

ADDITIONAL OBJECTION TO ENVIRONMENTAL PERMIT APPEAL

Email to: ETC@planninginspectorate.gov.uk

From: [REDACTED]

Address: [REDACTED]

Calder Valley Skip Hire Limited – Environmental Permit Appeal – Reference APP/EPR/603

DOCUMENTS included with this Objection:

1. [REDACTED] Objection to Environmental Permit Appeal Ref APP_EPP_603_FINAL+Documents
2. CVSH Environmental Permit Appeal Objection from 1017 residents-No Signatures Text ONLY
3. Email: URGENT MISSING DOCUMENTS RE_ NOTICE OF APPEAL - CALDER VALLEY SKIP HIRE LIMITED - BELMONT INDUSTRIAL ESTATE
4. Email: RE_ Calder Valley Skip Hire Limited – Environmental Permit Appeal – Reference APP_EPR_603 CORRECTION
5. IncineratorObjection6-2-23_0001_Rick_Davis
6. Email: _Re_ CVSH consultant report
7. Annual-Status-Report-2022_Air Quality
8. HD21 Draft-Environmental-Permit-Discussed-at-Hearing-Showing-Amendments

GROUND OF OBJECTION

1. This statement of objection is submitted in addition to any previous representations and objections that I have made in relation to this appeal. I attach a copy of the previous objection for ease of reference. Document 1 above.
2. I object to the grant of an Environmental Permit for the reasons set out here and in my previous document and attachments.
3. I object to the grant of an Environmental Permit for the reasons set out in my document number 2 the “CVSH Environmental Permit Appeal Objection from 1017 residents-No Signatures Text ONLY”.

BACKGROUND OF THE APPEAL

4. As stated previously, the Appellant has appealed on the ground of a “deemed refusal” due to the failure by the 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).
5. 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 of the Appellant to provide the additional information is the primary reason for the submission of the appeal.
6. Calderdale Council in its Statement of Case and opening submission (Points 54 – 57) has wrongly accepted the arguments put forward by the Appellant and conceded the Appeal on the basis that it considers “ *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 Belmont Industrial Estate and that no further evidence has been put forward to undermine the original quashed decision to grant the Permit.* The Council’s

Statement of Case and opening submission 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. Nor does the Council appear to be fulfilling the role of regulator by validating the technical data before it.

Law and Guidance

7. 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 my objections. These are reflected in the Council's statement of case at point 5 *"Determination of an environmental permit application is an objective and technical consideration and is entirely separate to planning permission. The environmental permitting regime has four 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. In the case of waste incineration Directive 2006/12/EC of the European Parliament and of the Council 1 Hearing Bundle ("HB") Tab 22 2 A SWIP would not be a Part A or B installation. Nevertheless the guidance deals with air quality and management issues and is considered relevant to the appeal application. of 5 April 2006 on Waste, and Directive 2010/75/EU3 of the European Parliament and of the Council of 24 November 2010 on Industrial Emissions (Integrated Pollution Prevention and Control) contain provision that seek to protect human health and the environment through the requirements and limits that are imposed. 6. Schedule 13 of the EPR 2016 requires that: "The regulator must exercise its relevant functions so as to ensure compliance with the ... provisions of the Industrial Emissions Directive"*.
8. In spite of this statement the Council's case accepts the Appellant's faulty arguments and ignores its clear duty to "protect the environment and human health."
9. Regardless of the arguments from the Council and the Appellant it remains 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.
10. 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 in this appeal 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. If there is insufficient information to make the judgement then the same decision is required, the permit should be refused.
11. 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

12. The Statements of Case in this appeal note that Mr Malcolm Powell 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."

13. 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 was attached to my original objection. **Permission to apply was granted on all grounds by [REDACTED] sitting as a judge of the High Court.**
14. 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.
15. In the Appellant's Legal Response to Third Party Objections 18.11.22 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. A copy of the order of the High Court granting permission for judicial review on all grounds was attached to my original objection.
16. 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 unless satisfied that there is an arguable ground for judicial review which has a reasonable prospect of success.
17. Even if a claim is arguable, the judge must refuse permission:
- unless he or she considers that the applicant has a sufficient interest in the matter to which the application relates; and
 - 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.

OBLIGATIONS OF THE REGULATOR

18. 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.
19. 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

Consultation and Documentation

20. It is not clear that the complete set of documents for the Application and the Appeal have been set out and made available to the public. There appear to be documents missing from the Council's web site (eg an Electronic Hearing Bundle was produced but is not on the site), some persons have had access to documents while others appear not to have seen relevant documents. I repeatedly requested of the Council (examples in documents 3 and 4 above) that the set of complete documents should be made available. On 10 Feb 2023, this is not yet the case. For example, the drawings and technical detail accompanying the new application are not present on the web site, nor are the hearing documents complete. There are no Start-up and Commissioning documents available – do they exist?

21. This omission might well have disadvantaged residents and all parties from fully understanding and commenting on the Environmental Permit appeal. I find it difficult to understand what limits to emissions and protections for the environment and human health (such as walkers on the footpath across the site) apply when the SWIP is being implemented and commissioned. This difficulty remains equally in normal operation, should breaches occur what will stop them? How long can they continue, and how will the public know? The documentation is incomplete, has mistakes and does not control the emissions from the SWIP.

Start up and commissioning

22. The Council has emphasised that the Permit conditions are the means by which the regulator will control emissions and ensure minimal impact on the environment and Human health – but emphasising the point made in the document **“2. CVSH Environmental Permit Appeal Objection from 1017 residents-No Signatures_Text ONLY”** at point 5

“the permit includes insufficient 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 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.”

23. This is particularly true of start-up and commissioning of the SWIP – there is no detail of the process steps, the design or validation of how the SWIP will be implemented and no documentation covering milestones, technical checkpoints and certainly non-operational emissions to allow any understanding of the process or permit conditions that will be required. How has the regulator assessed this period which will represent the most risk and the most extreme period of operation, how is this to be controlled in the Permit conditions or at all when it does not appear in the documentation? This lack of detail is a reason for refusing the appeal.

Plant design and fit-out

24. The lack of design documents and the inconsistencies in the build space and overall engineering of the SWIP have been well documented in so far as they can be with limited information by **“2. CVSH Environmental Permit Appeal Objection from 1017 residents-No Signatures_Text ONLY”** and [REDACTED] in document **5. IncineratorObjection6-2-23_0001_Rick_Davis**. The regulator statement of case asserts at point 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.”*

25. At point 52 it states *“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.* There is nothing that demonstrates in the documents or the Draft permit conditions how an untested unknown system incinerating waste of untested composition will be controlled either from commissioning and start up or in normal operation. The conditions attached to the draft permit (**8. HD21 Draft-Environmental-Permit-Discussed-at-Hearing-Showing-Amendments**) were once again changed at the hearing by the Appellant and the Council. The changes were in places contrary to the Council’s previous position on elements such as additional monitoring and fire risk and control. There is much detail remaining untested or unclear. The document no.2 attached to this objection contains more detail about the issues arising in terms of this issue.

Stack Height Uncertainty

26. There remains the suggestion that the stack height will be changed if it does not perform as modelled. If there is any doubt then the permit should be refused and if that height is not optimal to protect human health and the environment it should not be permitted.

27. In addition to my previous question regarding the arrival by the Appellant on a stack height of 12 Metres, the information revealed by the Inspector's request for clarification (**HD24 – WYG (now Tetra Tech) comments on Stack Height**) appears to show that the Stack height has not been reviewed for the purposes of Environmental Permitting. The documents suggest that the only modelling was in a planning context and that the criteria used for planning would not be as stringent as for environmental permitting. This as it stands does not satisfy the requirements under Schedule 13. The fact that the 12 Metres stack height is not BAT (or best practise) is also a question which has not been addressed. This is a reason for refusal of the permit appeal and has been identified in the AQC report, since it has not been adequately addressed.

Air Quality Issues

28. Reading the Air Quality report 2022 (Annual-Status-Report-2022_Air Quality) it calls into question the assertion that NO₂ pollution is falling and states in fact that in 2021, the measured concentration of NO₂ increased within five of the eight AQMAS, and is likely reflective of the increased travel activity relative to 2020, when there were more COVID-19 restrictions. There is of course a delay in obtaining air quality data but even with the lower levels currently there has been no technical review of projections from 2023 onwards when traffic levels are not affected by Covid restrictions. The now historic assertions of pollution levels within limits has not been reviewed based on likely future levels caused by the local plan or other factors which have changed since the original assessments and modelling.

29. In the documents submitted for the Environmental Permit the air quality data is, so far as I can see, from a period some years ago, similarly the weather data. It therefore seems that the modelled air quality, rather than based on measurement is based on an optimistic projection from an uncertain base.

30. The draft Environmental Permit inherently describes limiting pollution to legal minimum levels, it has no conditions or mechanisms to stop the operation immediately should such levels exceed minimum levels. It appears to have no mechanism for monitoring emissions let alone ceasing them if minimum safe levels are exceeded while implementing or testing or commissioning the SWIP. This does and cannot *protect human health and the environment through the requirements and limits*.

The Council's decision

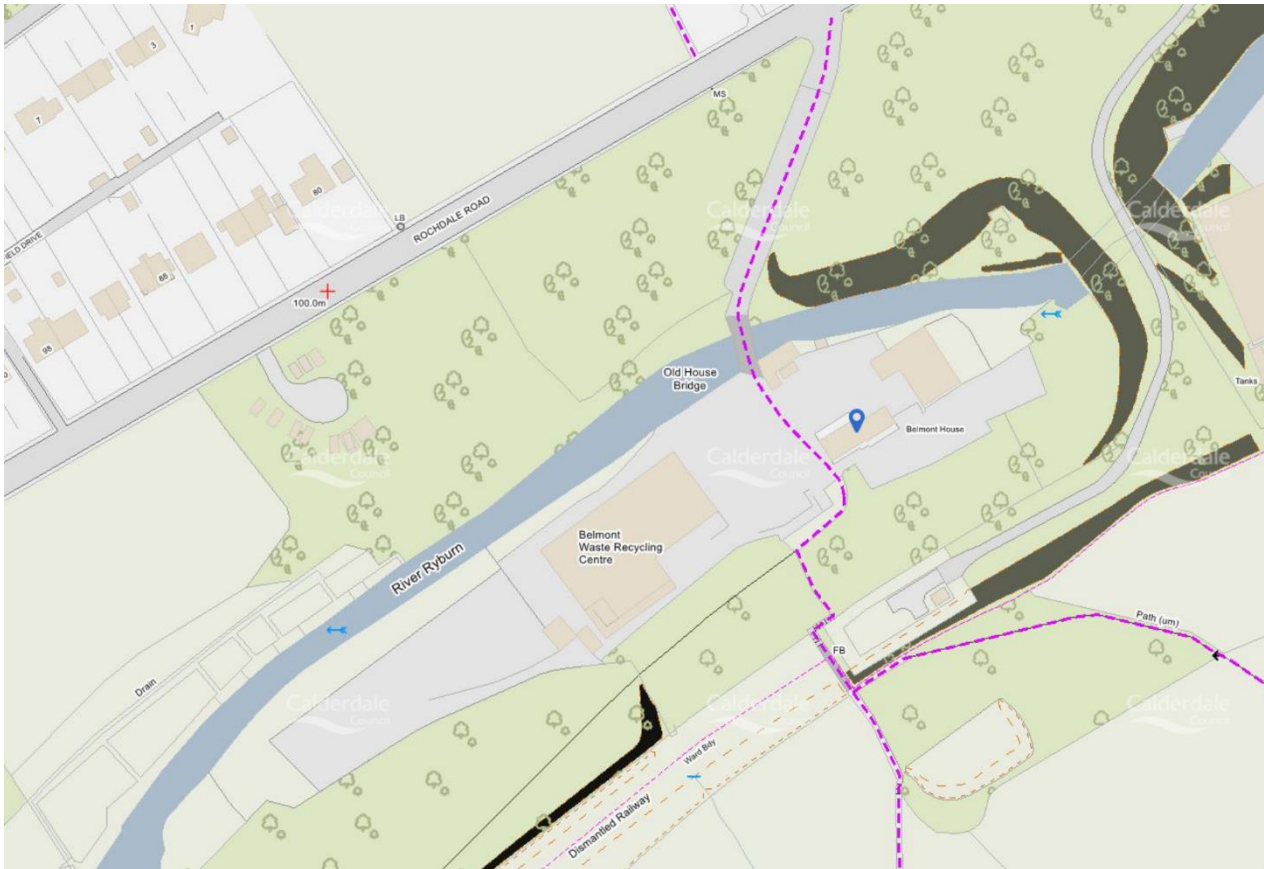
31. The Council's statement of case and latterly the Council's opening submissions concede the Environmental Permit Appeal, citing that there is no basis to counter the permit granted in 2021.

32. There are no documents showing how this decision of the Council was made or the basis of this decision. As a Key Decision for the Council which residents were led to believe would be open and transparent and would be made by Cabinet, this is not acceptable.

33. A Cabinet Member has documented in correspondence included in third party objection (listed on the Council's Hearing website as "CVSH-objections-1.pdf" at pages 175 – 176) how the Cabinet decision was made to concede the Appeal and yet the same Cabinet Member has also signed the community's objection "**2. CVSH Environmental Permit Appeal Objection from 1017 residents-No Signatures_Text ONLY**". In other documents (**HD5 – CMBC Note on Delegated Authority**) it is implied that it was a delegated decision by the Council Officers. This lack of transparency and confusion is contrary to the EIR and difficult to understand given the clear opposition from residents to this Appeal. It is also difficult to reconcile with an Air Quality Strategy that puts air quality at the heart of everything the Council do, where the Council is the regulator of a polluting SWIP that Cabinet have in effect approved.

Footpath

34. There is a footpath across the site, and the Inspector will have seen the route of the path on his site visit. The footpath is not shown on any diagram or plan presented as part of the Environmental Permit Application and although it is well used by the public, there has been no consideration as to the significant impacts on the human health of the public from emissions or safety of users of the path. There is no monitoring at ground level and the footpath is ignored in the monitoring plan. To effectively control effects on human health the emissions at ground level on the footpath should be measured as part of the permit conditions.



35. Picture above from Calderdale Rights of way online HX6 3LL ([Leisure and culture map | Calderdale Council](#))

36. As pointed out in “**2. CVSH Environmental Permit Appeal Objection from 1017 residents-No Signatures_Text ONLY**” at point 145 according to the RPS document of 15 March “*The SWIP sits within the thermal treatment building, which is located immediately adjacent to the WTS and can only be accessed through the WTS. there is a security fence on the boundary*” which they say prevents any unauthorised access (they say to prevent arson). This is not the case because they have omitted consideration of the public’s right to pass and repass on the footpath at all times and the description of access from the WTS is patently not correct. The operation of loading the SWIP crosses the footpath and is not via the WTS. These details mean the Appellants Fire Protection Plan (FPP) is invalid – in itself another reason to refuse the permit.

Permit conditions

37. As part of the Planning Appeal decisions (Appeal Decisions APP/A4710/W/18/3205776 & APP/A4710/W/18/3205783) an R1 condition was attached to the SWIP operation. Condition 8 , Page 99 of the electronic hearing bundle “*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*”.

38. The scheme would in effect ensure that the SWIP would achieve and continue to maintain the R1 status. Is the scheme documentation within the Environmental permit documentation. The issue with this in terms of SWIP operation and assessment are documented in document “**2. CVSH Environmental Permit Appeal Objection from 1017 residents-No Signatures_Text ONLY**”. The regulatory effectiveness of this are seriously called into question by the document above “**6. Email_Re_ CVSH consultant report** “. Since this continuing status is fundamental to the operation of the SWIP and intrinsic to the waste operation. Permit conditions should also cover this scheme in order to avoid the split between planning and permitting which has dogged the operation to date to ensure the requirement is captured and reported as part of ongoing operation? If the R1 monitoring is left out of the Environmental Permit conditions, it is likely to fall by the wayside like so many of the Planning conditions. This will undermine the whole basis of approval for the SWIP.

39. The waste acceptance process for the SWIP should be supported by monitoring of waste volumes and types daily and weekly and reporting as part of the permit conditions to monitor the R1 condition and Scheme.
40. Several residents have pointed out the lack of complete documents for the Application/appeal. It would be expected that complete documents would inform suggested permit conditions. It is likely that the missing documents have reduced the scrutiny and review of the permit conditions if not made it impossible to contribute effectively to this consultation. This should not be a reason for agreement on the Appeal.
41. The draft permit **HD21 Draft Environmental Permit Discussed at Hearing Showing Amendments**, which was confirmed by the Council's Head of Legal to be the final draft has serious flaws as pointed out in **2. CVSH Environmental Permit Appeal Objection (from over 1000 residents - No Signatures) TEXT**.
 - a. Point 83 – 87 the removal of additional monitoring to allay concerns over the SWIP operation is not explained and seems to move further away from controlling emissions and harm.
 - b. Point 147, Condition 2.3 on the draft permit does not adequately addresses the issue raised by the Council to the original condition.
42. The permit document **HD21 Draft Environmental Permit Discussed at Hearing Showing Amendments** shows in Section 4 the limits of emissions to air – meaning the levels that are permitted. The monitoring of the limits is covered by Section 5 of the draft permit. And action in the event of significant breaches of conditions is in section 7. This is described for example as follows for an incident or accident Condition 7.1 In the event of any incident or accident significantly affecting the environment the operator shall (1) immediately inform the Regulator; (2) immediately take the steps set out in the documents 'Accident Management Plan', 'Fire Prevention Plan' and 'Environmental Management System for the Small Waste Co-incineration Plant' to limit the environmental consequences and to prevent further accidents or incidents;(3) take such complementary measures as required by the Regulator to limit the environmental consequences and to prevent further accidents and incidents.
43. What constitutes a "significant breach" is not defined nor is any timescale or control to remedy those breaches other than the actual emissions are to be reported to the regulator quarterly one month in arrears. And the various plans (Fire, Accident and Environment) will be invoked. There is nothing detailing how those breaches are controlled, or how the pollution which the Council asserts will be managed by this Permit is kept within acceptable and safe limits. Nor is it clear how the effect on the environment and human health will be controlled.
44. It is stated that there will be no emissions to water, but it is not clear how this will be achieved. If emission limits to air are exceeded the actions required by the permit do not control the SWIP or its pollution, they report it. It is not sufficient to rely on the statutory provisions for control as these are more limited. Actual conditions which cease operation or have timescales associated would be more certain and enforceable. Currently the Permit as drafted would allow environmental limits to be exceeded in abnormal situations – for example start up for an unlimited period? If the Permit is not enforceable then there is no control provided by such a permit.
45. The permit uses undefined terms such as "permissible periods of abnormal operation" - does this include start up or testing? These terms should be defined and clear and currently the permit does not provide control of the operation or protect the environment or human health, for example walkers on the footpath would be at risk in construction and start up testing and commissioning where it seems limits would not apply.
46. Since the SWIP operates for 24 hours will the regulator be available 24 hours a day. Can limit breaches continue overnight or until the Regulator decides what is to be done. How will operations be ceased if limits are exceeded outside of office hours? The process lacks detail and is untested. The Permit conditions should be subject to testing and validation as part of the start up/commissioning.
47. The monitoring and reporting of emissions such as they are within the Permit – do not allow any assessment of emissions and no information of such by any persons other than the operator or the regulator, potentially up to 4 months after the event.

48. The emission reports format should be known, agreed in advance and available in real time. The systems should report in real time, publicly and this could replace the reduced monitoring the Council has agreed. The Permit conditions as they stand do not control the SWIP and obscure important emission data from residents. Reporting should be real time and part of the Permit, and this must include at ground level on the footpath. If reporting is real time then confidence could be built over the period of commissioning and start up and continue into normal operation.

CONCLUSION

49. 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.

50. The Council as regulator appears to have washed its hands of its role, but this does not remove the requirement for protection of the environment and human health. The Council's mistaken position to concede this Appeal, added to the gaps of detail and information particularly over design and start up plus the outstanding questions and inconsistencies mean that the impact on the environment and human health of the SWIP cannot be controlled by permit conditions since there is not enough information to determine these sufficiently robustly.

51. For the reasons set out under the heading "Summary of Main Grounds of Objection in the **"2. CVSH Environmental Permit Appeal Objection from 1017 residents-No Signatures Text ONLY"** (my document number 2) and for the reasons set out here and in my previous document and attachments the Permit should not be granted, and the Appeal should be refused.

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

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OBJECTION TO ENVIRONMENTAL PERMIT APPEAL

Email to: ETC@planninginspectorate.gov.uk

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”)**
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**

GROUND 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 an 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 dissimilar 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		Principal Contacts	
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Job Number	J12920
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Report Prepared By:	
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Document Status and Review Schedule

Report No.	Date	Status	Reviewed by
J12920/A/F2	26 November 2021	Final Report	

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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	<p>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.</p> <p>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.</p> <p>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 than negligible cannot be immediately discounted. This is based on information provided by the applicant about the baseline and process contribution from the incinerator stack.</p>
2	Benzo(a)pyrene	<p>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.</p> <p>The applicant needs to provide more information to justify that the contribution is insignificant.</p>
3	Stack Height Determination	<p>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.</p>
4	Ecological Impacts	<p>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.</p>
5	Roads Modelling Verification and Model Adjustment	<p>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.</p>

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 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.
7	Human Health Risk Assessment for Persistent Organic Pollutants	<p>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.</p> <p>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.</p>
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	<p>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.</p> <p>It is not entirely unusual that multiple permits exist with different regulators on the same site.</p>

Executive Summary Table		
No.	Issue	Conclusion
		<p>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.</p> <p>However, many of the issues raised in this section, are procedural. Consequently, such matters are best judged by a legal professional.</p>
12	Installation Boundaries	<p>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.</p>
13	Further request for information	<p>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.</p>

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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 compiled 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] 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], 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., SO₂, HF, HCl), volatile organic compounds (VOCs), particulates, heavy metals and odour.
- 2.3 [REDACTED] 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 ES¹. 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 quality². 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 quality³.

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 NO₂ 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 guidance⁴ 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 than *negligible* cannot be immediately discounted⁵. 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 NO₂ value of 40 µg/m³ measured in 2019 at diffusion tube SB22⁶, 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/m³. This value acts as the point at which a 0.2 µg/m³ (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/m³ (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/m³ (ADMS, Leeds Bradford met data), 0.2 µg/m³ (ADMS, Bingley met data), 0.2 µg/m³ (ADMS, Leeds Bradford met data, variable surface roughness) and 0.2 µg/m³ (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/m³, 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, [REDACTED], (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 $1 \mu\text{g}/\text{m}^3$ 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 $0.004 \text{ ng}/\text{Nm}^3$ to $1 \mu\text{g}/\text{m}^3$. 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 plants⁸. 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.

