMENTAL PERMIT APPEAL

Email to: [redacted]

From: [redacted]
Address: [redacted]

Calder Valley Skip Hire Limited – Environmental Permit Appeal – Reference APP/EPP/603

DOCUMENTS included with this Objection:

1. **Air Quality and Permit Review: Calderdale Valley Skip Hire Small Waste Incineration Plant – November 2021 - Air Quality Consultants Limited.** Note this is the same as the Appellant has submitted except for the correction of the reference to "unpredicting sites" to "underpredicting sites" in Issue 5. ("**AQC Report**")

2. **Advice - October 2022 - by [redacted] ("Counsel's Opinion")**

3. **Technical Note – Calder Valley Skip Hire Small Waste Permit Incineration Plant – October 2022 – Air Quality Consultants Limited ("AQC Technical Note")**

4. **High Court Order granting permission for Judicial Review – 23 July 2021. ("High Court Order")**

GROUNDS OF OBJECTION

1. I object to the grant of an Environmental Permit for the reasons set out in this document and attachments.

Basis of the Appeal

2. The Appellant has appealed on the ground of a "deemed refusal" due to the failure by regulator to give notice of determination of the application for the Permit within the statutory time-period. However, the Statement of Case of the Appellant which seeks to set out the merits of the appeal very much centres around its incorrect contention that it is impermissible for anyone to revisit any of the air quality issues considered by the Planning Inspector [redacted] in his planning permission decisions dated 4 February 2020 during the environmental permitting process both as a matter of law and as a matter of Central Government guidance as contained in the National Planning Policy Framework (NPPF).

3. The Appellant seeks to persuade the regulator and the Inspector hearing this appeal that none of the outstanding matters raised by the Calderdale Council's experts (Tetra Tech) or in the AQC Report can be taken into consideration in the decision as to whether or not to grant an Environmental Permit. It appears that the refusal to provide the additional information is the primary reason for the submission of the appeal.

4. Calderdale Council in its Statement of Case has wrongly accepted the arguments put forward by the Appellant and conceded the Appeal on the basis that it considers it is prevented from seeking the further information advised by its technical advisors (who were acting under delegated power of the Council as its "competent persons") and on the basis

that no further evidence has been put forward to undermine the original quashed decision to grant the Permit. The Council's Statement of Case makes no reference whatsoever to the AQC Report and the evidence in that which has been provided to counter the original decision to grant the Environmental Permit.

Law and Guidance

5. The correct position in relation to the law and guidance on the process that should be followed and the matters that can be taken into account in relation to the determination of an Environmental Permit application and appeal are set out in detail in the Counsel's Opinion and ACQ Technical Note attached with this objection.

6. From these documents it is clear that the Planning Inspector did <u>not</u> conclude that an Environmental Permit should be granted, or on what terms, and those matters were <u>not</u> within his remit. The Planning Inspector's conclusions on air quality do <u>not</u> bind the regulator or Inspector who will be dealing with this Environmental Permit appeal.

7. Since the planning appeal decision, the Environmental Permit decision has been made and been the subject of expert reports on behalf of CVSH, the Council and local residents as well as subject to a successful judicial review. The environmental permit decision will need to take the changed circumstances and additional information into account. Consequently, if it is found during the process of reviewing the permit application that the proposal is harmful to health or the environment then the Environmental Permit <u>must</u> be refused.

8. CVSH have mentioned, but not advanced, the possibility of arguing that the planning appeal decision gives rise to an issue estoppel in respect of air quality matters. An issue estoppel arises where a determination of an issue in one set of proceedings binds the parties to those proceedings in the future. Issue estoppel does not arise in relation to judgements as to whether planning permission should be granted. Whilst a grant of planning permission does, of course, give rise to the rights in the permission, it does not bind the parties as to the merits of the application.

Relevance of High Court Order granting Permission for Judicial Review

9. The Statements of Case in this appeal note that [redacted]l brought successful judicial review proceedings against the original grant of the Environmental Permit. The claimant's statement of facts and grounds in the judicial review noted:

   "61. CVSH take points which are not part of the Council's reasoning and assert erroneously (i) that air quality is not a matter for environmental permitting (when it is the purpose of environmental permitting) and (ii) that the view of a Planning Inspector on planning merits amounts to an issue estoppel. Issue estoppel can only arise in public law decisions which are determinative of an issue, such as the legal grounds in a planning enforcement notice appeal, rather than exercises of discretion or judgments as to future circumstances."

10. The Council and CVSH resisted the proceedings. Ground 3 concerned regard to environmental permitting guidance. CVSH contended that because of the Planning Inspector's decision '*It would have been unlawful for the Council to seek to refuse the permit on the basis that the proposal would have an impact which was more than negligible' (Summary Grounds, para 29*). To do so would have been '*a flagrant disregard' of what is now paragraph 188 of the National Planning Policy Framework (Summary Grounds, para 29).* A copy of the High Court Order granting permission to apply for judicial review is attached to this objection. <u>Permission to apply was granted on all grounds</u>.

Permission would not have been granted if the High Court had agreed that CVSH's main argument on this point was correct. Had the High Court agreed with CVSH (and now the Council) it would have been fatal to the grounds which addressed air quality issues previously considered by the Planning Inspector. CVSH and the Council are in error continuing to try to put forward these arguments despite the judgment in the High Court Order.

Obligations of the Regulator

11. It is the permitting authority that has the responsibility and statutory obligation to determine whether operational stack emissions from regulated facilities covered under the EPR are controlled to prevent significant impacts on human health and the environment. Combined with ensuring statutory minimum emission limit values can be met, predictive air quality assessments are the only data available to the permitting authority at application stage to determine the potential impact on human health and the environment and, consequently, the degree to which emissions are/can be controlled.

12. Irrespective of whether operational air quality effects have been discussed at planning stage, the local authority permitting function, as regulator for SWIPs, can, and must, ensure that operational phase assessments of stack emissions are robust. If any aspect of the air quality assessment of operational stack emissions is not considered to be robust, further information should be sought by the local authority permitting function, and provided by the applicant, before determining the application.

Outstanding Issues preventing Grant of a Permit

13. As part of the process for the redetermination of the Environmental Permit the Council appointed Tetra Tech to undertake a further review of the amended permit application and the AQC Report and the outcome was that, acting under the delegated powers of the Council, agreeing with points made by AQC, Tetra Tech required additional information before a decision was taken. Further information was therefore requested by the Council in relation to the assessment of 1-hour mean NO2 concentrations, and a sensitivity test regarding uncertainty within the air quality assessments. CVSH refused to provide that information based on its incorrect assertion of the law and guidance.

14. As part of the redetermination process CVSH instructed RPS to undertake a review of the AQC Report. The subsequent report by RPS has been provided by the Appellant as part of the appeal documents and is attached to the AQC Technical Note. That RPS report however ignored the items listed in the AQC Report (1) Uncertainty (3) Stack Height (5) Road Modelling Verification and Model Adjustment (6) Assessment of 1 hour- mean NO2 Concentrations (10) Surface Roughness. The reason it did so was solely because it followed the (incorrect) legal advice from CVSH's lawyers to the effect that it was considered impermissible to revisit the air quality issues determined by the Planning Inspector during the environmental permitting process.

15. It is to be wondered (given the Appellant has sought to address other issues raised by AQC), whether the resistance of the Appellant to address these issues is not so much due to its interpretation of the law and guidance, but the fact that if they are properly addressed now in the terms of the environmental permitting regime, the results would lead to a conclusion that the Environmental Permit should be refused.

16. The Appellant seeks to find an issue with the failure of the AQC Report to list the Planning Inspector's decision. AQC have confirmed in the AQC Technical Note that they reviewed the documents and Planning Inspector's decision. They confirm that, although the planning appeal decision was sent to AQC, it was not considered material for the review

of the air quality impacts at permitting stage. They state that*, as previously demonstrated, both in terms of legislation and supporting guidance, it is the permitting regime that must determine whether the assessment of operational air quality effects of stack emissions is robust with respect to controlling emissions under the EPR. The planning regime serves an entirely separate purpose.*

17. The further information required by Tetra Tech and the issues raised by AQC ((1) Uncertainty (3) Stack Height (5) Road Modelling Verification and Model Adjustment (6) Assessment of 1 hour- mean NO2 Concentrations (10) Surface Roughness) all continue to remain relevant and unresolved. It is my view, supported by that of Counsel's Opinion and the AQC Technical Note that a permit should not be granted until they are adequately addressed and found to have satisfactory outcomes. Given that the Appellant has refused and continues to refuse to address these points, the appeal should be dismissed, and the permit refused.

Conclusion

18. It is clear that the Council as regulator has once again misdirected itself as to the applicable law, guidance and process for the determination of the Environmental Permit application. The Council has erred in law and consequently acted unlawfully in relying on this error of law in (i) not defending its original decision to require additional information and (ii) not defending the appeal based on the Tetra Tech report that required the additional information before the permit application could be determined. The Council once again has no rational basis for failing to follow the Tetra Tech recommendation that more information should be obtained as set out above.

19. In those circumstances, I request that the Secretary of State dismisses this appeal and directs the Council to refuse to grant and Environmental Permit to the Appellant for the operation of the SWIP and associated plant at the Appeal Site.

Air Quality CONSULTANTS

Air Quality and Permit Review:
Calderdale Valley Skip Hire Small Waste Incineration Plant

November 2021

Experts in air quality management & assessment

Document Control

Client	[redacted]	Principal Contacts	[redacted]

Job Number	[redacted]

Report Prepared By:	[redacted]

Document Status and Review Schedule

Report No.	Date	Status	Reviewed by
[redacted]	26 November 2021	Final Report	[redacted]

This report has been prepared by Air Quality Consultants Ltd on behalf of the Client, taking into account the agreed scope of works. Unless otherwise agreed, this document and all other Intellectual Property Rights remain the property of Air Quality Consultants Ltd.

In preparing this report, Air Quality Consultants Ltd has exercised all reasonable skill and care, taking into account the objectives and the agreed scope of works. Air Quality Consultants Ltd does not accept any liability in negligence for any matters arising outside of the agreed scope of works. The Company operates a formal Quality Management System, which is certified to ISO 9001:2008, and a formal Environmental Management System, certified to ISO 14001:2004. QMF 08.

When issued in electronic format, Air Quality Consultants Ltd does not accept any responsibility for any unauthorised changes made by others.

When printed by Air Quality Consultants Ltd, this report will be on Evolve Office, 100% Recycled paper.

Air Quality Consultants Ltd
23 Coldharbour Road, Bristol BS6 7JT Tel: 0117 974 1086
12 Airedale Road, London SW12 8SF Tel: 0208 673 4313
aqc@aqconsultants.co.uk

Registered Office: 12 St Oswalds Road, Bristol, BS6 7HT
Companies House Registration No: 2814570

Executive Summary

A review of the Environmental Permit application and associated air quality technical information for the Calder Valley Skip Hire (CVSH) Small Waste Incinerator Plant (SWIP) has been undertaken.

While no 'Major' issues have been found that, individually, are likely to significantly alter the conclusions stated by the applicant within its air quality assessments; there are areas of uncertainty with the applicant's roads modelling verification and assessment of the significance of benzo(a)pyrene emissions that, combined, could affect the conclusions of the assessment. Furthermore, additional justification is considered to be required on the suitability of the proposed stack height. As the air quality assessment is a supporting document of the permit application, these issues affect the determination of the permit and introduce uncertainty as to whether enough information has been requested by CMBC to robustly determine the application.

A number of other 'Moderate' issues have been identified, such as the absence of any assessment of the total bodily intake of polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans (collectively referred to as 'dioxins') and dioxin-like polychlorinated biphenyls (PCBs), and no assessment of impacts on local wildlife sites within 2 km in the latest air quality assessment addendum.

With regard to the Environmental Permit application itself, several areas have been identified that introduce uncertainty with respect to the ability of the plant and/or of the Operator to comply in full with the requirements of Chapter IV of the IED. However, it is expected that such issues could be resolved with further requests for information, rather than a fundamental inability of the plant to meet the requirements of IED and of the permit. Despite this, it is a requirement that all information required to determine an application is provided and the permitting authorities should not determine an application until they are satisfied they have received all relevant information. Therefore, we believe further information is required in order for the permit application to be robustly determined.

Furthermore, there are several areas (such as the transport of Air Pollution Control residues through the WTS installation boundary) where it is advised legal opinion is sought before deciding whether to pursue this as a matter for further consideration.

For ease of reading, the issues have been summarised in the table below; however, these should always be considered in context of the complete discussion points raised in the main body of the report before reaching any conclusions.

Executive Summary Table		
No.	**Issue**	**Conclusion**
Review of Air Quality Assessment		
Moderate Issues		
1	Uncertainty	Uncertainty is an inherent component of any scientific method. The uncertainty assigned to a result represents the range of values around the result in which the true value is expected to lie. The true value is a conceptual term, which can never be exactly determined. The basis for challenge three of the judicial review is that WYG's (acting as expert reviewer for Calderdale Metropolitan Borough Council) sensitivity modelling identified more than negligible impacts as being possible. This focusses on the assumption that either the background or the process contribution from the applicant's site could be greater than that reported in the assessment. The WYG report states that it is possible that moderate adverse effects may occur, but then goes on to discount these without any real justification. While we do not necessarily agree with the way WYG has undertaken its sensitivity analysis (adding arbitrary percentages to different baselines), we do agree that the potential for impacts greater then negligible cannot be immediately discounted. This is based on information provided by the applicant about the baseline and process contribution from the incinerator stack.
2	Benzo(a)pyrene	Within the 2019 additional air quality assessment, the applicant predicts a 'worst-case' Benzo(a)pyrene process contribution, i.e., that relating to emissions from the SWIP processes in isolation, of 9% of the Air Quality Standard, and predicted environmental concentration of 98.4%, i.e., the SWIP process contribution plus contributions from other emission sources. This level of impact is presented at the location of maximum impact anywhere on the modelled grid. The applicant needs to provide more information to justify that the contribution is insignificant.
3	Stack Height Determination	The applicants chosen stack height has not been demonstrated to meet the principle of BAT. The applicant has not demonstrated all pollutant contributions to nearby receptors are insignificant; the stack height should be at a height where the cost of increasing the stack becomes disproportionate to the marginal environmental benefit gained unless an insignificant process contribution can be identified at a lower stack height. This has not been demonstrated in this case.
4	Ecological Impacts	The applicant has not assessed the impacts at nearby ancient woodland and local nature reserve ecological sites within their ES addendum or their 2019 additional Air Quality Assessment. These sites are within the 2 km screening distance for assessment of ecological sites required by the Environment Agency.
5	Roads Modelling Verification and Model Adjustment	Examination of the applicant's verification analysis has shown the model to underpredict at monitoring sites SB20 and SB22 (which are located approximately 35 m from Receptor 8) and overpredict at monitoring sites SB3 and AQS4 (which are located nearly 450 m from Receptor 8). Given that Receptor 8 is close to the underpredicting sites, and is registering at or above the objective (depending on the year chosen), the methodology for the model verification, and approach to calculating the correction factor, may not be suitably precautionary.

Executive Summary Table		
No.	**Issue**	**Conclusion**
6	Assessment of 1-hour mean NO_2 Concentrations	The applicant has not undertaken an assessment against the short-term NO_2 objective using the half-hourly emissions limit within IED and their permit. Rather, the daily average emission concentration has been used for assessing hourly mean impacts. As the plant is permitted to discharge NOx at levels up to 400 mg/Nm^3 for a period of 30-minutes, there is the potential for hourly averaged emission concentrations to exceed the daily averaged emission limit that has been modelled leading to potential underestimation of hourly mean impacts.
7	Human Health Risk Assessment for Persistent Organic Pollutants	No HHRA for dioxins and furans and PCBs has been undertaken. Such an assessment addresses impacts relating to bioaccumulation in the food chain for pollutants which cannot be adequately assessed by referring to ambient air quality standards. In practice, the methods available for such an assessment are relatively crude and thus tend to be over-precautionary, but the results can still provide reassurance as to the scale of impacts. The experience of the reviewers, consistent with research and the latest position of Public Health England, is that waste incineration plant meeting the IED emission limits and with an appropriately optimised stack height, only provide negligible contributions to the TDI and the more precautionary TWI. However, in this case, due to the potential issues identified with the justification of the selected stack height, a HHRA should not just be viewed as a procedural exercise.
Minor Issues		
8	Carbon Monoxide 1-hour EAL	The applicant has not undertaken an assessment against the Carbon Monoxide 1-hour Environmental Assessment Level (EAL) of 30,000 µg/m^3. In the experience of the reviewers, carbon monoxide emissions are generally insignificant compared to the environmental standards. As there are no predicted significant effects towards the 8-hour CO objective, lack of consideration of the 1-hour EAL is unlikely to alter the conclusion of the assessment.
9	TOC Emissions	The applicant has not undertaken an assessment of the likely emissions of total organic compounds (TOC). It is a requirement within chapter IV of IED that emissions to air from waste incineration plants shall not exceed the emission limit value of 10 mg/Nm^3 for TOC; therefore, any robust assessment should consider the sites impact from TOC.
10	Surface Roughness	It is unclear why the applicant has chosen to use such a high surface roughness value within their sensitivity analysis. This has the potential to over represent the turbulence effects in the area.
Review of Permitting Application		
11	Implications of Multiple Permits on the Same Site	The proposed Calder Valley Skip Hire site consists of an existing household, commercial and industrial waste transfer station, including treatment, and the proposed Schedule 13 SWIP. The waste operations in the waste transfer station are regulated by the Environment Agency under Environmental Permit EPR/SP3196ZQ, whilst the operations of the SWIP were to be regulated by Calderdale Metropolitan Borough Council under Environmental Permit S13/005. It is not entirely unusual that multiple permits exist with different regulators on the same site.

Executive Summary Table		
No.	**Issue**	**Conclusion**
		One potential complicating factor of the proposed permitting arrangement at the site relates to the transport of Air Pollution Control residues (APCr). APCr are classed as hazardous waste principally due to their high pH content. The WTS permit does not allow the acceptance of hazardous waste. However, due to the way that the permit boundaries are defined, APCr must be transported through the WTS permitted installation boundary before it leaves the wider site. It is unclear whether the transportation of APCr through the WTS installation boundary would convey a degree of 'acceptance', or whether this would simply be considered the same as APCr transport on the wider road network. If this was to constitute 'acceptance', then the WTS would be operating outside the conditions of its permit. In any case, it would have been advisable for the Accident Management Plan for the WTS to be updated to reflect that there is the potential for hazardous waste to pass through its installation boundary. However, many of the issues raised in this section, are procedural. Consequently, such matters are best judged by a legal professional.
12	Installation Boundaries	From review of the introductory note in the Environmental Permit for the WTS permit and surrender notice, it is clear the intent was to remove (partial surrender) only the area associated with the SWIP installation from the existing WTS permit. We suspect any apparent area of unregulated land has arisen through accidental omission/interpretation of the figures, rather than specific intent, and better quality images or revised plans could resolve such matters. However, as currently drafted, it does appear there is a small area of land that is not regulated under either permit.
13	Further request for information	There are a number of issues, detailed from Paragraph 4.23 onwards, that require clarification before the robustness of the applicant's permit application can be suitably determined. Without this further information, it cannot be robustly determined that the applicant's operation will meet with the requirements of IED, the Environmental Permitting Regulations, or minimise harm to people and the environment.

Contents

1 Introduction

1.1 Air Quality Consultants Ltd (AQC) has been commissioned to review the Environmental Permit application and associated air quality technical information for the Calder Valley Skip Hire (CVSH) Small Waste Incinerator Plant (SWIP).

1.2 This report has been complied by reviewing the following documents:

- Schedule 13 SWIP Permit Application document and associated appendices (written by RPS);
- Schedule 13 Environmental Permit (ref. S13/005) issued by Calderdale Metropolitan Borough Council (CMBC);
- Schedule 5 notice for further information from CMBC to the permit application and the applicant’s Schedule 5 response;
- CVSH Environmental Permit for the existing Waste Transfer Station (EPR/SP3196ZQ/V002) and Schedule 7 site plan;
- ES Addendum To 2017 ES Chapter 7: Air Quality (written by RPS);
- Appendix 3.1- Environmental Statement Addendum – Additional Air Quality Assessment (written by RPS); and
- Environmental Permit Application S13/005 Small Waste Incineration Plant Air Quality Considerations (written by WYG).

1.3 The site already has planning permission. An Environmental Permit to operate a Schedule 13 Small Waste Incineration Plant was granted by CMBC under the Environmental Permitting (England and Wales) Regulations 2016, as amended (‘EPR’), on 9 February 2021. However, the permit was quashed by the High Court on the 17 September 2021 following an application for judicial review. Four grounds of challenge were put forward, and CMBC and CVSH consented to the permit being quashed on the basis of Ground 1 with the parties reserving their positions in relation to the other grounds:

- **Ground of Challenge 1** - The decision was unlawful because the Council erred in law in believing that, if the application was not determined on 8 February 2021, then it would be deemed to be refused. Consequently, the Council acted unlawfully, by relying on this error of law, in: (a) not having requested further information as an option and in deciding to approve the application without requesting further information; (b) deciding to use urgency to disapply the call-in procedures.
- **Ground of Challenge 2** - The Cabinet had no rational basis for failing to follow the WYG recommendation that more information be obtained on habitats and emissions, including sulphur dioxide.

- **Ground of Challenge 3** - The Council failed to have regard to relevant considerations, namely guidance in the Environmental Permitting General Guidance Manual on Policy and Procedures for A2 and B installations (GGM) on the assessment of harm. It applied a test which was not in the guidance.
- **Ground of Challenge 4** - The SWIP environmental permit and the varied waste management licence permit on most of the remainder of the site leave an unregulated area around the incinerator building. The incinerator could not therefore operate. There is also a series of activities which are part of the incinerator operation, as described in the application, which would take place in the Waste Management Licence ("WML").

1.4 The above grounds of challenge have been considered during writing of this review, with the following also considered:

- whether the air quality assessment is robust;
- whether the reported conclusions are supported by the evidence provided;
- whether the information presented is sufficient to understand the likely air quality impacts of the scheme; and
- whether the permit application is robust in its measures to protect the environment and nearby residents and is in line with the air quality assessment undertaken.

1.5 Where errors or omissions have been identified in the air quality assessment, they have been categorised as either a:

- **Major Issue** - in the opinion of the reviewer, any one individual failing would be highly likely to invalidate the reported conclusions;
- **Moderate Issue** - weaknesses have been identified which, individually, may or may not affect the conclusions; or
- **Minor Issue** - weaknesses have been identified but the professional experience of the reviewers suggests that each one, in isolation, would be unlikely to affect the conclusions of the assessment. There remains, however, the potential for multiple minor issues to combine to invalidate the reported conclusions. Minor issues have also been identified where the material presented is misleading or otherwise inappropriate to inform consultation.

1.6 A review of any material related to the construction phase and to the release of odours has not been undertaken. Both of these impacts can generally be effectively controlled by standard mitigation practices. Additionally, SWIP permits only consider operational phase emissions, not construction.

2 Competence

2.1 [redacted] experience in the field of air quality assessment. He has been part of the Environment Agency's Air Quality Modelling and Assessment Unit (AQMAU), which is embedded within the National Permitting Service. He has thus reviewed many technical reports for large installations, including energy from waste facilities, on behalf of Central Government. He has advised Central Government whether the material submitted is sufficient for the granting of permits and has also provided a similar service for local governments. In addition, he regularly undertakes air quality assessments for AQC, covering a mixture of uses, including industrial installations, energy centres and waste facilities. He has experience using a range of dispersion models including ADMS-Roads, ADMS-5 and Breeze AERMOD to complete quantitative modelling assessments, for both planning and permitting purposes. He is a Member of the Institute of Air Quality Management and an Associate Member of the Institution of Environmental Sciences.

2.2 [redacted] experience, specialising in industrial emissions. He is a member of the Institute of Air Quality Management, has previously contributed his time to, and authored publications on behalf of, the Energy Institute's Emissions Working Group, and has acted as peer reviewer for the Journal of Air & Waste Management. His expertise includes ambient and stack emissions monitoring, emission inventory development and reporting, atmospheric dispersion modelling, abatement of air emissions, environmental permitting, Best Available Technique (BAT) assessments, cost-benefit analysis and compliance assessment. He has extensive experience in the quantification and assessment of emissions from a variety of releases, covering point source emissions, flare emissions, fugitive emissions and emissions from mobile transport sources, including marine vessels, on-road and off-road vehicles and rail locomotives. He has detailed knowledge of the technologies and techniques to reduce concentrations of combustion and non-combustion related pollutants, including oxides of nitrogen, acid gases (e.g., SO_2, HF, HCl), volatile organic compounds (VOCs), particulates, heavy metals and odour.

2.3 [redacted] at Air Quality Consultants Ltd. and is thus technical lead of one of the largest specialist air quality teams in the UK. He has more than two decades of experience in air quality modelling and assessment and has been responsible for more than one thousand air quality assessments, covering a range of different types of development, including Energy from Waste facilities. He is a member of the Institution of Environmental Sciences (IES), a member of the Institute of Air Quality Management (IAQM), and a chartered scientist (CSci). He has advised Defra, the Environment Agency, the Joint Nature Conservation Committee (JNCC), Highways England, the Scottish Government, Transport Scotland, Transport for London, and numerous local authorities. He also contributed to several of the air quality guidance documents cited in the ES[1]. He currently advises the UK Government on air quality as part of its Air Quality Expert Group (AQEG). He has recently advised the UK Government on issues related to, amongst others: ultrafine airborne particles; impacts of vegetation on air pollution; air pollution from agriculture; non-exhaust emissions from road traffic; methods for assessing impacts on air quality; emissions of volatile organic compounds; impacts of greenhouse gas reduction measures on UK air quality; and the effects of COVID-19 on UK air quality[2]. His specific area of expertise within AQEG relates to air quality assessment in the development control process, including assessing the air quality impacts of proposed industrial emissions sources on ambient air quality[3].

1 i.e. Defra's Local Air Quality Management Technical Guidance, and guidance documents from the Institute of Air Quality Management (IAQM) on land-use planning and development control, and assessment of dust from demolition and construction.

2 https://uk-air.defra.gov.uk/library/aqeg/publications.

3 https://uk-air.defra.gov.uk/library/aqeg/about

3 Review of Air Quality Assessment

Summary

3.1 Following a review of the documents listed in Paragraph 1.2, no 'Major' issues have been found that are likely to significantly alter the conclusions stated by the applicant within their air quality assessments.

3.2 There are potential uncertainties with the assessment of nitrogen dioxide impacts within the nearby Air Quality Management Area (AQMA), 670 m away, that may suggest greater than *negligible* impacts are possible.

3.3 Other 'Moderate' issues identified include the assessment of the significance of benzo(a)pyrene emissions, justification for the selected stack height, the absence of any assessment of the total bodily intake of polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans (collectively referred to as 'dioxins') and dioxin-like polychlorinated biphenyls (PCBs), and no assessment of impacts on local wildlife sites within 2 km in the latest air quality assessment addendum.

Major Issues

3.4 No major issues have been identified following the review of the air quality assessment and various addenda.

Moderate Issues

Uncertainty

3.5 Uncertainty is an inherent component of any scientific method. The uncertainty assigned to a result represents the range of values around the result in which the true value is expected to lie. The true value is a conceptual term, which can never be exactly determined.

3.6 Dispersion modelling is associated with inherent uncertainties due to the attempts made within the model to replicate atmospheric turbulence, a stochastic process, using deterministic methods. Additional uncertainty arises from assumptions made by the model user in defining e.g., surface characteristics, treatment of building induced effects and treatment of terrain, and uncertainty in the model input data e.g., uncertainty in emission estimates and meteorological input data.

3.7 For some scientific tests, it is relatively straightforward to determine the level of uncertainty. However, when considering the uncertainty associated with the result from a dispersion model, this task is much more complicated, since not only is there uncertainty in the measurements and parameters input to the model, there is also uncertainty associated with imperfect knowledge or approximations made within the model itself. It can be extremely complex to quantify the uncertainty associated with each of these factors and model uncertainty is highly site specific.

3.8 Dispersion models which are used for regulatory applications in the UK are generally expected to achieve a performance of 50% of predicted hourly concentrations being within a factor of two of monitored ambient concentrations.

3.9 However, some factors may decrease the model performance, particularly as the complexity of the model domain increases. For example, the uncertainty in any particular model's prediction is likely to be greater in large, urban areas than compared to predictions made in a flat, rural location away from buildings or other obstructions impeding atmospheric flow. Conversely, other factors may improve model performance; considering the statistics of the modelled and monitored ambient concentrations, which is relevant for regulatory applications, rather than concentrations paired in time and space, increases the performance. Similarly, increasing the averaging time, for instance from hourly to 3-hourly, 24-hour and annual will generally improve the model performance.

3.10 In this case, due to the complexity of the terrain within the modelling domain, as well as monitoring data within the nearby AQMA measuring at or above the NO_2 Air Quality Standard, small levels of uncertainty have the potential to change the categorised impacts and, potentially, the conclusions of the assessment.

3.11 Because of this, the applicant has undertaken a number of sensitivity tests to understand the potential consequences of uncertainty in the modelling. The applicant has generally undertaken the sensitivity tests in accordance with best practice guidance[4] by using multiple dispersion models, multiple sites providing meteorological data, multiple years of meteorological data, assessment of calm meteorological conditions and multiple surface roughness values. While we do not agree with the applicant's surface roughness sensitivity (see Paragraph 3.36), the sensitivity analysis, overall, seems robust.

3.12 The basis for challenge three of the judicial review is that WYG's (acting as expert reviewer for CMBC) sensitivity modelling identified more than negligible impacts as being possible. This focusses on the assumption that either the background or the process contribution from the applicant's site could be greater than that reported in the assessment. The WYG report states that it is possible that moderate adverse effects may occur, but then goes on to discount these without any real justification.

3.13 While we do not necessarily agree with the way WYG have undertaken its sensitivity analysis (adding arbitrary percentages to different baselines), we do agree that the potential for impacts greater then *negligible* cannot be immediately discounted[5]. This is based on the following:

---

4 Defined by the Environment Agency in its *Environmental permitting: air dispersion modelling reports guidance*. https://www.gov.uk/guidance/environmental-permitting-air-dispersion-modelling-reports#carry-out-sensitivity-analysis

5 Using the impact table (Table 6.3) and methodology contained within the IAQM Land-Use Planning & Development Control: Planning For Air Quality guidance.

- taking the NO_2 value of 40 µg/m^3 measured in 2019 at diffusion tube SB22[6], 35m away from receptor 8 (Mill West), and used within the assessment to identify effects in the AQMA, compounded by the potential issue identified with the applicant's model verification (see Paragraph 3.23), it is not certain that the baseline concentration in the AQMA will be below 37.8 µg/m^3. This value acts as the point at which a 0.2 µg/m^3 (0.5%) increase from baseline conditions could be considered '*slight adverse*' under impact descriptors published by the IAQM.

- at receptor 8 (Mill West), the applicant predicts within their ES chapter addendum a process contribution of 0.09 µg/m^3 (this has been obtained using the AERMOD modelling software and meteorological ('met') data from Leeds Bradford airport). They further predict values of 0.19 µg/m^3 (ADMS, Leeds Bradford met data), 0.2 µg/m^3 (ADMS, Bingley met data), 0.2 µg/m^3 (ADMS, Leeds Bradford met data, variable surface roughness) and 0.2 µg/m^3 (ADMS, Leeds Bradford met data, calm conditions) within their 2019 Additional Air Quality Assessment. It is unclear why the applicant has focussed on results from the AERMOD run, which are lower, without providing justification, especially when the terrain module within the dispersion model appears to have the biggest impact on results. Basing the assessment solely on results from the AERMOD model would also appear contrary to the applicant's own statement in their 2019 Additional Air Quality Assessment (Paragraph F10):

  "Neither model is "better" than the other in terms of their ability to take terrain and topography into account; their algorithms simply provide alternative forecasts. Nevertheless, it could be argued that ADMS has a more sophisticated approach to processing complex terrain, in that it calculates the impacts of terrain on plume spread and allows for the impacts of hill wakes."

  We would agree that ADMS has a more sophisticated treatment of terrain effects, with previous reviews by Carruthers et al. (2011)[7] suggesting that in some situations, because of its less sophisticated treatment of terrain, AERMOD may only "*act as a screening model in this case, whereas ADMS may predict more realistic concentrations*".

- as three of the five modelled scenarios by the applicant results in an increase of 0.2 µg/m^3, coupled with the uncertainty regarding the baseline concentration within the AQMA, using impact descriptor tables within the IAQM planning guidance, it is judged that a *slight adverse* impact is feasible.

---

6 2020 data was not available at the time of writing and could not be used as representative air quality conditions due to the impacts of the Covid-19 pandemic.

7 Carruthers, D.J., Seaton, M.D., McHugh, C.A., Sheng. X., Solazzo, E and Vanvyve, E., (2011). *Comparison of the Complex Terrain Algorithms Incorporated into Two Commonly Used Local-Scale Air Pollution Dispersion Models (ADMS and AERMOD) using a Hybrid Model*. Journal of the Air & Waste Management Association, 61, 1227-1235

Benzo(a)pyrene

3.14 Within the 2019 additional air quality assessment, the applicant predicts a ‘worst-case’ Benzo(a)pyrene (B(a)P) process contribution (PC), i.e., that relating to emissions from the SWIP processes in isolation, of 9% of the Air Quality Standard (AQS), and predicted environmental concentration (PEC) of 98.4%, i.e., the SWIP process contribution plus contributions from other emission sources. This level of impact is presented at the location of maximum impact anywhere on the modelled grid.

3.15 This prediction is based on an emission concentration of 1 $\mu g/m^3$ derived from typical emissions data of B(a)P in the 2006 Waste Incineration BAT Reference (BREF) document. In December 2019, an update to the 2006 BREF was introduced that confirmed B(a)P emissions from 48 reference lines incinerating predominantly municipal wastes ranged from 0.004 ng/Nm^3 to 1 $\mu g/m^3$. In that respect, the assumed emission concentration for B(a)P can be viewed as precautionary. However, in combination with the previous discussion on model uncertainty, as the PEC approaches 100% and no evidence is presented about level of significance of this level of impact, it is not considered possible to definitively conclude no significant effects based on the data presented. In particular, the average B(a)P concentration at the Leeds Millshaw monitoring site between 2014 and 2017 has been used to define baseline concentrations, rather than the maximum. The maximum annual mean concentration during this period exceeds the objective.

3.16 However, it is important to recognise that this prediction is made based on the maximum predicted value at any location in the model domain. AQS apply only where there is ‘relevant exposure’ and, for the purpose of assessing compliance with the B(a)P objective, which is expressed as an annual mean assessment metric, relevant exposure only occurs at e.g., residential properties and schools. It is expected that model predictions at the specific human receptors considered in the assessment would be lower than the maximum predicted value, and could possibly be at a level where no significant effect could be concluded. However, this should be confirmed by the applicant by providing tabulated data for each specified receptor location where there is relevant exposure.

Stack Height Determination

3.17 Appendix D of the 2019 Additional Air Quality Assessment details how the requirement for a 12 m stack was determined. However, this analysis (in Graph D1) shows that the air quality impacts would be appreciably smaller if a taller stack were chosen, even when the stack is increased by just a few metres. A cursory examination of these graphs shows that 12 m does not represent a point at which further height increases have diminishing returns in terms of reduction in the predicted ground level concentration. In practice, the justification for a 12 m stack appears to be that most impacts can, with this stack height, be described as ‘*negligible*’. However, as identified previously, there are valid reasons to suggest impacts could be greater than negligible.

3.18 The Environment Agency has produced internal draft stack height assessment guidance with a particular emphasis on incineration plants[8]. This guidance has previously been provided by the Environment Agency to the reviewers as an example of a methodology it would accept for determining the minimum required stack height for incineration plants.

3.19 The guidance clarifies that the stack height, according with the principles of Best Available Technique (BAT), can be defined as the 'knee-point' of a graph plotting the reduction in process contribution as a function of increasing stack height (the method actually uses stack costs, but stack height is often used as a proxy for cost). Figure 1 provides an example figure depicting the knee-point (blue arrow) from this guidance document.

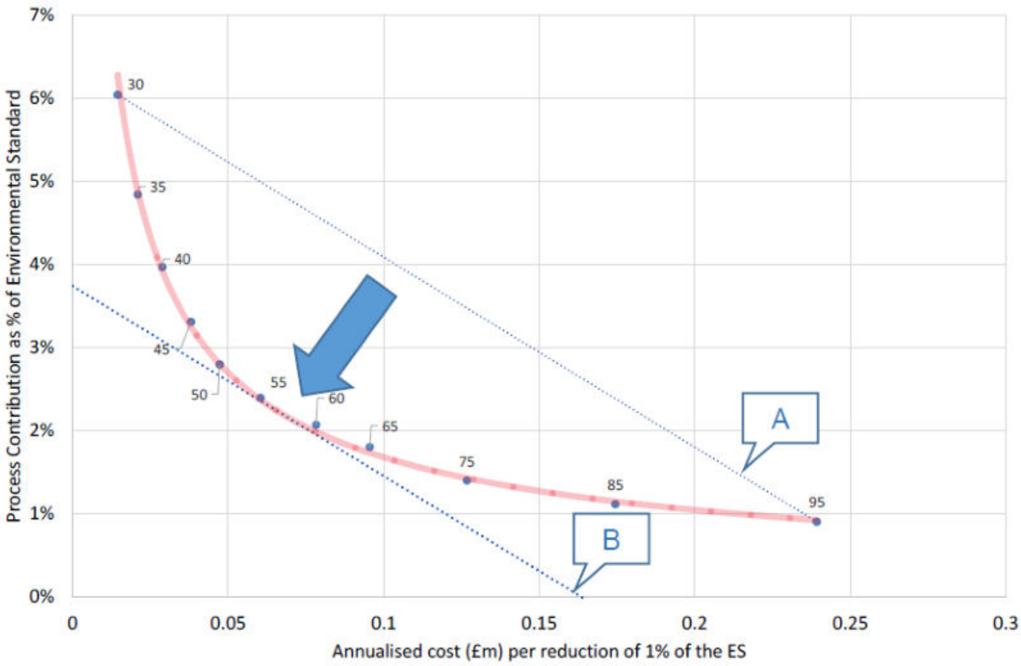


Figure 1: Visual depiction of the 'knee-point' on a stack height assessment graph

3.20 The Environment Agency guidance clarifies that where an impact is defined as 'insignificant' for a particular stack height, i.e., where long-term process contributions are less than 1% of the relevant AQS, or where short-term process contributions are less than 10% of the AQS, further increases in stack height are not necessary as it follows that any further reduction in impact will also be insignificant.

3.21 Hence, it is possible for the BAT stack height to occur before the knee-point. Where this is the case, the shorter stack height would be considered BAT. For this particular plant, it is evident that the selected stack height of 12 m occurs before the knee-point. However, process contributions at 12 m

8 Environment Agency, 2017. EPR Permit – Stack Height Assessment. Environment Agency Internal Guidance (draft) V0.5 November 2017

for several pollutants cannot be defined as insignificant[9]. Consequently, the applicant has failed to demonstrate that a stack height corresponding to the principle of BAT[10] has been selected, and further justification should be provided.

Ecological impacts

3.22 The applicant has not assessed the impacts at nearby ancient woodland and local nature reserve ecological sites within their ES addendum or their 2019 additional Air Quality Assessment. These sites are within the 2 km screening distance for assessment of ecological sites required by the Environment Agency. This assessment has been undertaken for the original 2017 ES chapter; however, this assessment is not considered fully robust as it is not clear if ammonia and hydrogen fluoride emissions have been accounted for when considering the impacts of nutrient nitrogen and acid deposition.

Roads Modelling Verification and Model Adjustment

3.23 We are satisfied that the applicant's use of 28 μg/m^3 as a background NO_2 concentration is likely to be appropriate due to its location within the study area and its designation as an urban background site. The applicant has further undertaken roads modelling to determine the local baseline exposure at each chosen receptor.

3.24 In accordance with best practice guidance, the applicant has sought to verify the predictions from its road traffic emissions model by comparison with monitoring data. The applicant has applied a correction factor of 1.0704 to their modelled road-NOx concentration before converting to NO_2. Examination of the applicant's verification analysis has shown the model to underpredict at monitoring sites SB20 and SB22 (which are located approximately 35 m from Receptor 8) and overpredict at monitoring sites SB3 and AQS4 (which are located nearly 450 m from Receptor 8). Given that Receptor 8 is close to the underpredicting sites, and is registering at or above the objective (depending on the year chosen), the methodology for the model verification, and approach to calculating the correction factor, may not be suitably precautionary.

3.25 Given the issues previously discussed with respect to model uncertainty and the proximity of the predicted impacts to the annual mean NO_2 objective, it is deemed more appropriate to use a location-specific model adjustment factor for receptors within or in close proximity to the AQMA. This is because monitoring sites SB20 and SB22 clearly provide a better representation of air quality conditions where NO_2 concentrations of 0.2 μg/m^3 (0.5%) are predicted. The effect of this would be

9 This refers to the Environment Agency criteria for insignificance (stated within their online guidance page: https://www.gov.uk/guidance/air-emissions-risk-assessment-for-your-environmental-permit), which is used within internal EA guidance documents to assist in the determination of stack height suitability.

10 Refers to the principle of BAT rather than any specific BAT conclusions (BATc) contained with the BREF documents, which only apply to Part A1 installations, or other BAT requirements in Process Guidance Notes which only apply to Part B installations.

to increase model predictions within and in close proximity to the AQMA. This might, in turn, result in a different classification of impact descriptors as previously discussed.

Assessment of 1-hour mean NO_2 Concentrations

3.26 Annex VI of the Industrial Emissions Directive (IED) provides two sets of emission limit values applicable to waste incineration plant (including SWIP). These are defined as a daily average emission limit and a 100th percentile 30-minute mean emission limit. For emissions of NO_x, the daily average emission limit is 200 mg/Nm^3 and the 30-minute mean emission limit is 400 mg/Nm^3. Both sets of limits were included in the permit that was initially granted for the plant.

3.27 The applicant has not undertaken an assessment against the short-term NO_2 objective using the half-hourly emissions limit within IED and the permit. Rather, the daily average emission concentration has been used for assessing hourly mean impacts. As the plant is permitted to discharge NO_x at levels up to 400 mg/Nm^3 for a period of 30-minutes, there is the potential for hourly averaged emission concentrations to exceed the daily averaged emission limit that has been modelled leading to potential underestimation of hourly mean impacts.

3.28 Similar findings are concluded with respect to e.g., the approach to assessing short-term SO_2 impacts.

Human Health Risk Assessment for Persistent Organic Pollutants

3.29 Dioxins and dioxin-like PCBs are a class of compounds known as Persistent Organic Pollutants (POPs). Whilst generally present at low levels in environmental media i.e., in air, water and soil, due to their persistence in the environment and bioaccumulative nature i.e., the rate of intake of these compounds by an organism exceeds the rate of excretion, dioxins and dioxin-like PCBs can become concentrated in the food chain, particularly in fatty foods such as milk and milk products, and in certain meats and fish.

3.30 As the majority of human exposure to this group of compounds is through ingestion, rather than inhalation, no air quality standards or other ambient air quality guidelines exist. Consequently, it is generally a requirement that any installation discharging these compounds undertake a human health risk assessment (HHRA) that considers exposure through all pathways, i.e., through both inhalation and ingestion, to estimate the total bodily uptake of dioxin and dioxin-like PCBs as a result of installation activities, and compare such predictions against the tolerable daily intake (TDI) established by the Food Standards Agency's Committee on Toxicity of Chemicals in Food, Consumer Products and the Environment (COT) and the tolerable weekly intake (TWI) established by the European Food Standards Agency.

3.31 No HHRA for dioxins and furans and PCBs has been undertaken. Such an assessment addresses impacts relating to bioaccumulation in the food chain for pollutants which cannot be adequately assessed by referring to ambient air quality standards.

3.32 In practice, the methods available for such an assessment are relatively crude and thus tend to be over-precautionary, but the results can still provide reassurance as to the scale of impacts. The experience of the reviewers, consistent with research and the latest position of Public Health England, is that waste incineration plant meeting the IED emission limits and with an appropriately optimised stack height, only provide negligible contributions to the TDI and the more precautionary TWI. However, in this case, due to the potential issues identified with the justification of the selected stack height, a HHRA should not just be viewed as a procedural exercise.

Minor Issues

Carbon Monoxide 1-hour EAL

3.33 The applicant has not undertaken an assessment against the Carbon Monoxide (CO) 1-hour Environmental Assessment Level (EAL) of 30,000 µg/m^3. In the experience of the reviewers, carbon monoxide emissions are generally insignificant compared to the environmental standards. As there are no predicted significant effects towards the 8-hour CO objective, lack of consideration of the 1-hour EAL is unlikely to alter the conclusion of the assessment.

TOC Emissions

3.34 The applicant has not undertaken an assessment of the likely emissions of total organic compounds (TOC). It is a requirement within chapter IV of IED that emissions to air from waste incineration plants shall not exceed the emission limit value of 10 mg/Nm^3 for TOC; therefore, any robust assessment should consider the sites impact from TOC.