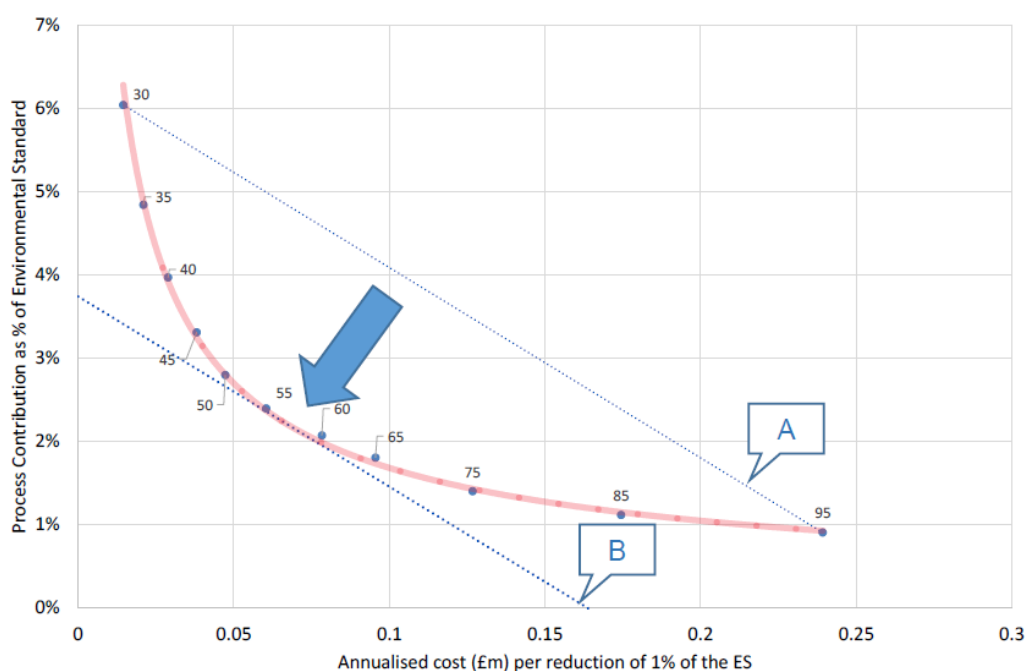


Figure 1: Visual depiction of the 'knee-point' on a stack height assessment graph

- 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 insignificant⁹. Consequently, the applicant has failed to demonstrate that a stack height corresponding to the principle of BAT¹⁰ 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/m³ as a background NO₂ 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-NO_x concentration before converting to NO₂. 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 NO₂ 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 NO₂ concentrations of 0.2 µg/m³ (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 within 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 NO₂ 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/Nm³ and the 30-minute mean emission limit is 400 mg/Nm³. 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 NO₂ 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/Nm³ 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 SO₂ 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 $\mu\text{g}/\text{m}^3$. 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 $\mu\text{g}/\text{m}^3$ 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 Plants¹¹ 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 valley¹ 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 be 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 [REDACTED].

³ In *Esdell* at 923 [REDACTED] 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 [REDACTED].

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 [REDACTED]. 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.

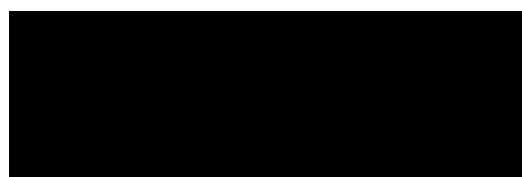
⁷ Environmental Permitting (England and Wales) Regulations 2016, Sched 13, para 4.

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]

[Redacted]

21st October 2022

¹⁰ [Redacted] v *Secretary of State for the Environment* [1990] 2 AC 273 at 290 per [Redacted] 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	██████████	Principal Contacts	██████████
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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].
- 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] 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], 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., SO₂, HF, HCl), volatile organic compounds (VOCs), particulates, heavy metals and odour.
- 2.3 [REDACTED] 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 Guidance¹, reference is made to the Environment Agency's Guidance² 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

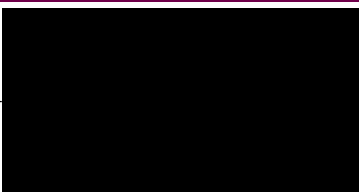


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Appendices

Appendix A - Policy and Legislative Context and Assessment Methodology
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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 should not be re-visited 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 PM₁₀, 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/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.*
- *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/m³ 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/Nm³ to 1 µg/m³. 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)				Average
	2014	2015	2016	2017	
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/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/Nm³ 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/m³ 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 ($\mu\text{g.m}^{-3}$) at Short-Term Emission Limit Values (Scenario 1) – Results Across the Modelled Grid

Pollutant	Averaging Period	EAL ($\mu\text{g.m}^{-3}$)	Max PC ($\mu\text{g.m}^{-3}$)	Max PC as % of EAL	Criteria (%)	AC ($\mu\text{g.m}^{-3}$)	PEC ($\mu\text{g.m}^{-3}$)	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 ($\mu\text{g.m}^{-3}$) at Long-Term Emission Limit Values (Scenario 2) – Results Across the Modelled Grid

Pollutant	Averaging Period	EAL ($\mu\text{g.m}^{-3}$)	Max PC ($\mu\text{g.m}^{-3}$)	Max PC as % of EAL	Criteria (%)	AC ($\mu\text{g.m}^{-3}$)	PEC ($\mu\text{g.m}^{-3}$)	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 $30,000 \mu\text{g.m}^{-3}$ 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 $30 \mu\text{g.m}^{-3}$ 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 $5 \mu\text{g.m}^{-3}$ and the impacts are potentially significant. When the TOC PC is added to the AC, the PEC of $0.51 \mu\text{g.m}^{-3}$ 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 ($\mu\text{g.m}^{-3}$)	PC as % of the EAL*
1		1.20E-06	0
2		5.92E-07	0
3		5.80E-07	0
4		7.18E-07	0
5		1.72E-06	1
6		1.44E-06	1
7		2.27E-05	N/A
8		1.32E-06	1
9		1.61E-06	1
10		1.15E-06	0
11		1.25E-06	1
12		2.48E-07	0
13		2.43E-07	0
14		1.30E-06	1
15		1.65E-06	1
16		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

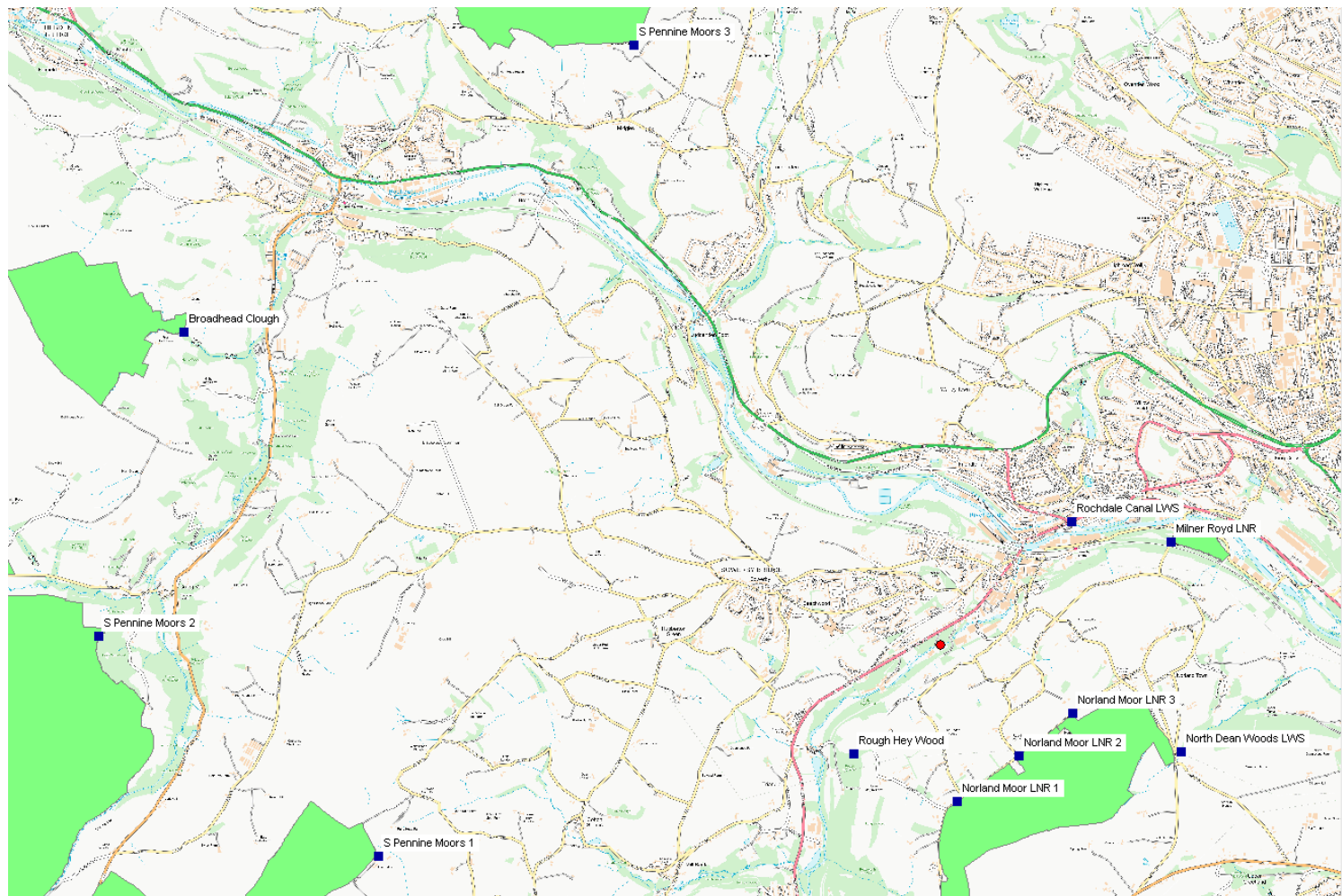
- 6.1 *The applicant has not assessed the impacts at nearby ancient woodland and local nature reserve ecological sites within their ES addendum or their 2019 additional Air Quality Assessment. These sites are within the 2 km screening distance for assessment of ecological sites required by the Environment 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 (NO_x), sulphur dioxide (SO₂), ammonia (NH₃) 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 ($\mu\text{g.m}^{-2}.\text{s}^{-1}$) has been calculated by multiplying the ground level NO_2 and NH_3 concentrations ($\mu\text{g.m}^{-3}$) 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 $\mu\text{g.m}^{-2}.\text{s}^{-1}$ have been converted to units of $\text{kg.ha}^{-1}.\text{year}^{-1}$ 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 $\text{keq.ha}^{-1}.\text{year}^{-1}$, has been calculated by multiplying the dry deposition flux ($\text{kg.ha}^{-1}.\text{year}^{-1}$) 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 $\mu\text{g.m}^{-2}.\text{s}^{-1}$. 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 ($\text{keq.ha}^{-1}.\text{year}^{-1}$). 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 $\mu\text{g.m}^{-2}.\text{s}$. 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 $\text{keq.ha}^{-1}.\text{year}^{-1}$.
- 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 NO_x, SO₂, NH₃ 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 NO_x, SO₂ and NH₃ 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⁻³Annual-Mean SO₂ Critical Level = 10 µg.m⁻³Annual-Mean NH₃ 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 ($\mu\text{g.m}^{-3}$)	HF PC/Critical Level (%)	Daily-Mean HF PC ($\mu\text{g.m}^{-3}$)	HF PC/Critical Level (%)	Daily-Mean NOx PC ($\mu\text{g.m}^{-3}$)	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 = $0.5 \mu\text{g.m}^{-3}$ Daily-Mean HF Critical Level = $5 \mu\text{g.m}^{-3}$ Daily-Mean Nox Critical Level = $75 \mu\text{g.m}^{-3}$

- 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 NH₃ 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 ($\text{kgN.ha}^{-1}.\text{yr}^{-1}$)	N Deposition PC ($\text{kgN.ha}^{-1}.\text{yr}^{-1}$)	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 NO_x and NH₃. Paragraph 6.12 outlines that the sulphur component of acid deposition considers the contribution from SO₂, 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 (NH₃), 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 (PM₁₀ and PM_{2.5}), nitrogen dioxide (NO₂), sulphur dioxide (SO₂), ozone (O₃), 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 µg.m ⁻³	2020 (a)
PAHs	Annual (a)	0.00025 µg.m ⁻³ B[a]P	-
Sulphur Dioxide (SO ₂)	Annual (b)	50 µg.m ⁻³	-
Hydrogen Chloride	1 hour (c)	750 µg.m ⁻³	-
Hydrogen Fluoride	1 hour (c)	160 µg.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 (µg.m ⁻³)	Short-Term EAL (µg.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 ($\mu\text{g.m}^{-3}$)	Short-Term EAL ($\mu\text{g.m}^{-3}$)
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.

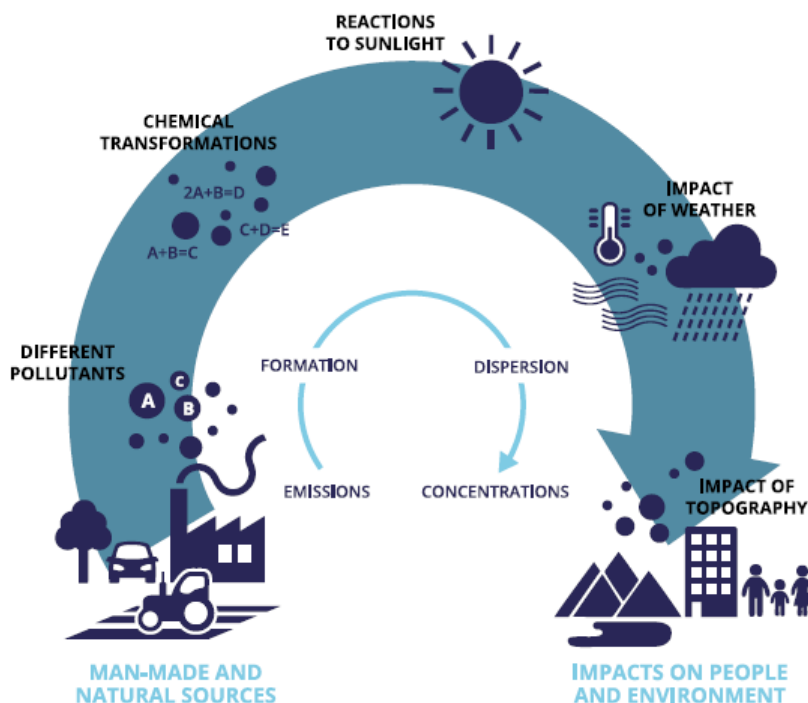
A.21 In line with the guidance set out in the NPPG, the Environmental Health Department at CMBC was consulted to agree the scope and methodology for this assessment. [REDACTED], agreed that the approach to the assessment was reasonable [15].

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	1.28E-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)

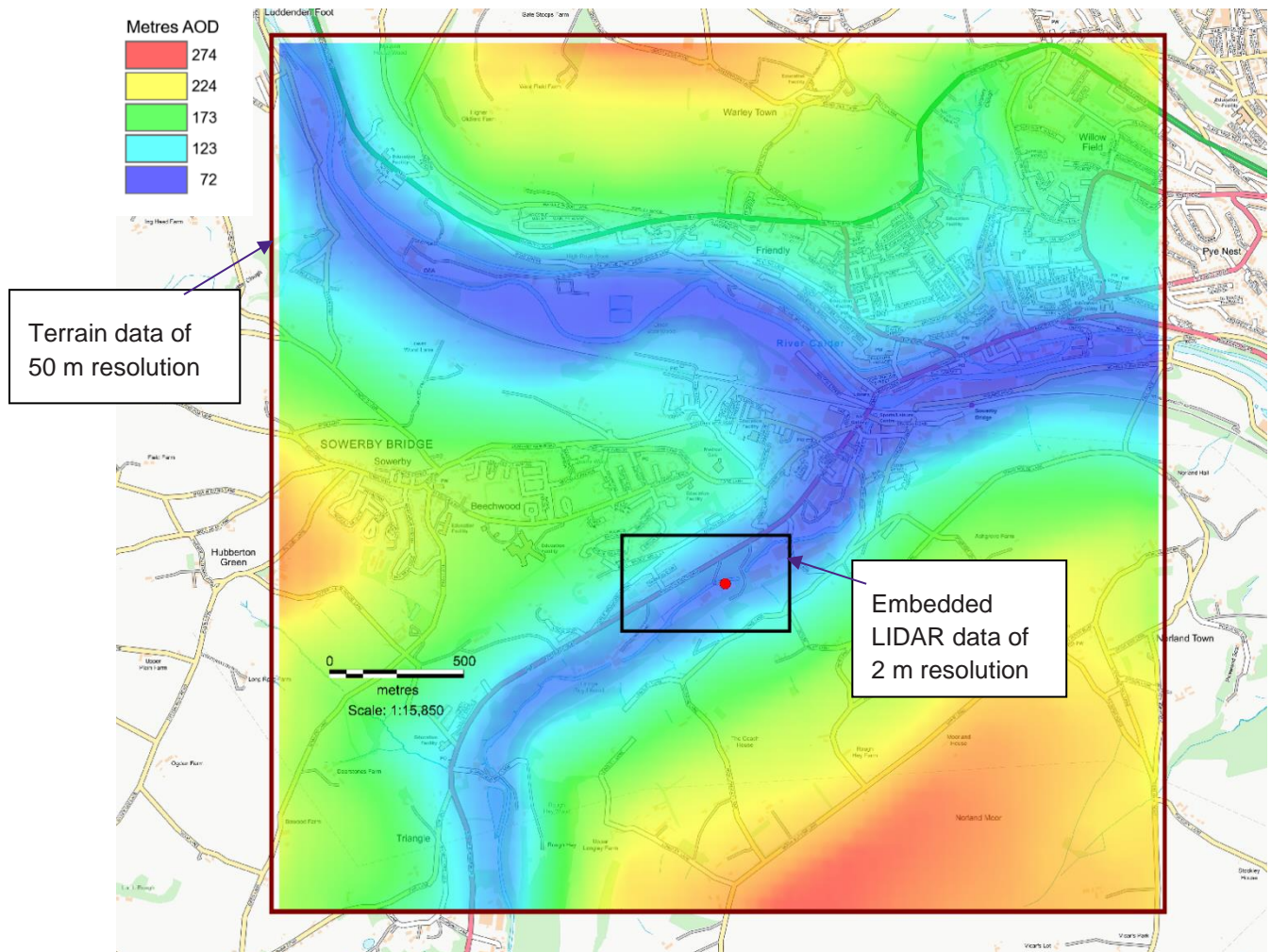
(d) Antimony (Sb), Arsenic (As), Lead (Pb), Chromium (Cr), Cobalt (Co), Copper (Cu), Manganese (Mn), Nickel (Ni), and Vanadium (V)

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. PM₁₀). Furthermore, all particles are also assumed to be less than 2.5 µm in diameter (i.e. PM_{2.5}). In reality, the PM₁₀ 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 PM₁₀ concentration. Therefore, this can be considered a conservative estimate of the likely particulate emissions in each size fraction.

Terrain

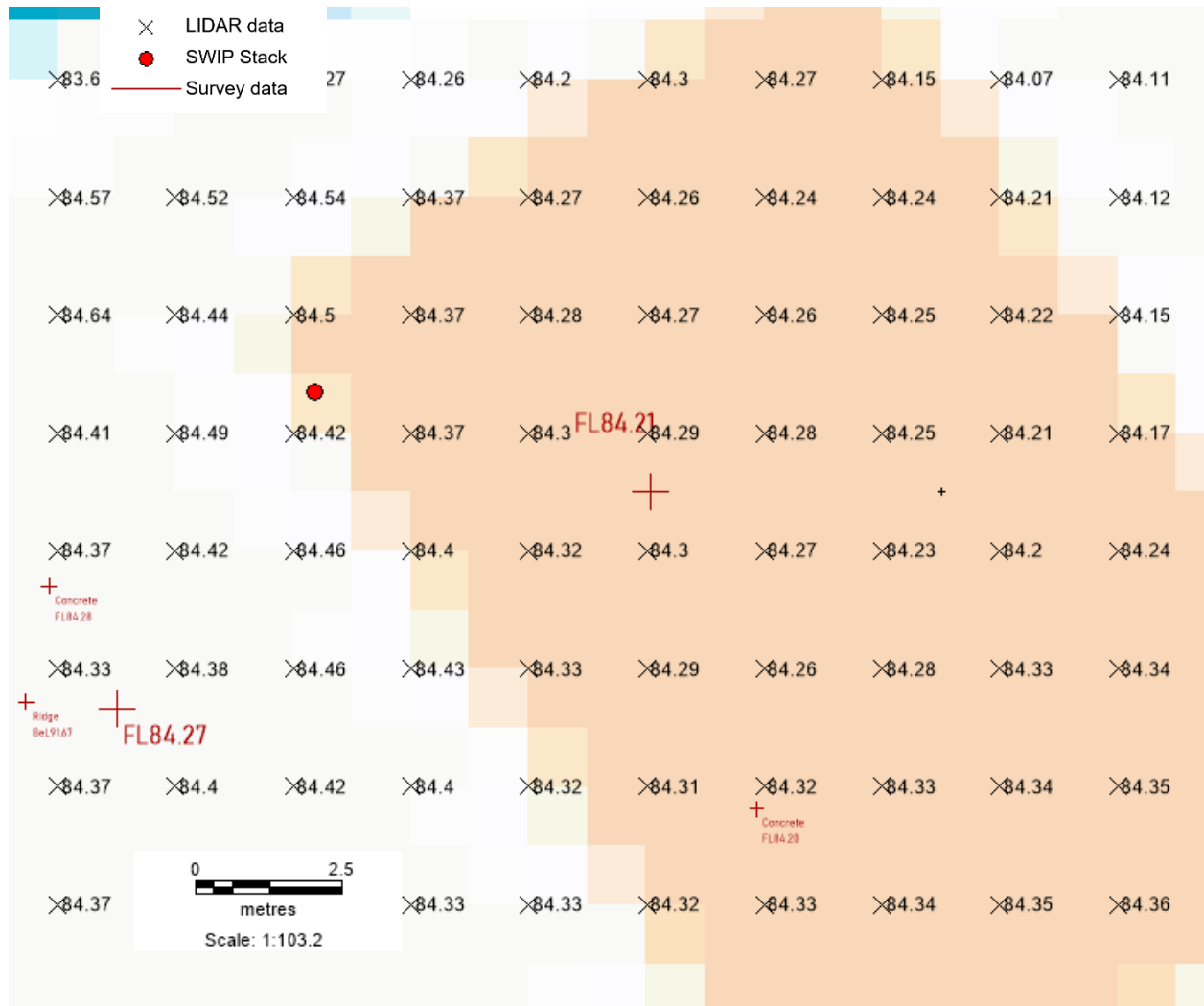
A.36 The presence of elevated terrain can significantly affect (usually increase) ground level concentrations of pollutants emitted from elevated sources such as stacks, by reducing the distance between the plume centre line and ground level and by increasing turbulence and, hence, plume mixing. A complex 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