3.35 As the exact speciation, or composition, of TOC cannot be known, best practice guidance by the Environment Agency suggests comparing TOC impacts against the benzene AQS. Such an assessment was undertaken within the original 2017 ES chapter in respect to the annual mean benzene AQS. The Environment Agency has recently introduced a 24-hour mean benzene environmental assessment level (EAL) of 30 µg/m^3 which should be assessed against for completeness. However, it is accepted that the air quality assessment was produced before the publication of this new EAL.

Surface Roughness

3.36 It is unclear why the applicant has chosen to use such a high surface roughness value within its sensitivity analysis. The applicant has used a value of 1.0 m (which the ADMS user guide suggests represents cities and woodlands) within their main modelling run. As there is an area of woodland surrounding the site, this is deemed suitable. It is unclear why the applicant, within their sensitivity analysis, has created a variable surface roughness file and used a value of 1.5 m (which the ADMS user guide suggests represents large urban areas) for the nearby woodland. In conjunction with using a value of 1.0 m for the rest of the modelling domain, where the majority of the land is judged representative of a suburban area/small town, where a value of 0.5 m is deemed more appropriate, this has the potential to over represent the turbulence effects in the area.

4 Review of the Environmental Permit and Application

Scope of the Review

4.1 The review of the Environmental Permit and associated application documentation has been performed based on the review team's experience of delivering permit applications for similar facilities and taking into account guidance produced by Defra and the Environment Agency. However, where aspects relate to the interpretation of legislation, the opinion of a legal professional is recommended. AQC does not have the experience or capability to comment on matters concerning legal interpretation.

Summary

4.2 Following a review of the documents supporting the permit application for the SWIP installation, and the Environmental Permit itself, several areas have been identified that introduce uncertainty with respect to the ability of the plant and/or of the Operator to comply in full with the requirements of Chapter IV of the IED. However, it is expected that such issues could be resolved with further requests for information, rather than a fundamental inability of the plant to meet the requirements of IED and of the permit. **Despite this, it is a requirement that all information required to determine an application is provided and the permitting authorities should not determine an application until they are satisfied they have received all relevant information. Consequently, this additional information should have been requested to provide confidence that these conditions can be met and, on that basis, we are in agreement that the first Ground for Challenge is robust**.

4.3 In respect to the fourth Ground for Challenge, a view on this is complicated by the uncertainty in the extents of the installation boundaries for the SWIP permit and the separate waste operations permit. This uncertainty results from the poor image definition of the boundary in the respective installation boundary figures. From review of the introductory note in the Environmental Permit for the other on-site waste operations and surrender notice, it is clear the intent was to remove (partial surrender) only the area associated with the SWIP installation. However, it does appear that there is a small area of land not covered by either permit. We suspect this has arisen through accidental omission, or poor definition of the images, rather than intent, and better quality images could resolve such matters.

4.4 Potential procedural issues have been identified relating to the transport of Air Pollution Control residues through the installation boundary of the adjacent waste transfer station and whether this conveys a degree of acceptance. If such an action did imply acceptance, the waste transfer station would be operating outside of the conditions of its permit, which only allows the acceptance of non-hazardous waste. This is an area where it is strongly advised legal opinion is sought before deciding whether to pursue this as a matter for further consideration.

Permitting Context

4.5 Incineration plants accepting non-hazardous waste and incinerating that waste at a rate less than 3 tonnes per hour are regulated under Schedule 13 of the EPR as SWIP. This requires the plant to comply with certain requirements of IED, including the Chapter IV Special Provisions for Waste Incineration Plants and Waste Co-Incineration Plants[11] and, unless excluded under Article 44, hold a permit to operate that reflects these requirements. As clarified in the Environment Agency's *Environmental permitting guidance: waste incineration*, permits for SWIP are issued by the local authority.

4.6 SWIP are not required to meet the Best Available Technique Conclusions (BATc) for waste incineration as defined by the European Commission; these only apply to incineration plant incinerating waste at a rate greater than 3 tonnes per hour. Additionally, unless the SWIP also meets the definition of a 'Part B' process under Schedule 1, Section 5.1 of the EPR, it does not need to meet the BAT requirements in Defra's Process Guidance Notes. The SWIP at this installation does not meet the definition of a Part B listed activity and, consequently, BAT requirements do not apply.

4.7 It is possible for a permit to cover more than one regulated facility. However, Defra's *Environmental Permitting: Core Guidance* explains this is generally only possible where the regulator is the same for each facility, the operator is the same for each facility, and all the facilities are on the same site. In that sense, the guidance explains that a single environmental permit cannot cover regulated facilities with different regulators, i.e., a single permit cannot generally be granted that covers activities usually regulated separately by the Environment Agency and the local authority.

4.8 However, the guidance also explains that powers are available by an appropriate authority under Regulation 33 of the EPR to direct an Agency or the local authority to assume the functions of the other if this leads to simpler regulation. Where this direction does occur, the aim is to allocate responsibility to the Regulator of the major activity on-site.

4.9 There is no formal guidance that defines the extents of a Schedule 13 SWIP process. The limits of the specified activity are generally taken to be consistent with those defined in permits for larger waste incineration installations e.g., operation of the furnace, boilers and auxiliary burners; facilities for the treatment of exhaust gases; facilities for the receipt, storage and handling of incoming wastes and raw materials (including fuels); facilities for the storage and disposal of surface water and waste process water; facilities for the storage of residues pending off-site disposal/recovery; and facilities for the generation of electricity to be consumed on-site or exported to the Grid.

---

[11] With the exception of some sub-articles relating to provisions for the categories of waste to be included in the permit which can be co-incinerated in certain categories of waste co-incineration plants, requirements for continuous monitoring of dioxins and heavy metals, and certain communications to the Commission.

Implications of Multiple Permits on the Same Site

4.10 The proposed CVSH site consists of an existing household, commercial and industrial waste transfer station (WTS), including treatment, and the proposed Schedule 13 SWIP. The waste operations in the WTS are regulated by the Environment Agency under Environmental Permit EPR/SP3196ZQ, whilst the operations of the SWIP were to be regulated by CMBC under Environmental Permit S13/005.

4.11 As identified in paragraph 4.7, whilst it is possible for a single permit to cover more than one regulated facility, this is generally not the case where the permit would cover regulated facilities with different regulators unless the Secretary of State confers powers on one regulator to assume the responsibilities of the other. In Defra's *General Guidance Manual on Policy Procedures for A2 and B Installations*, it additionally states:

"*Where several activities from different Parts of Schedule 1 are carried out in or as part of the same installation, the installation will be permitted according to what can be described as the "highest common denominator" (Schedule 1, Part 1, paragraph 2 to the EP regulations). So if Part A1, A2 and B activities were carried out at an installation, it would be permitted as an A1 installation and therefore by the Environment Agency*."

4.12 Like Schedule 13 SWIP facilities, Part B installations are regulated by local authorities. The above guidance suggests it is possible in some circumstances for the Environment Agency to assume the responsibility for regulating installations from the local authority. However, neither the WTS, nor the SWIP are a Part A1, A2 or B installation.

4.13 In that respect, it is not entirely unusual that multiple permits exist with different regulators on the same site.

4.14 In terms of the interlinked nature between the two permits and the ability of each to control operations across the site as a whole, it is necessary first to define the boundary and type of operations covered by each regulated facility.

4.15 The SWIP takes pre-sorted RDF from the WTS. This pre-sorting is a physical treatment activity and the provisions for this activity are covered by Table S1.1 of the WTS environmental permit (*physical treatment including manual and mechanical sorting/separation, screening, shredding, crushing, compaction or drying of non-hazardous waste for disposal (no more than 50 tonnes per day) or recovery*). Temporary storage of the RDF is also accounted for by the R13 and D15 description in Table S1.1 (dependent on whether the RDF is sent for disposal or recovery).

4.16 The SWIP permit limits the type of waste that can be accepted within the SWIP installation to RDF (EWC waste code 19 12 10) and further details that only RDF from the adjacent WTS is to be accepted. Whilst it is clear that the SWIP could not operate without the WTS under these restrictions, there is no requirement from the permitting perspective for the SWIP permit to cover procedures for the acceptance, storage and treatment of the incoming household, commercial and industrial waste to the wider site as these provisions are already made in another operating permit. To introduce such controls in the SWIP permit would lead to double regulation. This is no different in practice to a standalone SWIP taking RDF from an off-site facility, i.e., the SWIP would not be expected to introduce controls that lead to the formulation of RDF at another off-site facility. From the perspective of the SWIP permit, the incoming waste is the RDF, not the household, commercial and industrial waste.

4.17 There is a similar argument to make for the handling of bottom ash residues from the SWIP if the WTS was to temporarily store bottom ash. Condition 6.1 of the SWIP permit requires that, where appropriate, residues are recycled, directly in the plant or outside. The WTS effectively acts as an interim storage facility for ash residues prior to recycling. The WTS permit allows the acceptance of bottom ash through the inclusion of EWC code 19 01 12 in its permit and temporary storage of bottom ash pending off-site recycling would be covered by the R13 description in Table S1.1.

4.18 There is precedent for this permitting approach at larger integrated waste management facilities in the UK where, within the same wider site, a WTS provides pre-sorted/treated waste to an incineration plant, and the WTS handles ash residues from the incineration plant, but with the WTS and incineration plant operating under different permits. The one differentiating factor in these instances is that the incineration plant is much larger, so regulated as a Part A1 installation by the Environment Agency i.e., there is a common regulator.

4.19 However, one potential complicating factor of the proposed permitting arrangement at the site relates to the transport of Air Pollution Control residues (APCr). APCr are classed as hazardous waste principally due to their high pH content. The WTS permit does not allow the acceptance of hazardous waste. However, due to the way that the permit boundaries are defined, APCr must be transported through the WTS permitted installation boundary before it leaves the wider site. It is unclear whether the transportation of APCr through the WTS installation boundary would convey a degree of 'acceptance', or whether this would simply be considered the same as APCr transport on the wider road network. If this was to constitute 'acceptance', then the WTS would be operating outwith the conditions of its permit. In any case, it would have been advisable for the Accident Management Plan for the WTS to be updated to reflect that there is the potential for hazardous waste to pass through its installation boundary.

4.20 The above issue, and indeed many of the issues raised in this section, are procedural. Consequently, such matters are best judged by a legal professional.

Installation Boundaries

4.21 It does appear from initial inspection of the respective installation boundary figures that there could be a small area of land not covered by either permit. However, such an analysis is complicated by the quality/resolution of the images that depict the respective installation boundaries, the different base mapping used and the absence of a scale on the installation boundary in the SWIP permit. As such, it is difficult to identify the potential implications.

4.22 From review of the introductory note in the Environmental Permit for the WTS permit and surrender notice, it is clear the intent was to remove (partial surrender) only the area associated with the SWIP installation from the existing WTS permit. We suspect any apparent area of unregulated land has arisen through accidental omission/interpretation of the figures, rather than specific intent, and better quality images or revised plans could resolve such matters.

Further information requirements

4.23 The following aspects represent additional information which, in the opinion of AQC based on its experience preparing permit applications for similar facilities, should have been provided to enable CMBC to be able to robustly determine the permit application. **Without this information, or without the requirement to supply this information in a pre-operational condition, the permit should not have been determined.**

Waste Acceptance

4.24 Article 52(1) of IED requires Operators of incineration plant to "*take all necessary precautions concerning the delivery and reception of waste in order to prevent or to limit as far as practicable the pollution of air, soil, surface water and groundwater as well as other negative effects on the environment, odours and noise, and direct risks to human health*."

4.25 RDF produced from the adjacent WTS will be delivered to the SWIP building using a front loader and loaded directly into the hopper of the SWIP or temporarily stored within a bunker in the SWIP building. However, other than a general reference to storing materials on a concrete floor that will be maintained, no detailed information has been provided of the measures to prevent loss of containment from the waste bunker and consequent fugitive discharges to land and groundwater. For example, the British Standard to which concrete would be constructed and its tightness class has not been specified. These details are typically requested by the Environment Agency when determining applications for Part A1 waste incineration plant.

4.26 Additionally, no details are provided on any waste acceptance procedures to confirm that the waste received within the SWIP installation boundary is compliant with the conditions of the permit. Whilst the potential risk of receiving non-compliant or off-specification waste will be minimised from the pre-sorting in the WTS, the potential risk of non-compliant wastes entering the SWIP installation boundary cannot be totally discounted. Loading waste directly into the hopper minimises the potential for non-compliant wastes to be identified and removed. Without acceptance measures in place at the SWIP, the SWIP is effectively outsourcing its responsibilities for waste acceptance to the WTS, but the WTS is not covered by this article of IED.

4.27 No details are provided for the location and design measures for a quarantine area for temporarily storing non-compliant waste. Additionally, no details are provided as to how waste arriving at the SWIP will be weighed to ensure it remains compliant with the permitted annual waste throughput, and that the feed rate does not exceed two tonnes per hour. There is, however, a condition in the permit that requires the mass of each type of waste to be determined prior to accepting the waste on-site. If the incoming waste was not weighed, the Operator would be non-compliant with the conditions of the permit and could be subject to enforcement action.

Operational Envelope and Validation of Combustion Conditions

4.28 Natural variation in the composition of waste, in particular its calorific value (CV), can affect the ability of an incineration plant to control combustion. All incinerators have an operational envelope defined by the calorific value of the waste and the waste throughput. In practice, the safe operation of incinerators, particularly those recovering energy, is governed by the thermal input, which is a product of the CV and waste throughput. When the CV is low, it is possible for a higher amount of waste throughput. Conversely, when the CV is high, the waste throughput has to be restricted to maintain a constant thermal input.

4.29 It is common to provide a firing diagram with an application for an incineration plant that identifies the calorific value and waste throughput range over which stable combustion conditions can be maintained. Although RDF is a relatively homogeneous waste stream, certainly compared to municipal waste, natural variations in CV will occur due to the variation in the fractional composition of individual components making up the RDF. No firing diagram has been provided with the application, nor has any information been provided to demonstrate that the plant can operate within the expected range of variation in RDF CV.

4.30 Information on the typical composition of RDF from various literature sources are cited in the Schedule 5 response. This information would have been a suitable proxy if the plant was accepting RDF from a variety of sources. However, the SWIP is limited to accepting RDF produced exclusively in the WTS. As such, it would have been appropriate to request that further information be provided on the composition of RDF obtained from the CVSH WTS, rather than relying on literature values.

4.31 Article 50(2) of IED requires that incineration plants "*…shall be designed, equipped, built and operated in such a way that the gas resulting from the incineration of waste is raised, after the last injection of combustion air, in a controlled and homogeneous fashion and even under the most unfavourable conditions, to a temperature of at least 850 °C for at least two seconds*". The applicant has provided an email which displays the output of a Computational Fluid Dynamics (CFD) model that demonstrates this condition is just met for the specific SWIP to be installed (minimum 2.03 s residence time).

4.32 However, other than an image providing the fluid trajectories and temperature, the email provides no information on the specific method used to develop these calculations, nor does it clarify under which operating conditions, in terms of waste throughput and CV, the predictions are valid for. There can be no certainty, based on the information provided, that the CFD modelling has been based on the most unfavourable conditions under which the SWIP can operate.

4.33 There is a condition (Condition 5.8) that requires the Operator to verify the minimum residence time and temperature requirements using actual measurements within one month of the plant being commissioned. However, the purpose of providing theoretical calculations of these parameters at permit application stage is to demonstrate the plant at least has the ***potential*** of meeting the minimum requirements of Article 50(2).

Accidents and Incidents

4.34 Article 46(5) of IED requires that incineration plant should be designed to prevent the unauthorised and accidental release of any polluting substances into soil, surface water and groundwater. Accidents and incidents are discussed very briefly in Section 5.4 of the permit application. Section 5.4.3 states that an Accident Management Plan has been developed as part of the Environmental Management System for the existing WTS and this will be updated to include aspects associated with the operation of the SWIP. However, beyond that, no details are provided of the potential accident scenarios associated with the operation of the SWIP and an assessment of their environmental risk, nor is there any pre-operational condition that would require the Operator to make available inspection of the updated procedures prior to commissioning of the facility.

4.35 Condition 7.1(2) of the permit requires the Operator to take steps set out in the document 'Accident Management Plan' to limit the environmental consequences and to prevent further accidents or incidents. However, based on information provided to AQC, an update to the Accident Management Plan does not appear to have taken place. As the Competent Authority for Schedule 13 SWIP, it is incumbent of CMBC to review such procedures prior to waste being accepted within the SWIP installation boundary. Risks associated with the current operation of the WTS are materially different to those associated with the operation of the SWIP, and the existing Accident Management Plan cannot be relied upon to adequately mitigate the risks of accidents associated with the SWIP.

4.36 Furthermore, no information has been provided on any fire detection and suppression systems installed within the SWIP building, nor has a formal Fire Prevention Plan (FPP) been produced. The Environment Agency's *Fire prevention plans: environmental permits* guidance clarifies that its Fire Prevention Plan guidance "*… applies to operators that accept* ***any*** *amount of combustible waste*." (emphasis added). Paragraph 2.1.6 in the Schedule 5 response seems to suggest the Operator will rely on the FPP established for the existing WTS for controlling fires at the SWIP. However, this FPP is not considered valid for the SWIP as, whilst it refers to combustible RDF, the SWIP introduces e.g., new potential ignition sources, new operations, and does not explicitly define how fires will be controlled within the SWIP building in response to the change of operations. It would have been advisable that a bespoke FPP for the SWIP was produced.

4.37 Provision of an adequate FPP is not necessarily a minimum requirement for determining a permit application, particularly where a design is still in development. However, where a FPP is not provided with the application, there should at least be a pre-operational condition in place that requires a FPP to be provided for inspection prior to waste being accepted within the installation boundary.

Fugitive Emissions to Land and Groundwater

4.38 As identified above, IED requires the Operator implement measures to prevent the unauthorised release of polluting substances to land and groundwater. In addition to the incoming waste and residues, other polluting substances stored within the SWIP installation boundary include urea for NO_x control and gas oil for start-up and temperature safeguarding.

4.39 No information has been provided in the application of measures in place to contain leaks, spillages or catastrophic failure of the urea and gas oil storage tanks. Consequently, the potential risk of fugitive emissions to land and groundwater is unquantified.

4.40 Best practice guidance for containment systems for the prevention of pollution are described in CIRIA C736. No reference is made in the application to this guidance, or indeed to any other best practice guidance for containment systems to prevent fugitive emissions to land and groundwater.

IN THE MATTER OF AN APPEAL BY CALDER VALLEY SKIP HIRE LIMITED AGAINST THE REFUSAL OF CALDERDALE METROPOLITAN BOROUGH COUNCIL TO GRANT AN ENVIRONMENTAL PERMIT FOR THE OPERATION OF A SMALL WASTE INCINERATION PLANT

AND IN THE MATTER OF LAND AT BELMONT INDUSTRIAL ESTATE, ROCHDALE ROAD, SOWERBY BRIDGE, WEST YORKSHIRE, HX6 3LL

ADVICE

1. I am instructed to advise [redacted] on the relevance of a planning appeal decision to the determination of an environmental permit appeal.

Background

2. The application site is Calder Valley Skip Hire, Belmont Industrial Estate, Rochdale Road, Sowerby Bridge. Despite its name, it is a small, single occupier site at the bottom of the steep sided valley[1] of the River Ryburn. On the north western side of the valley are the residential areas of Sowerby and Sowerby Bridge.

3. On 4th February 2020 a planning Inspector granted permission on appeal for:

> "construction of external flue, and change of use of existing building from recycling use (B2) to heat and energy recovery process (sui generis) and introduction of mechanical drying of inert soils and aggregates (B2) adjacent to the existing recycling shed together with the installation in underground ducts of pipes connecting the energy recovery plant in the said building to the dryer"

4. He also granted planning permission for:

> "Recycling centre with indoor sorting shed and widening of access from Rochdale Road (as amended) without complying with conditions attached to planning permission Ref. 04/02712/FUL"

5. This permission altered hours of operation and lifted a prohibition on burning.

---

[1] A description applied in the 2020 Planning Appeal Decision, para 25.

6. The decision followed an eight day inquiry. Having considered air quality in detail at paragraphs 22 to 64, the Inspector concluded that 'the effect of the proposal on living conditions in the local area, with particular reference to air quality, would be acceptable' (para 64). He said that the lack of material harm would be ensured by 'a combination of the imposition of planning conditions, which I deal with below, and the regulatory controls likely to the associated with the required Environmental Permit' (para 57, 61).

7. Calder Valley Skip Hire Limited ("CVSH") applied for an environmental permit for the incinerator in August 2020. The application was considered by Calderdale Council's Cabinet on 8th February 2021 who resolved to approve it. The permit was issued on 10th February 2021.

8. [redacted] then brought judicial review proceedings against the grant of the permit. The claimant's statement of facts and grounds noted:

> "61. CVSH take points which are not part of the Council's reasoning and assert erroneously (i) that air quality is not a matter for environmental permitting (when it is the purpose of environmental permitting) and (ii) that the view of a Planning Inspector on planning merits amounts to an issue estoppel. Issue estoppel can only arise in public law decisions which are determinative of an issue, such as the legal grounds in a planning enforcement notice appeal, rather than exercises of discretion or judgments as to future circumstances."

9. The Council and CVSH resisted the proceedings. Ground 3 concerned regard to environmental permitting guidance. CVSH contended that because of the Planning Inspector's decision 'It would have been unlawful for the Council to seek to refuse the permit on the basis that the proposal would have an impact which was more than negligible' (Summary Grounds, para 29). To do so would have been 'a flagrant disregard' of what is now paragraph 188 of the National Planning Policy Framework (Summary Grounds, para 29).

10. Paragraph 188 of the NPPF reads:

> "The focus of planning policies and decisions should be on whether proposed development is an acceptable use of land, rather than the control of processes or emissions (where these are subject to separate pollution control regimes). Planning decisions should assume that these regimes will operate effectively. Equally, where

a planning decision has been made on a particular development, the planning issues should not be revisited through the permitting regimes operated by pollution control authorities."

11. Permission to apply for judicial review was granted by [redacted] on all grounds on 23rd July 2021. The Council and CVSH subsequently agreed to the quashing of the environmental permit on the ground that the Council had erroneously believed that the permit application had to be determined on 8th February 2021. The parties' positions on the other grounds were reserved.

12. CVSH have subsequently appealed against the non-determination of the permit application. Their Statement of Case makes extensive reference to the planning appeal decision. At paragraphs 22 to 24 they say:

> "22. Paragraph 188 of the NPPF, 2021 explains concisely the different roles played respectively by the planning regime and the environmental permitting regime. Applying that advice when air quality has been made an important planning issue, the planning regime decides whether the proposed development is an acceptable use of land taking into account air quality impacts and in doing so making the assumption that the environmental permitting regime will operate effectively. By contrast, the permitting regime is concerned with the control of processes and/or emissions, in this case the control of the processes of the SWIP and the control of emissions from the stack arising from combustion within the SWIP. It is submitted that because the two regimes have different roles to play, paragraph 188 goes on to state that where a planning decision has been made on a particular development the planning issues should not be re-visited through the permitting regimes operated by pollution control authorities.
>
> 23. The practical application of that advice in this case appears clearly from paragraphs 57 and 61 of the Appeal Decisions in which the Inspector, having made his findings on air quality, sets out his conclusions on the effect on air quality of the development and in concluding that it would not materially harm the health and safety of users of the nearby Air Quality Management Area (AQMA2) and the site and its surroundings and the quality and enjoyment of the environment there he stated that it would be possible to ensure that that remained the case through a combination of the planning conditions and the regulatory controls likely to be

associated with the required environmental permit. Accordingly, it is submitted that in determining the permit application the focus should be the setting of the regulatory controls in and by the environmental permit and should not be an attempt to re-visit any of the air quality planning issues which the Inspector decided.

24. Notwithstanding that the Appellant has made submissions to that effect to the Council on a number of occasions and that principle was accepted by the Council's Cabinet when resolving to grant the permit on 8 February 2021 the purported request for further information made by the Council 14 months later on 21 April 2022 seeks to re-visit two of the air quality planning issues, namely, short-term NO2 concentrations and uncertainty, directly contrary to the advice in paragraph 188 of the NPPF, 2021."

13. The Statement of Case does then discuss the information available and the merits of the application. It also says at paragraph 33:

"The Appellant reserves its right to rely upon issue estoppel and related principles of law should the need arise in this appeal to do so."

14. In its Statement of Case the Council concedes that the appeal should be allowed (para 54). Having referred to the NPPF para 188, the Council said (para 40):

"in short, the planning system decides whether the development is an acceptable use of land taking into account air quality impacts. It does so by assuming that the environmental permitting regime will operate effectively."

15. Its position is:

"The Council is advised that following the grant of planning permission for the SWIP and subject to ensuring that the relevant provisions of the Industrial Emissions Directive set out in Schedule 13 to EPR 2016 are satisfied and controlled by permit conditions, the Appellant is entitled to the grant of an environmental permit"

Assessment

16. The principles to be applied to decision making when there are one or more consent regimes governing the site or activity are:

(i) Each consent should be determined in accordance with the criteria relevant to that regime;

(ii) There may be overlaps between regimes: some factors may be considerations under two or more regimes;[2]

(iii) Absent legislation cutting down the scope of one regime in the event of an overlap, a determination under one regime does not prevent the same factors from being considered again but from the perspective of the other regulatory regime;

(iv) The existence of another regime may be relevant to decision making.[3] For example, a planning authority can take into account that an activity will be subject to environmental permitting when determining a planning application;[4]

(v) A regulator may proceed on the basis that other regulatory regimes will be operating effectively;

(vi) However, a regulator is not obliged to assume the existence of another regime will render the impacts addressed by that regime immaterial to its own decisions;[5]

(vii) It does not follow that the grant of the first consent will mean that consent should be granted under the other regulatory regime;[6]

(viii) A decision by regulator A and its findings or reasoning may be relevant to decision making by regulator B. To what extent it is relevant will be affected by:

(a) To what extent the regulators are applying the same criteria, including legislative tests or policy;

---

[2] *Esdell Caravan Park v Hemel Hempstead Rural District Council* [1966] 1 Q.B. 895 at 925 per Lord Denning MR.

[3] In *Esdell* at 923 Lord Denning suggested that planning authorities should deal with caravan applications in outline, leaving the detail of control to caravan site licensing but did not seek to insist on it

[4] *Gateshead Metropolitan Borough Council v Secretary of State for the Environment* [1995] Env LR 37 at 44 per Glidewell LJ.

[5] For example, dust and noise at issue in *Hopkins Developments Ltd v First Secretary of State* [2006] EWHC 2823 (Admin), [2007] Env LR 14 or odours in *Harrison v Secretary of State for Communities and Local Government* [2009] EWHC 3382 (Admin), [2010] Env LR 17 were not immaterial because action could be taken against them by the affected neighbours (in private or statutory nuisance) or regulators (under environmental permits).

[6] *Gateshead* at 49-50 per Glidewell LJ. He said that the then regulator, HM Inspectorate of Pollution 'should not consider that the grant of planning permission inhibits them from refusing authorisation if they decide in their discretion that this is the proper course.'

(b) Whether regulator A's decision relied upon effective regulation by regulator B. In those circumstances the first decision may say very little about what regulator B should decide;

(c) Whether circumstances or available information have changed since the first decision.

The present case

17. The issue of air quality was considered extensively in the planning appeal. The Inspector's conclusion was that any impact would be acceptable in planning terms, given the existence of the environmental permitting regime. He did not conclude that an environmental permit should be granted, or on what terms, and those matters were not within his remit.

18. The Environmental Permit decision on the small waste incinerator plant must be taken so as to ensure compliance with various provisions of the Industrial Emissions Directive.[7] These include that waste gases 'shall be discharged in a controlled way by means of a stack the height of which is calculated in such a way as to safeguard human health and the environment'[8] and that emission limit values to air and water are adhered to.[9]

19. Consequently, if it is found that the proposal is harmful to human health or the environment then the environmental permit must be refused. The planning appeal Inspector's conclusions on air quality do not bind the Inspector who will be dealing with the environmental permit appeal.

20. The environmental permit decision maker will also take into account the relevant government guidance.

21. Since the planning appeal decision the environmental permit application has been made and it has been the subject of expert reports on behalf of CVSH, the Council and local residents as well as a judicial review. The environmental permit decision will need to take the changed circumstances and additional information into account.

[7] Environmental Permitting (England and Wales) Regulations 2016, Sched 13, para 4.
[8] IED, article 46(1).
[9] IED, article 46(2),(3).

Estoppel

22. CVSH have mentioned, but not advanced, the possibility of arguing that the planning appeal decision gives rise to an issue estoppel in respect of air quality matters. An issue estoppel arises where a determination of an issue in one set of proceedings binds the parties to those proceedings in the future. Issue estoppel does not arise in relation to judgements whether planning permission should be granted. Whilst a grant of planning permission does, of course, give rise to the rights in the permission, it does not bind the parties as to the merits of the application.[10]

23. If any matters arise out of this advice, please do not hesitate to contact me in Chambers.

[redacted]

39 Essex Chambers [redacted]
81 Chancery Lane
London WC2A 1DD 21st October 2022

[10] *Thrasyvoulou v Secretary of State for the Environment* [1990] 2 AC 273 at 290 per Lord Bridge of Harwich where he distinguishes between the fact of a grant of planning permission and the merits judgement in a refusal: 'A decision to grant planning permission creates, of course, the rights which such a grant confers. But a decision to withhold planning permission resolves no issue of legal right whatever. It is no more than a decision that in existing circumstances and in the light of existing planning policies the development in question is not one which it would be appropriate to permit. Consequently, in my view, such a decision cannot give rise to an estoppel per rem judicatam.'

Air Quality Consultants

Technical Note:
Calder Valley Skip Hire Small Waste Incineration Plant

October 2022

Experts in air quality management & assessment

Document Control

Client	[redacted]	**Principal Contacts**	[redacted]

Job Number	[redacted]

Report Prepared By:	[redacted]

Document Status and Review Schedule

Report No.	Date	Status	Reviewed by
[redacted]	24 October 2022	Final Report	[redacted]

Air Quality Consultants Ltd
23 Coldharbour Road, Bristol BS6 7JT Tel: 0117 974 1086
24 Greville Street, Farringdon, London, EC1N 8SS Tel: 020 3873 4780
aqc@aqconsultants.co.uk

Registered Office: 23 Coldharbour Road, Bristol BS6 7JT
Companies House Registration No: 2814570

Contents

1 Introduction

1.1 Air Quality Consultants Ltd (AQC) has been commissioned to provide a professional opinion on air quality regulation of a small waste incineration plant (SWIP) in Calderdale. In particular, the relationship between the Planning and Environmental Permitting Regulation ('EPR') regimes, which in this case, are both regulated by Calderdale Metropolitan Borough Council (CMBC). This note has been produced as part of a representation to the Environmental Permitting Appeal, by Calder Valley Skip Hire Limited (APP/EPR/603) for the operation of the SWIP. This technical note has been completed on behalf of [redacted] and [redacted]

1.2 AQC has previously provided a technical review of the Appellant's (previously Applicant's) permit resubmission air quality information (report ref: [redacted]), with the initial granting of the permit Quashed during a Judicial Review (an overview of the background to the case is presented in Paragraph 1.5).

1.3 Since AQC's previous review, the Appellant has provided additional evidence, produced by their commissioned consultancy RPS, that considers AQC's omission of the planning appeal decision document from its list of reviewed documents as significant. This was judged by RPS as significant due to their view that as air quality was examined at great lengths during the Planning Application and subsequent Planning Appeal, certain aspects need not be revisited under the EPR. RPS's full comments can be seen in Paragraphs 1.2 to 1.7 within the amended report (Appendix A1).

1.4 AQC is not presenting further evidence relating to the assessment of impacts; however, it is AQC's view that a regulatory body should be able to fully understand the air quality impacts of pollution control devices from a potentially regulated facility regardless of how it has been assessed at the Planning stage. In this case, any information relating to the Appellant's stack or other abatement systems, which are the primary measures of emissions control, in this case, come within the remit of the EPR regime, regardless of the view taken by the Planning Authority. AQC's full view is presented in Section 3.

Background

1.5 For context, a summary of the preceding applications and associated decisions have been included below:

Planning Application

- A Planning Application submitted by Calder Valley Skip Hire, dated 1st February 2017, for the operation of a SWIP, was refused by CMBC notice dated 2th January 2018. CMBC gave a single reason for the refusal, which related to air quality.
- Planning Permission for the construction and operation of a SWIP was granted on Appeal by a Decision Letter dated 4th February 2020.

Environmental Permit Application

- Calder Valley Skip Hire submitted an Environmental Permitting Application on 6th August 2020 and permission was granted by a decision of the Council's Cabinet on 8th February 2021, and an Environmental Permit was issued by the Council on 10th February 2021.
- A Judicial Review claim was brought against the Environmental Permitting decision on the 9th April 2021, and granted permission on the 23rd July 2021. A Quashing Order by consent was made by the High Court on 14th September 2021 and entered on 17th September 2021.
- The effect of the Quashing Order was to revert the status of the original Permit Application to that of undetermined, with the Council under a duty to redetermine the Application and either to grant or refuse it. By 23rd May 2022, with the redetermination having not occurred, the Appellant served notice on the Council pursuant to paragraph 15(1) of Schedule 5 to the Environmental Permitting (England and Wales) Regulations 2016 with the effect that the Appellant's Permit Application was deemed to have been refused on that date and giving rise to the Appeal against non-determination.
- The start date of Calder Valley Skip Hire's Appeal to the Planning Inspectorate was Tuesday 21st June 2022. No notice of the appeal was published by Calderdale Metropolitan Borough Council. Interested Parties now have until the 26th October 2022 to submit a representation.

2 Competence

2.1 [redacted] is a [redacted] experience in the field of air quality assessment. He has been part of the Environment Agency's Air Quality Modelling and Assessment Unit (AQMAU), which is embedded within the National Permitting Service. He has thus reviewed many technical reports for large installations, including energy from waste facilities, on behalf of Central Government. He has advised Central Government whether the material submitted is sufficient for the granting of permits and has also provided a similar service for local governments. In addition, he regularly undertakes air quality assessments for AQC, covering a mixture of uses, including industrial installations, energy centres and waste facilities. He has experience using a range of dispersion models including ADMS-Roads, ADMS-5 and Breeze AERMOD to complete quantitative modelling assessments, for both planning and permitting purposes. He is a Member of the Institute of Air Quality Management and a Member of the Institution of Environmental Sciences.

2.2 [redacted], specialising in industrial emissions. He is a member of the Institute of Air Quality Management, has previously contributed his time to, and authored publications on behalf of, the Energy Institute's Emissions Working Group, and has acted as peer reviewer for the Journal of Air & Waste Management. His expertise includes ambient and stack emissions monitoring, emission inventory development and reporting, atmospheric dispersion modelling, abatement of air emissions, environmental permitting, Best Available Technique (BAT) assessments, cost-benefit analysis and compliance assessment. He has extensive experience in the quantification and assessment of emissions from a variety of releases, covering point source emissions, flare emissions, fugitive emissions and emissions from mobile transport sources, including marine vessels, on-road and off-road vehicles and rail locomotives. He has detailed knowledge of the technologies and techniques to reduce concentrations of combustion and non-combustion related pollutants, including oxides of nitrogen, acid gases (e.g., SO_2, HF, HCl), volatile organic compounds (VOCs), particulates, heavy metals and odour.

2.3 [redacted] relevant experience in the field of air quality. She has been responsible for numerous assessments for a range of infrastructure developments including power stations, road schemes, ports, airports and residential/commercial developments. The assessments have covered operational and construction impacts, including odours. She also provides services to local authorities in support of their LAQM duties, including the preparation of Review and Assessment and Action Plan reports, as well as audits of Air Quality Assessments submitted with planning applications. She has provided expert evidence to a number of Public Inquiries, and is a Member of the Institute of Air Quality Management and a Chartered Scientist.

3 Technical Statement

3.1 Under Part 3, Regulation 32(5)(c) of the Environmental Permitting (England and Wales) Regulations 2016 ('EPR'), local authorities hold the relevant functions of the "regulator" for discharging the requirements of Schedule 13 of the EPR. Section 3 of the Schedule 13 requires that regulators must ensure that every application for the grant of an environmental permit for a small waste incineration plant (SWIP) includes the information specified in Article 44 of the Industrial Emissions Directive ('IED'), with Article 44(1) requiring that the regulator ensures an application for a permit includes a description of the measures which are envisaged to guarantee that:

"the plant is designed, equipped and will be maintained and operated in such a manner that the requirements of this Chapter [editorial note – this refers to Chapter IV of the IED which sets special provisions for waste incineration and co-incineration plant] are met taking into account the categories of waste to be incinerated or co-incinerated."

3.2 Section 4(1)(h) of the EPR further requires that the local authority permitting function, as regulator, is required to:

"…exercise its relevant functions so as to ensure compliance with the following provisions of the Industrial Emissions Directive… (h) Article 46."

3.3 Article 46(1) within Chapter IV of IED requires that:

"Waste gases from waste incineration plants and waste co-incineration plants shall be discharged in a controlled way by means of a stack the height of which is calculated in such a way as to safeguard human health and the environment."

3.4 Hence, it is clear that, under the EPR, it is the local authority permitting function that is responsible for determining whether the height of a stack serving a SWIP is sufficient to safeguard human health and the environment. To reach a conclusion concerning the acceptability of the proposed stack height, the permitting authority is required to consider the predicted air quality impacts for that stack height. Hence, it has to be satisfied that such an assessment, including its underlying methodology, is robust before determining whether a permit can be granted.

3.5 In Defra's Environmental Permitting: Core Guidance[1], reference is made to the Environment Agency's Guidance[2] for developments requiring planning permission and environmental permits. Within the Environment Agency's guidance, it is stated:

---

[1] Defra.2020. *Environmental Permitting: Core Guidance. For the Environmental Permitting (England and Wales) Regulations 2016 (SI 2016 No 1154).*

[2] Environment Agency.2012.*Guidance for developments requiring planning permission and environmental permits.*

"Local planning authorities are responsible for determining planning applications… When deciding on a planning application, planning authorities should:

- *Be confident the development will not result in unacceptable risks from pollution when considering if the development is an appropriate use of the land.*
- *Not focus on controlling pollution where it can be controlled by other pollution regulations, such as EPR."*

3.6 Consequently, local authorities responsible for determining applications at planning stage are required to consider whether the proposed development represents an appropriate use of the land, not consider controlling pollution from regulated activities covered under the EPR. Detailed assessment of operational stack emissions with respect to controlling emissions under the EPR is the primary responsibility for the permitting regime, not planning. This is further clarified in the Environment Agency's Draft EPR Permit – Stack Height Assessment guidance:

"The detailed assessment of impact of emissions from the installation is carried out under permitting, not planning. So while a stack height may have been set under planning, it does not necessarily mean the planning authority would not accept a different stack height, or that we are bound to conclude that the height is acceptable just because it is specified in the planning and the ES will not be breached."

3.7 Paragraph 188 of the National Planning Policy Framework states:

"The focus of planning policies and decisions should be on whether proposed development is an acceptable use of land, rather than the control of processes or emissions (where these are subject to separate pollution control regimes). Planning decisions should assume that these regimes will operate effectively. Equally, where a planning decision has been made on a particular development, the planning issues should not be revisited through the permitting regimes operated by pollution control authorities."

3.8 Whilst the NPPF states planning issues should not be revisited through the permitting regimes, it is clear from the statutory responsibility imposed on permitting authorities through the EPR that this should be restricted to aspects of the air quality assessment that determine whether the proposed development represents an acceptable use of the land, not pollution control aspects. This would include, for example, not revisiting aspects related to construction phase assessments, or assessment of vehicle emissions beyond the installation boundary by the permitting authority.

3.9 However, it is the permitting authority that has the responsibility and statutory obligation to determine whether operational stack emissions from regulated facilities covered under the EPR are controlled to prevent significant impacts on human health and the environment. Combined with ensuring statutory minimum emission limit values can be met, predictive air quality assessments are the only data available to the permitting authority at application stage to determine the potential impact on human health and the environment and, consequently, the degree to which emissions are/can be controlled.

3.10 Irrespective of whether operational air quality effects have been discussed at planning stage, the local authority permitting function, as regulator for SWIPs, can, and must, ensure that operational phase assessments of stack emissions are robust. If any aspect of the air quality assessment of operational stack emissions is not considered to be robust, further information should be sought by the local authority permitting function, and provided by the applicant, before determining the application.

3.11 Hence, although the planning appeal decisions document was sent to AQC, it was not considered material for the review of air quality impacts at permitting stage. As previously demonstrated, both in terms of legislation and supporting guidance, it is the permitting regime that must determine whether the assessment of operational air quality effects of stack emissions is robust with respect to controlling emissions under the EPR. The planning regime serves an entirely separate purpose.

A1 RPS's Full Comment

Response to Air Quality Consultants Ltd Review of Air Quality Assessment

Calder Valley Small Waste Incineration Plant

For Calder Valley Skip Hire Ltd

www.rpsgroup.com

Quality Management

Prepared by	[redacted]	Principal Air Quality Consultant	15/03/2022
Reviewed & checked by		Technical Director	15/03/2022
Authorised by		Technical Director	15/03/2022
Date of Issue	15/03/2022	**Revision Number**	Rev 3
Job Number	[redacted]		

Revision History

Rev	Date	Status	Reason for revision	Comments
0	28/01/2022	-	-	-
1	04/02/2022	-	-	-
2	01/03/2022	-	Legal comments	-
3	15/03/2022	-	-	-

Calculations or models file name, link and location

Prepared by	[redacted]	Principal Air Quality Consultant	15/03/2022
Checked by		Technical Director	15/03/2022

DISCLAIMER

RPS has used reasonable skill and care in completing this work and preparing this report, within the terms of its brief and contract and taking account of the resources devoted to it by agreement with the client. We disclaim any responsibility to the client and others in respect of any matters outside the stated scope. This report is confidential to the client and we accept no responsibility to third parties to whom this report, or any part thereof, is made known. The opinions and interpretations presented in this report represent our reasonable technical interpretation of the data made available to us. RPS accepts no responsibility for data provided by other bodies and no legal liability arising from the use by other persons of data or opinions contained in this report.

Except for the provision of professional services on a fee basis, RPS does not have a commercial arrangement with any other person or company involved in the interests that are the subject of this report.

This document has been compiled using the resources and in accordance with the scope of work agreed with the client. No liability is accepted by RPS for any use of this document, other than the purpose for which it was prepared. RPS does not accept any responsibility or liability for loss whatsoever to any third party caused by, related to or arising out of any use or reliance on the document.

Contents

Tables, Figures and Appendices

Tables

Figures

Appendices

1 Introduction

1.1 This report has been produced in response to the comments raised in the Air Quality Consultants Ltd (AQC) review of the Air Quality Assessment. The AQC review highlighted ten potential issues related to the air quality assessment within the context of the redetermination of an application for a Schedule 13 EPR environmental permit (the Permitting Application) for a small waste incineration plant (SWIP). Other potential issues related to the Permitting Application are addressed in a separate report.

1.2 Although AQC refer in passing to the fact that planning permission has already been granted, AQC make no reference to the Appeal Decisions dated 4 February 2020 or to the findings of the detailed assessment of the Inspector appointed by the Secretary of State as set forth in those Appeal Decisions. AQC list the documents which it has reviewed in compiling its report and the list of documents does not include the said Appeal Decisions. The reason for that omission is not known but the omission is considered to be very significant.

1.3 The planning regime and the environmental permitting regime are separate but complementary. Because that is so Central Government has consistently provided guidance on the different roles that each regime plays. It is provided in paragraph 188 of the National Planning Policy Framework (NPPF) 2021 that:

"*The focus of planning policies and decisions should be on whether proposed development is an acceptable use of land, rather than the control of processes or emissions (where these are subject to separate pollution control regimes). Planning decisions should assume that these regimes will operate effectively. Equally, where a planning decision has been made on a particular development the planning issues <u>should not be re-visited</u> through the permitting regimes operated by pollution control authorities.*" (our emphasis).

1.4 That approach has been consistent Government policy in every version of the NPPF since the first version was published in March 2012. As is apparent from the Appeal Decision air quality considerations were front and centre as planning issues for determination in the Appeal Decision made by the Planning Inspector in relation to the SWIP and related development. The Appeal Decision of the Secretary of State's appointed Inspector were issued only after an Environmental Impact Assessment which included air quality and after an extremely thorough Public Inquiry at which the Council was represented on matters that focussed primarily on air quality.

1.5 Where that is the case, it is the purpose of the planning decision to consider air quality impacts in order to determine whether the proposed development is an acceptable use of land. The air quality assessment within that context will assume that emissions to air will be effectively controlled by the environmental permit. Once the planning decision has been made, after consideration of air quality impacts, that the proposed development is an acceptable use of land the role of the regulator considering an environmental permit application is in the case of development of this kind to consider whether, having regard to the plant concerned and the relevant provisions of the Industrial Emissions Directive (IED) listed in Schedule 13 to the EPR, emissions will be effectively controlled by permit conditions so as, amongst other considerations, not to exceed any of the emission limit values in the IED, to impose those conditions which are necessary for that purpose and thereby to put in place the control of emissions upon which the planning decision has been based. It is because the role of the regulator in such circumstances is circumscribed in that manner that the guidance states that where a planning decision has been made on a particular development the planning issues (which in this case included air quality issues) should not be revisited through the environmental permitting regime.