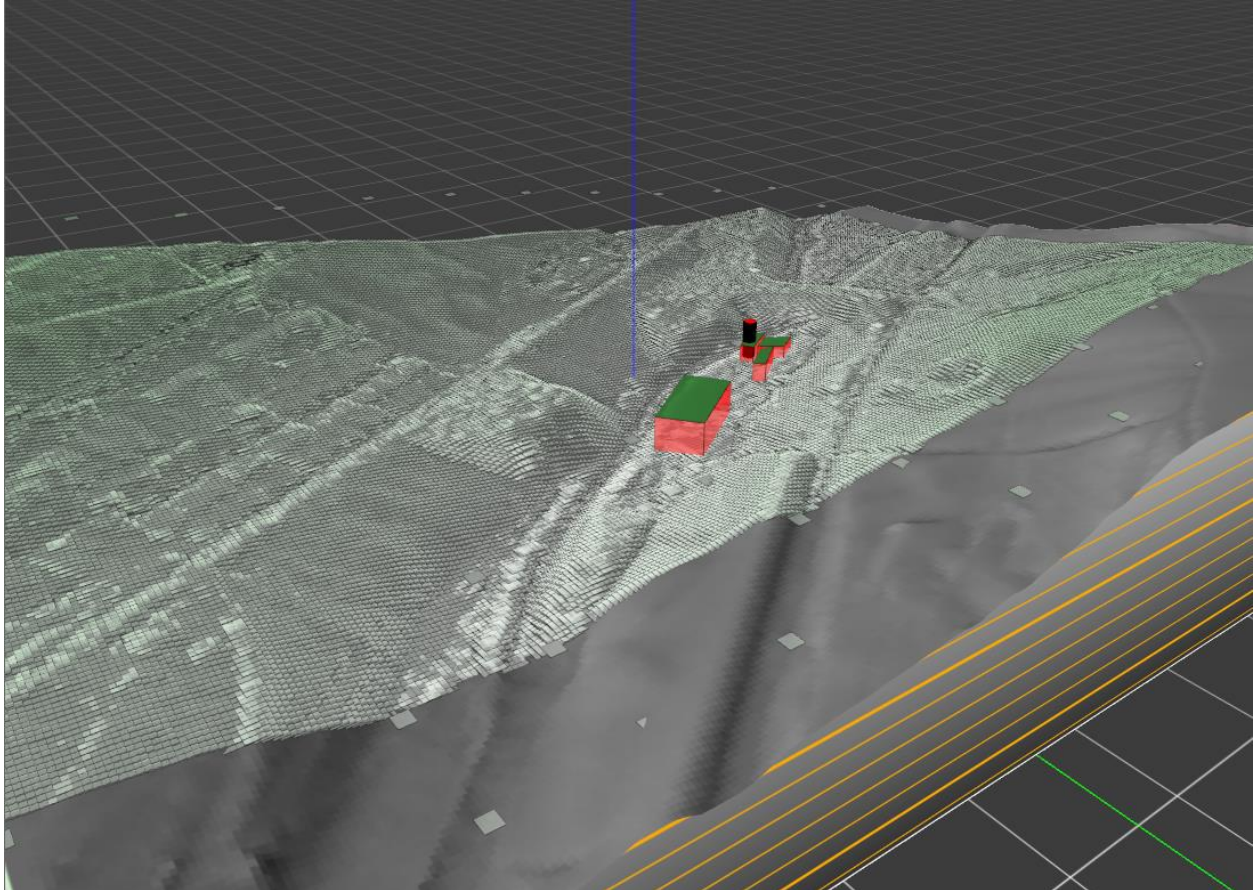


A.37 Figure 3.3 below shows the LIDAR data values and topographical survey values closest to the SWIP stack. This figure shows close agreement between the LIDAR data and the surveyed data. The LIDAR data value closest to the SWIP stack is 84.42 m AOD. This indicates that the stack height would be approximately 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.

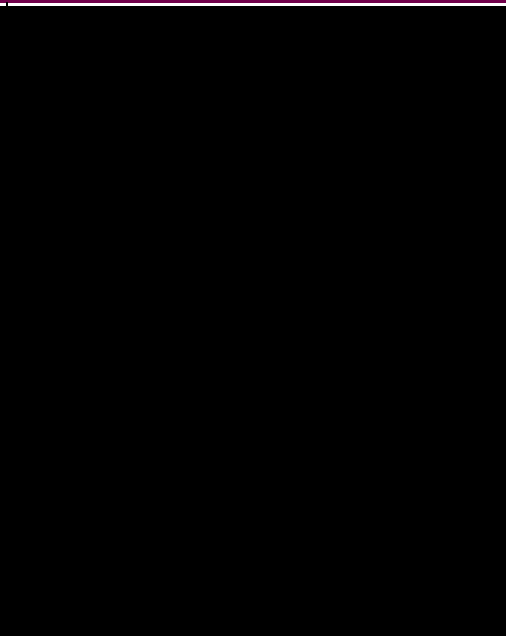
Table 3.3 Dimensions of Buildings Included Within the Dispersion Model

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		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

- ## Planning Significance Criteria for Development Impacts on the Local Area

- www.rpsgroup.com

"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/>)
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- 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





**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

████████████████████

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 ██████████ 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 from 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*

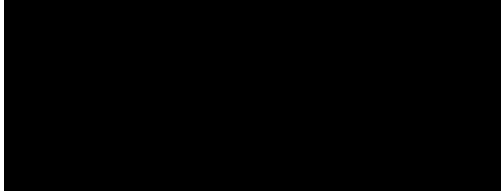
☐

Criminal case NOT suitable for hearing by a Single Judge*

☐

[*Tick if applicable]

Directions as to venue, if applicable:



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

**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 PM₁₀),
ozone, nitrogen dioxide, sulfur dioxide
and carbon monoxide



World Health
Organization

WHO global air quality guidelines

Particulate matter (PM_{2.5} and PM₁₀),
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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

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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 Gherzi, 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).

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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.

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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
<i>Global update 2005</i>	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
NO₂	nitrogen dioxide
O₃	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
PM₁₀	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
SO₂	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 (O₃), nitrogen dioxide (NO₂) and sulfur dioxide (SO₂). *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 $\leq 2.5 \mu\text{m}$) and PM₁₀ (particles with an aerodynamic diameter of $\leq 10 \mu\text{m}$).

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}, PM₁₀, 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}, PM₁₀, 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/m ³	Annual	35	25	15	10	5
	24-hour ^a	75	50	37.5	25	15
PM ₁₀ , µg/m ³	Annual	70	50	30	20	15
	24-hour ^a	150	100	75	50	45
O ₃ , µg/m ³	Peak season ^b	100	70	–	–	60
	8-hour ^a	160	120	–	–	100
NO ₂ , µg/m ³	Annual	40	30	20	–	10
	24-hour ^a	120	50	–	–	25
SO ₂ , µg/m ³	24-hour ^a	125	50	–	–	40
CO, mg/m ³	24-hour ^a	7	–	–	–	4

^a 99th percentile (i.e. 3–4 exceedance days per year).

^b Average of daily maximum 8-hour mean O₃ concentration in the six consecutive months with the highest six-month running-average O₃ 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/m ³	1-hour	200
SO ₂ , µg/m ³	10-minute	500
CO, mg/m ³	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	<ol style="list-style-type: none">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	<ol style="list-style-type: none">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/cm³ (24-hour mean). High PNC can be considered $> 10\,000$ particles/cm³ (24-hour mean) or $20\,000$ particles/cm³ (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	<ol style="list-style-type: none">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 PM₁₀, i.e. particles with an aerodynamic diameter of equal to or less than 10 µm). However, other commonly measured air pollutants such as ozone (O₃), nitrogen dioxide (NO₂), sulfur dioxide (SO₂) 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}, PM₁₀, 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 $\leq 0.1 \mu\text{m}$; 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 PM₁₀ 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/m³. 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 or 10 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/m³ 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/m³, mostly in small island nations, to 120–140 µg/m³ 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/m³. 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}, PM₁₀ and UFP), gaseous pollutants (including ammonia (NH₃), 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 PM₁₀ 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}, PM₁₀ 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 PM₁₀ 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 PM₁₀, 21% and 46% met the air quality guidelines, respectively. In contrast, only seven countries (2%) adopted the WHO annual mean air quality guidelines for PM₁₀ 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}, PM₁₀, 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 PM₁₀, 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) mortality⁴ (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 caused 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 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	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
		PM₁₀
• 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 <i>Global update 2005</i>	Health outcomes selected for updating in the 2021 air quality guidelines	Justification for health outcome selection
O ₃	No long-term guideline provided	<ul style="list-style-type: none">• All-cause mortality• Respiratory mortality	<p>CAUSALITY DETERMINATION (REFERENCE)</p> <ul style="list-style-type: none">• Suggestive causality for mortality (US EPA, 2013)• Suggestive causality for respiratory mortality (Health Canada, 2013) <p>SUPPORTING CONSIDERATIONS</p> <ul style="list-style-type: none">• 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) <p>OTHER RELEVANT CAUSAL DETERMINATIONS (REFERENCE)</p> <ul style="list-style-type: none">• 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 <i>Global update 2005</i>	Health outcomes selected for updating in the 2021 air quality guidelines	Justification for health outcome selection
NO ₂	Respiratory effects in children	<ul style="list-style-type: none">• All-cause mortality• Respiratory mortality	CAUSALITY DETERMINATION (REFERENCE) <ul style="list-style-type: none">• Suggestive causality for total mortality (US EPA, 2016)• Suggestive causality for total mortality (Health Canada, 2016a))
			SUPPORTING CONSIDERATIONS <ul style="list-style-type: none">• 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) <ul style="list-style-type: none">• 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 <i>Global update 2005</i>	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 <i>Global update 2005</i>	Health outcomes selected for updating in the 2021 air quality guidelines
PM _{2.5} and PM ₁₀ (contd)		Justification for health outcome selection
		PM (any size fraction) <ul style="list-style-type: none">• Causal for all-cause mortality (Health Canada, 2013)
		SUPPORTING CONSIDERATIONS <ul style="list-style-type: none">• Cardiovascular and respiratory mortality also considered in causal determination of respiratory/cardiovascular effects (US EPA, 2009) (see other relevant causal determinations)• PM₁₀, supported by evidence from PM_{2.5}
		OTHER RELEVANT CAUSAL DETERMINATIONS (PM_{2.5}) (REFERENCE) <ul style="list-style-type: none">• 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 <i>Global update 2005</i>	Health outcomes selected for updating in the 2021 air quality guidelines	Justification for health outcome selection
O ₃	Daily mortality	<ul style="list-style-type: none">• Hospital admissions and emergency room visits related to asthma• All-cause mortality	<p>CAUSALITY DETERMINATION (REFERENCE)</p> <ul style="list-style-type: none">• 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) <p>SUPPORTING CONSIDERATIONS</p> <ul style="list-style-type: none">• 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 O₃ in young healthy adults. Equally strong evidence demonstrates associations of ambient O₃ 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 <i>Global update 2005</i>	Health outcomes selected for updating in the 2021 air quality guidelines
		Justification for health outcome selection
O ₃		<ul style="list-style-type: none">• 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
(contd)		
		OTHER RELEVANT CAUSAL DETERMINATIONS (REFERENCE) <ul style="list-style-type: none">• 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 <i>Global update 2005</i>	Health outcomes selected for updating in the 2021 air quality guidelines
NO ₂		Justification for health outcome selection
	Bronchial responsiveness in asthmatics	<p>CAUSALITY DETERMINATION (REFERENCE)</p> <ul style="list-style-type: none">• 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) <p>SUPPORTING CONSIDERATIONS</p> <ul style="list-style-type: none">• 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 <i>Global update 2005</i>	Health outcomes selected for updating in the 2021 air quality guidelines	Justification for health outcome selection
NO ₂ (contd)			<ul style="list-style-type: none">• Strongest evidence for relationships of short-term NO₂ exposure with respiratory effects is for asthma exacerbations. More uncertainty exists with independent effect of short-term NO₂ 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 NO₂ 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 <i>Global update 2005</i>	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	<ul style="list-style-type: none">• Hospital admissions and emergency room visits related to asthma	CAUSALITY DETERMINATION (REFERENCE) <ul style="list-style-type: none">• Causal for respiratory effects (US EPA, 2015)• Causal in adults for respiratory effects (Health Canada, 2016b) SUPPORTING CONSIDERATIONS <ul style="list-style-type: none">• Experimental studies demonstrate lung function decrements and respiratory symptoms at very short-term exposures (i.e. 5–10 minutes) to SO₂ 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 short-term SO₂ exposures, particularly for children
		<ul style="list-style-type: none">• All-cause mortality^d	
		<ul style="list-style-type: none">• Respiratory mortality^d	

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 SO₂-all-cause mortality and SO₂-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 SO₂ 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 SO₂ 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 $\mu\text{g}/\text{m}^3$ 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 $\mu\text{g}/\text{m}^3$ of short-term exposure (in the order of hours to days) to ambient 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 NO₂ and O₃ and all-cause and respiratory mortality: a systematic review and meta-analysis (Huangfu & Atkinson, 2020).
- Short-term exposure to particulate matter (PM₁₀ and PM_{2.5}), nitrogen dioxide (NO₂), and ozone (O₃) and all-cause and cause-specific mortality: systematic review and meta-analysis (Orellano et al., 2020).

- Short-term exposure to sulfur dioxide (SO₂) 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	<ul style="list-style-type: none"> 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) 	<ul style="list-style-type: none"> Exposure to the pollutant of interest in occupational settings or as a result of indoor exposure exclusively
Exposure	<ul style="list-style-type: none"> Long-term exposure (in the order of months to years) to ambient air PM_{2.5}, PM₁₀, O₃ and NO₂ expressed in a concentration unit (µg/m³, ppb) For the NO₂ systematic review, NO_x studies may be included 	<ul style="list-style-type: none"> Less than 1 year of data available No exclusion criteria applied based on adjustment for co-pollutants
Comparator	<ul style="list-style-type: none"> Exposure to lowest levels of the air pollutant of interest in the same or a control population 	–
Outcome	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> Human epidemiological studies such as: <ul style="list-style-type: none"> 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. 	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> 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) 	<ul style="list-style-type: none"> Exposure to the pollutant of interest in occupational settings or as a result of indoor exposure exclusively
Exposure	<ul style="list-style-type: none"> Short-term exposure (in the order of hours to 7 days) to ambient air PM_{2.5}, PM₁₀, O₃, NO₂, SO₂ and CO, from any source expressed in a concentration unit (µg/m³, ppb) For NO₂ systematic review, NO_x studies may be included 	<ul style="list-style-type: none"> No exclusion criteria were applied based on adjustment for co-pollutants
Comparator	<ul style="list-style-type: none"> Exposure to lowest levels of the air pollutant of interest in the same or a control population 	–
Outcome	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> Human epidemiological studies such as: <ul style="list-style-type: none"> 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 	<ul style="list-style-type: none"> 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}, PM₁₀, ozone, nitrogen dioxide). In addition, cardiovascular and lung cancer mortality are considered for some pollutants (PM_{2.5}, PM₁₀).

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}, PM₁₀, 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}, PM₁₀, ozone and

nitrogen dioxide. It is also the case for cause-specific mortality and PM_{2.5} and PM₁₀. 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. Gasparri, 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 PM₁₀ 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 PM₁₀, 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 PM₁₀, 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 PM₁₀ 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}, PM₁₀, 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}, PM₁₀, 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}, PM₁₀, 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 ($\text{PM}_{2.5}$) or 10 μm (PM_{10}).

3.2.2 Recommended AQG level for long-term exposure to $\text{PM}_{2.5}$

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 $\text{PM}_{2.5}$ 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 $\text{PM}_{2.5}$ 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 $\mu\text{g}/\text{m}^3$ $\text{PM}_{2.5}$, 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 $\mu\text{g}/\text{m}^3$ (Pinault et al., 2016), 3.2 $\mu\text{g}/\text{m}^3$ (Cakmak et al., 2018), 3.5 $\mu\text{g}/\text{m}^3$ (Pinault et al., 2017), 4.8 $\mu\text{g}/\text{m}^3$ (Villeneuve et al., 2015) and 6.7 $\mu\text{g}/\text{m}^3$ (Weichenthal et al., 2014). Weichenthal et al. (2014) found no effect. The Villeneuve et al. (2015) study provided no evidence of an effect of $\text{PM}_{2.5}$ on all non-accidental mortality below 8 $\mu\text{g}/\text{m}^3$. The study by Di et al. (2017a) has the next lowest 5th percentile (7.1 $\mu\text{g}/\text{m}^3$) and the study by Hart et al. (2015) the next lowest (7.8 $\mu\text{g}/\text{m}^3$). The average $\text{PM}_{2.5}$ level across these five studies with the lowest exposure measurements in the systematic review is 4.2 $\mu\text{g}/\text{m}^3$. A sensitivity analysis disregarding the Villeneuve et al. (2015) and Weichenthal et al. (2014) studies produced a mean of 4.9 $\mu\text{g}/\text{m}^3$ $\text{PM}_{2.5}$. 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 $\mu\text{g}/\text{m}^3$ $\text{PM}_{2.5}$). The data obtained support a long-term AQG level of no more than 5 $\mu\text{g}/\text{m}^3$, based on the association between long-term $\text{PM}_{2.5}$ 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 $\text{PM}_{2.5}$ 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 $\text{PM}_{2.5}$ 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 $\mu\text{g}/\text{m}^3$ based on the five studies with the lowest 5th percentiles and 4.1–6.2 $\mu\text{g}/\text{m}^3$ 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 $\text{PM}_{2.5}$ AQG level of no more than 5 $\mu\text{g}/\text{m}^3$.

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 $\text{PM}_{2.5}$ 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 $\text{PM}_{2.5}$ and all-cause mortality, defined as mortality from NCD plus lower respiratory illness, over a range of 2.4–80 $\mu\text{g}/\text{m}^3$ (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/m ³)
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/m ³)	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/m ³)	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/m ³)	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/m ³)	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);

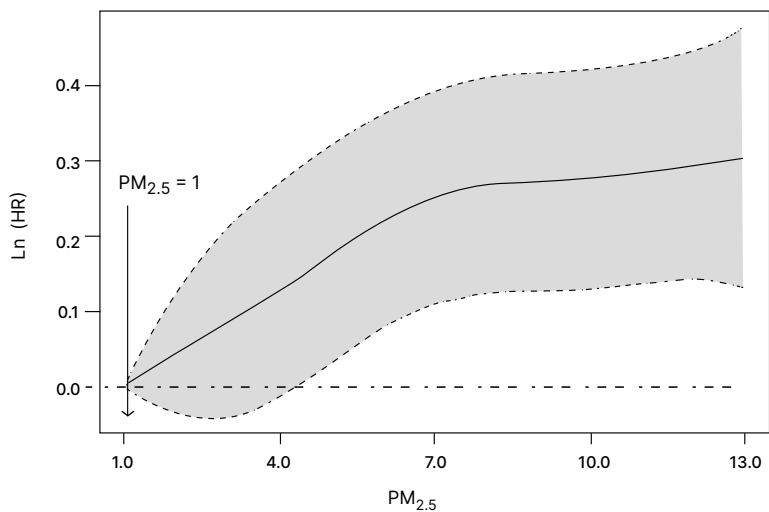
P25: 25th percentile; SD: standard deviation.

^a Per 10 µg/m³.

^b Reported in paper or by authors on request.

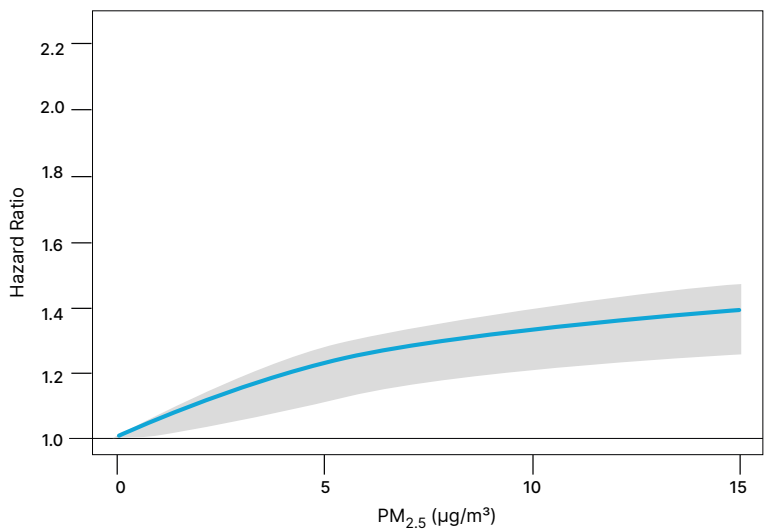
^c Calculated from mean and standard deviation using the following formula: Me(di)an – 1.645 × SD.

Fig. 3.1. CRF for long-term PM_{2.5} exposure (µg/m³) and all non-accidental mortality



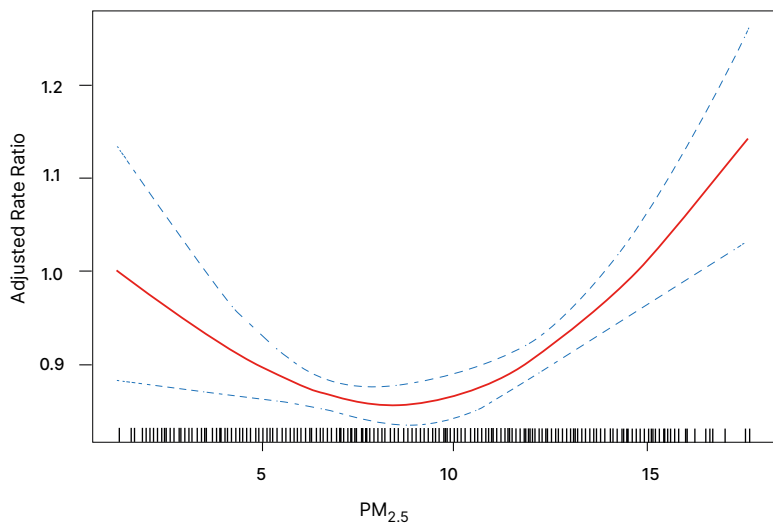
Ln (HR): log HR, with an HR of 1 at a PM_{2.5} concentration of 1 µg/m³.
Source: Pinault et al. (2016).