1.6 In conformity with what is set out above Calderdale Metropolitan Borough Council and Calder Valley Skip Hire Ltd (CVSH) agreed in a Statement of Common Ground dated 26 September 2019 that:

"The appeal proposals are centred upon the treatment of residual waste in a small waste incineration plant (SWIP) (as defined in the Environmental Permitting (England and Wales) Regulations 2016). The SWIP together with associated plant will be required to meet all statutory industrial emissions standards and, under the environmental permit, such specific standards as applicable and in force from time to time in relation to incineration plants for the protection of human health and the environment. The control of emissions from the flue or stack associated with the SWIP would be regulated and enforced under the pollution control regime in accordance with such statutory and other regulatory standards and so as to ensure that there is no breach of any applicable emission limit values."

1.7 As is recorded in paragraph 28 of the Appeal Decisions the Council confirmed that the concerns upon which its reason for refusal of planning permission was based related to Nitrogen Dioxide and not to any of the other potential emissions to air from the scheme. After adding that the Environmental Statement Addendum confirmed that the predicted process contributions of other potential emissions, including PM_{10}, $PM_{2.5}$ and hexavalent chromium (Cr VI), would not be significant, the Inspector stated that he had not been provided with any compelling evidence to the contrary.

1.8 This report addresses four of the potential issues raised by AQC related to the air quality assessment. Issue number 7 relates to the Human Health Risk Assessment which has been considered in a separate report. The said four potential issues are identified in paragraph 1.9 below. If those instructing AQC wished to raise these issues they should have done so and presented evidence in relation to them at the above-mentioned Public Inquiry where they were given ample opportunity to do so. They did not. It would be open to CVSH to take the position that, for that reason, these four potential issues should not be raised in the context of the Permitting Application. Without prejudice to that, this report proceeds to address them for the sake of completeness and transparency. By contrast, issues numbers 1, 3, 5, 6 and 10 have not been considered in this report as they relate to issues which were specifically addressed in the Environmental Statements and the detailed evidence presented and tested at the above-mentioned Public Inquiry, resulting in the fully detailed and reasoned Appeal Decisions granting planning permission for the SWIP and related development, which are unchallenged.

1.9 The four potential issues this report addresses are reproduced below:

- *'Issue 2 – Benzo(a)pyrene - Within the 2019 additional air quality assessment, the applicant predicts a 'worst-case' Benzo(a)pyrene process contribution, i.e., that relating to emissions from the SWIP processes in isolation, of 9% of the Air Quality Standard, and predicted environmental concentration of 98.4%, i.e., the SWIP process contribution plus contributions from other emission sources. This level of impact is presented at the location of maximum impact anywhere on the modelled grid.*

  The applicant needs to provide more information to justify that the contribution is insignificant.

- *Issue 4 – Ecological Impacts - The applicant has not assessed the impacts at nearby ancient woodland and local nature reserve ecological sites within their ES addendum or their 2019 additional Air Quality Assessment. These sites are within the 2 km screening distance for assessment of ecological sites required by the Environment Agency.*

- *Issue 8 – Carbon Monoxide 1-hour EAL - The applicant has not undertaken an assessment against the Carbon Monoxide 1-hour Environmental Assessment Level (EAL) of 30,000 µg/m^3. In the experience of the reviewers, carbon monoxide emissions are generally insignificant compared to the environmental standards. As there are no predicted significant effects towards the 8-hour CO objective, lack of consideration of the 1-hour EAL is unlikely to alter the conclusion of the assessment.*

- *Issue 9 – TOC Emissions - The applicant has not undertaken an assessment of the likely emissions of total organic compounds (TOC). It is a requirement within chapter IV of IED that* *emissions to air from waste incineration plants shall not exceed the emission limit value of 10 mg/Nm³ for TOC; therefore, any robust assessment should consider the sites impact from TOC'.*

1.10 In addressing those four potential issues this report does so entirely without prejudice to what we have set out above and without any intention to revisit in the course of this environmental permitting redetermination process the air quality issues which were determined by the Planning Inspector in the Appeal Decisions referred to above or the findings and detailed assessment of the Planning Inspector on air quality issues set forth in those Appeal Decisions. Further, in addressing those four potential issues in this report it is not the intention to detract from the entitlement of CVSH to rely upon the above-mentioned Statement of Common Ground agreed with Calderdale MBC including the common ground recorded in the Appeal Decisions. This includes, in particular, what is stated in paragraph 6.2 below of this report.

1.11 The additional assessment work undertaken to respond to the issues raised has followed the same methodology as the original assessment work. The policy and legislative context and the assessment methodology are reproduced from the Environmental Statement Addendum, July 2019 in Appendix A for ease of reference. In doing so, we do not place any of the content of Appendix A, particularly the assessment methodology, in issue in this Permitting Application. The methodology was found by the Secretary of State's appointed Inspector to be sound in the above-mentioned Appeal Decisions. The following sections of this report reproduce the relevant extract from the AQC review in italics, followed by the RPS response.

2 Issue 2 – Benzo(a)pyrene

AQC Ltd Comment

2.1 *Within the 2019 additional air quality assessment, the applicant predicts a 'worst-case' Benzo(a)pyrene (B(a)P) process contribution (PC), i.e., that relating to emissions from the SWIP processes in isolation, of 9% of the Air Quality Standard (AQS), and predicted environmental concentration (PEC) of 98.4%, i.e., the SWIP process contribution plus contributions from other emission sources. This level of impact is presented at the location of maximum impact anywhere on the modelled grid.*

2.2 *This prediction is based on an emission concentration of 1 μg/m^3 derived from typical emissions data of B(a)P in the 2006 Waste Incineration BAT Reference (BREF) document. In December 2019, an update to the 2006 BREF was introduced that confirmed B(a)P emissions from 48 reference lines incinerating predominantly municipal wastes ranged from 0.004 ng/Nm^3 to 1 μg/m^3. In that respect, the assumed emission concentration for B(a)P can be viewed as precautionary. However, in combination with the previous discussion on model uncertainty, as the PEC approaches 100% and no evidence is presented about level of significance of this level of impact, it is not considered possible to definitively conclude no significant effects based on the data presented. In particular, the average B(a)P concentration at the Leeds Millshaw monitoring site between 2014 and 2017 has been used to define baseline concentrations, rather than the maximum. The maximum annual mean concentration during this period exceeds the objective.*

2.3 *However, it is important to recognise that this prediction is made based on the maximum predicted value at any location in the model domain. AQS apply only where there is 'relevant exposure' and, for the purpose of assessing compliance with the B(a)P objective, which is expressed as an annual mean assessment metric, relevant exposure only occurs at e.g., residential properties and schools. It is expected that model predictions at the specific human receptors considered in the assessment would be lower than the maximum predicted value, and could possibly be at a level where no significant effect could be concluded. However, this should be confirmed by the applicant by providing tabulated data for each specified receptor location where there is relevant exposure.*

RPS response

2.4 An atmospheric dispersion model was used to predict the Process Contribution (PC) for the stack emission concentrations across a grid of receptors and at selected sensitive receptors. The PC was added to the background Ambient Concentration (AC) to calculate a Predicted Environmental Concentration (PEC). The PC and PEC were compared with the relevant Environmental Assessment Level (EAL).

2.5 The original assessments used an emission concentration for benzo(a)pyrene (B[a]P) of 0.001 $mg.Nm^{-3}$, which is equivalent to the 1 $\mu g.m^{-3}$ quoted by AQC Ltd.

2.6 As stated by AQC Ltd, the baseline concentration (the AC) for B[a]P was derived from the average of measured concentrations of polycyclic aromatic hydrocarbons (PAHs) at the Leeds Millshaw monitoring site. B[a]P is one of many PAHs that are potentially emitted from SWIPs.

2.7 The most recently monitored annual-mean PAHs concentrations considered in the assessment are summarised in Table 2.1.

Table 2.1 Annual-Mean PAHs Concentrations ($ng.m^{-3}$)

Monitoring Site	Concentration ($ng.m^{-3}$)				
	2014	2015	2016	2017	Average
Leeds Millshaw	0.26	0.20	0.25	0.19	0.22

2.8 The assessment compared the AC of PAHs added to the PC for B[a]P with the EAL of B[a]P. Therefore, the conclusion that the PEC is below the EAL was conservative.

2.9 Nevertheless, for the purposes of this response the maximum measured concentration of 0.26 $ng.m^{-3}$ (i.e. 2.6E-04 $\mu g.m^{-3}$) has been used as the baseline concentration instead of the average of 0.22 $ng.m^{-3}$ used in the original assessment.

2.10 The results using this higher baseline concentration are shown in Section 5.

3 Issue 8 – Carbon Monoxide 1-hour EAL

AQC Ltd Comment

3.1 *The applicant has not undertaken an assessment against the Carbon Monoxide (CO) 1-hour Environmental Assessment Level (EAL) of 30,000 µg/m3. In the experience of the reviewers, carbon monoxide emissions are generally insignificant compared to the environmental standards. As there are no predicted significant effects towards the 8-hour CO objective, lack of consideration of the 1-hour EAL is unlikely to alter the conclusion of the assessment.*

RPS response

3.2 The AQC comment concludes that consideration of the hourly-mean EAL for CO is unlikely to alter the conclusion of the assessment. Nevertheless, further analysis has been undertaken and the maximum hourly-mean carbon monoxide (CO) PC has been compared with the 1-hour EAL of 30,000 µg.m^{-3} in Section 5.

4 Issue 9 – TOC Emissions

AQC Ltd Comment

4.1 *The applicant has not undertaken an assessment of the likely emissions of total organic compounds (TOC). It is a requirement within chapter IV of IED that emissions to air from waste incineration plants shall not exceed the emission limit value of 10 mg/Nm^3 for TOC; therefore, any robust assessment should consider the sites impact from TOC.*

4.2 *As the exact speciation, or composition, of TOC cannot be known, best practice guidance by the Environment Agency suggests comparing TOC impacts against the benzene AQS. Such an assessment was undertaken within the original 2017 ES chapter in respect to the annual mean benzene AQS. The Environment Agency has recently introduced a 24-hour mean benzene environmental assessment level (EAL) of 30 µg/m^3 which should be assessed against for completeness. However, it is accepted that the air quality assessment was produced before the publication of this new EAL.*

RPS response

4.3 Total organic compounds (TOCs) have been assessed in Section 5.

5 B[a]P, CO and TOC Results

5.1 The plant is designed to meet the emission concentration limits set out in the Industrial Emissions Directive (IED). The emission rates used for TOCs and CO have been derived from the short and long-term emission concentration limits in the IED.

5.2 For B[a]P, the emission concentration was obtained from the IPPC Reference Document on the Best Available Techniques for Waste Incineration (August 2006). The emission concentration is the concentration at the point of release i.e. the top of the stack. These are used to derive an emission rate in $g.s^{-1}$ from the stack. This emission rate is an input to the model which predicts concentrations at receptors, taking into account the dispersion of pollutants after leaving the stack.

5.3 The emission rates for CO and B[a]P are the same as in the 2019 ES Addendum Additional Air Quality Assessment report and have been reproduced in Table 5.1 for ease of reference.

Table 5.1 Emission Rates

Pollutant	Parameter (unit)	Short-term Emission Limit Value – Scenario 1	Long-term Emission Limit Value – Scenario 2
TOCs	IED Emission Limit Value ($mg.Nm^{-3}$)	20*	10*
	Emission rate ($g.s^{-1}$)	0.026	0.012
CO	IED Emission Limit Value ($mg.Nm^{-3}$)	100*	50*
	Emission rate ($g.s^{-1}$)	0.13	0.06
B[a]P	Emission concentrations obtained from the IPPC Reference Document on the Best Available Techniques for Waste Incineration (August 2006) ($mg.Nm^{-3}$)	-	0.001
	Emission rate ($g.s^{-1}$)	-	1.28E-06

Note: $mg.Nm^{-3}$ refers to mg of pollutant per cubic metre at reference conditions (or normalised). The reference conditions are temperature 273 K, pressure 101.3 kPa, 11% oxygen, dry gas
*As outlined in Appendix A, paragraph A.4, for the purposes of this assessment for those pollutants having only one IED emission limit (for a single averaging period), the facility has been assumed to operate at that limit (with the exception of arsenic and Chromium VI, as discussed later in the Appendix). Where more than one limit exists for a pollutant, the half-hourly mean emission limit value has been used to calculate short-term (≤ 24-hour average) peak ground-level concentrations (Scenario 1) (again, with the exception of arsenic and Chromium VI, as discussed later in the Appendix). The daily mean emission limit value has been used for these pollutants to calculate long-term (greater than 24-hour average) mean ground-level concentrations (Scenario 2).
.

5.4 Table 5.2 and Table 5.3 show the maximum predicted Process Contributions across the modelled grid. The modelled grid is outlined in paragraph A.43 of Appendix A. As explained by AQC, the point of maximum impact may not necessarily be a location where there is relevant exposure.

The PCs at sensitive receptors will be lower than the maximum across the grid. These PCs are the predicted concentrations at a receptor and have been compared with the relevant EALs.

Table 5.2 Predicted Maximum Process Contributions (µg.m^{-3}) at Short-Term Emission Limit Values (Scenario 1) – Results Across the Modelled Grid

Pollutant	Averaging Period	EAL (µg.m^{-3})	Max PC (µg.m^{-3})	Max PC as % of EAL	Criteria (%)	AC (µg.m^{-3})	PEC (µg.m^{-3})	Is PC Potentially Significant?	Is PEC Potentially Significant?
CO	1 hour (maximum)	30,000	220.1	1	10	-	-	No	-
TOCs*	24 hour (maximum)	30	26.0	87	10	0.58	26.5	Yes	No

*Consistent with the Environment Agency's *'Air emissions risk assessment for your environmental permit'* guidance, as the substances in the TOCs are unknown, the TOCs are assumed to be 100% benzene. The EAL and AC are for benzene. This is a highly conservative approach.

Table 5.3 Predicted Maximum Process Contributions (µg.m^{-3}) at Long-Term Emission Limit Values (Scenario 2) – Results Across the Modelled Grid

Pollutant	Averaging Period	EAL (µg.m^{-3})	Max PC (µg.m^{-3})	Max PC as % of EAL	Criteria (%)	AC (µg.m^{-3})	PEC (µg.m^{-3})	Is PC Potentially Significant?	Is PEC Potentially Significant?
CO	1 hour (maximum)	30,000	110.0	0	10	-	-	No	-
TOCs*	24 hour (maximum)	30	13.0	43	10	0.58	13.6	Yes	No
	24 hour (annual mean)	5	0.22	4	1	0.29	0.51	Yes	No
B[a]P	1 hour (annual mean)	2.5E-04	2.2E-05	9	1	2.6E-04	2.8E-04	Yes	Yes

*Consistent with the Environment Agency's *'Air emissions risk assessment for your environmental permit'* guidance, as the substances in the TOCs are unknown, the TOCs are assumed to be 100% benzene. The EAL and AC are for benzene. This is a highly conservative approach.

5.5 The maximum hourly mean CO PC does not exceed 10% of the EAL of 30,000 µg.m^{-3} and the impacts can be scoped out as insignificant. This is consistent with AQC's comment that consideration of the hourly-mean EAL for CO would not alter the conclusion of the assessment.

5.6 On the highly conservative basis that all TOC is present in the form of benzene (which is not plausible) the daily mean TOC PC exceeds 10% of the benzene EAL of 30 µg.m^{-3} and the impacts are potentially significant. However, when the PC is added to the AC in both scenario 1 and scenario 2, the daily mean PEC is less than the benzene EAL and the impacts can be scoped out as insignificant.

5.7 The annual-mean TOC PC exceeds 1% of the benzene EAL of 5 µg.m^{-3} and the impacts are potentially significant. When the TOC PC is added to the AC, the PEC of 0.51 µg.m^{-3} is less than the benzene EAL and the impacts can be scoped out as insignificant.

5.8 For B[a]P, when the maximum across the modelled grid is considered, the PC exceeds 1% of the B[a]P EAL. The PEC exceeds the EAL and the impacts across the modelled grid are potentially significant if there is relevant exposure at the point of maximum impact. This is a conservative approach as the AC used is the maximum measured concentration of all PAHs, not just B[a]P, over a four-year period.

5.9 Further analysis has been undertaken for B[a]P to determine the predictions at locations where there is relevant exposure. For TOCs and CO, the predictions at locations with relevant exposure have not been considered further as the maximum PEC across the modelled grid is below the EAL and therefore predictions at relevant exposure will be lower. AQC make this point in issue 2 (reproduced at paragraph 2.3 above).

5.10 Table 5.4 presents the annual-mean B[a]P concentrations predicted at the façades of receptors i.e. locations where there is relevant human exposure.

Table 5.4 Maximum Predicted Annual-Mean B[a]P Impacts at Receptor Locations

Receptor ID	Receptor Name	Annual-Mean PC ($\mu g.m^{-3}$)	PC as % of the EAL*
1	28 Rochdale Road	1.20E-06	0
2	9 Breck Lea	5.92E-07	0
3	Sacred Heart Catholic Primary	5.80E-07	0
4	Haugh End House	7.18E-07	0
5	84 Rochdale Road	1.72E-06	1
6	Highfield Jerry Lane	1.44E-06	1
7	Spring Bank Industrial Estate**	2.27E-05	N/A
8	Mill West (AQMA)	1.32E-06	1
9	Ivy Cottage	1.61E-06	1
10	Cottage	1.15E-06	0
11	Black Sowerby Croft	1.25E-06	1
12	Prospect Terrace	2.48E-07	0
13	Hullen Edge	2.43E-07	0
14	Bank House	1.30E-06	1
15	Mill House Farm	1.65E-06	1
16	Mill House Lodge	1.24E-06	0

*The PC as a percentage of the EAL is rounded to the nearest whole number, in line with the EPUK/IAQM guidance. PCs of <0.5% round down to 0%.
**Annual-mean EALs do not apply at workplaces

5.11 The PC does not exceed 1% of the EAL at all relevant discrete receptors modelled and the resulting effects are not considered to be significant. At receptor 7 Spring Bank Industrial Estate the annual-mean EAL does not apply but the PC has been included for information.

6 Issue 4 – Ecological Impacts

AQC Ltd Comment

6.1 *The applicant has not assessed the impacts at nearby ancient woodland and local nature reserve ecological sites within their ES addendum or their 2019 additional Air Quality Assessment. These sites are within the 2 km screening distance for assessment of ecological sites required by the Environment Agency. This assessment has been undertaken for the original 2017 ES chapter; however, this assessment is not considered fully robust as it is not clear if ammonia and hydrogen fluoride emissions have been accounted for when considering the impacts of nutrient nitrogen and acid deposition.*

RPS response

6.2 Following the Planning Inquiry, the Inspector recorded in paragraph 94 of the Appeal Decisions that Calderdale Metropolitan Borough Council and CVSH agreed that the proposal would not have an adverse impact on sensitive ecological receptors including protected species, habitats and wildlife corridors and would not harm the adjacent woodland. The Inspector also noted in the same paragraph of his Appeal Decisions that he had not been provided with any compelling evidence to the contrary. In those circumstances, there is no justification for either Calderdale or objectors to take any different position in the context of environmental permitting.

6.3 As outlined in AQC's comment, the air quality impacts at ancient woodland and local nature reserves were assessed in the original 2017 ES chapter. In addition, the impacts at the South Pennine Moors were assessed in Appendix E of the 2019 ES Addendum that AQC reviewed.

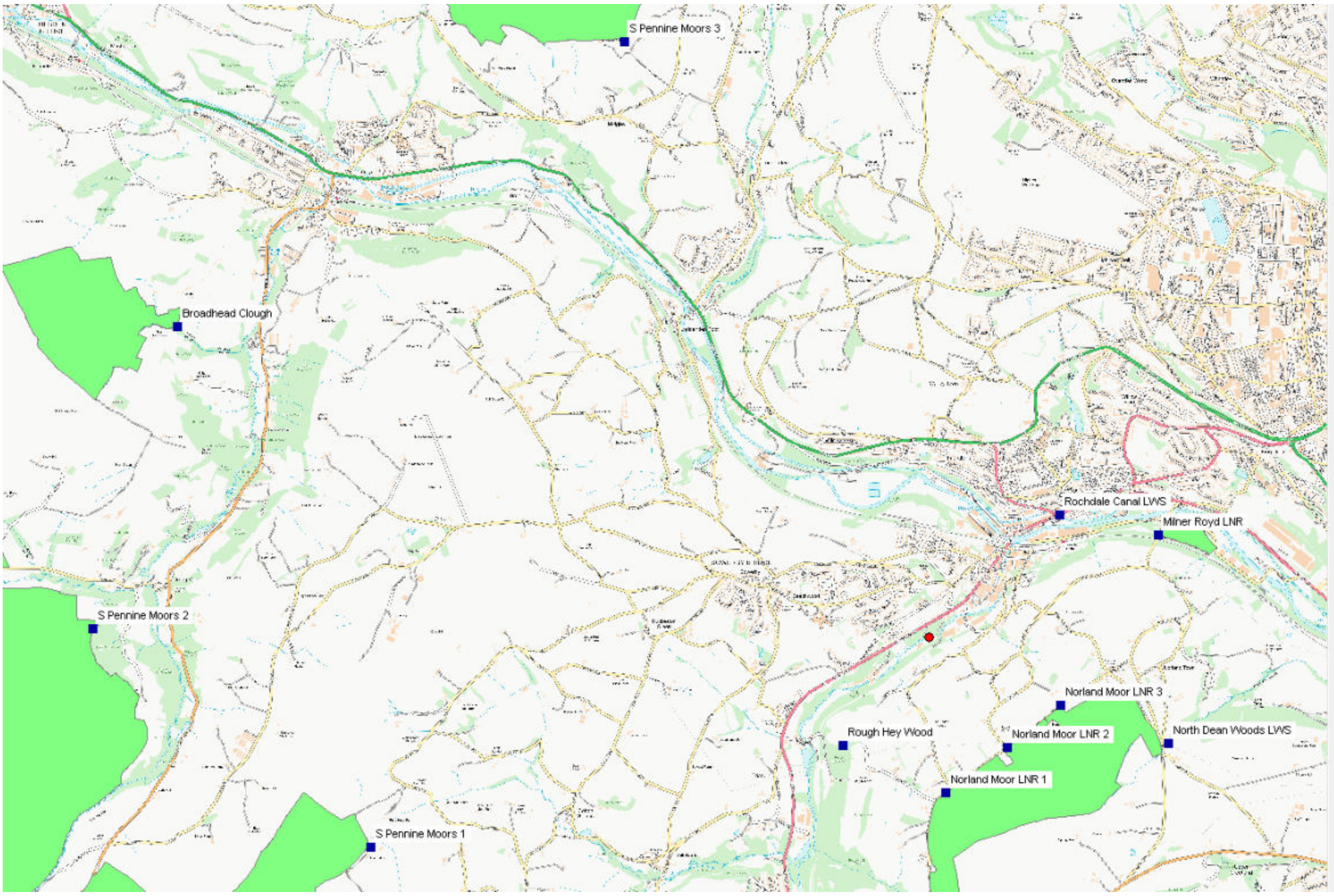
6.4 Air quality impacts have been predicted at discrete locations within the nature designations closest to the source of emissions, at the following sites as shown in Figure 1.

- South Pennine Moors Special Area of Conservation (SAC), Special Protection Area (SPA) and Site of Special Scientific Interest (SSSI)
- North Dean Woods Local Wildlife Site (LWS);
- Norland Moor LWS/ Local Nature Reserve (LNR);
- Milner Royd LNR;
- Rochdale Canal LWS;
- Rough Hey Wood (ancient woodland); and

- Rochdale Canal LWS.

6.5 This covers all the nature designations assessed in the 2017 ES chapter and the 2019 ES Addendum and uses the more detailed terrain data outlined in paragraphs A.36 to A.38 of Appendix A. Whereas the 2017 ES chapter used AERMOD dispersion model and the 2019 ES Addendum used the ADMS dispersion model, the assessment of ecological impacts referred to below has been carried out using the ADMS dispersion modelling software throughout. We address and answer below AQC's comment about ammonia and hydrogen fluoride emissions.

Figure 1 Ecological Receptors Modelled



Critical Levels

6.6 Critical levels are maximum atmospheric concentrations of pollutants for the protection of vegetation and ecosystems and are specified within relevant European air quality directives and corresponding UK air quality regulations. Process Contributions (PCs) and Predicted Environmental Concentrations (PECs) of nitrogen oxides (NOx), sulphur dioxide (SO_2) ammonia (NH_3) and hydrogen fluoride (HF) have been calculated for comparison with the relevant critical levels.

Critical Loads

6.7 Critical loads refer to the quantity of pollutant deposited, below which significant harmful effects on sensitive elements of the environment do not occur, according to present knowledge.

6.8 HF was not considered in the nutrient nitrogen (as it contains no nitrogen) or acid deposition calculations. HF is very reactive and will be preferentially removed by the acid gas abatement. Any deposition from residual HF in the flue gas emissions will occur very close to the stack and HF is unlikely to travel as far as the nearest nature conservation site (approx. 1 km away). On that basis, HF has not been included in the acid deposition calculations. This has been agreed with AQC.

Critical Loads – Nutrient Nitrogen Deposition

6.9 Percentage contributions to nutrient nitrogen deposition have been derived from the results of the ADMS dispersion modelling. Deposition rates have been calculated using empirical methods recommended by the EA, as follows:

- The deposition flux ($\mu g.m^{-2}.s^{-1}$) has been calculated by multiplying the ground level NO_2 and NH_3 concentrations ($\mu g.m^{-3}$) by the deposition velocity. The EA guidance provides deposition velocities of 0.0015 $m.s^{-1}$ for short habitats and 0.003 $m.s^{-1}$ for forests for NO_2 and 0.02 $m.s^{-1}$ for short habitats and 0.03 $m.s^{-1}$ for forests for NH_3.
- Units of $\mu g.m^{-2}.s^{-1}$ have been converted to units of $kg.ha^{-1}.year^{-1}$ by multiplying the dry deposition flux by the standard conversion factor of 96 for NO_2 and the wet deposition flux by 259.7 for NH_3.

6.10 Predicted contributions to nitrogen deposition have been calculated and compared with the relevant critical load range for the habitat types associated with the designated site. These have been derived from the APIS database. Where no 'site relevant critical loads' are available in the APIS database, site specific data has been sourced from the APIS database for the location instead. Where the habitat type is unknown the most sensitive habitat is used. Data sourced from the location are shown with an asterisk.

Critical Loads – Acidification

6.11 The acid deposition rate, in equivalents $keq.ha^{-1}.year^{-1}$, has been calculated by multiplying the dry deposition flux ($kg.ha^{-1}.year^{-1}$) by a conversion factor of 0.071428 for N and adding the deposition rate for S. The acid deposition rate for S has been calculated by multiplying the ground level SO_2 concentration by the deposition velocity to derive the deposition flux $\mu g.m^{-2}.s^{-1}$. For short habitats the deposition velocity is 0.012 $m.s^{-1}$ and for forests it is 0.024 $m.s^{-1}$. This has then been multiplied by a conversion factor of 157.7 and 0.0625 (i.e. 9.86) to determine the acid deposition arising from S (keq.ha^{-1}.year^{-1}). This takes into account the degree to which a chemical species is acidifying, calculated as the proportion of N or S within the molecule.

6.12 The acid contribution from HCl has been added to the S contribution. The acid deposition rate for HCl has been calculated by multiplying the ground level HCl concentration by the deposition velocity to derive the deposition flux in units of µg.m^{-2}.s. For short habitats the deposition velocity is 0.025 m.s^{-1} and for forests it is 0.060 m.s^{-1}. This has then been multiplied by a conversion factor of 8.63 to convert to keq.ha^{-1}.year^{-1}.

6.13 Wet deposition in the near field is not significant compared with dry deposition for N [1] and therefore for the purposes of this assessment, wet deposition has not been considered.

6.14 Predicted contributions to acid deposition have been calculated and compared with the minimum critical load function for the habitat types associated with each designated site as derived from the APIS database.

Significance Criteria

6.15 The PCs and PECs have been compared against the relevant critical level/load for the relevant habitat type/interest feature. Based on current Environment Agency guidelines [2] and the Institute of Air Quality Management *A guide to the assessment of air quality impacts on designated nature conservation sites* [3] the following criteria have been used to determine if the impacts are significant:

- If the long-term PC does not exceed 1% of relevant critical level/load the emission is considered not significant;
- If the short-term PC does not exceed 10% of relevant critical level/load the emission is considered not significant; and
- If the long-term PC exceeds 1% or the short-term PC exceeds 10% but the resulting PEC is below 100% of the relevant critical level/load, the emission is not considered significant.

Results

6.16 The maximum predicted PCs of NOx, SO_2, NH_3 and HF (from ADMS modelling utilising Leeds-Bradford 2013 – 2017 meteorological data) are compared with the relevant Critical Levels in Table 6.1 and Table 6.2.

Table 6.1 Predicted Annual-Mean Nox, SO_2 and NH_3 Concentrations at Designated Habitat Sites

Habitat Receptor	Annual-Mean NO_X PC (µg.m^{-3})	NO_X PC/Critical Level (%)	Annual-Mean SO_2 PC (µg.m^{-3})	SO_2 PC/Critical Level (%)	Annual-Mean NH_3 PC (µg.m^{-3})	NH_3 PC/Critical Level (%)
S Pennine Moors 1	0.01	0	<0.005	0	<0.0005	0
Broadhead Clough	<0.005	0	<0.005	0	<0.0005	0
S Pennine Moors 2	<0.005	0	<0.005	0	<0.0005	0
S Pennine Moors 3	<0.005	0	<0.005	0	<0.0005	0
S Pennine Moors 4	<0.005	0	<0.005	0	<0.0005	0
Rough Hey Wood	0.07	0	0.02	0	0.002	0
Norland Moor LNR 1	0.02	0	0.01	0	0.001	0
Norland Moor LNR 2	0.02	0	0.01	0	0.001	0
Norland Moor LNR 3	0.05	0	0.01	0	0.001	0
Milner Royd LNR	0.09	0	0.02	0	0.002	0
North Dean Woods LWS	0.03	0	0.01	0	0.001	0
Rochdale Canal LWS	0.12	0	0.03	0	0.003	0
Maximum	0.09	0	0.03	0	0.003	0

Annual-Mean NO_X Critical Level = 30 µg.m^{-3}
Annual-Mean SO_2 Critical Level = 10 µg.m^{-3}
Annual-Mean NH_3 Critical Level = 1 µg.m^{-3}

Table 6.2 Predicted HF and Daily-Mean Nox Concentrations at Designated Habitat Sites

Habitat Receptor	Weekly-Mean HF PC (µg.m^{-3})	HF PC/Critical Level (%)	Daily-Mean HF PC (µg.m^{-3})	HF PC/Critical Level (%)	Daily-Mean NOx PC (µg.m^{-3})	NOx PC/Critical Level (%)
S Pennine Moors 1	0.002	0	0.004	0	0.43	1
Broadhead Clough	<0.0005	0	0.002	0	0.19	0
S Pennine Moors 2	0.001	0	0.003	0	0.34	0
S Pennine Moors 3	<0.0005	0	0.001	0	0.07	0
S Pennine Moors 4	<0.0005	0	0.001	0	0.05	0
Rough Hey Wood	0.012	2	0.015	0	1.47	2
Norland Moor LNR 1	0.002	0	0.005	0	0.53	1
Norland Moor LNR 2	0.002	0	0.006	0	0.63	1
Norland Moor LNR 3	0.006	1	0.014	0	1.41	2
Milner Royd LNR	0.004	1	0.008	0	0.81	1
North Dean Woods LWS	0.003	1	0.008	0	0.79	1
Rochdale Canal LWS	0.008	2	0.015	0	1.47	2
Maximum	0.008	2	0.015	0	1.47	2

Weekly-Mean HF Critical Level = 0.5 µg.m^{-3}
Daily-Mean HF Critical Level = 5 µg.m^{-3}
Daily-Mean Nox Critical Level = 75 µg.m^{-3}

6.17 The maximum PCs of nutrient nitrogen (N) deposition are compared against the relevant Critical Loads (CLs) in Table 6.3. As outlined in paragraph 6.9, the N Deposition PC considers the NOx and NH_3 contribution. There are various interest features within the habitat sites that are sensitive to N deposition. Only the results for the most-sensitive interest features are shown. Data on Critical Loads have been obtained from the UK Air Pollution Information System (APIS) database [4].

Table 6.3 Predicted Nitrogen Deposition at Designated Habitat Sites

Designation	Habitat Site	N Deposition Critical Load (kgN.ha^{-1}.yr^{-1})	N Deposition PC (kgN.ha^{-1}.yr^{-1})	N Deposition PC/ Critical Load (%)
SAC	South Pennine Moors (maximum)	5	0.002	0
SPA	South Pennine Moors (maximum)	3	0.002	0
SSSI	South Pennine Moors (maximum)	5	0.002	0

Designation	Habitat Site	N Deposition Critical Load ($kgN.ha^{-1}.yr^{-1}$)	N Deposition PC ($kgN.ha^{-1}.yr^{-1}$)	N Deposition PC/ Critical Load (%)
SSSI	Broadhead Clough	5	0.001	0
Ancient Woodland	Rough Hey Wood	10*	0.029	0
LNR	Norland Moor (maximum)	5*	0.012	0
LNR	Milner Royd	10*	0.022	0
LWS	North Dean Woods	10*	0.013	0
LWS	Rochdale Canal	5*	0.028	1

CLF = Critical Load Function (info at http://www.apis.ac.uk/clf-guidance)
* Where no 'site relevant critical loads' are available in the APIS database, site specific data has been sourced from the APIS database for the location instead. Where the habitat type is unknown the most sensitive habitat is used. Data sourced from the location are shown with an asterisk.

6.18 The maximum PCs of acid deposition are compared against the relevant Critical Loads in Table 6.4. As outlined in paragraph 6.11, the nitrogen component of acid deposition is derived from the N Deposition PC and therefore considers the contribution from NOx and NH_3. Paragraph 6.12 outlines that the sulphur component of acid deposition considers the contribution from SO_2, to which the contribution from HCl concentrations has been added. There are various interest features within the habitat sites that are sensitive to acid deposition. Only the results for the most-sensitive interest features are shown. Data on Critical Loads have been obtained from the UK Air Pollution Information System (APIS) database.

Table 6.4 Predicted Acid Deposition at Designated Habitat Sites

Designation	Habitat Site	Critical Loads ($keq.ha^{-1}.yr^{-1}$)			PC ($keq.ha^{-1}.yr^{-1}$)		PC / CLF (%)
		Min N	Max N	Max S	N	S	
SAC	South Pennine Moors (maximum)	0.32	0.57	0.25	1.66E-04	4.06E-04	0
SPA	South Pennine Moors (maximum)	0.18	0.51	0.19	1.66E-04	4.06E-04	0
SSSI	South Pennine Moors (maximum)	0.22	0.56	0.19	1.66E-04	4.06E-04	0
SSSI	Broadhead Clough	0.22	0.66	0.24	6.62E-05	1.62E-04	0
Ancient Woodland	Rough Hey Wood	0.14*	1.56*	1.413*	2.09E-03	4.09E-03	0
LNR	Norland Moor (maximum)	0.18*	0.67*	0.49*	3.31E-04	8.11E-04	0
LNR	Milner Royd	0.14*	1.56*	1.413*	1.56E-03	3.82E-03	0

Designation	Habitat Site	Critical Loads (keq.ha^{-1}.yr^{-1})			PC (keq.ha^{-1}.yr^{-1})		PC / CLF (%)
		Min N	Max N	Max S	N	S	
LWS	North Dean Woods	0.14*	1.56*	1.413*	9.46E-04	1.85E-03	0
LWS	Rochdale Canal	0.18*	0.67*	0.49*	2.02E-03	4.94E-03	1

CLF = Critical Load Function (info at http://www.apis.ac.uk/clf-guidance)

Conclusion

6.19 The maximum predicted PCs do not exceed 1% of the relevant annual-mean or 10% of the relevant weekly/daily-mean Critical Levels / Critical Loads at all habitat sites. In line with current Environment Agency guidelines [5], the effects can be screened out as insignificant.

Appendix A - Policy and Legislative Context and Assessment Methodology

A.1 The additional assessment work undertaken to respond to the issues raised has followed the same methodology as the original assessment work. Appendix A reproduces the relevant policy and legislative context and the assessment methodology for ease of reference. All table and figure numbers are identical to those in the original assessment report.

Emission Limits

Industrial Emissions Directive Limits

A.2 The plant would be designed and operated in accordance with the requirements of the Industrial Emissions Directive (2010/75/EU) [6], known hereafter as the IED, which requires adherence to emission limits for a range of pollutants.

A.3 Emission limits in the IED are specified in the form of half-hourly mean concentrations; daily-mean concentrations; mean concentrations over a period of between 30 minutes and 8 hours; or, for dioxins and furans, mean concentrations evaluated over a period of between six and eight hours.

A.4 For the purposes of this assessment for those pollutants having only one emission limit (for a single averaging period), the facility has been assumed to operate at that limit (with the exception of arsenic and Chromium VI, as discussed later). Where more than one limit exists for a pollutant, the half-hourly mean emission limit value has been used to calculate short-term (≤ 24-hour average) peak ground-level concentrations (Scenario 1) (again, with the exception of arsenic and Chromium VI, as discussed later). The daily mean emission limit value has been used for these pollutants to calculate long-term (greater than 24-hour average) mean ground-level concentrations (Scenario 2). The IED emission limit values are provided in Table 2.1.

Table 2.1 Relevant Industrial Emissions Directive Limit Values

Pollutant	Scenario 1 Short-Term Emission Limits (mg.Nm^{-3})	Scenario 2 Daily-Mean Emission Limits (mg.Nm^{-3})
Particles	30	10
Hydrogen Chloride (HCl)	60	10
Hydrogen Fluoride (HF)	4	1
Sulphur Dioxide (SO_2)	200	50
Nitrogen Oxides (NO_X)	400	200
Carbon Monoxide (CO)		50
Group 1 metals (a)	-	0.05 (d)
Group 2 metals (b)	-	0.05 (d)

Pollutant	Scenario 1 Short-Term Emission Limits (mg.Nm^{-3})	Scenario 2 Daily-Mean Emission Limits (mg.Nm^{-3})
Group 3 metals (c)	-	0.5 (d)
Dioxins and furans	-	0.0000001 (e)

Notes: All concentrations referenced to temperature 273 K, pressure 101.3 kPa, 11% oxygen, dry gas.
(a) Cadmium (Cd) and thallium (Tl).
(b) Mercury (Hg).
(c) Antimony (Sb), arsenic (As), lead (Pb), chromium (Cr), cobalt (Co), copper (Cu), manganese (Mn), nickel (Ni), and vanadium (V).
(d) All average values over a sample period of a minimum of 30 minutes and a maximum of 8 hours.
(e) Average values over a sample period of a minimum of 6 hours and a maximum of 8 hours. The emission limit value refers to the total concentration of dioxins and furans calculated using the concept of toxic equivalence (TEQ).

A.5 Ammonia (NH_3), polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs) are not specifically regulated under the IED. For the purposes of this assessment, the emission concentrations in Table 2.2 have been used for these pollutants to calculate long-term (greater than 24-hour average) mean ground-level concentrations (Scenario 2).

Table 2.2 Modelled Emission Concentrations for non-IED-Regulated Pollutants

Pollutant	Scenario 2 Emission Concentrations (mg.Nm^{-3})
NH_3	5
PCBs	0.005
B[a]P	0.001

Notes: All concentrations referenced to temperature 273 K, pressure 101.3 kPa, 11% oxygen, dry gas.
Emission concentrations obtained from the IPPC Reference Document on the Best Available Techniques for Waste Incineration (August 2006)

Waste Framework Directive

A.6 Directive 2008/98/EC [7] of the European Parliament and Council on Waste requires member states to ensure that waste is recovered or disposed of without harm to human health and the environment. It requires member states to impose certain obligations on all those dealing with waste at various stages. Operators of waste disposal and recovery facilities are required to obtain a permit, or register a permit exemption. Retention of the permit requires periodic inspections and documented evidence of the activities in respect of waste.

A.7 The Waste Framework Directive (WFD) requires member states to take appropriate measures to establish an integrated and adequate network of disposal installations. The WFD also promotes environmental protection by optimising the use of resources, promoting the recovery of waste over its disposal (the “waste hierarchy”).

A.8 Annex II A and B of the WFD provide lists of the operations which are deemed to be “disposal” and “recovery”, respectively. The terms are mutually exclusive and an operation cannot be a disposal and recovery operation simultaneously. Where the operation is deemed to be a disposal operation, the permit will contain more extensive conditions than for a recovery operation.

A.9 The principal objective of a recovery operation is to ensure that the waste serves a useful purpose, replacing other substances which would have been used for that purpose. Where the combustion of waste is used to provide a source of energy, the operation is deemed to be a recovery operation.

A.10 The EPR 2016 implements the WFD in the UK. As such, the Environment Agency is responsible for implementing the obligations set out in the WFD for most activities and waste operations but local authorities are responsible for implementing the WFD obligations in respect of generally smaller scale facilities including SWIPs.

Ambient Air Quality Legislation and National Policy

Ambient Air Quality Criteria

A.11 There are several European Union (EU) Air Quality Directives and UK Air Quality Regulations that will apply to the operation of the proposed facility. These provide a series of statutory air quality limit values, target values and objectives for pollutants, emissions of which are regulated through the IED.

A.12 There are some pollutants regulated by the IED which do not have statutory air quality standards prescribed under current legislation. For these pollutants, a number of non-statutory air quality objectives and guidelines exist which have been applied within this assessment. The Environment Agency website provides further assessment criteria in its online guidance.

The Ambient Air Quality Directive and Air Quality Standards Regulations

A.13 The 2008 Ambient Air Quality Directive (2008/50/EC) [8] aims to protect human health and the environment by avoiding, reducing or preventing harmful concentrations of air pollutants; it sets legally binding concentration-based limit values, as well as target values. There are also information and alert thresholds for reporting purposes. These are to be achieved for the main air pollutants: particulate matter (PM_{10} and $PM_{2.5}$), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), ozone (O_3), carbon monoxide (CO), lead (Pb) and benzene. This Directive replaced most of the previous EU air quality legislation and in England was transposed into domestic law by the Air Quality Standards (England) Regulations 2010 [9], which in addition incorporates the 4th Air Quality Daughter Directive (2004/107/EC) that sets targets for ambient air concentrations of certain toxic heavy metals (arsenic, cadmium and nickel) and polycyclic aromatic hydrocarbons (PAHs). Member states must comply with the limit values (which are legally binding on the Secretary of State) and the Government and devolved administrations operate various national ambient air quality monitoring networks to measure compliance and develop plans to meet the limit values. The objectives are not legally binding. The statutory air quality limit values are listed in Table 2.3.

Table 2.3 Summary of Relevant Statutory Air Quality Limit Values and Air Quality Objectives

Pollutant	Averaging Period	Objectives/ Limit Values	Not to be Exceeded More Than	Target Date
Nitrogen Dioxide (NO_2)	1 hour	200 µg.m^{-3}	18 times per calendar year	-
	Annual	40 µg.m^{-3}	-	-
Particulate Matter (PM_{10})	24 Hour	50 µg.m^{-3}	35 times per calendar year	-
	Annual	40 µg.m^{-3}	-	-
Particulate Matter ($PM_{2.5}$)	Annual	25 µg.m^{-3}	-	01.01.2020 (a)
				01.01.2015 (b)
Carbon Monoxide	Maximum daily running 8 hour mean	10,000 µg.m^{-3}	-	-
Sulphur Dioxide (SO_2)	15 minute	266 µg.m^{-3}	> 35 times per calendar year	-
	1 hour	350 µg.m^{-3}	> 24 times per calendar year	-
	24 hour	125 µg.m^{-3}	> 3 times per calendar year	-
Lead	Annual	0.25 µg.m^{-3}	-	-
Arsenic (As)	Annual (b)	0.006 µg.m^{-3}	-	-
Cadmium (Cd)	Annual (b)	0.005 µg.m^{-3}	-	-
Nickel (Ni)	Annual (b)	0.02 µg.m^{-3}	-	-

(a) Target date set in UK Air Quality Strategy 2007
(b) Target date set in Air Quality Standards Regulations 2010

Non-Statutory Air Quality Objectives and Guidelines

A.14 The Environment Act 1995 established the requirement for the Government and the devolved administrations to produce a National Air Quality Strategy (AQS) for improving ambient air quality, the first being published in 1997 and having been revised several times since, with the latest published in 2007 [10]. The Strategy sets UK air quality standards and objectives for the pollutants in the Air Quality Standards Regulations plus 1,3-butadiene and recognises that action at national, regional and local level may be needed, depending on the scale and nature of the air quality problem.

A.15 Non-statutory air quality objectives and guidelines also exist within the World Health Organisation Guidelines [11] and the Expert Panel on Air Quality Standards Guidelines (EPAQS) [12]. The non-statutory objectives and guidelines are presented in Table 2.4.