Fig. 3.2. CRF for long-term PM_{2.5} exposure (µg/m³) and all non-accidental mortality



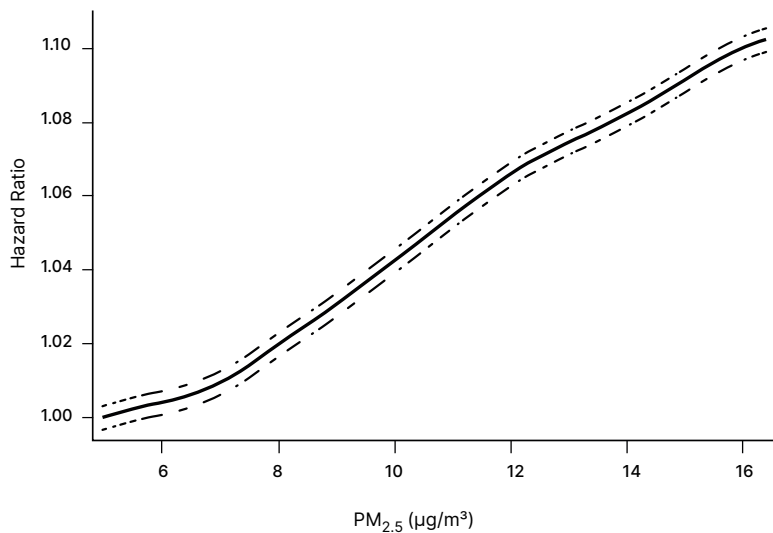
Source: reprinted from Pinault et al. (2017) with permission from Elsevier.

Fig. 3.3. CRF for long-term PM_{2.5} exposure (µg/m³) and all non-accidental mortality



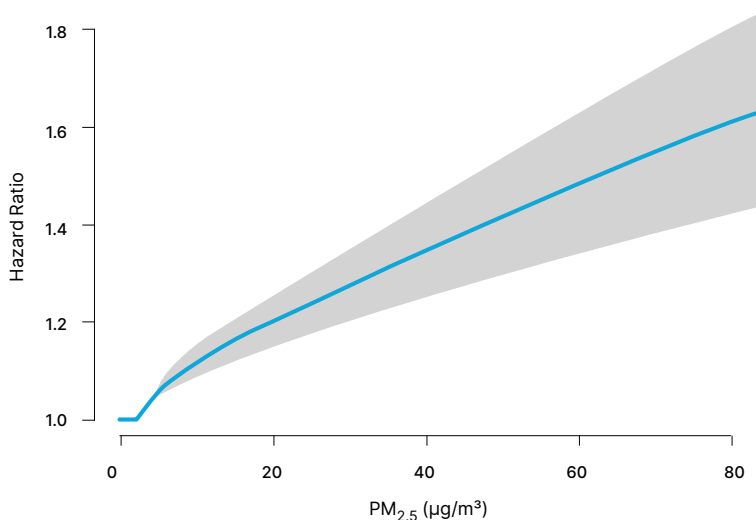
Source: reprinted from Villeneuve et al. (2015) with permission from the publisher. Copyright © 2015 Wolters Kluwer Health, Inc. All rights reserved.

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 $\mu\text{g}/\text{m}^3$, based on the association between short-term $\text{PM}_{2.5}$ 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 $\text{PM}_{2.5}$ compared with the RR for all-cause mortality, with RRs of 1.0092 (95% CI: 1.0061–1.0123) per 10 $\mu\text{g}/\text{m}^3$ 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 $\mu\text{g}/\text{m}^3$, the estimated excess mortality on such a day would be 0.72–0.92% for $\text{PM}_{2.5}$. 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 $\mu\text{g}/\text{m}^3$ for $\text{PM}_{2.5}$.

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](#).

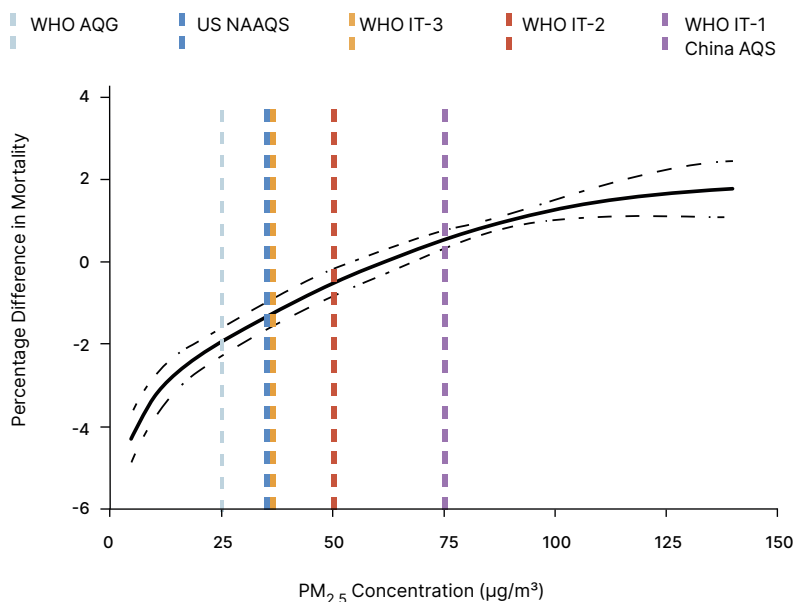
Table 3.6. Recommended short-term (24-hour) AQG level and interim targets for PM_{2.5}^a

Recommendation	PM _{2.5} (µg/m ³)
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 PM₁₀

3.3.1 Recommended AQG level for long-term exposure to PM₁₀

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 PM₁₀ 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 PM₁₀ 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 PM₁₀, 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 PM₁₀ 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 PM₁₀.

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 PM₁₀ 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 PM₁₀ 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, PM₁₀ 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 PM₁₀ (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 PM₁₀ 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 PM₁₀ 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 PM₁₀ 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 PM₁₀ AQG level of 15 µg/m³. This is based on an evaluation of the studies on the long-term effects of PM₁₀ on mortality only, without taking into consideration that a large proportion of PM₁₀ is made up of PM_{2.5}. As in most situations PM_{2.5} is about 50–80% of PM₁₀ by weight, the annual PM₁₀ 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 PM₁₀ 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 PM₁₀

Recommendation	PM ₁₀ (µg/m ³)
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 PM₁₀ at the AQG level were arbitrarily set at 100, then it will be 122, 114, 106 and 102, respectively, in populations exposed to PM₁₀ 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 PM₁₀ 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 PM₁₀ 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/m ³)	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.

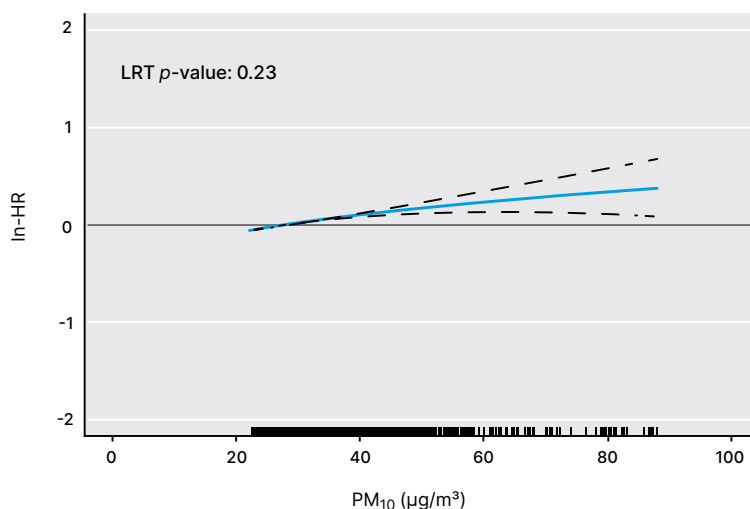
^a Per 10 µg/m³.

^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 ($\mu\text{g}/\text{m}^3$)



In: 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 PM₁₀ 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 PM₁₀, 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 PM₁₀. 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 PM₁₀ 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 PM₁₀ concentration of 45 µg/m³ compared with a day with a PM₁₀ 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 PM₁₀ 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 PM₁₀ 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 PM₁₀.

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) PM₁₀ 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 PM₁₀^a

Recommendation	PM ₁₀ (µg/m ³)
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 PM₁₀ at the AQG level is arbitrarily set at 100, then it will be 104, 102, 101 and 100.2, respectively, in populations exposed to PM₁₀ 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 PM₁₀ 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 (O₃) 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 (NO₂) 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 $\mu\text{g}/\text{m}^3$ (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 $\mu\text{g}/\text{m}^3$ (Weichenthal, Pinault & Burnett, 2017), 56 $\mu\text{g}/\text{m}^3$ (Cakmak et al., 2018) and 68 $\mu\text{g}/\text{m}^3$ (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 $\mu\text{g}/\text{m}^3$ (Lipsett et al., 2011). The average of the three lowest 5th percentile values is either approximately 60 or 64 $\mu\text{g}/\text{m}^3$ (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 $\mu\text{g}/\text{m}^3$ ozone, based on the average concentrations of either 60 $\mu\text{g}/\text{m}^3$ or 64 $\mu\text{g}/\text{m}^3$. The data obtained support a long-term, peak-season AQG level of no more than 60 $\mu\text{g}/\text{m}^3$, 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 $\mu\text{g}/\text{m}^3$. 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 $\mu\text{g}/\text{m}^3$ 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 $\mu\text{g}/\text{m}^3$ 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 $\mu\text{g}/\text{m}^3$) (EEA, 2020).

The recommendation is a peak season ozone AQG level of 60 $\mu\text{g}/\text{m}^3$ (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 $\mu\text{g}/\text{m}^3$ and an interim target 2 of 70 $\mu\text{g}/\text{m}^3$ 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- $\mu\text{g}/\text{m}^3$ 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 ($\mu\text{g}/\text{m}^3$)
Interim target 1	100
Interim target 2	70
AQG level	60

^a Average of daily maximum 8-hour mean O₃ concentration in the six consecutive months with the highest six-month running-average O₃ 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 ($\mu\text{g}/\text{m}^3$)	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 $\mu\text{g}/\text{m}^3$.

^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 ($\mu\text{g}/\text{m}^3$)	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 $\mu\text{g}/\text{m}^3$.

^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 ($\mu\text{g}/\text{m}^3$)	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 $\mu\text{g}/\text{m}^3$.

^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

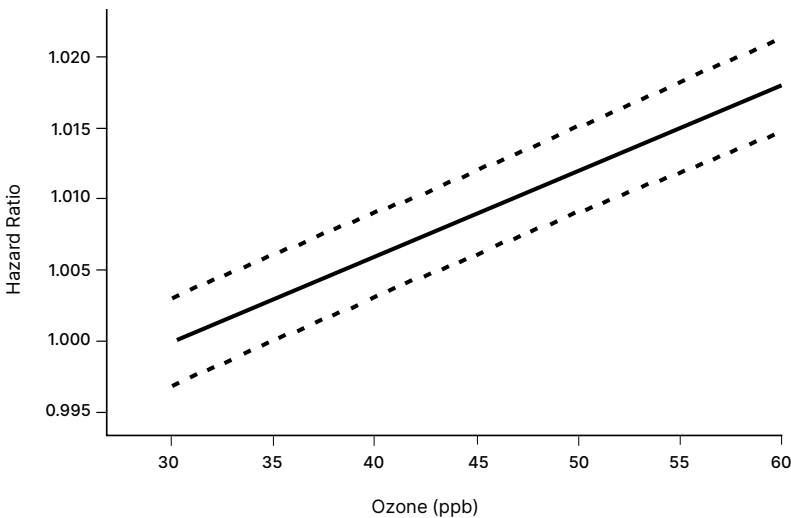
Study	Me(di)an ($\mu\text{g}/\text{m}^3$)	SD	P5	P25	HR (95% CI) ^a
Lim et al. (2019)	92.4	15.2	62.3 ^b	–	1.040 (1.020–1.060)
Kazemiparkouhi et al. (2020)	110.0	–		100.0	1.018 (1.016–1.020)

–, data unavailable; P5: 5th percentile (of the distribution of concentrations assigned to study participants); P25: 25th percentile; SD: standard deviation.

^a Per 10 $\mu\text{g}/\text{m}^3$.

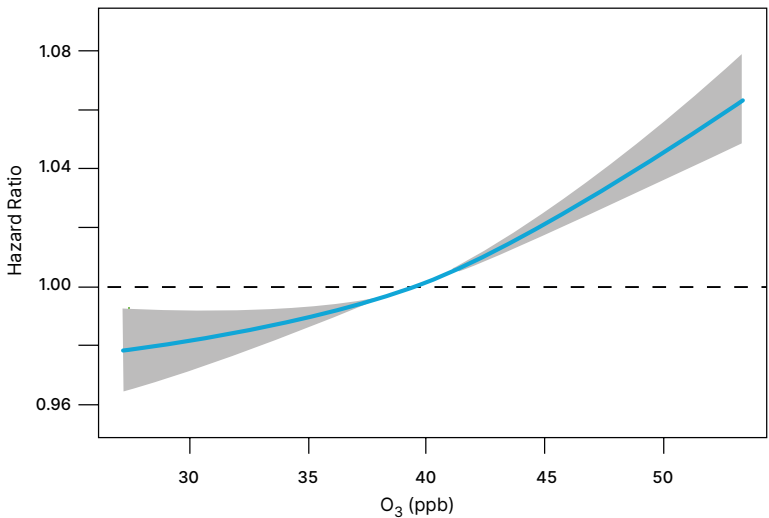
^b Reported in paper or by authors on request.

Fig. 3.8. Association between peak-season, long-term ozone exposure (ppb) and all non-accidental mortality^a



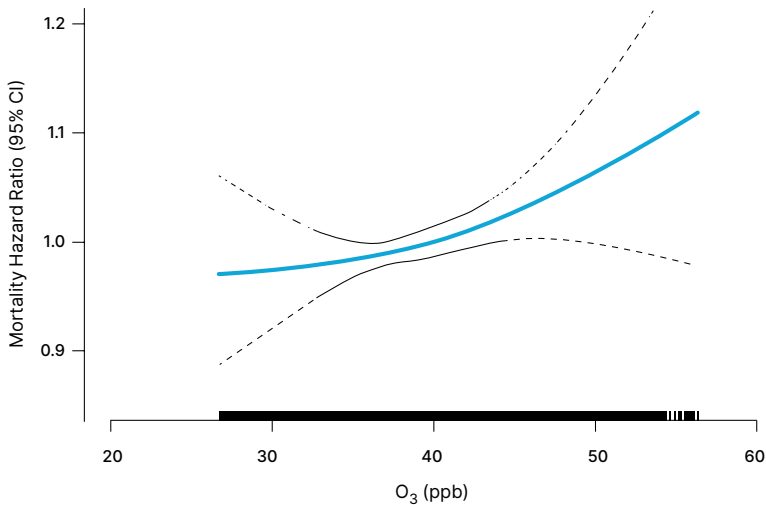
^a Note that the units for ozone are in ppb; these need to be multiplied by 2 to arrive at concentrations expressed in $\mu\text{g}/\text{m}^3$. HR is expressed relative to the 5th percentile of the distribution of ozone concentrations, which was 30 ppb. Source: reprinted from Di et al. (2017a) with 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 $\mu\text{g}/\text{m}^3$. 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 $\mu\text{g}/\text{m}^3$. 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. Copyright © 2019 American Thoracic Society. All rights reserved. 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 $10 \mu\text{g}/\text{m}^3$ 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 $100 \mu\text{g}/\text{m}^3$ 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 $60 \mu\text{g}/\text{m}^3$ 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 $76.4 \mu\text{g}/\text{m}^3$ and a warm-season mean of $94.2 \mu\text{g}/\text{m}^3$ (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 $60 \mu\text{g}/\text{m}^3$ corresponds to an annual mean of $48.7 \mu\text{g}/\text{m}^3$. Calculating the short-term AQG level using a ratio of 2 between the 99th percentile and annual mean produced a value of $120 \mu\text{g}/\text{m}^3$, and dividing that number by the 1.24 ratio of the peak (warm) season to annual average concentrations produced a value of $97 \mu\text{g}/\text{m}^3$, which was rounded up to a proposed short-term AQG level of $100 \mu\text{g}/\text{m}^3$.

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 $100 \mu\text{g}/\text{m}^3$ compared with a day with an 8-hour maximum ozone concentration of $60 \mu\text{g}/\text{m}^3$. With an RR for all-cause mortality of 1.0043 per $10 \mu\text{g}/\text{m}^3$, 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 $100 \mu\text{g}/\text{m}^3$ 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 $\mu\text{g}/\text{m}^3$, 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 $\text{RR} = 1.012$ (95% CI: 1.008–1.016) per 10 $\mu\text{g}/\text{m}^3$, which would produce an excess morbidity of 4.8% for a day at the proposed short-term AQG level of 100 $\mu\text{g}/\text{m}^3$ compared with a day at the proposed long-term AQG level of 60 $\mu\text{g}/\text{m}^3$. 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 $\text{RR} = 1.0018$ (95% CI: 1.0012–1.0024) per 10 $\mu\text{g}/\text{m}^3$, 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](#).

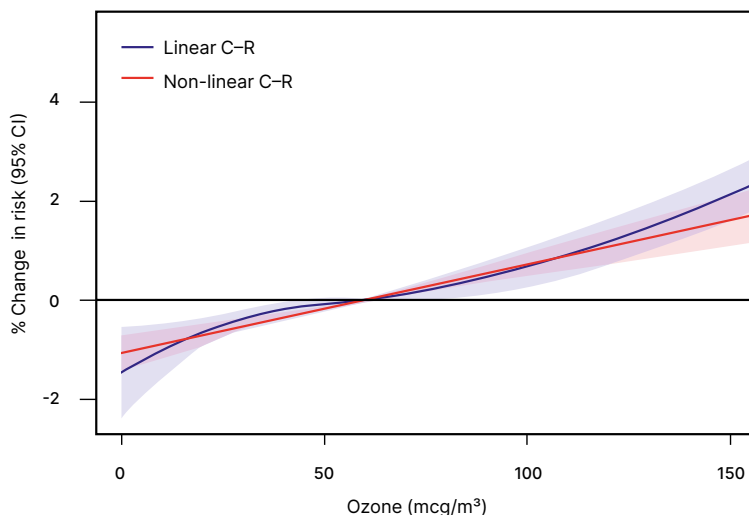
Table 3.15. Recommended short-term (8-hour) daily maximum AQG level and interim targets for ozone^a

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 ($\mu\text{g}/\text{m}^3$) and all-cause mortality^a



C-R: concentration–response.

^a The change in risk is expressed relative to a mean ozone concentration of about $60 \mu\text{g}/\text{m}^3$.

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 PM₁₀ 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 $-2.7 \mu\text{g}/\text{m}^3$ (Yorifuji et al., 2013) and $4.0 \mu\text{g}/\text{m}^3$ (Bentayeb et al., 2015) (both estimated) and $6.3 \mu\text{g}/\text{m}^3$ (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 $7.3 \mu\text{g}/\text{m}^3$ (Tonne & Wilkinson, 2013), $8.3 \mu\text{g}/\text{m}^3$ in two separate studies (Hart et al., 2011, 2013), $9.6 \mu\text{g}/\text{m}^3$ (Turner et al., 2016) and $10.3 \mu\text{g}/\text{m}^3$ (Carey et al., 2013). The average of these five 5th percentile values was $8.8 \mu\text{g}/\text{m}^3$; 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: $8.8 \mu\text{g}/\text{m}^3$ nitrogen dioxide. The data obtained support a long-term AQG level of no more than $10 \mu\text{g}/\text{m}^3$, 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 (Klompmaaker 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-term 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/m³ 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 ($\mu\text{g}/\text{m}^3$)	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 $\mu\text{g}/\text{m}^3$.

^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 ($\mu\text{g}/\text{m}^3$)	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 $\mu\text{g}/\text{m}^3$.

^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 ($\mu\text{g}/\text{m}^3$)	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)
Klompaker 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 $\mu\text{g}/\text{m}^3$.

^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

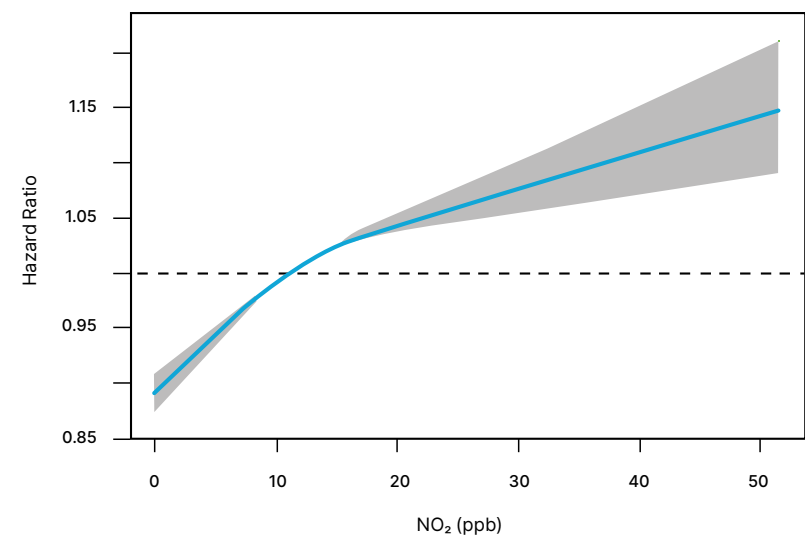
Study	Me(di)an ($\mu\text{g}/\text{m}^3$)	SD	P5	P25	HR (95% CI) ^a
Klompaker et al. (2020)	23.1	–	–	19.3	0.980 (0.890–1.070)
Hvidtfeldt et al. (2019)	25.0	–	17.9 ^b	–	1.030 (0.970–1.100)
Eum et al. (2019)	26.7	–	–	18.2	1.027 (1.023–1.030)

–, data unavailable; P5: 5th percentile (of the distribution of concentrations assigned to study participants); P25: 25th percentile; SD: standard deviation.

^a Per 10 $\mu\text{g}/\text{m}^3$.

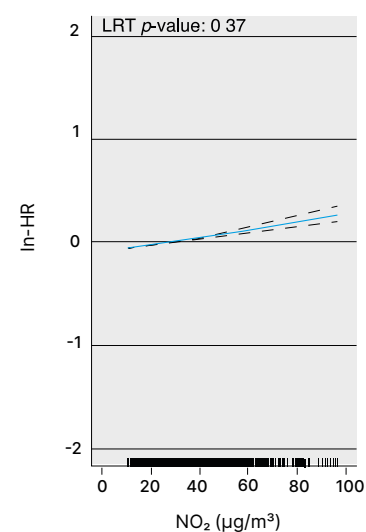
^b Reported in paper or by authors on request.