Table 2.4 Non-Statutory Air Quality Objectives and Guidelines

Pollutant	Averaging Period	Guideline	Target Date
Particulate Matter ($PM_{2.5}$)	Annual	Target of 15% reduction in concentrations at urban background locations	Between 2010 and 2020 (a)
	Annual	25 $\mu g.m^{-3}$	2020 (a)
PAHs	Annual (a)	0.00025 $\mu g.m^{-3}$ B[a]P	-
Sulphur Dioxide (SO_2)	Annual (b)	50 $\mu g.m^{-3}$	-
Hydrogen Chloride	1 hour (c)	750 $\mu g.m^{-3}$	-
Hydrogen Fluoride	1 hour (c)	160 $\mu g.m^{-3}$	-

Notes:
(a) Target date set in UK Air Quality Strategy 2007
(b) World Health Organisation Guidelines
(c) EPAQS recommended guideline values

Environmental Assessment Levels

A.16 The Environment Agency's on-line guidance entitled '*Environmental management – guidance, Air emissions risk assessment for your environmental permit*' [13] provides further assessment criteria in the form of Environmental Assessment Levels (EALs).

A.17 Table 2.5 presents all available EALs for the pollutants relevant to this assessment.

Table 2.5 Environmental Assessment Levels (EALs)

Pollutant	Long-Term EAL ($\mu g.m^{-3}$)	Short-Term EAL ($\mu g.m^{-3}$)
Nitrogen Dioxide (NO_2)	40	200
Carbon Monoxide (CO)	-	10,000
Sulphur Dioxide (SO_2)	50	266
Particulates (PM_{10})	40	50
Particulates ($PM_{2.5}$)	25	-
Hydrogen chloride (HCl)	-	750
Hydrogen fluoride (HF)	16 (monthly average)	160
Arsenic (As)	0.003	-
Antimony (Sb)	5	150

Pollutant	Long-Term EAL (µg.m^{-3})	Short-Term EAL (µg.m^{-3})
Cadmium (Cd)	0.005	-
Chromium (Cr)	5	150
Chromium VI ((oxidation state in the PM_{10} fraction)	0.0002	-
Cobalt (Co)	0.2 (a)	6 (a)
Copper (Cu)	10	200
Lead (Pb)	0.25	-
Manganese (Mn)	0.15	1500
Mercury (Hg)	0.25	7.5
Nickel (Ni)	0.02	-
Thallium (Tl)	1 (a)	30 (a)
Vanadium (V)	5	1
PAHs	0.00025 B[a]P	-

Notes: (a) EALs have been obtained from the EA's earlier Horizontal Guidance Note EPR H1 guidance note as no levels are provided in the current guidance.

A.18 Within the assessment, the statutory air quality limit and target values are assumed to take precedence over objectives, guidelines and the EALs, where appropriate. In addition, for those pollutants which do not have any statutory air quality standards, the assessment assumes the lower of either the EAL or the non-statutory air quality objective or guideline where they exist.

Assessment Methodology

A.19 Neither the NPPF nor the NPPG is prescriptive on the methodology for assessing air quality effects or describing significance; practitioners continue to use guidance provided by Defra and non-governmental organisations, including Environmental Protection UK (EPUK) and the Institute of Air Quality Management (IAQM). However, the NPPG does advise that "*Assessments should be proportionate to the nature and scale of development proposed and the level of concern about air quality, and because of this are likely to be locationally specific. The scope and content of supporting information is therefore best discussed and agreed between the local planning authority and applicant before it is commissioned.*" It lists a number of areas that might be usefully agreed at the outset.

A.20 This air quality assessment covers the elements recommended in the NPPG. The approach is consistent with Defra's Local Air Quality Management Technical Guidance: LAQM.TG16 [14]. It includes the key elements listed below:

- assessment of the existing air quality in the study area (existing baseline) and prediction of the future air quality without the development in place (future baseline), using official government estimates from Defra, publicly available air quality monitoring data for the area, and relevant Air Quality Review and Assessment (R&A) documents;

- a quantitative prediction of the future operational-phase air quality impact with the development in place (with any necessary mitigation), focusing on the impacts of the stack emissions on the local area, including Sowerby Bridge AQMA.

A.21 In line with the guidance set out in the NPPG, the Environmental Health Department at CMBC was consulted to agree the scope and methodology for this assessment. The Pollution Control Officer, Tommy Moorhouse, agreed that the approach to the assessment was reasonable [15].

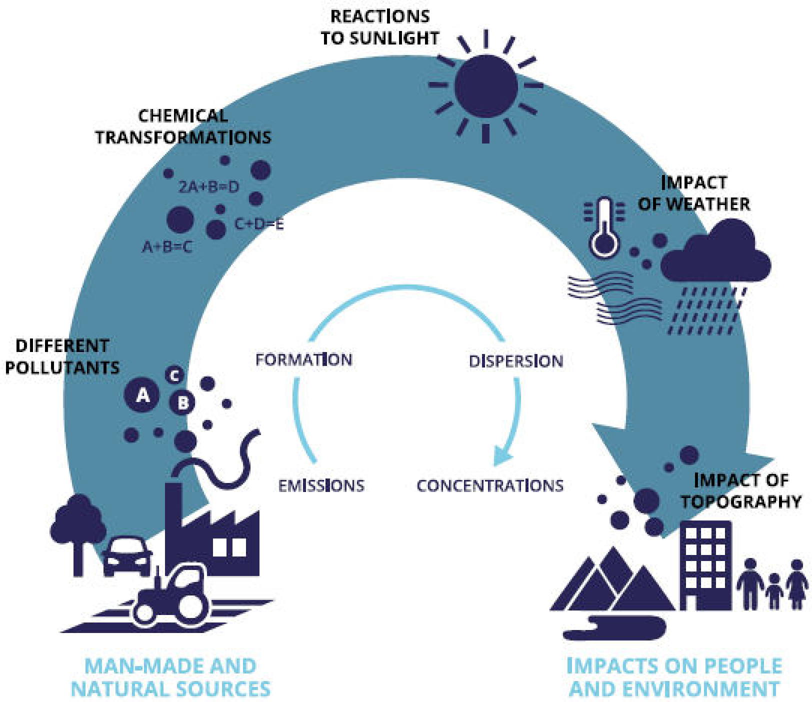
A.22 Air quality guidance advises that the organisation engaged in assessing the overall risks should hold relevant qualifications and/or extensive experience in undertaking air quality assessments. The RPS air quality team members involved at various stages of this assessment have professional affiliations that include Fellow and Member of the Institute of Air Quality Management, Chartered Chemist, Chartered Scientist, Chartered Environmentalist and Member of the Royal Society of Chemistry and have the required academic qualifications for these professional bodies. In addition, the Director responsible for authorising all deliverables has over 25 years' experience.

Operational Phase - Methodology

Atmospheric Dispersion Modelling of Pollutant Concentrations

A.23 In urban areas, pollutant concentrations are primarily determined by the balance between pollutant emissions that increase concentrations, and the ability of the atmosphere to reduce and remove pollutants by dispersion, advection, reaction and deposition. An atmospheric dispersion model is used as a practical way to simulate these complex processes; such a model requires a range of input data, which can include emissions rates, meteorological data and local topographical information. The model used and the input data relevant to this assessment are described in the following sub-sections.

Figure 6.2 Air Pollution: From Emissions to Exposure



Source: European Environment Agency (2016) Explaining Road Transport Emissions: A Non-technical Guide

A.24 The atmospheric pollutant concentrations in an urban area depend not only on local sources at a street scale, but also on the background pollutant level made up of the local urban-wide background, together with regional pollution and pollution from more remote sources brought in on the incoming air mass. This background contribution needs to be added to the fraction from the modelled sources, and is usually obtained from measurements or estimates of urban background concentrations for the area in locations that are not directly affected by local emissions sources. Background pollution levels are described in detail in Section 4.

Dispersion Model Selection

A.25 A number of commercially available dispersion models are able to predict ground level concentrations arising from emissions to atmosphere from elevated point sources. Modelling for this study has been undertaken using ADMS 5, a version of the ADMS (Atmospheric Dispersion Modelling System) developed by Cambridge Environmental Research Consultants (CERC) that models a wide range of buoyant and passive releases to atmosphere either individually or in combination. The model calculates the mean concentration over flat terrain and also allows for the effect of plume rise, complex terrain, buildings and deposition. Dispersion models predict atmospheric concentrations within a set level of confidence and there can be variations in results between models under certain conditions; the ADMS 5 model has been formally validated and is widely used in the UK and internationally for regulatory purposes.

A.26 ADMS comprises a number of individual modules each representing one of the processes contributing to dispersion or an aspect of data input and output. Amongst the features of ADMS are:

- An up-to-date dispersion model in which the boundary layer structure is characterised by the height of the boundary layer and the Monin-Obukhov length, a length scale dependent on the friction velocity and the heat flux at the surface. This approach allows the vertical structure of the boundary layer, and hence concentrations, to be calculated more accurately than does the use of Pasquill-Gifford stability categories, which were used in many previous models (e.g. ISCST3). The restriction implied by the Pasquill-Gifford approach that the dispersion parameters are independent of height is avoided. In ADMS the concentration distribution is Gaussian in stable and neutral conditions, but the vertical distribution is non-Gaussian in convective conditions, to take account of the skewed structure of the vertical component of turbulence;
- A number of complex modules including the effects of plume rise, complex terrain, coastlines, concentration fluctuations and buildings;
- A facility to calculate long-term averages of hourly mean concentration, dry and wet deposition fluxes and radioactivity, and percentiles of hourly mean concentrations, from either statistical meteorological data or hourly average data; and
- A facility to run the main model options of the US EPA-approved dispersion model, AERMOD, using ADMS meteorological data from the ADMS 5 interface.

Model Input Data

Meteorological Data

A.27 The most important meteorological parameters governing the atmospheric dispersion of pollutants are wind direction, wind speed and atmospheric stability as described below:

- Wind direction determines the sector of the compass into which the plume is dispersed;
- Wind speed affects the distance that the plume travels over time and can affect plume dispersion by increasing the initial dilution of pollutants and inhibiting plume rise; and
- Atmospheric stability is a measure of the turbulence of the air, and particularly of its vertical motion. It therefore affects the spread of the plume as it travels away from the source. New generation dispersion models, including ADMS, use a parameter known as the Monin-Obukhov length that, together with the wind speed, describes the stability of the atmosphere.

A.28 For meteorological data to be suitable for dispersion modelling purposes, a number of meteorological parameters need to be measured on an hourly basis. These parameters include wind speed, wind direction, cloud cover and temperature. There are only a limited number of sites where the required meteorological measurements are made.

A.29 The year of meteorological data that is used for a modelling assessment can have a significant effect on source contribution concentrations. Dispersion model simulations have been performed using five years of data from Leeds-Bradford Airport between 2013 and 2017.

A.30 Wind roses have been produced for each of the years of meteorological data used in this assessment and are presented in Figure 1.

Stack Parameters and Emissions Rates used in the Model

A.31 Flue gases are emitted from an elevated stack to allow dispersion and dilution of the residual combustion emissions. The stack needs to be of sufficient height to ensure that pollutant concentrations are acceptable by the time they reach ground level. The stack also needs to be high enough to ensure that releases are not within the aerodynamic influence of nearby buildings, or else wake effects can quickly bring the undiluted plume down to the ground.

A.32 A stack height determination has been undertaken to establish the height at which there is minimal additional environmental benefit associated with the cost of further increasing the stack. The Environment Agency removed their detailed guidance, Horizontal Guidance Note EPR H1 [13] for undertaking risk assessments on 1 February 2016; however, the approach used here by RPS is consistent with that EA guidance which required the identification of "*an option that gives acceptable environmental performance but balances costs and benefits of implementing it*."

A.33 The stack height determination has focused on identifying the stack height required to overcome the wake effects of nearby buildings. This involved running a series of atmospheric dispersion modelling simulations to predict the ground-level concentrations with the stack at different heights: starting at 12 metres and extending up in 1 metre increments, until a height of 18 metres was reached. The stack height determination indicated a 12 m stack height was appropriate.

A.34 Stack emissions characteristics modelled are provided in Table 3.1 and the mass emissions are provided in Table 3.2.

Table 3.1 Stack Characteristics

Parameter	Unit	Value
Stack height	m	12
Internal diameter	m	0.4
Efflux velocity	$m.s^{-1}$	21.3
Efflux temperature	° C	300
Normalised volumetric flow (Dry, 0°C, 11% O_2)	$m^3.s^{-1}$	1.28

Table 3.2 Mass Emissions of Released Pollutants

Pollutant	Short-Term Mass Emission Rate ($g.s^{-1}$)	Long-Term (a) Mass Emission Rate ($g.s^{-1}$)
Particulates	0.04	0.01
HCl	0.08	0.01
HF	5.11E-03	1.28-03
SO_2	0.26	0.06
NO_X	0.51	0.26
CO	0.13	0.06
Group 1 Metals Total (b)	-	6.38E-05
Group 2 Metals (c)	-	6.38E-05
Group 3 Metals Total (d)	-	6.38E-04
Dioxins and furans	-	1.28E-10
NH_3	-	6.38E-03
PCBs	-	6.38E-06
B[a]P	-	1.28E-06

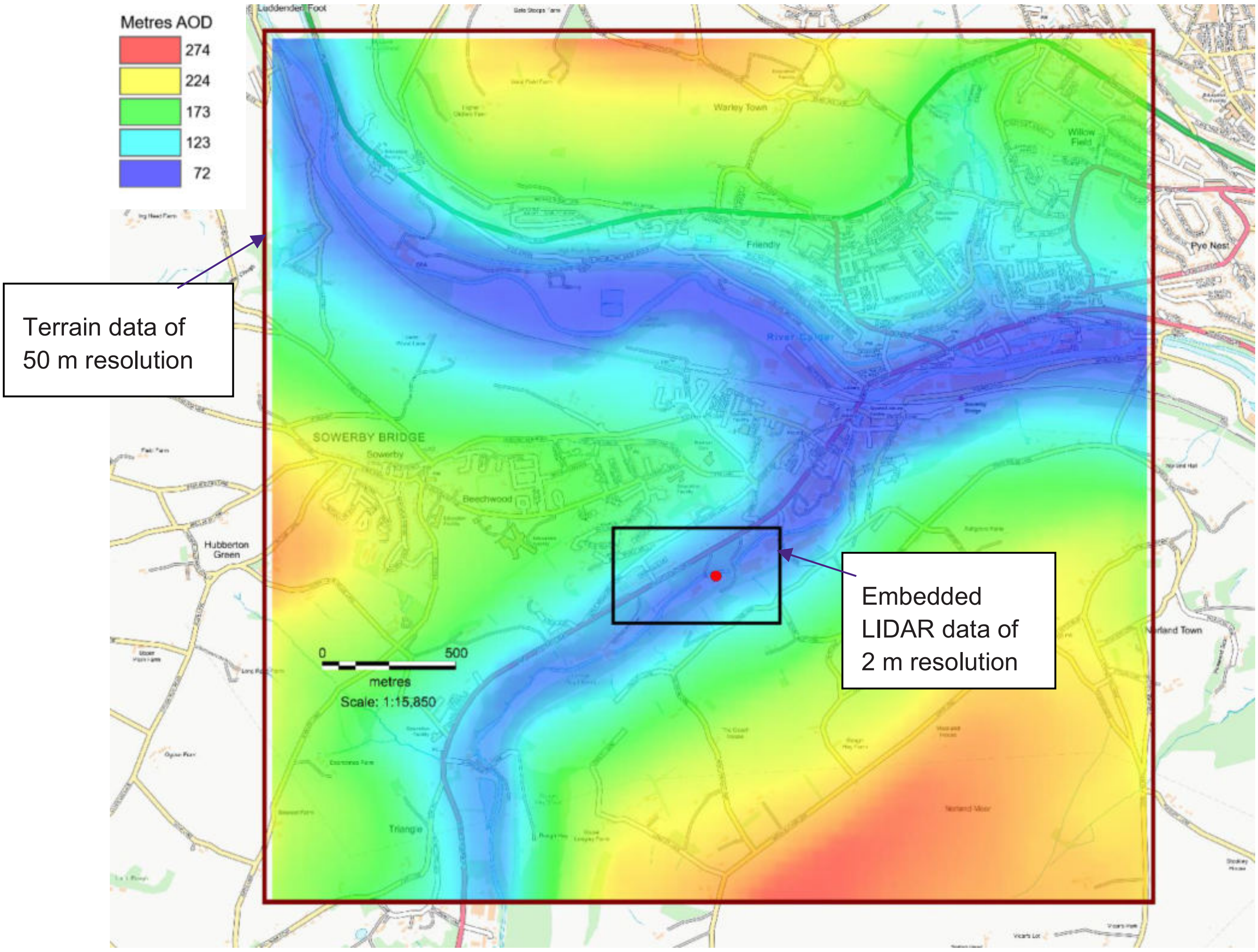
Notes:
(a) For averaging periods of 24 hours or greater.
(b) Cadmium (Cd) and thallium (Tl)
(c) Mercury (Hg)
(d) Antimony (Sb), Arsenic (As), Lead (Pb), Chromium (Cr), Cobalt (Co), Copper (Cu), Manganese (Mn), Nickel (Ni), and Vanadium (V)

A.35 Emission limits in the IED are provided for total particles. For the purposes of this assessment, all particles are assumed to be less than 10 µm in diameter (i.e. PM_{10}). Furthermore, all particles are also assumed to be less than 2.5 µm in diameter (i.e. $PM_{2.5}$). In reality, the PM_{10} and $PM_{2.5}$ concentrations will be a smaller proportion of the total particulate emissions and the $PM_{2.5}$ concentration will be a smaller proportion of the PM_{10} concentration. Therefore, this can be considered a conservative estimate of the likely particulate emissions in each size fraction.

Terrain

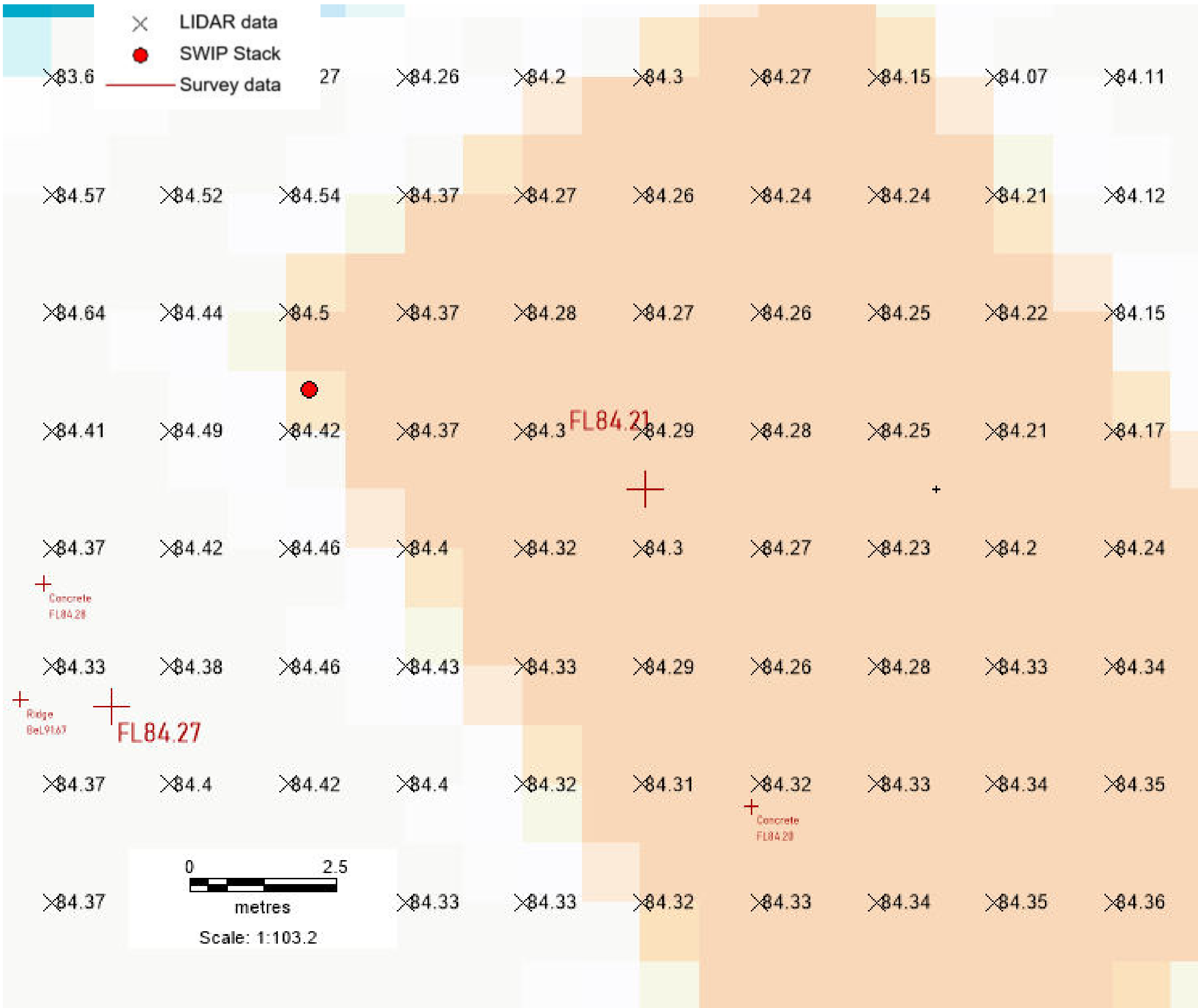
A.36 The presence of elevated terrain can significantly affect (usually increase) ground level concentrations of pollutants emitted from elevated sources such as stacks, by reducing the distance between the plume centre line and ground level and by increasing turbulence and, hence, plume mixing. A complex terrain file was used within the model. The terrain data used in the model comprises terrain data of 50 m resolution for the whole study area, supplemented with 2 m resolution government-published LIDAR data [16] for a smaller area encompassing the Application Site. This is shown graphically in Figure 3.2 below.

Figure 3.2 Complex Terrain Data Used in Model



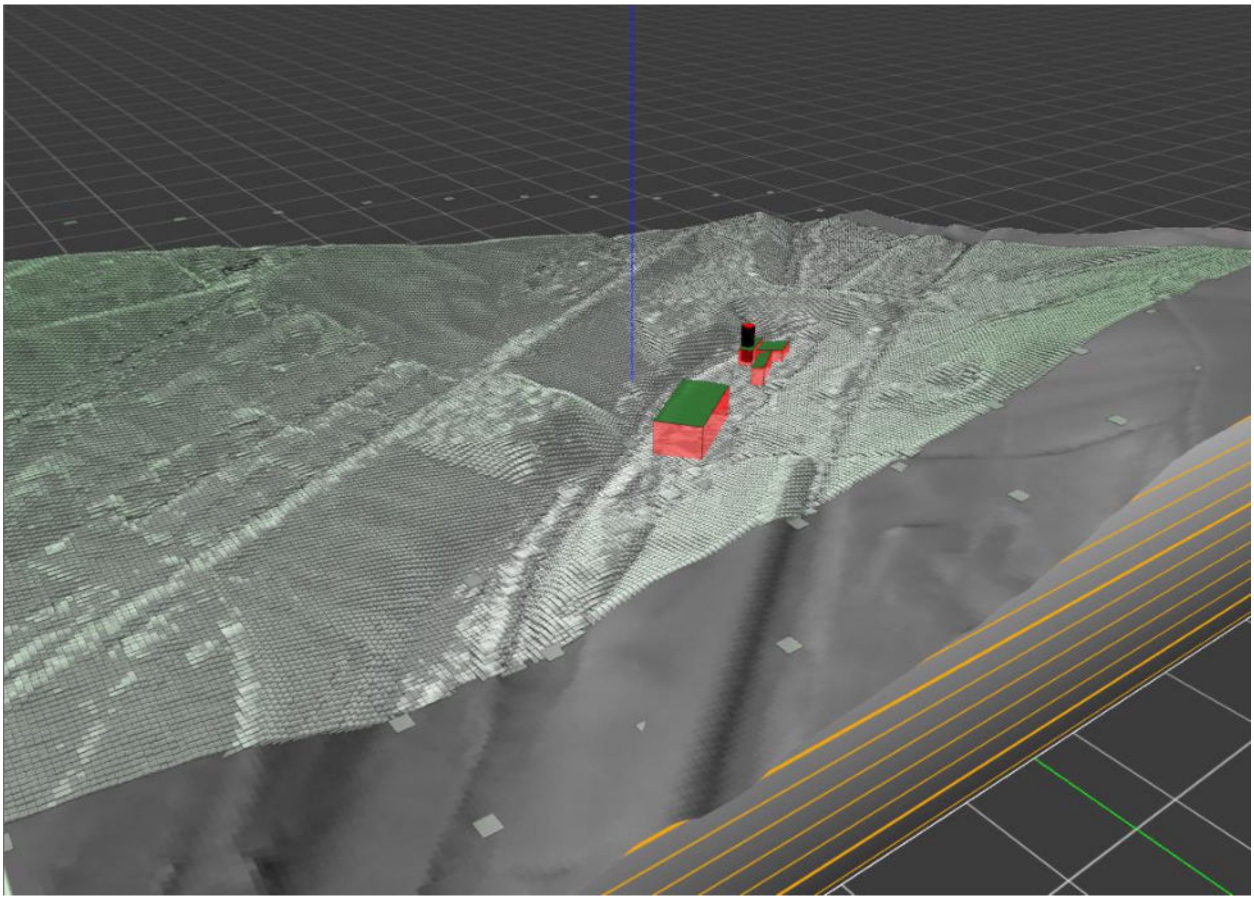
A.37 Figure 3.3 below shows the LIDAR data values and topographical survey values closest to the SWIP stack. This figure shows close agreement between the LIDAR data and the surveyed data. The LIDAR data value closest to the SWIP stack is 84.42 m AOD. This indicates that the stack height would be approximately 96.4 m AOD (i.e., 12 m above ground level).

Figure 3.3 LIDAR Data and Topographical Survey Data Close to SWIP Stack



A.38 Figure 3.4 is a 3D view of the complex terrain file, stack and buildings modelled (note that the stack is not to scale). This figure demonstrates that the high-resolution of the terrain data used represents well the features of the valley in the vicinity of the Application Site.

Figure 3.4 3D View of Complex Terrain Data Used in Model



Surface Roughness

A.39 The roughness of the terrain over which a plume passes can have a significant effect on dispersion by altering the velocity profile with height, and the degree of atmospheric turbulence. This is accounted for by a parameter called the surface roughness length.

A.40 A surface roughness length of 1 m, which the software developer recommends for use in woodland, was used within the ADMS model to represent the average surface characteristics across the study area.

A.41 A sensitivity test has been undertaken using a variable surface roughness file. This is detailed within Appendix F.

Building Wake Effects

A.42 The dominant building structures (i.e. with the greatest dimensions likely to promote turbulence) were confirmed with [redacted] and are listed in Table 3.3. These were included in the model.

Table 3.3 Dimensions of Buildings Included Within the Dispersion Model

Name	Building Centre (x, y)	Height (m)	Length (m)	Width (m)	Angle (Degrees)
SWIP Process Building	405352, 422842	8	18.5	6.5	57
Feed Storage	405360, 422836	6	13.2	12.2	148
Office	405340, 422821	9	5.9	18.9	142
Recycling Building	405279, 42295	15	20.7	42.8	144

Receptors

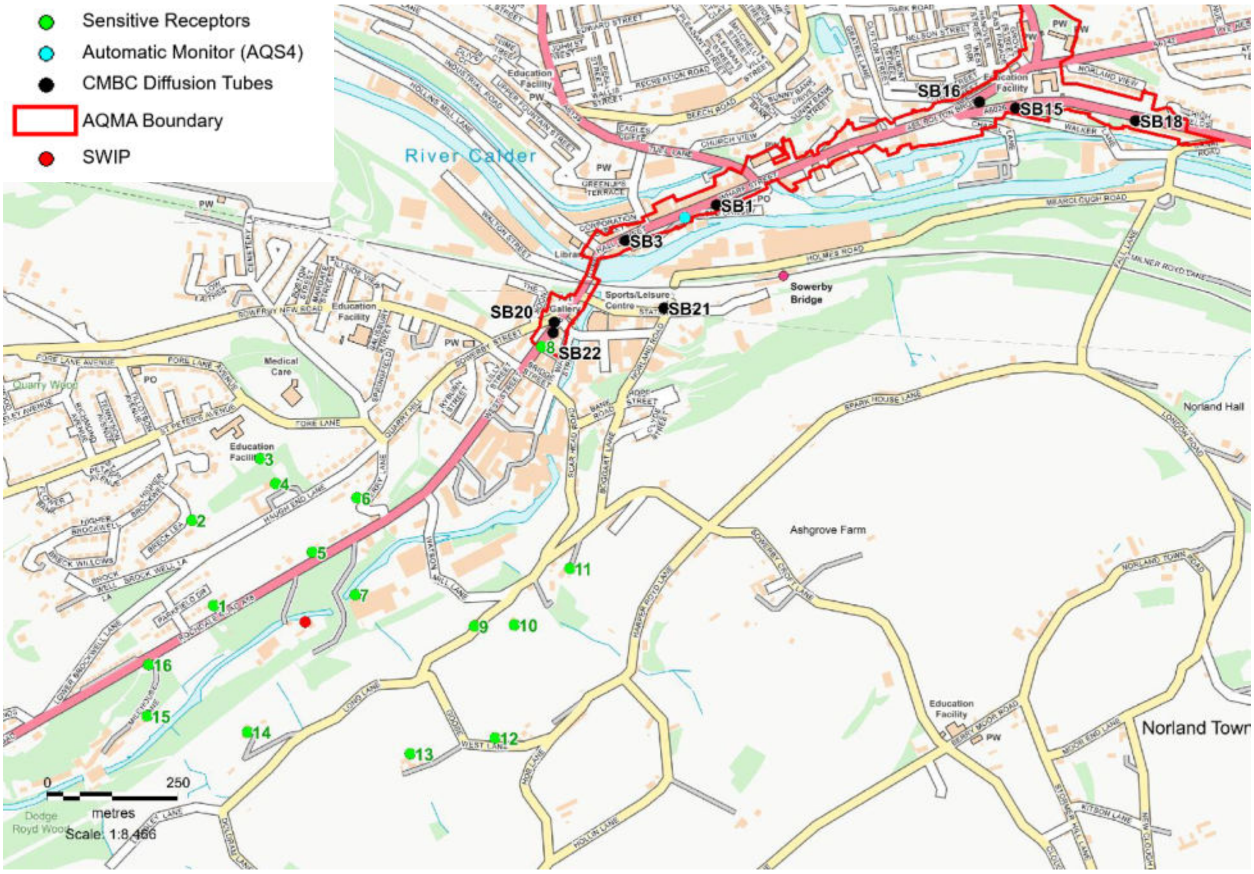
A.43 Concentrations have been modelled across a 1 km by 1 km grid, with a spacing of 20 m, at a height of 1.5 m, centred on the proposed development.

A.44 In addition, concentrations have been modelled at the 16 selected sensitive receptors modelled in the 2017 Environmental Statement. These receptors are listed in Table 3.4 and shown in Figure 3.5.

Table 3.4 Modelled Sensitive Receptors

ID	Description	x	y
1	[redacted]	405174	422873
2		405133	423036
3		405263	423154
4		405293	423106
5		405363	422975
6		405448	423079
7		405445	422894
8		405801	423368
9		405673	422834
10		405749	422836
11		405855	422944
12		405712	422620
13		405550	422590
14		405239	422631
15		405047	422662
16		405050	422760

Figure 3.5 Modelled Sensiitve Receptors and Local Air Quality Monitors



A.45 The annual, daily and hourly-mean AQS objectives apply at the front and rear façades of all residential properties and at Sacred Heart Catholic Primary School. The daily and hourly-mean AQS objectives only, apply at Spring Bank Industrial Estate.

Planning Significance Criteria for Development Impacts on the Local Area

A.46 The Environmental Protection UK (EPUK)/ Institute of Air Quality Management (IAQM) Land-Use Planning & Development Control: Planning For Air Quality document has been used for assessing the impacts of NO_2, and long-term PM_{10} and $PM_{2.5}$, as the pollutants most commonly associated with assessment by that method. (For assessing the significance of other pollutants, the Environment Agency's approach has been used, as discussed later)

A.47 The EPUK & IAQM Land-Use Planning & Development Control: Planning For Air Quality document advises that:

"The significance of the effects arising from the impacts on air quality will depend on a number of factors and will need to be considered alongside the benefits of the development in question. Development under current planning policy is required to be sustainable and the definition of this includes social and economic dimensions, as well as environmental. Development brings opportunities for reducing emissions at a wider level through the use of more efficient technologies and better designed buildings, which could well displace emissions elsewhere, even if they increase at the development site. Conversely, development can also have adverse consequences for air quality at a wider level through its effects on trip generation."

A.48 When describing the air quality impact at a sensitive receptor, the change in magnitude of the concentration should be considered in the context of the absolute concentration at the sensitive receptor. Table 3.5 provides the EPUK & IAQM approach for describing the long-term air quality impacts at sensitive human-health receptors in the surrounding area.

Table 3.5 Impact Descriptors for Individual Sensitive Receptors

Long term average concentration at receptor in assessment year	% Change in concentration relative to Air Quality Assessment Level			
	1	2-5	6-10	>10
75 % or less of AQAL	Negligible	Negligible	Slight	Moderate
76 -94 % of AQAL	Negligible	Slight	Moderate	Moderate
95 - 102 % of AQAL	Slight	Moderate	Moderate	Substantial
103 – 109 % of AQAL	Moderate	Moderate	Substantial	Substantial
110 % or more than AQAL	Moderate	Substantial	Substantial	Substantial

1. AQAL = Air Quality Assessment Level, which may be an air quality objective, EU limit or target value, or an Environment Agency 'Environmental Assessment Level (EAL)'.
2. The table is intended to be used by rounding the change in percentage pollutant concentration to whole numbers, which then makes it clearer which cell the impact falls within. The user is encouraged to treat the numbers with recognition of their likely accuracy and not assume a false level of precision. Changes of 0%, i.e. less than 0.5% will be described as negligible.
3. The table is only designed to be used with annual mean concentrations.
4. Descriptors for individual receptors only; the overall significance is determined using professional judgement. For example, a 'moderate' adverse impact at one receptor may not mean that the overall impact has a significant effect. Other factors need to be considered.
5. When defining the concentration as a percentage of the AQAL, use the 'without scheme' concentration where there is a decrease in pollutant concentration and the 'with scheme;' concentration for an increase.
6. The total concentration categories reflect the degree of potential harm by reference to the AQAL value. At exposure less than 75% of this value, i.e. well below, the degree of harm is likely to be small. As the exposure approaches and exceeds the AQAL, the degree of harm increases. This change naturally becomes more important when the result is an exposure that is approximately equal to, or greater than the AQAL.

7. It is unwise to ascribe too much accuracy to incremental changes or background concentrations, and this is especially important when total concentrations are close to the AQAL. For a given year in the future, it is impossible to define the new total concentration without recognising the inherent uncertainty, which is why there is a category that has a range around the AQAL, rather than being exactly equal to it.

A.49 The human-health impact descriptors above apply at individual receptors. The EPUK & IAQM guidance states that the impact descriptors *"are not, of themselves, a clear and unambiguous guide to reaching a conclusion on significance. These impact descriptors are intended for application at a series of individual receptors. Whilst it maybe that there are 'slight', 'moderate' or 'substantial' impacts at one or more receptors, the overall effect may not necessarily be judged as being significant in some circumstances."*

A.50 The above criteria and matrix are for assessing the long-term impacts; for short term impacts the EPUK/IAQM guidance states that:

"*The Environment Agency uses a threshold criterion of 10% of the short term AQAL as a screening criterion for the maximum short term impact. This is a reasonable value to take and this guidance also adopts this as a basis for defining an impact that is sufficiently small in magnitude to be regarded as having an insignificant effect. Background concentrations are less important in determining the severity of impact for short-term concentrations, not least because the peak concentrations attributable to the source and the background are not additive.*

Where such peak short term concentrations from an elevated source are in the range 10-20% of the relevant AQAL, then their magnitude can be described as small, those in the range 20-50% medium and those above 50% as large. These are the maximum concentrations experienced in any year and the severity of this impact can be described as slight, moderate and substantial respectively, without the need to reference background or baseline concentrations. That is not to say that background concentrations are unimportant, but they will, on an annual average basis, be a much smaller quantity than the peak concentration caused by a substantial plume and it is the contribution that is used as a measure of the impact, not the overall concentration at a receptor. This approach is intended to be a streamlined and pragmatic assessment procedure that avoids undue complexity."

A.51 Professional judgement by a competent, suitably qualified professional is required to establish the significance associated with the consequence of the impacts. This judgement is likely to take into account the extent of the current and future population exposure to the impacts and the influence and/or validity of any assumptions adopted during the assessment process.

Environment Agency Significance Criteria

A.52 For assessing the significance of other pollutants, the on-line Environment Agency (EA) guidance entitled 'Environmental management – guidance, Air emissions risk assessment for your environmental permit' [13] has been used. This guidance provides details for screening out substances for detailed assessment. In particular, it states that:

"To *screen out a PC for any substance so that you don't need to do any further assessment of it, the PC must meet both of the following criteria:*

- *the short-term PC is less than 10% of the short-term environmental standard*
- *the long-term PC is less than 1% of the long-term environmental standard*

If you meet both of these criteria you don't need to do any further assessment of the substance.

If you don't meet them you need to carry out a second stage of screening to determine the impact of the PEC."

A.53 It continues by stating that:

"You must do detailed modelling for any PECs not screened out as insignificant."

A.54 It then states that further action may be required where:

- *"your PCs could cause a PEC to exceed an environmental standard (unless the PC is very small compared to other contributions – if you think this is the case contact the Environment Agency)*
- *The PEC is already exceeding an environmental standard"*

A.55 On that basis, the results of the detailed modelling presented in this report have been used as follows:

- The effects are not considered significant if the short-term PC is less than 10 % of the short-term Air Quality Assessment Level (AQAL) or the PEC is below the AQAL; and
- The effects are not considered significant if the long-term PC is less than 1 % of the long-term AQAL or the PEC is below the AQAL.

A.56 The Air Quality Assessment Level refers to the AQS air quality objective and the EU limit value.

References

1 Approaches to modelling local nitrogen deposition and concentrations in the context of Natura 2000 - Topic 4

2 https://www.gov.uk/guidance/air-emissions-risk-assessment-for-your-environmental-permit#screening-for-protected-conservation-areas

3 IAQM (2019) A guide to the assessment of air quality impacts on designated nature conservation sites

4 Air Pollution Information System, www.apis.ac.uk

5 https://www.gov.uk/guidance/air-emissions-risk-assessment-for-your-environmental-permit#screening-for-protected-conservation-areas

6 Directive 2010/75/EC Of The European Parliament And Of The Council of 24 November 2010 on industrial emissions

7 Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on Waste

8 Council Directive 2008/50/EC of 21 May 2008 on ambient air quality and cleaner air for Europe.

9 Defra, 2010, The Air Quality Standards (Wales) Regulations.

10 Defra, 2007, The Air Quality Strategy for England, Scotland, Wales and Northern Ireland. Volume 2.

11 World Health Organisation Guidelines (http://www.who.int/en/)

12 Expert Panel on Air Quality Standards (www.defra.gov.uk/environment/airquality/panels/aqs/index.htm)

13 Environment Agency 2016, Environmental management – guidance. Air emissions risk assessment for your environmental permit. .gov.uk website: https://www.gov.uk/guidance/air-emissions-risk-assessment-for-your-environmental-permit#environmental-standards-for-air-emissions.

14 Defra (2016) Local Air Quality Management Technical Guidance, 2016 (LAQM.TG16)

15 Email from [redacted] to [redacted] dated 07/06/2019

16 Defra Digital Terrain Model (DTM) Lidar Data available from: https://environment.maps.arcgis.com/apps/MapJournal/index.html?appid=c6cef6cc642a48838d38e722ea8ccfee

Contact

[redacted]
RPS Consulting Services Ltd
6-7 Lovers Walk
Brighton
BN1 6AH
T: +44(0) 1237 546 800
E: kathryn.barker@rpsgroup.com

In the High Court of Justice
Queen's Bench Division
Administrative Court

CO Ref: CO/1295/2021

In the matter of an application for Judicial Review

The Queen on the application of

[redacted]

Claimant

versus
CALDERDALE METROPOLITAN BOROUGH COUNCIL

Defendant

CALDER VALLEY SKIP HIRE LTD

Interested party

Application for permission to apply for Judicial Review
NOTIFICATION of the Judge's decision (CPR Part 54.11, 54.12)

Following consideration of the documents lodged by the Claimant and the Acknowledgement(s) of service filed by the Defendant and / or Interested Party

Order by [redacted] **sitting as a judge of the High Court**

1.Permission is hereby granted on all grounds.

2. CPR Rule 45.43 applies as this is an Aarhus Convention claim

3. The Interested party's application for disclosure for disclosure of the names of the Benbow group and their resources as an aid to an application to vary the costs limits under CPR 45.43 is refused.

Observations concerning the grant of permission:

Grounds 1 and 2

1. There is no dispute but that council was misdirected as to the effect of delaying a decision further. The argument that it made no difference because the council had been informed by the intervener that it would serve a notice deeming refusal if a decision was not made that day is fallacious. The council may or may not have been moved by such information. It may have decided to call the intervenor's bluff if it thought that it could

pursue further enquiries without this resulting in an automatic refusal. The intervenor, in such a circumstance, would have been left to consider whether it was quicker to await the outcome of those enquiries or serve the notice and launch an appeal.

2. That the misdirection had an effect on the council's, decision not to request further information, as suggested by WYG, and to disapply the call-in procedure, is arguable and has a realistic prospect of success.

Ground 3

3. It is arguable, to the request degree, that the council substituted the test of "significant harm" , which appears to be taken form the WYG report, for the Environmental Permitting General Guidance Manual test which focuses on the question as to whether the proposed installation would cause anything beyond a negligible increase. The application of an alternative test in this could have made a difference to the outcome in view of WYG's advice that sensitivity modelling identified more than negligible impacts as being possible.

Ground 4

4. There is a difference of between the parties as to what activities are permitted in the part of the site covered by neither the SWIP or the WML. There is undoubtedly part of the site which is not covered by either which may be subject to activities associated with the proposed incinerator and question as to whether this is a good point and one which has not been taken into account in the decision to grant the SWIP is sufficiently arguable for the grant of permission.

Reason for refusing the interested party's application

5. The identities of the members of the Benbow group and their means is not relevant to a variation application. By analogy with claims in which orders for security or payment-in are said to stifle claims, the question to consider is whether the claimant can obtain funds from other sources not whether his backers could access such funds; for the analogous case of security and payment- in see *Goldrail Travel Ltd v Onur Air Tasimacilik AC[2017] UKSC 57.* The evidence of his access to funds is that relating to the response to the crowd funding appeal. The claimant has Aarhus protection, the object of which is to prevent environmental claims being stifled by costs. That is his position. The fact that there may be others, sympathetic to his cause, who have greater resources than he, does not moderate

the stifling impact of a higher costs cap unless they are prepared to provide him with additional financial support, which they have not done in response to the crowd funding appeal.

Case management directions

1. The defendant and any other person served with the claim form who wishes to contest the claim or support it on additional grounds must file and serve detailed grounds for contesting the claim or supporting it on additional grounds and any written evidence, within 35 days of service of this order.

2. Any reply and any application by the claimant to lodge further evidence must be lodged within 21 days of the service of detailed grounds for contesting the claim.

3. The claimant must file and serve a trial bundle not less than 4 weeks before the date of the hearing of the judicial review, in both hard and soft copy.

4. The claimant must file and serve a skeleton argument not less than 21 days before the date of the hearing of the judicial review.

5. The defendant and any interested party must file and serve a skeleton argument not less than 14 days before the date of the hearing of the judicial review.

6. All skeletons are to be filed in hard and soft copy.

7. The claimant must file an agreed bundle of authorities, not less than 3 days before the date of the hearing of the judicial review in hard and soft copy.

Listing Directions
The application is to be listed for 2 days with a further day for reading; the parties to provide a written time estimate within 7 days of service of this order if they disagree with this direction.

Case NOT suitable for hearing by a Deputy High Court Judge* ☐

Criminal case NOT suitable for hearing by a Single Judge* ☐

[*Tick if applicable]

Directions as to venue, if applicable:

[redacted]

Signed [redacted] 23rd July 2021

The date of service of this order is calculated from the date in the section below

---

For completion by the Administrative Court Office

On the 29th July 2021 a copy of this order was emailed to

[redacted]

Notes for the Claimant

To continue the proceedings a fee is payable.

For details of the current fee please refer to the Administrative Court fees table at https://www.gov.uk/court-fees-what-they-are. Failure to pay the fee or submit a certified application for fee remission may result in the claim being struck out. The form to make an application for remission of a court fee can be obtained from the Justice website https://www.gov.uk/get-help-with-court-fees

You are reminded of your obligation to reconsider the merits of your claim on receipt of the defendant's evidence.