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 as 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 $10 \mu\text{g}/\text{m}^3$ 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](#)) (Moshhammer 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 $10 \mu\text{g}/\text{m}^3$ 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 $\mu\text{g}/\text{m}^3$ 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 $\mu\text{g}/\text{m}^3$ compared with a day with a 24-hour nitrogen dioxide concentration of 10 $\mu\text{g}/\text{m}^3$. With an RR for all-cause mortality of 1.0072 per 10 $\mu\text{g}/\text{m}^3$, 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 $\mu\text{g}/\text{m}^3$ 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 $\mu\text{g}/\text{m}^3$, 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 $\mu\text{g}/\text{m}^3$, which would produce an excess morbidity 2.1% on a day at the proposed short-term AQG level of 25 $\mu\text{g}/\text{m}^3$ compared with a day at the proposed long-term AQG level of 10 $\mu\text{g}/\text{m}^3$. As is the case when considering mortality in step 3, under compliance with the long-term AQG level, days with concentrations close to 25 $\mu\text{g}/\text{m}^3$ 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 make 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 et 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.

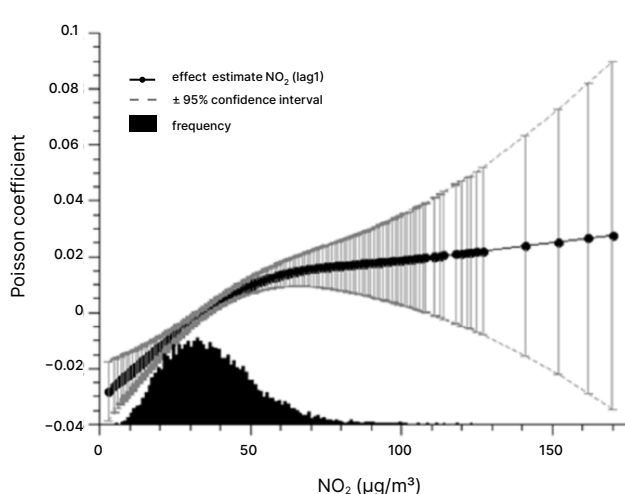
Table 3.21. Recommended short-term (24-hour) AQG level and interim targets for nitrogen dioxide^a

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 ($\mu\text{g}/\text{m}^3$) 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 $10 \mu\text{g}/\text{m}^3$.

Source: Moshhammer 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 (SO₃) 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 (NH₄HSO₄), 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/m³ and 1 mg/m³ = 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 $10 \mu\text{g}/\text{m}^3$ 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 $10 \mu\text{g}/\text{m}^3$ 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 $10 \mu\text{g}/\text{m}^3$ 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 $1 \mu\text{g}/\text{m}^3$. 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 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 $0 \mu\text{g}/\text{m}^3$. With an RR of 1.010 per $10 \mu\text{g}/\text{m}^3$, any $10\text{-}\mu\text{g}/\text{m}^3$ 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 $10 \mu\text{g}/\text{m}^3$.

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 $\text{PM}_{2.5}$, 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 $0 \mu\text{g}/\text{m}^3$ concentration, would be expected at a daily mean of about $30 \mu\text{g}/\text{m}^3$ (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 $40 \mu\text{g}/\text{m}^3$. The rationale is that with a ratio of about 4 between the 99th percentile and annual mean, $40 \mu\text{g}/\text{m}^3$ would correspond to an increase of $30 \mu\text{g}/\text{m}^3$ over an annual mean of $10 \mu\text{g}/\text{m}^3$, 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 $10 \mu\text{g}/\text{m}^3$ 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 $\mu\text{g}/\text{m}^3$, 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 $\mu\text{g}/\text{m}^3$ and an interim target 2 of 50 $\mu\text{g}/\text{m}^3$ 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 $\mu\text{g}/\text{m}^3$ 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- $\mu\text{g}/\text{m}^3$ 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/m ³)
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 detectable 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. Gasparri, 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}, PM₁₀, 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/m ³)
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				AQG level
		1	2	3	4	
PM _{2.5} , µg/m ³	Annual	35	25	15	10	5
	24-hour ^a	75	50	37.5	25	15
PM ₁₀ , µg/m ³	Annual	70	50	30	20	15
	24-hour ^a	150	100	75	50	45
O ₃ , µg/m ³	Peak season ^b	100	70	–	–	60
	8-hour ^a	160	120	–	–	100
NO ₂ , µg/m ³	Annual	40	30	20	–	10
	24-hour ^a	120	50	–	–	25
SO ₂ , µg/m ³	24-hour ^a	125	50	–	–	40
CO, mg/m ³	24-hour ^a	7	–	–	–	4

^a 99th percentile (i.e. 3–4 exceedance days per year).

^b Average of daily maximum 8-hour mean O₃ concentration in the six consecutive months with the highest six-month running-average O₃ 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/m ³	1-hour	200
SO ₂ , µg/m ³	10-minute	500
CO, mg/m ³	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
PM₁₀, µg/m³	Annual	20	15
	24-hour ^a	50	45
O₃, µg/m³	Peak season ^b	–	60
	8-hour ^a	100	100
NO₂, µg/m³	Annual	40	10
	24-hour ^a	–	25
SO₂, 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 O₃ concentration in the six consecutive months with the highest six-month running-average O₃ 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 PM₁₀ 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 PM₁₀ was based on studies that had actually measured PM₁₀, without taking into consideration the ratios between PM₁₀ and PM_{2.5}. In 2005 based on empirical data, a PM₁₀ : PM_{2.5} ratio of 2 was used to establish the PM₁₀ AQG levels. The GDG notes that the empirical PM₁₀ : PM_{2.5} ratios have not changed, but the method used to derive the AQG levels has changed. The resulting PM₁₀ annual AQG level is less protective than the PM_{2.5} annual AQG level in most practical circumstances.
4. The 24-hour AQG for PM₁₀ 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 PM₁₀ is not much lower in 2021 than in 2005. The resulting PM₁₀ 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						
<i>n</i> (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						
<i>n</i> (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						
<i>n</i> (UI), in 000s	1 351 (1193–1515)	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						
<i>n</i> (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						
<i>n</i> (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						
<i>n</i> (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						
<i>n</i> (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 $\mu\text{g}/\text{m}^3$ 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 $\text{PM}_{2.5}$ 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 $\text{PM}_{2.5}$ mass concentrations; thus, compliance with $\text{PM}_{2.5}$ 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 $\text{PM}_{2.5}$ 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 $\text{PM}_{2.5}$ mass. Including BC/EC as an indicator of local emission reductions might compensate for the limited ability to influence total $\text{PM}_{2.5}$ 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 $0.2\text{--}0.4\text{ }\mu\text{g}/\text{m}^3$ in rural sites, $1.0\text{--}2.0\text{ }\mu\text{g}/\text{m}^3$ in urban background stations and $1.4\text{--}5.1\text{ }\mu\text{g}/\text{m}^3$ 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 $\text{PM}_{2.5}$. 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 $0.65\text{ }\mu\text{g}/\text{m}^3$ to $3.9\text{ }\mu\text{g}/\text{m}^3$, while for elemental carbon the means generally ranged from $0.47\text{ }\mu\text{g}/\text{m}^3$ to $3.5\text{ }\mu\text{g}/\text{m}^3$ and reached $7.5\text{--}8.8\text{ }\mu\text{g}/\text{m}^3$ 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 $1.08\text{--}1.15\text{ }\mu\text{g}/\text{m}^3$ for black carbon and $0.5\text{--}0.8\text{ }\mu\text{g}/\text{m}^3$ 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 $1\ \mu\text{m}$ 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 (PM₁₀, 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 PM₁₀. 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 PM₁₀ 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 PM₁₀ 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 PM₁₀ 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 PM₁₀ 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 PM₁₀ 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 RBPM₁₀ and RBPM_{2.5} levels without the dust contribution.
- Determine the net dust PM (NDPM) levels in PM₁₀ and PM_{2.5} (NDPM₁₀ and NDPM_{2.5}) for the regional background by subtracting RBPM₁₀ and RBPM_{2.5} from the bulk PM₁₀ and PM_{2.5} levels at the reference regional background-monitoring site.
- At the nearby urban area, NDPM₁₀ 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 NDPM₁₀ and NDPM_{2.5} values from the urban PM₁₀ and PM_{2.5} levels, are the APM loads during the dust days (APM₁₀ 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 PM₁₀ reductions observed in most reviewed studies. PM₁₀ reductions varied within 7–30% of the daily mean PM₁₀ 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; O₃: 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

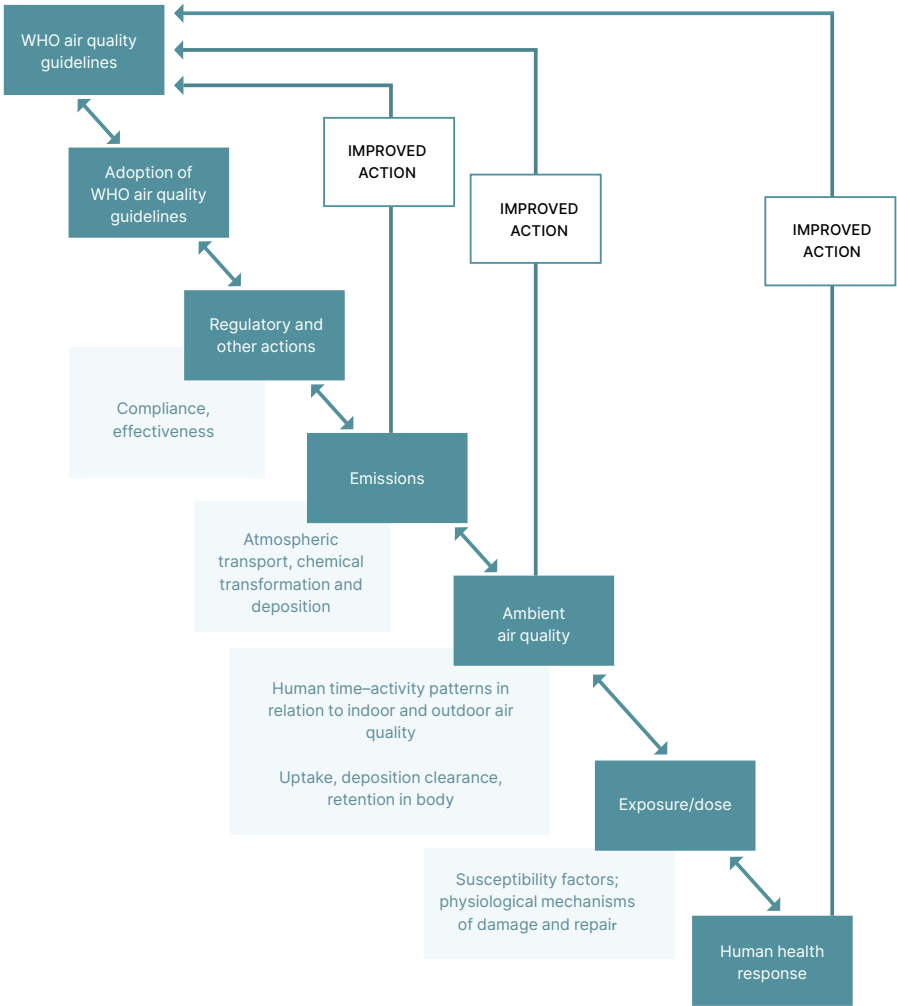
**Monitoring and
evaluation of
the guidelines**

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 from 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 well 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.

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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	Jie Chen	Institute for Risk Assessment Sciences, Utrecht University, Utrecht, the Netherlands
All-cause and cause-specific mortality	Gerard Hoek	Institute for Risk Assessment Sciences, Utrecht University, Utrecht, the Netherlands
Long-term exposure to O ₃ and NO ₂	Richard Atkinson	Population Health Research Institute, St George's, University of London, London, England, the United Kingdom
All-cause and respiratory mortality	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	Ariel Bardach	Institute for Clinical Effectiveness and Health Policy (IECS-CONICET), Buenos Aires, Argentina
All-cause and cause-specific mortality	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	Pablo Orellano	Centre for Research and Technology Transfer San Nicolás, National Technology University (UTN-CONICET), San Nicolás, Argentina
All-cause and respiratory mortality	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 Gherzi	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	Econometrics 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 <i>United States vs Mountain State Carbon, LLC</i>
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 ($\text{PM}_{2.5}$) 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 PM₁₀ (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. PM₁₀ 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 PM₁₀ 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 PM₁₀ 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
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	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	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	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	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 NO₂ and O₃ 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 (O₃) and nitrogen dioxide (NO₂) 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 NO₂ and O₃. 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 NO₂ and 20 for O₃. 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 NO₂ 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 O₃ 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 O₃ 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 NO₂ 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 NO₂ and O₃ for all causes of mortality except for NO₂ and COPD mortality where the certainty of the evidence was judged as high.

Table A3.2. Certainty of evidence profile for NO₂ 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/m ³

Table A3.3. Certainty of evidence profile for NO₂ 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 µg/m ³

Table A3.4. Certainty of evidence profile for NO₂ 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 µg/m ³

Table A3.5. Certainty of evidence profile for NO₂ 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/m ³

Table A3.6. Certainty of evidence profile for O₃ 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/m ³

Table A3.7. Certainty of evidence profile for O₃ 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/m ³

Table A3.8. Certainty of evidence profile for O₃ 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 (<i>n</i> =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/m ³

Table A3.9. Certainty of evidence profile for O₃ 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/m ³

A3.3 Short-term exposure to particulate matter (PM₁₀ and PM_{2.5}), nitrogen dioxide (NO₂), and ozone (O₃) 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 (PM₁₀, PM_{2.5}), nitrogen dioxide (NO₂), and ozone (O₃), on all-cause mortality, and PM₁₀ 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/m³ 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 NO₂, but when considering a 1-hour maximum exposure. We found positive associations between pollutants and all-cause mortality for PM₁₀ (RR: 1.0041; 95% CI: 1.0034-1.0049), PM_{2.5} (RR: 1.0065; 95% CI: 1.0044-1.0086), NO₂ (24-hour average) (RR: 1.0072; 95% CI: 1.0059-1.0085), and O₃ (RR: 1.0043; 95% CI: 1.0034-1.0052). PM₁₀ 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 PM₁₀, PM_{2.5}, NO₂, and O₃ and all-cause mortality, and between PM₁₀ 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 contd

Exposure – outcome	Limitations in studies	Indirectness	Inconsistency	Imprecision	Publication bias	Large effect size	Upgrade			Certainty of evidence
							Downgrade	Confounding	Concentration-response gradient	
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 () , CRF-s, concentration–response functions; (I), 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
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 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 (moderate); CRFs, concentration-response functions; I, 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)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	Moderate ⊗⊗⊗⊗
	No differences between studies with low/moderate versus high RoB	The research question in the studies reflects the original question.	80% prediction interval did not include unity.	Number of mortality cases higher than 100,000.	Publication bias was not detected.	Unmeasured confounding could influence the effect estimate.	Several potential confounders that would shift the RR in both directions.	No significant association detected in the main analysis.	
O ₃ – all-cause mortality	(0)	(0)	(0)	(0)	(0)	(+1)	(0)	(+1)	High ⊗⊗⊗⊗
	No differences between studies with low/moderate versus high RoB	The research question in the studies reflects the original question.	80% prediction interval did not include unity.	Number of mortality cases higher than 100,000.	Publication bias detected, but no difference between multicity and single-city studies was observed.	Unmeasured confounding would not suffice to explain away the effect estimate.	Several potential confounders that would shift the RR in both directions.	Significant positive association detected in the main analysis.	

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 (SO₂) 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 (SO₂) 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 SO₂ 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 SO₂ (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 SO₂ (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 SO₂ (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 SO₂ (24-hour average) – respiratory mortality and SO₂ (1-hour max.) – all-cause mortality, and funnel plot asymmetry

for SO₂ (24-hour average) – all-cause mortality. The certainty of evidence was high in two combinations, i.e. SO₂ (24-hour average) – all-cause mortality and SO₂ (1-hour max.) – respiratory mortality, moderate in one combination, i.e. SO₂ (24-hour average) – respiratory mortality, and low in the remaining one combination.

Conclusions: Positive associations were found between short-term exposure to ambient SO₂ 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	Downgrade			Upgrade			Certainty of evidence
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 multic study showed a clinically meaningful association.	(0) Publication bias possibly detected, but a positive significant association was estimated when using multic study 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 multic 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	Upgrade		Concentration-response gradient	Certainty of evidence
							Downgrade			
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 RR in both not significant directions.	(0) Several potential confounders that would shift the RR in both directions.	(0) The association was not significant.		
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.		

Certainty of evidence, starting from moderate certainty (); 1, 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 (O₃), nitrogen dioxide (NO₂), and sulphur dioxide (SO₂) 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 O₃, NO₂, or SO₂. 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/m³ increase of ambient concentrations was 1.008 (95%CI: 1.005, 1.011) for maximum 8-hour daily or average 24-hour O₃, 1.014 (95%CI: 1.008, 1.020) for average 24-hour NO₂, 1.010 (95%CI: 1.001, 1.020) for 24-hour SO₂, 1.017 (95%CI: 0.973, 1.063) for maximum 1-hour daily O₃, 0.999 (95%CI: 0.966, 1.033) for 1-hour NO₂, and 1.003 (95%CI: 0.992, 1.014) for 1-hour SO₂. Heterogeneity was observed in all pollutants except for 8-hour or 24-hour O₃ and 24-hour NO₂. In general, we found no significant differences between subgroups that can explain this heterogeneity. Sensitivity analysis based on the RoB showed certain differences in NO₂ and SO₂ 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 O₃ and 24-hour NO₂, moderate for 24-hour SO₂, 1-hour O₃, and 1-hour SO₂, and low for 1-hour NO₂.

Conclusion: Short-term exposure to daily O₃, NO₂, and SO₂ 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	Downgrade					Upgrade			Certainty of evidence
	Limitations in studies	Indirectness	Inconsistency	Imprecision	Publication bias	Large effect size	Confounding	Concentration–response gradient	
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)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	Moderate ⊗⊗⊗⊗
	Differences between studies with low/moderate versus high RoB were not evaluated.	The research question in the studies reflects the original question	80% prediction interval included unity, but is not twice the 95%CI	Number of asthma exacerbations higher than 150,000.	Publication bias was not evaluated	E-value was not calculated, because the pooled RR is not significant.	Several potential confounders that would shift the RR in both directions.	No significant association detected in the main analysis.	
NO ₂ (1-h) – ERV or HA	(0)	(0)	(0)	(-1)	(0)	(0)	(0)	(0)	Low ⊗⊗⊗⊗
	No differences between studies with low/moderate versus high RoB.	The research question in the studies reflects the original question	80% prediction interval included unity, but is not twice the 95%CI	Number of asthma exacerbations lower than 150,000.	Publication bias was not evaluated	E-value was not calculated, because the pooled RR is not significant.	Several potential confounders that would shift the RR in both directions.	No significant association detected in the main analysis.	
SO ₂ (1-h) – ERV or HA	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	Moderate ⊗⊗⊗⊗
	Differences between studies with low/moderate versus high RoB were not evaluated.	The research question in the studies reflects the original question	80% prediction interval included unity, but is not twice the 95%CI	Number of asthma exacerbations higher than 150,000.	Publication bias was not evaluated	E-value was not calculated, because the pooled RR is not significant.	Several potential confounders that would shift the RR in both directions.	No significant association detected in the main analysis.	

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}, PM₁₀, 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.

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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, [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 (NO₂).

12. The Inspector, consistent with both parties' case, referred to the air quality limits in England in respect of NO₂ 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 µg/m³ as an annual mean
- 200 µg/m³ 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 NO₂ would be likely to be exceeded. However, there had been a history of exceedance of the annual mean AQO of 40 µg/m³. This was attributable to traffic related pollution.

14. [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 concluded¹ that for sensitive receptors in the vicinity of R8 (a particular monitoring point) the CVSH experts' predicted annual mean for NO₂ baseline contribution of 35.5 µg/m³ was likely to be reasonably reliable.

¹ Paragraph 37.

15. [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 NO₂ contribution from the point source at R8 would be 0.19 µg/m³ 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. [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 Directive⁴ 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 Jenkins 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 NO₂ 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. [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 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, [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 NO₂ concentrations; and,

(b) uncertainty.

Concentration of NO₂

45. The Environmental Statement Addendum (“ESA”), July 2019 and evidence presented to the Inquiry addressed this subject. Predicted short-term NO₂ 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 NO₂ 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 NO₂; 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 [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.

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 
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Halifax
HX6 3LL

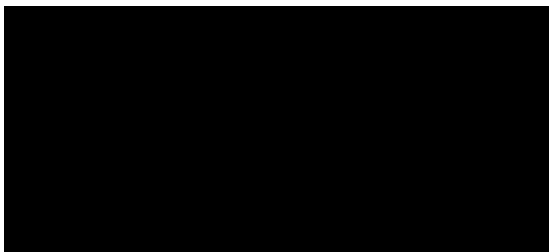
Calderdale Metropolitan Borough Council ("the Council"), in the exercise of the powers conferred upon it by regulation 13 of the Environmental Permitting (England and Wales) Regulations 2016 ("the 2016 Regulations") hereby gives you notice as follows:

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



Date...20 June 2018.....

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:-

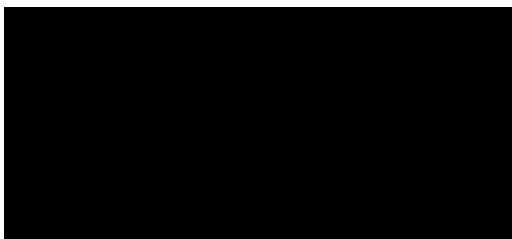
First, the air modelling is not considered to be adequate and the proposed chimney is not sufficient to achieve safe dispersal of potential pollutants. The proposal depends on theoretical modelling and further changes may be required in the light of actual operation. It is therefore critical that the 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 NO_x 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 NO_x 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 be refused.

End of Schedule 1

Signed on behalf of the Council



Date.....20 June 2018.....

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 PERMIT APPEAL - REFERENCE APP/EPR/603

STATEMENT OF OBJECTION FROM over 1000 Residents

1. We would like to thank the Inspector for granting the Adjournment of the Appeal reference APP/EPR/603 and Notice of Further Written Submission to the Planning Inspectorate. This has allowed us to put forward pertinent information related to your decision on the Appellant’s application for an environmental permit to operate a small waste incineration plant under the Environmental Permitting (England and Wales) Regulations 2016 permit application (the **“Permit Application”**).
2. Many residents have been effectively restricted from putting forward meaningful objections due to there being several documents that are missing from the Calderdale Council website. These missing documents contain all of the drawings, specifications and other details in the Appendices to the Appellant’s Environmental Permit Application. The documents have been previously published in the electronic hearing bundle to the Appeal, but are not available to the general public via the Calderdale Council website. This Objection references many of the documents that are missing from the Calderdale Council website.

Background

3. The following are relevant for the determination of applications for a SWIP and appeals in relation to them:
 - Environmental Permitting (England and Wales) Regulations 2016 (**“Permit Regulations”**)
 - Regulation 13
 - Part 1 Schedule 5
 - Schedule 13
 - Schedule 6
 - Defra.2020. Environmental Permitting: Core Guidance. For the Environmental Permitting (England and Wales) Regulations 2016 (SI 2016 No 1154) (**“Core Guidance”**)

Summary of Main Grounds of Objection

4. Schedule 13 provides that the regulator must ensure that every application for the grant of an environmental permit includes the information specified in Article 44 of the Industrial Emissions Directive. It is the Objectors view, backed up by the information in this submission and the reports of technical experts already submitted as part of the Appeal process, that this requirement has not been satisfied and therefore a permit should not be granted and the appeal should be refused.
5. Further in relation to Schedule 13, the Objectors do not consider that the application for the permit includes sufficient 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 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.

6. The Objectors do not consider that the application meets the requirements under Schedule 13 that requires the 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. In addition to the submissions already made by the Objectors regarding the stack height, the Council has now provided confirmation (documents HD17 and HD24) that the stack height was not looked at for the purposes of the environmental permit application. The only modelling was in the planning context and that was still subject to caveats and submission of a further assessment. The documents suggest that the criteria used for planning would not have been as stringent as that used for an environmental permit application.
7. Under Paragraph 13 of Part 1, Schedule 5, the regulator has a positive obligation to refuse an application for an environmental permit if it considers that the following two conditions will not be satisfied. The conditions are that the applicant for the grant of the permit must:
 - be the operator of the regulated facility.
 - operate the regulated facility in accordance with the environmental permit.

On the basis of the information set out in this submission and the reports of technical experts already submitted as part of the Appeal process, the Objectors consider that the regulator could not be reasonably satisfied that the facility either can or will be operated in accordance with the permit conditions proposed. Therefore, a permit should not be granted and the appeal should be refused.

The Objectors comments on the Appellant's "legal response to third party objections" for the Appeal ref. APP/EPR/603

8. The Appellant's "legal response to third party objections" at paragraphs 13, 14, 15 and 16 quotes the obligations placed on the applicant and on the regulator in respect of the permit application. In particular, the legal response states the requirement of Article 44 of the IED which specifies the information required as

"a description of the measures which are envisaged to guarantee that the following requirements are met"

and

"The plant is designed, equipped and will be maintained and operated in such a manner that the requirements of this Chapter are met taking into account the categories of waste to be incinerated or co-incinerated"

9. The Appellant's "legal response to third party emissions" at paragraph 22 states

"This is so because the relevant regulatory regime as set out in the EPR Sched.13 is concerned only with the control of processes and emissions from the plant so that what the applicant has to provide by way of information is, in this respect, limited to establishing that the plant is designed, equipped and will be maintained and operated in such a manner that the requirements of Chapter IV of the IED will be met taking into account the categories of waste to be incinerated and the requirements in terms of control of emissions are limited to what is set out in Article 46 (1) and (2).

10. And paragraph 36 states

"As set out above, NPPF paragraph 188 expressly provides that planning decisions should assume that separate pollution control regimes, i.e. in this case the separate environmental permitting regime, will operate effectively. To that end, the land-use air quality issues proceeded upon the basis that emissions would be no greater than the maximum levels allowed by the IED. The Inspector refers to this assumption in paragraph 43 of the Appeal Decisions. In those circumstances, in accordance with paragraph 188 of the NPPF (previously paragraph 183) the function, in the context of a SWIP, of the environmental permitting regime is the control of processes or emissions so as to ensure, both through an assessment of the processes, i.e. the design and operation of the SWIP plant, and the control of emissions to air from its stack (see Art 44 of the IED-para 15 of these instructions). Such control is achieved both by assessing the design and operations of the SWIP and by permit conditions, so as to make sure that the stack emissions assumptions referred to by the Inspector in paragraph 43 of the Appeal Decisions are in fact satisfied."

11. However, what the Appellant's "legal response to third party objections" for the Appeal ref. APP/EPR/603 does not state is the requirement of paragraph 5.14 of the Core Guidance which states

"If a regulated facility also needs planning permission, it is recommended that the operator should make both applications in parallel whenever possible. This will allow the environmental regulator to start its formal consideration early on, thus allowing it to have a more informed input to the planning process."

12. and Paragraph 42 of the NPPF which states

"Wherever possible, parallel processing of other consents should be encouraged to help speed up the process and resolve any issues as early as possible".

13. The Inspector for the Planning Appeal reference APP/A4710/W/18/3205776 might reasonably have expected, therefore, that the design for the SWIP and Environmental Permit Application had progressed in parallel with the Planning Application. However, the Objectors, having reviewed the Appellant's Permit Application, are of the opinion that, even for the Environmental Permit Application there has been no meaningful design carried out by the Appellant, nor has there been any assessment of equipping, let alone provision of guarantees as required by Article 44 of the IED.

14. The Appellant's "legal response to third party objections" at paragraph 25 goes on to state

"Accordingly, the Appellant submits that information required by Article 44, and which guarantees that the relevant requirements of Chapter 4 are met in terms of emissions (Article 46), was submitted to the Council and is now before the Inspector. Accordingly, the requirements of Schedule 13 (the only schedule applicable to the permit under consideration in this case), are satisfied, and there is no good reason to withhold the permit."

15. However, in addition to the extensive lack of design for the Environmental Permit Application the Objectors have found the Environmental Permit Application and its associated appendices are contradictory and confusing such that it is not clear at all what is being provided, and it is substantially non-compliant with the appropriate sections of regulations and guidance. For the avoidance of doubt, the appropriate regulations and guidance are repeated below from earlier in this objection:

- Environmental Permitting (England and Wales) Regulations 2016 ("**Permit Regulations**")
 - Regulation 13
 - Part 1 Schedule 5
 - Schedule 13
 - Schedule 6

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

16. It is the Objectors opinion that the evidence presented in this Objection confirms that the extent of missing information, inconsistencies of information and non-compliances with appropriate regulations are sufficient for a refusal of the Permit Application.

The Objector's comments on the Calderdale Council Statement of Case for the Appeal ref. APP/EPR/603.

17. The Calderdale Council Statement of Case Paragraph 6 states that

"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".

18. However, the Objectors are not aware that planning permission addresses in any detail either the construction or operation of the SWIP. In fact, Paragraph 188 of the NPPF, 2021 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)".

19. Construction and operation are part of environmental permitting, confirmed by reference to the Industrial Emissions Directive Article 44(a) which states

“An application for a permit for a waste incineration plant or waste co-incineration plant 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 this chapter are met taking into account the categories of waste to be incinerated or co-incinerated.”,

20. and the Core Guidance paragraph 5.9 which states

“Where proposals involve substantial expenditure, whether on construction work, equipment, software, procedures or training, operators should normally make an application when they have drawn up full designs but before any work commences (whether on a new regulated facility or when making changes to an existing one).”

21. The Calderdale Council Statement of Case Paragraph 22 states that

“CVSH applied for an environmental permit for the SWIP in August 2020”.

This is six months after the 4th February 2020 Planning Decision.

22. However, paragraph 5.14 of the Core Guidance states

“If a regulated facility also needs planning permission, it is recommended that the operator should make both applications in parallel whenever possible. This will allow the environmental regulator to start its formal consideration early on, thus allowing it to have a more informed input to the planning process.”,

23. and Paragraph 42 of the NPPF states

“Wherever possible, parallel processing of other consents should be encouraged to help speed up the process and resolve any issues as early as possible”.

24. Parallel processing of the planning application and the environmental consent application for the SWIP has not happened. The Objectors consider that this has contributed to the many issues and delays with both the planning permission and the environmental consent, as explained in this Objection.

25. The Calderdale Council Statement of Case Paragraph 52 states

“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”

26. and Paragraph 53 states

“The Conclusion reached by the Council in determining to grant the permit in February 2021 was correct. No further evidence has been provided to undermine the assessment made”

27. and Paragraph 54 states

“The Council has concluded that there are no legitimate grounds or basis to revisit the grant of a permit subject to appropriate conditions”

28. and Paragraph 55 states

“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”.

29. The Calderdale Council invitation to the Secretary of State to grant an environmental permit appears to be based on the planning permission, with the provisions of the Industrial Emissions Directive and the Environmental Permitting (England and Wales) Regulations 2016 (SI 2016 No 1154) being subject to conditions in the permit.

30. However, by reference to the Industrial Emissions Directive Article 44 (a) and the Core Guidance, the Objectors consider that the Appellant should carry out sufficient design and provide guarantees for the design and equipping prior to submission of a permit application. The Objector’s opinion appears to be confirmed in the Appellant’s “legal response to third party submissions” paragraphs 22 and 36 (paragraphs 8 and 9 of this Objection).

31. The advice to Calderdale Council, confirmed in “The Council Statement of Case” Paragraph 52, was that

“the relevant provisions of the Industrial Emissions Directive set out in Schedule 13 to EPR 2016 are satisfied and controlled by permit conditions”,

However, in the opinion of the Objectors, this is an incorrect interpretation of the Industrial Emissions Directive Article 44 (a) and the Core Guidance.

32. The Council Statement of Case paragraph 5 states that 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 purpose of the Permit Regulations. However, it says, in the absence of a specific guidance document the Core Guidance directs local authorities to the “GGM” ‘General Guidance Manual on Policy and Procedures for A2 and B Installations’. The Objectors have been unable to find any reference in the Core Guidance that directs local authorities as suggested by the Council. The Core Guidance simply signposts the GGM in relation to A2 and B installations - paragraph 1.8 and 4.4 of the Core Guidance in particular. The GGM itself says nothing about SWIPs. In paragraph 1.1 of the Core Guidance, it states that it “aims to provide comprehensive help for those operating, regulating or interested in “regulated facilities” that are covered by the [Permit Regulations]” whilst at paragraph 1.4 noting that it is complemented by a range of other government guidance relating to specific aspects of the Permit Regulations. At paragraph 3.39 the Core Guidance specifically references SWIPs.

MAIN GROUNDS OF OBJECTION

33. **Schedule 13 of the Permit Regulations provides that the regulator must ensure that every application for the grant of an environmental permit includes the information specified in Article 44 of the Industrial Emissions Directive. It is the Objector's view, backed up by the information in this submission and the reports of technical experts already submitted as part of the Appeal process, that this requirement has not been satisfied and therefore a permit should not be granted and the appeal should be refused. (First Main Ground of Objection)**
34. The SWIP is a smaller version of a larger (over 3 tonnes per hour) energy from waste facility. It has all the same complex features as a larger facility. The main differentiating feature is that, due to its size, it is under local authority regulation instead of Environment Agency regulation.
35. A further feature of this particular permit application is that the operator of the proposed SWIP appears to have no experience of operating a waste incineration facility, and has relied on the services of RPS for the permit application and for representations at the Appeal.
36. The only drawings and technical information accompanying the CVSH Schedule 13 Permit Application are
- RPS Drawing ref. JER1902-PER-001 Rev D. A drawing that purports to show "Emission Points" but fails to show the APC residue emissions point, a basic error by the Appellant and its consultant RPC. It is also the only plan drawing provided which shows the proposed plant equipment layout.
 - [REDACTED] Drawing ref. 9677_17_03 Rev C. A drawing showing the Belmont industrial site as a whole.
 - [REDACTED] Drawing ref. 9677_17.35 Rev A. A drawing showing drainage to the Belmont Industrial site as a whole
 - I8-1000 Incinerator information sheet. An information sheet with limited detail and which is for a different incinerator to the incinerator shown on RPS Drawing ref. JER1902-PER-001 Rev D and described in the Schedule 13 Permit Application
 - Inciner8 Gas Analyser overview document. A document containing technical data on equipment for the measurement of emissions.
 - Inciner8 Pollution Control Systems information sheet. Another very brief non-technical document providing three options for emissions mitigation equipment without specifying the option to be used in the SWIP
 - [REDACTED] ZE- 200 – LT – 190-320 – EN T information sheet. A document containing technical data for the ORC unit.
 - RPS Process Diagram ref. JER 1902. A very basic plant diagram containing no meaningful plant process or technical information.

37. The majority of information that would explain how the main plant items in the SWIP will operate is not provided. There is no information at all for the heat exchanger or for the dryer. The incinerator and pollution control information is limited to brochures with very basic technical data. Other than the information sheet for the ORC unit there is nothing provided to explain what is included in the key plant items or how they relate to or connect together in terms of process, heat transfer, heat balance, steam system, and electrical system.
38. The plant diagram, contrary to its title of “process diagram”, does not explain the processes or how they link together. The plant equipment, other than the ORC unit, are not explained at all in terms of process or what they include or exclude.
39. Nearly all process and technical information is missing, a long way distant from the requirement to draw up full designs before making the permit application. In fact, the Objectors cannot find any information to suggest that there has been any meaningful process and engineering design or any meaningful space planning or any design health and safety risk assessments, or any designer appointments in this respect.
40. The Objectors consider that the Appellant’s Permit Application has not, therefore, complied with Paragraph 5.9 of the Core Guidance which states
“Where proposals involve substantial expenditure, whether on construction work, equipment, software, procedures or training, operators should normally make an application when they have drawn up full designs but before any work commences (whether on a new regulated facility or when making changes to an existing one).”
and the non-compliance is substantial.
41. The Objectors consider that the Appellant has not drawn up full designs and there is no information provided to suggest that there has been any meaningful process and engineering design or any meaningful space planning.
42. Calderdale Council has not refused the Permit Application on the basis of insufficient information, nor has it requested further information. However, Paragraph 7.7 of the Core Guidance states one of the reasons for regulator refusal as being that the operator information does not provide a reasonable basis to determine the permit conditions. The Objectors consider that the evidence that meaningful designs have not been drawn up is substantial, and that this should be considered as a key reason for refusal of the permit application.
43. One consequence of lack of design is that the plans for the equipping including the appointment of installation contractors for the equipping cannot be determined. The Industrial Emissions Directive Article 44 (a) requires that the Permit Application shall guarantee the equipping which the Objectors consider can only be achieved through guarantees from the installation contractors.
44. Paragraph 9.27 of the Core Guidance states
“The operator of any regulated facility should be financially capable of complying with the environmental permit. The regulator should consider an operator’s financial competence when determining the operator’s ability to comply with the conditions in its permit.”

45. There is no evidence provided of the procurement for the SWIP installation work, or of the costs of the work or how the costs will be funded.
46. The financial and contract information for the regulator to assess the operator's competence is not available, and it is the Objector's opinion that the regulator should not, therefore, accept the Permit Application.
47. The lack of design means it is not possible for the appointed installation contractors to provide commissioning information to determine permit conditions and guarantees through commissioning and testing of the plant, nor is it apparent how it will be possible for the regulator to protect the environment and human health during the commissioning and testing process. Commissioning and testing will present some of the greatest risks to the environment and yet it is not possible to review any plans or to understand where permit conditions can help control emissions.
48. Details are not provided of the building works associated with the SWIP proposals. Some issues to be addressed are:

- Spatial arrangement of the equipment, ensuring that all equipment is included and that there is adequate space for the equipment and for its operation and maintenance.
- How the building, equipment and services will be protected against the flooding that periodically occurs on the site. In this respect the Appellant's Environmental Statement to the Planning Appeal reference APP/A4710/W/18/3205776 relied on a RMA Flood Risk Assessment Addendum Report dated 26th June 2019. Paragraph 10 on page 3 of the Report states

"Therefore, the proposed change of use would relate to a FFL which is approximately 150mm below the estimated Flood Zone 3 flood level."

And paragraph 3 on page 4 of the Report states

"The EA's standing advice for minor extensions requires that FFLs should be no lower than 300mm above the estimated flood level."

The only reference to flooding in the Appellant's Permit Application is a note on RPS Drawing Nr. JER1902-PER-001 which states

"Upgrade lower section of industrial roller shutter doors to provide manual flood gates to protect building from flood water ingress"

The proposals to address flood risk to the building do not meet the requirements of the RMA Flood Risk Assessment Addendum Report dated 26th June 2019 or the Environment Agency advice to raise the floor levels to 300mm above the estimated flood level.

Objectors also consider that a flood risk assessment from the Environment Agency dated 2 December 2022 indicates a high flood risk for the site, which is worse than the medium to high flood risk in the RMA Flood Risk Report.

- Details of building works directly related to the equipment installation.

- The incineration plant will give out a lot of waste heat. The Objectors consider that there is a need for natural building ventilation to keep the building cool, but the Permit Application proposes sealing the building off against flooding, odours and noise emissions, thereby trapping the heat inside. Observations made by individuals on site visits indicate that there are blocks missing in the bottom of walls adjacent to the River Ryburn to allow water to escape. These holes are masked from the outside by steel cladding. There are no details showing how the walls are proposed to be sealed against water ingress (or egress).

RDF Classification and Acceptance

49. Chapter IV Article 45 of the Industrial Emissions Directive sets “Permit Conditions” for waste incineration and co-incineration plant. Article 45 (1) (a) states that the permit shall include

“a list of all types of waste which may be treated using at least the types of waste set out in the European Waste List established by decision 2000/532/EC, if possible, and containing information on the quantity of each type of waste, where appropriate.”

50. Environment Agency Guidance: Waste acceptance procedures for deposit or recovery 31 October 2022 states at paragraph 2

“Waste producers must classify their waste as hazardous or non-hazardous. They must make sure it is described (characterised) accurately.”

And paragraph 3 states

“If you have a permit to recover waste at your site you must have waste acceptance procedures in place to make sure you only accept waste that:

- *Is suitable for your activity*
- *Is allowed by your permit*
- *You considered in your risk assessment for your permit application”*

And paragraph 5 states

“When you apply for a bespoke waste recovery permit you must provide a copy of your waste acceptance procedures with your permit application.”

51. The Appellants Permit Application does not include the types of waste set out in the European Waste list established by decision 2000/532/EC, nor does it include any details for the calorific value of the RDF, nor does it include any details of RDF acceptance procedures for the SWIP described in the “Environment Agency Guidance: Waste acceptance procedures for deposit or recovery 31 October 2022”.
52. The RDF will have different composition to the various wastes received in the Appellant’s waste processing facility since the wastes will have been sorted to separate out material for combustion which is then shredded in further preparation for the SWIP. The Objectors consider that understanding the composition (including calorific value) of the RDF is essential to setting the parameters for the process design, equipping and operation of the SWIP. Waste, by its very

nature, is variable in its calorific value depending on its composition. The plant design will need to be informed by the composition of the RDF, to enable the equipping to be sized and guaranteed to meet the requirements of Chapter IV of the IED.

53. The Appellant, in its letter headed “Planning Condition 8 - Response to Questions concerning the R1 Calculation” as part of its Information to Discharge Condition 8 reference 17/00113/DISC4 for Planning Application reference 17/00113/WAM, under the heading “Selected CV of Waste”, stated at paragraph 4

“whilst the RDF will vary in composition the range is relatively limited, and therefore predictable, as it will comprise the residual, non-recyclable fraction of textiles, wood, paper, cardboard and plastics.”

And at paragraph 5

“based upon the type and limited range of the residual waste it is considered that the CV of 10MJ/kg expressed as a maximum is realistic.”

54. However, the Objectors consider that this stated maximum calorific value of 10MJ/kg is far too low since the main materials forming the RDF all have a higher CV than 10MJ/kg. The Gov.UK Digest of UK Energy Statistics (DUKES): calorific values and density of fuels states average gross calorific values in Table A 1.4

- | | |
|------------|-----------|
| • Textiles | 29.4MJ/kg |
| • Wood | 17Mj/kg |
| • Paper | 24.2Mj/kg |
| • RDF | 18.5Mj/kg |

55. Most fractions of the waste described by the Appellant will have a CV of more than 10Mj/kg. The Objectors consider that the Appellant’s argument for a maximum CV for the RDF of 10Mj/kg, stated in the Appellants “Planning Condition 8 - Response to Questions concerning the R1 Calculation” letter, is unsustainable.
56. Also, the calorific value of the RDF could be quite variable because of the range of calorific values of the different materials that could be processed to form the RDF at any one time. This would need to be managed on site as part of the pre-processing and waste acceptance procedures for the SWIP.
57. Certain characteristics for the RDF will need to be determined in order to design and subsequently manage the operation of the plant. The minimum calorific value of the waste will be required in order to provide the worst-case conditions for the purpose of verification of the residence time.
58. The average and maximum calorific value of the waste will be required in the process design to determine the heat load and heat transfer through the plant, sizing of the equipment and for the R1 plant efficiency calculation required to meet Condition 8 of the Planning Appeal reference APP/A4710/W/18/3205776

59. The Appellant, for the purpose of the design and the permit application must find a way of determining the calorific value range for the RDF, and find a way of controlling the RDF entering the furnace through Waste Acceptance Criteria and procedures so that the plant operates within its safe operating range.
60. The Industrial Emissions Directive Article 52 (2) requires the mass of each type of waste to be determined prior to accepting the waste at the waste incineration plant. The mass of the RDF has not been provided in the permit application. Unless the mass of the RDF is provided even the basics of plant design cannot be developed. For example, the capacity and frequency of loading the RDF into the proposed push mechanism, and storage for the RDF.
61. It could be argued, for example, if the calorific value of the waste is fixed at a maximum of 10MJ/kg instead of the DUKES Guidance of 18.5 MJ/kg, then, if RDF quantities are derived from records of the heat generated in the plant, it might appear that a lot more RDF is being burned than is actually the case, particularly if the density and quantity of RDF going into the furnace is not measured.
62. In this respect the Objectors have noted from the planning application, a document from the Appellant's lawyers entitled "Further Note on Residual Waste and Waste Returns". It states that, due to a fire that took place in January 2017, some of the equipment for pre-processing the waste was damaged, and is not intended to be replaced (and enhanced) unless the SWIP goes ahead, and that this will affect the composition of the RDF.
63. It seems that the RDF currently being produced will be different to the RDF that will be produced for the SWIP. There are no details provided of the composition of the RDF that will be produced in the future as a fuel for the plant. It does not seem possible, for example, to determine the amount of bottom ash produced by the SWIP without knowing how efficient the pre-processing operation is at improving the composition of the RDF, by removing non-combustible waste, for use in the SWIP.
64. The Objectors consider that, instead of trying to find a way of determining the composition of the RDF in accordance with Article 45 and 52(2) of the Industrial Emissions Directive, and developing waste acceptance criteria and procedures for the SWIP in accordance with the Environment Agency Guidance: Waste acceptance procedures for deposit or recovery 31 October 2022, the Appellant has avoided these matters which are fundamental to the design, equipping and operation of the facility, regulation of the facility, and meeting the Permitting requirements described in Article 44 of the Industrial Emissions Directive.
65. In summary, The Permit Application has not been duly made to meet the requirements of Article 44 of the Industrial Emissions Directive to describe the measures which are envisaged to guarantee that the plant is designed, equipped and will be maintained and operated to meet the Directive taking into account the categories of waste to be incinerated, nor does it meet the requirements of Paragraph 6.4 of the Core Guidance since the information in the Permit Application is not sufficiently comprehensive or adequate to make a determination.
66. The operator information does not provide a reasonable basis to determine the permit conditions, which is one of the reasons a regulator may decide to refuse a permit under the Permit Regulations and under Paragraph 7.7 of the Core Guidance.

67. **In relation to Schedule 13, the Objectors do not consider that the application for the permit includes sufficient 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 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. (Second Main Ground of Objection)**
68. Planning Appeal reference APP/A4710/W/18/3205776 states under the heading “Procedural Matters” at Paragraph 3 states
- “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 the 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 the formal decision set out above.”*
69. However, Objectors consider that the plant and equipment layout is flawed to the extent that the plant and equipment cannot fit into the existing building that is proposed to house it. This situation would conflict with and contradict the basis of the decision in the Planning Appeal reference APP/A4710/W/18/3205776 as set out in the decision under at Paragraph 3 (referred to above).. It would also be contrary to the boundary limits of “the site of the regulated facility” shown by a green line on RPS Drawing Nr. JER1902-PER-001 and defined in paragraph 7.24 of the Core Guidance.
70. The existing L shaped building, shown on RPS Drawing Nr. JER1902-PER-001, that will contain the new SWIP, is all one area with one part of the L shape being 17.715m x 11.922m on plan and the other part being 5.558m x 5.720m on plan. The Objectors consider that the building does not appear to be large enough to house the plant and equipment which appears to be crammed against outside walls.
71. The Objector’s review of the drawings has determined that space for maintenance of plant and equipment has not been considered in the layout of the equipment in the building. This is evidenced by reference to the ORC unit shown on RPS Drawing JER1902-PER-001, which can be seen is tight up to the flue gas treatment plant on one side and the building structure on the other side. It has no working space around it for operation and maintenance.
72. The Zuccato technical document reference SE-200-LT_190320 EN[9163] in Appendix D to the Permit Application (Electronic Hearing Bundle pages 134 to 141) shows the technical details of the ORC unit. Near the bottom of the last page of the document it highlights in bold print “the skid requires at least 1.5 meters of free space on all sides for easy maintenance access”. The space is simply not available for the required ORC unit maintenance, and cannot be made available due to the building and permit boundaries.
73. The scale of this spatial planning issue can again be seen by reference to RPS Drawing JER1902-PER-001. The small L part of the building size 5.558 x 5.720 metres, is shown containing most of the flue gas cleaning equipment, the ORC engine, the flue, and storage for the chemicals to be used in the process.

74. The same RPS Drawing JER1902-PER-001, which purports to show the “Emissions Points”, has identified in blue the bottom ash disposal emissions point from the furnace and the flue gas emissions point. However, it has failed to identify the fly ash residues emissions point which is also located in the small L shaped part of the building size 5.558 x 5.720 metres, and, according to paragraph 6 of the Non-Technical Summary of the Schedule 13 Environmental Permit Application, requires a separate enclosed space for a skip and access for skip removal to contain the potentially hazardous fly ash residues.
75. The same RPS Drawing JER1902-PER-001 fails to show the access required for flue gas monitoring, described in paragraph 3.13.9 of the Permit Application as to be provided in accordance with Government Guidance M1. (Which describes a walkway of about 1.5m around the flue pipe measured from the outside of the flue pipe).
76. Reference to page 2 Figure 1 Plant Diagram in the Zuccato technical document reference SE-200-LT_190320 EN[9163] in Appendix D to the Permit Application indicates that a cooling system will be required that is outside the scope of the ORC unit. RPS Drawing JER1902-PER-001 states that the residual heat will be used for the dryer. However, no details are shown on the drawing or elsewhere of how this method of cooling will be achieved or what space will be taken up by the cooling equipment.
77. The Zuccato technical document also indicates a connection to the electricity grid that will be outside the scope of the ORC unit. High voltage switchgear and transformers could be needed that will require to be physically separated from the main incineration plant for safety reasons, and again will take up space that has not been identified on RPS Drawing JER1902-PER-001.
78. The shredding of the material for combustion (See paragraph 3.2.3 of the RPS Schedule 13 Permit Application) will create an aerated highly combustible RDF with a relatively low mass. It is proposed to be stored inside the SWIP and loaded adjacent to the furnace, in the same space where hot ash from the furnace will be removed. The Objectors consider that this could create a significant fire and explosion risk. The Appellants operational risk assessment (Table 1 to the RPS Environmental Management System for the SWIP) has not identified this risk.
79. The Objectors consider that design risk assessments by a designer of the plant would have identified these risks and compelled the designer to redesign the spatial arrangement of the furnace area. Lack of identification of such a significant risk is further evidence that no meaningful design has taken place for this SWIP.
80. The Objectors consider that little thought has been given to the spatial planning of the plant and equipment which has resulted in the plant and equipment not being able to be contained within the building, or within the boundary limits of the site of the regulated facility. The Permit Application cannot therefore comply with paragraph 7.24 of the Core Guidance and the Permit Application is non-compliant with the requirement of Planning Appeal reference APP/A4710/W/18/3205776 Procedural Matters Paragraph 3 to contain the plant within the existing building.

81. **The Objectors do not consider that the application meets the requirements under Schedule 13 that requires the 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. (Third Main Ground of Objection)**
82. In addition to the submission already made by the Objectors regarding the stack height, the Council has now provided confirmation (documents HD17 and HD24) that the stack height was not looked at for the purposes of the Permit Application. The only modelling was in the planning context and that was still subject to caveats and submission of a further assessment. The documents suggest that the criteria used for planning would not have been as stringent as that used for an environmental permit application.
83. Furthermore, at the Hearing for Environmental Permit Appeal it was agreed by the Council and the Appellant, that paragraph 5.9 of the Appellant's Environmental Permit was removed. This paragraph required the measurement of air quality by passive diffusion tube at locations close to the SWIP.
84. One of the major concerns that the local community has had since the SWIP was first proposed is the location of the site at the bottom of the River Ryburn Valley, and the effect the topography will have on the emissions from the stack. The issues are the control of the emissions from the SWIP and the dispersal of the emissions into the local area.
85. The proposal for additional monitoring was also included as point 3 in the "CMBC Monitoring & Compliance Plan: Calder Valley Skip Hire (CVSH)" announced in a press release on the 11 March 2021 and produced by the Council following its original grant of the environmental permit in 2021. The relevant extract is set out below. It is unclear why the proposal previously agreed as part of the permit application and approval is now being set aside.

Action	Who	When/Frequency	Reporting to/ Comments
Improve the Air Quality monitoring capability in the relevant locality, and progress the offer from CVSH to support additional monitoring equipment	CMBC, Air Quality Strategic Group	Increase capability by 30/6/21	Additional monitoring devices will be placed in key locations in the Ryburn Valley based on the key impact areas identified through the modelling by RPS. The offer from CVSH to support additional monitoring will be progressed by CMBC Officers and all relevant updates will be shared with the Community Liaison Group. Improving the air quality monitoring capability will improve the evidence provided

			to CMBC's Air Quality Strategic Group thus supporting the wider ambition to improve air quality in and around Sowerby Bridge through schemes and initiatives such as "Something in the Air".
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86. The Industrial Emissions Directive Article 46(1) states

"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"

87. If testing is carried out in the local vicinity, as we consider was the intention of the Appellant's Environmental Statement paragraph 5.9, then the local community could be confident that the approach, based on estimated numbers and relied on by the Appellant's air quality consultants in the emissions modelling, is as expected. Without the passive diffusion tube measurements it seems unlikely that the Council as regulator could satisfy itself that the Industrial Emissions Directive, Article 46 (1) is being met.

88. The Incinerator shown on RPS Drawing reference JER1902-PER-001 is substantially different to the I8-1000 incinerator manufactured by Inciner8 shown in Appendix D – Technical Documents to the Permit Application (Page 122 of the Hearing Bundle). The Incinerator shown on RPS Drawing JER1902-PER-001 is also substantially different from the incinerator described in the Appellants Schedule 13 Permit Application. As well as inconsistencies in the submitted permit application documents, there are considerable doubts about compliance with the residence time requirements of the Industrial Emissions Directive Article 50 (2)

89. The I8-1000 medical incinerator manufactured by Inciner8 is described as the largest incinerator manufactured by Inciner8. It is top loaded, has a fixed grate and a burn rate of 1000kg/hour, and is a batch type top loading incinerator with suggested batch size of 5000kg.

90. Notwithstanding the details provided of the top loaded I8-1000 medical incinerator, RPS Drawing JER1902-PER-001 shows a side loading incinerator with what appears to be a side loading mechanism for the RDF feedstock, very different from the manufacturers standard top loading specification.

91. The Appellants Schedule 13 Permit Application Paragraph 3.3.1 states

"The SWIP will comprise a two-chamber combustion process that will both heat to promote gasification and thermally oxidise the off-gases to create heat. The SWIP will utilise a stoker-fired combustion system. The moving action of the stepped grate will transfer the fuel along the length of the primary combustion zone."

92. And at Paragraph 3.3.3

“As the burning fuel travels down the grate, the volatiles that are released burn above the bed of fuel and pass into the secondary and tertiary combustion zones of the boiler. The resulting ash will pass on down the grate where it is exposed to higher concentrations of oxygen (higher air fuel ration) to promote complete combustion (burn out).”

93. The Appellant’s Permit Application describes a much more sophisticated grate than the Inciner8 manufacturer provides. The grate proposed in the Permit Application is a continuous waste feeding stepped grate that will take significant internal space away from the combustion chamber. It will require hydraulic controls, the hydraulics located either side of and external to the furnace. The hydraulics will require space for maintenance which is not available in the building as the plant is laid out. The load capacity and feed rate will be substantially different from that described in the Inciner8 manufacturers information.

94. The Appellant’s Permit Application paragraph 3.3.3 describes a boiler integrated with the furnace, whereas RPS Drawing JER1902-PER-001 shows a heat exchanger that is separate from the furnace.

95. The Appellant appears, therefore, to be proposing to take the Inciner8 standard and purpose manufactured I8-1000 medical incinerator and then fundamentally alter it, which will require more space within the building, and is likely to alter its performance characteristics.

96. The residence time calculation in Appendix F to the Permit Application appears to be based on the simple primary box shape of the standard I8-1000 medical incinerator, and not on the incinerator described in the Permit Application. This raises doubts about the validity of the residence time calculation in Appendix F to the Appellants Permit Application.

97. The email from Solid Solutions dated 18 March 2020 (Permit Application Appendix F) describes that a batch of either 500kg or 1000kg of waste was used to calculate residence time. This is contrary to the Appellant’s Permit Application paragraph 3.3.1 which describes a continuous loading stepped grate system that is entirely different from the Inciner8 standard I8-1000 medical incinerator, and will require an entirely different approach to residence time calculation.

98. The Industrial Emissions Directive Article 50 (2) states

“Waste 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 the most unfavourable conditions, to a temperature of at least 850 °C for at least two seconds.”

99. The most unfavourable conditions for the incineration have not been defined, and, in particular, the characteristics including the range of calorific values are not determined. The incinerator described in the Permit Application is different to the I8-1000 incinerator used for the residence time tests. The Objectors do not consider, therefore, that the requirements of the Industrial Emissions Directive Article 50 (2) would be met.

100. There are no details provided for the heat exchanger other than shown on the RPS plan drawing ref. JER1902-PER-001D which states

“Clean air ducted from this outlet of the Heat Exchanger to the external dryer and separately to the ORC unit”.

101. The removal of heat from the process by air-to-air transfer, and prior to the turbine is unusual, it is normally transferred via a boiler system to produce steam which drives a turbine to generate electricity, thereby prioritising electricity production, with waste heat after the turbine being available for other equipment such as a dryer.

102. The Objectors are concerned about the unusual proposal to duct air from the heat exchanger to the dryer. There is no clean air inlet shown, and the air duct to the dryer is shown on the drawing exiting before the heat exchanger. There is a risk of uncontrolled emissions that would not register through the control system if, for example, there was a failure due to the high temperature and velocity of acid gases from the incinerator causing corrosion/erosion, which could lead to the escape of contaminated flue gases into the clean gases, and then to atmosphere via the dryer without any emissions mitigation or monitoring.

103. The Objectors consider the air duct from the heat exchanger to the dryer is a potentially uncontrolled gas emissions point. It does not meet the requirements under Schedule 13 that the 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.

104. **Under Paragraph 13 of Part 1, Schedule 5, the regulator has a positive obligation to refuse an application for an environmental permit if it considers that the following two conditions will not be satisfied. The conditions are that the applicant for the grant of the permit must:**

- **be the operator of the regulated facility.**
- **operate the regulated facility in accordance with the environmental permit.**

On the basis of the information set out in this submission and the reports of technical experts already submitted as part of the Appeal process, the Objectors consider that the regulator could not be reasonably satisfied that the facility either can or will be operated in accordance with the permit conditions proposed. Therefore, a permit should not be granted and the appeal should be refused. (Fourth Main Ground of Objection)

105. The contradictions described earlier in this Objection between the 13 Permit Application and the drawings and technical documents in the Appendices to the Permit Application, suggest that it is a document that has been amended from a document from a different energy from waste plant, rather than developed based on the Appellant's plant information shown in the Appendices or any plant designs.

106. Right from the start of the Permit Application there are contradictions. Paragraph 2 of the Non-Technical Summary states

“The SWIP will process up to 2 tonnes per hour (tph) of refuse derived fuel (RDF) produced from the residual non-recyclable fraction of the existing waste stream comprising primarily construction and demolition waste at the existing WTS located on the same site (EPR/SP3196ZQ). The maximum annual throughput will be 10,000 tonnes per annum (tpa) of RDF, all of which will come from the existing adjacent WTS activities.” and

107. Paragraph 1.1.2 of the Permit Application states

“The SWIP will process 1-2 tonnes per hour of refuse derived fuel” and

108. Paragraph 3.2.1 of the Permit Application states

“The facility will burn RDF (EWC 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 (tpa). All of the RDF will have been pre-treated within the adjacent WTS.”

109. Appendix D to the Permit Application contains an Inciner8 information sheet for their standard I8-1000 model (Page 122 of the Hearing Bundle). The information sheet states

“Burn rate 1000kg per hour”

110. The Permit Application is therefore stating and confirming that the SWIP will process up to twice as much RDF per hour as stated in the technical specification from its incinerator supplier.

111. The Industrial Emissions Directive Article 45(b) states

“the permit shall include the total waste incinerating or co-incinerating capacity of the plant.”

112. And Article 44(a) states

“An application for a permit for a waste incineration plant or waste co-incineration plant 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 this chapter are met taking into account the categories of waste to be incinerated or co-incinerated.”

113. The Article 44(a) requirement to guarantee the design requires that the design must be developed for the purpose of the permit, including the plant capacity. This is further confirmed by reference to Paragraph 5.9 of the Core Guidance which states

“Where proposals involve substantial expenditure, whether on construction work, equipment, software, procedures or training, operators should normally make an application when they have drawn up full designs but before any work commences (whether on a new regulated facility or when making changes to an existing one).”

114. The Objectors consider that, from the Appellant’s Permit Application, that it had no intention of drawing up full designs for the permitting as required by Paragraph 5.9 of the Core Guidance or of guaranteeing the design and equipping of the plant for the permitting as required by Article 44(a) of the Industrial Emissions Directive.

115. The Objectors consider that the Appellant's Permit Application has disregarded the requirements of the Industrial Emissions Directive and the Core Guidance, and does not intend to comply with the regulator requirements as outlined above.

116. By reference to our comments on the "Calderdale Council Statement of Case for the Appeal ref. APP/EPR/603" earlier in this Objection, Objectors consider that Calderdale Council, by inviting the Secretary of State to allow the appeal and direct the Council to grant an environmental permit to the Appellant, has agreed with the Appellant's approach to permitting.

117. The Core Guidance paragraph 7.2 states

"For all applications made under the EPR, the regulator must ensure that its determination delivers all relevant statutory requirements and provides the required level of protection to the environment."

118. The Objectors consider that Calderdale Council appears, therefore, to have disregarded the requirements of the Industrial Emissions Directive and the Core Guidance in making its invitation to the Secretary of State.

119. Furthermore, the Objectors consider that Calderdale Council has disregarded the recommendations of NPPF 42 and paragraph 5.14 of the Core Guidance to process the planning application in parallel with the environmental permit application.

R1 Status

120. The Objectors are (in addition to issues with the Permit Application) further concerned about regulatory compliance by both Calderdale Council and the Appellant in respect of their approach to the R1 efficiency index and the status of the SWIP as a recovery operation.

121. The planning permission granted following the planning appeal (reference APP/A4710/W/18/3205776) includes Condition 8 which requires that the Appellant demonstrates that electrical generation and/or heat recovery systems meet or exceed the equivalent of the R1 energy efficiency index and that 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.

122. Environment Agency Guidance: Waste Incinerator Plant: apply for R1 status 17 August 2021 paragraph 2 states that it will assess the submitted R1 data and confirm if R1 status is met. This is confirmed in the Appellant's legal advice to the Planning Appeal reference APP/A4710/W/18/3205776 titled "Municipal Solid Waste and the R1 Efficiency Formula" which states at paragraph 32

"An operator may seek R1 accreditation from the EA even if the incinerator is not dedicated to the processing of MSW"

123. It is further confirmed by reference to the Defra document entitled “Energy from Waste: A Guide to the Debate” dated February 2014 which states at paragraph 54 (page 24) which states

“The distinction between having R1 status or having a plant being classified as a disposal facility is important for planning purposes and in the application of the proximity principle. It is therefore important that operators strive towards demonstrating that energy from waste is a recovery operation according to the WFD definitions. Interested operators should contact the relevant competent authority (which in the footnote states is “the Environment Agency in England”) who, based on an application from the operator, will assess whether or not a municipal solid waste combustion facility meets or exceeds the threshold and can be considered a recovery operation.”

The Environment Agency in England appears to be the sole arbiter in assessing and deciding on R1 status.

124. However, the Appellant submitted its R1 calculations, in its “Calculation Spreadsheet” as part of its Information to Discharge Condition 8 reference 17/00113/DISC4 on Planning Application reference 17/00113/WAM. A letter from Calderdale Council dated 16 April 2021 confirmed that the details submitted satisfied that part of Planning Condition that requires details to be submitted and approved prior to commencement of development.

125. There is no reference to the Appellant obtaining R1 status from the Environment Agency in the information to discharge Condition 8.

126. Furthermore, the heat load is stated in paragraph 1.1.3 of the Permit Application as 1.25MW_t only marginally less than the 1.28MW of heat produced by the SWIP. It is apparent that the calculation does not take into account the heat losses through approximately 100 metres of ductwork containing hot gases that will be laid under a hardstanding to reach the drying plant, nor does it take into account that the drying plant will only operate as a drying plant between the hours of 7am and 6pm.

127. The Environment Agency Guidance states that the R1 value is to be calculated using the method in the European Commission: Guidelines on the interpretation of the R1 energy efficiency formula for incineration facilities dedicated to the processing of municipal solid waste according to annex II of directive 2008/98/EC on waste (**The European Commission’s R1 Guidance**).

128. Section 2.3 paragraph 1 of the European Commission’s R1 Guidance states

“It is important to note that the R1-formula system cannot be extended outside the “incineration facility” nor the “installation” as defined by the permit, and that installations outside the responsibility of the operator are to be excluded from the R1 system boundaries, in particular because the operator has no authority there.”

129. Other than the connection to the heat exchanger, the dryer plant and its hot air supply ductwork from the SWIP are outside the system boundary of the SWIP, and outside the control system of the SWIP. According to Section 2.3 paragraph 1 of the European Commission’s R1 Guidance the dryer plant and its associated ductwork is to be excluded from the R1 efficiency calculation. In such circumstances, the Objectors consider it would be unlikely that the SWIP could achieve R1 status.

130. The Appellant's Permit Application paragraph 1.5.2 states

"Before the first operation of the SWIP a scheme shall be submitted to and approved in writing by the local planning authority to demonstrate that the 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 (condition 8)."

131. However, the European Commission's R1 Guidance Section 4 paragraph 3 states

"It has to be taken into consideration that energy efficiency is largely dependent on the technical design of the facility and will only change to a limited extent during operation."

132. And paragraph 4 states

"The status of a facility should be known before the waste is treated, well in advance before the treatment begins, in order to comply with the stipulations of waste management contracts."

133. The Objectors consider that Section 4 paragraphs 3 and 4 of the European Commission's Guidance requires that the R1 efficiency calculation should be determined at the same time as the environmental permitting, based on actual design data generated by the plant design. This is further confirmed by reference to the Industrial Emissions Directive Article 42 (1) which states

"If waste co-incineration takes place in such a way that the main purpose of the plant is not the generation of energy or production of material products but rather the thermal treatment of waste, the plant shall be regarded as a waste incineration plant."

134. The Appellant's permit Application paragraph 1.1.3 states

"Heat produced by the SWIP, which is anticipated to be 1.28 MW_{th}, will be used within a new drying plant to be installed as part of the WTS activities also operated by CVSH in the existing WTS. An application to vary the existing waste permit and a partial (low risk) surrender application for the area containing the SWIP building will separately be submitted to the Environment Agency (EA)."

135. The drying plant is part of another permit, and it is not therefore under the control of the SWIP.

136. The Appellant's letter headed "Planning Condition 8 - Response to Questions concerning the R1 Calculation" as part of its Information to Discharge Condition 8 reference 17/00113/DISC4 on Planning Application reference 17/00113/WAM, under the heading "Selected CV of Waste", states at paragraph 6

"However, even if the average CV were to be higher than the expected maximum of 10MJ/kg whilst the heat input would increase there would be a corresponding increase in the heat output available for use."

137. The Appellant's calculation is not in accordance with the paragraph 3.2.1 of the European Commission's R1 Guidance which states

"Annex II to the WFD defines E_p (energy produced) as "annual energy produced as heat or electricity..." produced" in this context is to be interpreted as "produced and utilized" in the meaning of the generated energy that is recovered and effectively used."

138. The only reason that the Appellant's calculation of heat for use increases in proportion to heat input is because the Appellant has only identified the heat produced and has not identified its utilisation. The Appellant has therefore not complied the Environment Agency Guidance: Waste Incinerator Plant: apply for R1 status 17 August 2021, nor does the Appellant appear to have applied to the Environment Agency for R1 status.

139. Instead, The Objectors consider that the Appellant has created its own rules for R1 status and agreed them with Calderdale Council. Rules whereby it would be highly unlikely to fail to meet R1 status.

Fire Risk

140. There is historic information regarding existing waste operations at the Calder Valley Skip Hire Belmont site. There have been seven fire related incidents at the Belmont Site since 2015 which are set out below.

- **04/11/15**

Fire related to a piece of machinery on site.

- **10/08/16**

West Yorkshire Fire Service Performance Management and Activity Reports, Calder Valley Skip Hire, Trading Estate, Rochdale Road, Triangle, Sowerby Bridge, HX6 3LL state

"This was a hydraulic plant machine which was being used and which developed a fault and caught fire. Sprayed hot hydraulic oil onto recycling plant and a pile of recycling waste inside the building caught fire. The owner had used the mechanical digger to pull away some metal sheeting on the side of the building so that the fire in the pile of rubbish could be extinguished."

- **04/01/17**

West Yorkshire Fire Service Performance Management and Activity Reports, Calder Valley Skip Hire, Belmont Trading Estate, Rochdale Road, Triangle, Sowerby Bridge, HX6 3LL state

"The incident occurred in the Halifax station area and involve a fire in a single storey building. The building was 100% involved in the fire. The initial pre-determined attendance to the incident was two pumps due to the nature of the calls received. Appliances from Halifax and Illingworth were mobilised. At the height of the incident appliances from Odsal, Cleckheaton, Huddersfield, Rastrick and Mytholmroyd were mobilised: Welfare unit from Slaithwaite, Command Unit Sector Support from Rawdon, Hose layer and Hose layer Support from Mirfield, Command Unit Assistants from Bradford, Command Unit and Rapid

Deployment Safety Crew from Fairweather Green, 6 large jets, 2 ground monitors, 2 ultra light pumps and 1 aerial were used to bring the fire under control."

- **03/03/17**

West Yorkshire Fire Service Performance Management and Activity Reports, Calder Valley Skip Hire, Belmont Trading Estate, Rochdale Road, Triangle, Sowerby Bridge, HX6 3LL state

"One hose reel was used on a large pile of rubbish which looked to be smoking on our arrival so the hose reel was used to cool this down. There was no flame hence this being a false alarm."

- **28/01/2020**

Gases from decomposing waste actuated a fire alarm.

- **25/11/2020**

West Yorkshire Fire Service Performance Management and Activity Reports, Calder Valley Skip Hire, Belmont Trading Estate, Rochdale Road, Triangle, Sowerby Bridge, HX6 3LL state

"Property involved: Plant machinery 360 grab. Cause/motive: Accidental cause of fire: faulty fuel supply – petrol product. Extent of damage: Whole vehicle with no other properties affected. Notes: Fire was in a Case CX2 108 360 grab (plant machine). This was in an open sided portal framed waste transfer/management site. No fire spread to building or stored waste. Crews extinguished fire and protected surrounding waste whilst plant was removed from building by owners."

- **17/01/2022**

A large rubbish pile in the building was on fire. The pressure from a large pile of rubbish created a deep-seated fire within the pile of rubbish. The owner used a digger to move this as the Fire Brigade applied water via 2 hoses going down to the site from hydrant on Rochdale Road. The water was directed down a drain that leads to a bunded tank where the run off is treated prior to entering the River Ryburn adjacent to the site.

141. Due to the calm weather conditions at the time, the significant fire incident in early January 2017 led to an acrid smog that prevailed over the River Ryburn Valley and parts of the Calder Valley for several days, and affected the daily lives of residents in Sowerby Bridge.

142. The planning application for the SWIP was the subject of a petition from 1323 local residents presented to Calderdale Council by [REDACTED] on 27 April 2016. It should be of little surprise that local residents are furious with Calderdale Council regarding its approach to the environmental permitting.

143. It is clear from the number and frequency of fire related incidents on the site that the waste material, RDF material and waste processing operations pose a significant fire and health and safety risk. Yet the only mention in the Permit Application of fire relates to measures to address fires in the event of them occurring. There is nothing at all about fire prevention related to the handling, processing and transfer of the waste into the SWIP, or of fire prevention related to process operations within the SWIP.

144. Objectors consider it is relevant to the matter of operator competence that the SWIP is a very different operation to the existing sorting facility. The SWIP is a process plant and small power plant. It involves working with high temperatures, high pressure gases and liquids, and toxic chemicals as well as high voltage electricity and sophisticated controls and monitoring. A very different operation to the existing sorting facility.
145. The report by Air Quality Consultants dated November 2021 which has been submitted to the Appeal, highlighted areas where the Permit Application lacked sufficient detail. That included the lack of information about fire detection and suppression systems and the absence of a Fire Prevention Plan (paragraph 4.36). In response to that, the Appellant has submitted a document prepared by RPS dated 15 March 2022 "Calder Valley Skip Hire Environmental Management System for the Small Waste Incineration Plant". In paragraph 2.4.6 it relies on the provision of controlled access and security fencing around the boundary as a means of prevention against arson. The report fails to address the existence of a public footpath through the site which must be available for public access at all times.
146. The Appellant submitted a draft permit to the Appeal. The Council had submitted a response to the conditions attached (reference HD4). That contained the following relevant to a fire plan:
- "Condition 2.3 In the event of a fire in the small waste co-incineration plant building that uses firewater for firefighting polybooms shall be deployed across all entrances to the small waste co-incineration plant building to contain contaminated water from fire-fighting within the small waste co-incineration plant building*
- The polybooms will effectively be useless as the fire brigade will douse with water/foam in the event of a fire- what is required and mentioned in the article quoted above is a secondary containment system that holds waste water. AND before this water is released the operator will have to show that this water is safe to be released - currently no condition is proposed that would satisfy this."*
147. At the request of the Inspector the Appellant and Calderdale Council have provided a draft permit (as document referenced HD21), that contains a condition as follows:
- "Condition 2.3 In the event of a fire in the small waste co-incineration plant building that uses firewater for firefighting polybooms or other barrier (as approved by the Fire and Rescue Service and the Regulator) shall be deployed across all entrances to the small waste co-incineration plant building to contain contaminated water from fire-fighting within the small waste co-incineration plant building. Contaminated water shall be tested prior to removal to an off-site approved treatment facility.*
148. The Objectors do not consider that this condition adequately addresses the issue raised by the Council to the original condition. At present it appears that polybooms to the entrances are the only option identified to contain contamination in the event of a fire, which from the report of Air Quality Consultants could include the washing of toxic chemicals such as urea into the River Ryburn and onwards into the River Calder, with potential impacts on wildlife. It is clear that this measure would not be effective. Simply adding the possibility that the Fire and Rescue Service and the Regulator might come up with a better solution at some time in the future is not sufficient at the stage at which a permit is to be granted. There should be clear measures in place as part of the Permit Application.

149. It was noted at the planning inspection site visit that there were holes in the inside leaf of blockwork that appeared to be provided to allow drainage of floodwater. The holes do not show on the outside of the building as it is metal clad. Clearly, in the event of a fire these holes in the building fabric would allow the uncontrolled egress of fire water with the potential for pollution of the adjacent River Ryburn and onwards into the River Calder, with potential impacts on wildlife.

150. Furthermore, the holes in the building fabric would allow floodwater to flush through the plant with the further significant risks to the process equipment and the potential for uncontrolled pollution of the adjacent River Ryburn and onwards into the River Calder, with potential impacts on wildlife.

Summary

151. The Objectors consider that the SWIP Permit Application is not in accordance with either the relevant sections of the Industrial Emissions Directive or the Core Guidance. The Appellant has provided information in the Permit Application that is substantially non-compliant.

152. The Core Guidance paragraph 9.3 explains the requirements set out in the Permit Regulations, paragraph 13 of Schedule 5, in these terms:

“Following an application for the grant or transfer of an environmental permit, there is also a specific duty on the regulator not to grant or transfer the permit if it considers that the operator/new operator will not operate the facility in accordance with the permit. In making this decision the regulator should consider whether the operator cannot or is unlikely to operate the facility in accordance with the permit. The regulator might doubt whether the operator could or is likely to comply with the permit conditions if, for example, the operator:

- *Has an inadequate management system*
- *Demonstrates inadequate technical competence*
- *Has a record of poor behaviour or non-compliance with previous regulatory requirements*
- *Has inadequate financial competence”*

153. The Objectors consider that the evidence in this Objection is overwhelming that the Appellant’s Environmental Permit Application demonstrates inadequate technical competence, that the Appellant has provided no evidence of adequate financial competence and that evidence in the approved Planning Application reference 17/00113/WAM and in the Environmental Permit Application indicates an intention to avoid regulation and scrutiny rather than address compliance.

154. The Objectors consider that the evidence in this Objection is overwhelming that the Appellant’s Environmental Permit Application does not provide the information specified in Article 44 of the Industrial Emissions Directive to satisfy the requirements of Schedule 13 of the Environmental Permitting (England and Wales) Regulations 2016.

155. Further in relation to Schedule 13 of the Permit Regulations, the Objectors do not consider that the application for the permit includes sufficient 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 Chapter IV of the Industrial Emissions Directive 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.
156. The Objectors do not consider that the application meets the requirements under Schedule 13 of the Permit Regulations that requires the 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.
157. The Objectors do not consider that the Appellant will meet the condition in Paragraph 13 of Part 1, Schedule 5 of the Environmental Permitting (England and Wales) Regulations 2016, that the applicant must operate the regulated facility in accordance with the environmental permit.
158. On the basis of the information set out in this submission and the reports of technical experts already submitted as part of the Appeal process, the Objectors consider that the regulator could not be reasonably satisfied that the facility either can or will be operated in accordance with the permit conditions proposed. Therefore, the Objectors consider that a permit should not be granted and the appeal should be refused.

CALDER VALLEY SKIP HIRE LIMITED (“Appellant”)

ENVIRONMENTAL PERMIT APPEAL

REFERENCE APP/EPR/603

LIST OF REFERENCES

Legislation

- Environmental Permitting (England and Wales) Regulations 2016
 - Regulation 13
 - Part 1 Schedule 5
 - Schedule 13
 - Schedule 6
- Directive 2010/75/EU of the European Parliament and the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control) Industrial Emissions Directive

Government Guidance

- Defra.2020. Environmental Permitting: Core Guidance. For the Environmental Permitting (England and Wales) Regulations 2016 (SI 2016 No 1154)
- National Planning Policy Framework 2021
- European Waste List established by decision 2000/532/EC
- Environment Agency Guidance: Waste acceptance procedures for deposit or recovery dated 31 October 2022
- The Gov.UK Digest of UK Energy Statistics (DUKES): calorific values and density of fuels
- Gov.uk Guidance Monitoring stack emissions: measurement locations
- Environment Agency Guidance: Waste Incinerator Plant: apply for R1 status 17 August 2021
- the European Commission: Guidelines on the interpretation of the R1 energy efficiency formula for incineration facilities dedicated to the processing of municipal solid waste according to annex II of directive 2008/98/EC on waste
- DEFRA document entitled “Energy from Waste: A Guide to the Debate” dated February 2014

Supporting documents to the Appeal reference APP/EPR/603 against failure of Regulator (Calderdale Council) to give Notice of Determination of an Application for a Permit for a Small Waste Incineration Plant leading to “Deemed Refusal” of the Application.

- Inspectors Hearing Note 1 (HD 19)
- The Appellants legal response to third party objections (18th November 2022)

- Calderdale Council's Statement of Case (18th August 2022)
- Schedule 13 SWIP Application (August 2020)
- Schedule 13 Environmental Permit – Permit Reference (22nd November 2021) with Condition 5.9 included.
- CMBC Note on Draft EP (HD4)
- Tetra Tech – Stack Height Calculations 30th November 2022 (HD17)
- Draft Environmental Permit Discussed at Hearing (HD 21)
- WYG (now tetra Tech) comments on Stack Height (HD 24)

Supporting documents to the Appeal reference APP/EPR/603 not included on the Calderdale Council website for the Appeal, but part of the Appeal documents bundle. These documents being missing from the Council website has caused significant problems for local residents in making their objections.

- RPS Drawing ref. JER1902-PER-001 Rev D.
- [REDACTED] Drawing ref. 9677_17_03 Rev C.
- [REDACTED] Drawing ref. 9677_17.35 Rev A.
- I8-1000 Incinerator information sheet.
- Inciner8 Gas Analyser overview document.
- Inciner8 Pollution Control Systems information sheet.
- Zuccato Sk ZE- 200 – LT – 190-320 – EN T information sheet.
- RPS Process Diagram ref. JER 1902.
- Residence time calculation in Appendix F to the Appellants Permit Application

Other Documents

- Planning Decision on Appeal A Ref: APP/A4710/W/18/3205776
Belmont Industrial Estate, Rochdale Road, Sowerby Bridge, West Yorkshire, HX6 3BL
- Appellants legal advice to the Planning Appeal reference APP/A4710/W/18/3205776 titled "Municipal Solid Waste and the R1 Efficiency Formula"
- Appellants legal advice to the Planning Appeal reference APP/A4710/W/18/3205776 titled "Further Note on Residual Waste and Waste Returns"

- Appellant's letter headed "Planning Condition 8 - Response to Questions concerning the R1 to Discharge Condition 8 reference 17/00113/DISC4 on Planning Application reference 17/00113/WAM
- "Calculation" as part of its Information to Discharge Condition 8 reference 17/00113/DISC4 on Planning Application reference 17/00113/WAM
- Appellants R1 calculations as part of its Information to Discharge Condition 8 reference 17/00113/DISC4 on Planning Application reference 17/00113/WAM
- Calderdale Council letter dated 16 April 2021 approving Appellants R1 calculations to Discharge Condition 8 reference 17/00113/DISC4 on Planning Application reference 17/00113/WAM
- RMA Flood Risk Report dated 26th June 2019
- Environment Agency Flood Risk Report dated 2nd December 2022
- Freedom of Information request to the Fire Service dated 3 February 2017 together with response from the Fire Service

CALDER VALLEY SKIP HIRE LIMITED (“Appellant”)

ENVIRONMENTAL PERMIT APPEAL

REFERENCE APP/EPR/603

LIST OF ATTACHMENTS

Government Guidance

- DEFRA document entitled “Energy from Waste: A Guide to the Debate” dated February 2014
- The European Commission: Guidelines on the interpretation of the R1 energy efficiency formula for incineration facilities dedicated to the processing of municipal solid waste according to annex II of directive 2008/98/EC on waste
- European Waste List established by decision 2000/532/EC

Other Documents

- Calderdale Council letter dated 16 April 2021 approving Appellants R1 calculations to Discharge Condition 8 reference 17/00113/DISC4 on Planning Application reference 17/00113/WAM
- “Calculation” as part of its Information to Discharge Condition 8 reference 17/00113/DISC4 on Planning Application reference 17/00113/WAM
- Appellant’s letter headed “Planning Condition 8 - Response to Questions concerning the R1 to Discharge Condition 8 reference 17/00113/DISC4 on Planning Application reference 17/00113/WAM
- RMA Flood Risk Addendum Report dated 26th June 2019
- Planning Decision on Appeal A Ref: APP/A4710/W/18/3205776
Belmont Industrial Estate, Rochdale Road, Sowerby Bridge, West Yorkshire, HX6 3BL
- Appellants legal advice to the Planning Appeal reference APP/A4710/W/18/3205776 titled “Further Note on Residual Waste and Waste Returns”
- Appellants legal advice to the Planning Appeal reference APP/A4710/W/18/3205776 titled “Municipal Solid Waste and the R1 Efficiency Formula”
- Environment Agency Flood Risk Report dated 2 December 2022.
- Schedule 13 Environmental Permit – Permit Reference (22nd November 2021) with Condition 5.9 included.

[REDACTED]

From: [REDACTED]
Sent: 09 October 2022 17:38
To: [REDACTED]
Cc: [REDACTED]
Subject: URGENT MISSING DOCUMENTS RE: NOTICE OF APPEAL - CALDER VALLEY SKIP HIRE LIMITED - BELMONT INDUSTRIAL ESTATE

Dear [REDACTED]

I refer to the documents on the Councils web page relating to the Environmental Appeal below.
<https://www.calderdale.gov.uk/v2/businesses/licences/other/environmental-permits/current-recent-applications>

The Appellants appeal form states that they have submitted a number of technical reports and other documents. However those documents are not within the documents listed on your website. I believe that is an error and should be corrected. The Council has copies of all these documents.

I know that when the Appellant wrote to me including the appeal documents, he specifically said he had not included a number of documents as I personally already had a copy. That will not be the case for other members of the public and consultees. If you used his email (which was copied to [REDACTED]) as the basis for your upload that would explain why the list you have included is incomplete. This is the extract from that email with the missing documents listed.

I am sending you with this email copies of the Statements of Case in the appeal together with copies of those of the documents which were submitted to the Planning Inspectorate by this firm on behalf of the Appellant with the appeal other than:

- the Schedule 13 SWIP Permit Application submitted in August 2020, the environmental permit issued by the Council dated 10 February 2021,*
- the High Court Quashing Order dated 14 September 2021 and*
- the Air Quality and Permit Review prepared by Air Quality Consultants Limited (AQC) commissioned by Mr Powell dated 23 November 2021.*

Those documents, although submitted by us to the Planning Inspectorate with the appeal, are not sent to you with this email as, of course, you already have those documents.

Can you please arrange for the all the relevant documents that have been sent to the Planning Inspectorate to be uploaded and correct your notification.

Best Regards

[REDACTED]

From: [REDACTED]
Sent: 06 October 2022 12:31
To: [REDACTED]
Cc: [REDACTED]
Subject: NOTICE OF APPEAL - CALDER VALLEY SKIP HIRE LIMITED - BELMONT INDUSTRIAL ESTATE
Importance: High

Dear Sir/Madam

NOTICE OF APPEAL by Calder Valley Skip Hire Limited - Site At Belmont Industrial Estate, Rochdale Road, Sowerby Bridge, West Yorkshire, HX6 3BL Pursuant to Environmental Permitting (England and Wales)

Regulations 2106, Regulation 31 against failure of Regulator (Calderdale Council) to give Notice of Determination of an Application for a Permit for a Small Waste Incineration Plant leading to “Deemed Refusal” of the Application – Planning Inspectorate Appeal Reference APP/EPR/603

This Notice is provided to you as Calderdale Council considers you to be a person affected by, likely to be affected by, or with an interest in, the subject matter of the appeal referred to in the heading above.

That appeal has been submitted to the Planning Inspectorate and has been given Appeal Reference APP/EPR/603.

The start date of the Appeal is 21st June 2022 and this Notice should have been provided within ten working days of that date. We sincerely apologise for that failure which is corrected by this Notice. The Planning Inspectorate and the Appellant (Calder Valley Skip Hire Limited) have been notified of this course of action.

The subject matter of the Appeal is against the non-determination by Calderdale Council of an application for an Environmental Permit for the operation a small waste incinerator plant at the site detailed in the heading of this Notice. That non-determination resulted in the deemed refusal of the Application.

Background

The Appellant’s original Application was submitted on 6th August 2020 and 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 decision taken by the Council on 8th February 2021 and a Quashing Order by consent was made by the High Court on 14th September 2021, entered on 17th September 2021.

The effect of the Quashing Order was to revert the status of the original 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 referred to in this Notice.

Documents

Due to the procedural processes referred to above a significant amount of documentation has been produced.

The following are therefore available for inspection on the Council’s website from the following link <https://www.calderdale.gov.uk/v2/businesses/licences/other/environmental-permits/current-recent-applications>

1. Revised Permit Application Site Plan drawing number JER1902-0002-01.
2. SWIP Permit Decision Review prepared by RPS, consultants, on behalf of the Applicant dated 9 November 2021.
3. Response to the Review Report of AQC prepared by RPS, consultants, on behalf of the Applicant dated 15 March 2022.
4. Human Health Risk Assessment in respect of the SWIP prepared by Gair Consulting Limited, February 2022.
5. Environmental Management System Addendum for the SWIP prepared by RPS, consultants, on behalf of the Applicant, March 2022.

6. CFD Flow Simulation Report prepared by Solid Solutions, consultants, on behalf of the Applicant, March 2022.
7. A paginated set of correspondence between (1) the Applicant and the Applicant's solicitors and (2) the Council between September 2021 and May 2022 including a Technical Note dated 17 March 2022 and a Report dated 1 April 2022 prepared by Tetra Tech on behalf of the Council and including at pages 94-96 covering letter and the Notice of non-determination served by the Applicant on the Council dated 23 May 2022 pursuant to paragraph 15(1) of Schedule 5 Part 1 to EPR 2016.
8. Consolidated and Varied Environmental Permit issued to the Applicant by the Environment Agency dated 21 April 2021 in respect of the adjacent waste operation (replacing the original permit issued to the Applicant on 1 May 2007).
9. Appellant's Statement of Case.
10. The Council's Statement of Case.

Representations

If you wish to make representations in respect of this Appeal then you must do so within 15 working days after the date of this Notice and they must be in writing and quote Appeal Reference APP/EPR/603. By e-mail they should be sent to the Planning Inspectorate at ETC@planninginspectorate.gov.uk By post they must go to the Planning Inspectorate 3/A Eagle Wing, Temple Quay House, 2 The Square, Bristol. BS1 6PN.

The anticipated date for the Hearing to determine the Appeal is 29th and 30th November at a venue yet to be decided.

[REDACTED]
[REDACTED]
[REDACTED]
Calderdale Council
Town Hall
Halifax
HX1 1UJ
[REDACTED]
[REDACTED]

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[REDACTED]

From: [REDACTED]
Sent: 24 November 2022 17:18
To: [REDACTED]
Cc: [REDACTED]
Subject: RE: Calder Valley Skip Hire Limited – Environmental Permit Appeal – Reference APP/EPR/603 CORRECTION Please use this once.

Dear [REDACTED]

Thank you for your email.

I have now had a chance to speak to the Inspector with regard to the points you raise. Consequently, I can confirm that the Inspector is aware of your concerns but is unable to make a judgement at this late stage and will, instead, consider these matters at the hearing.

To that end, the Inspector would appreciate if either Mr Krantz or Mr Hughes (copied in) could add both of the Tetra Tech reports (dated 17/03/22 and 01/04/22) to the event bundle along with the consultation responses mentioned in the Council's Committee report.

Kind regards,

Matthew

[REDACTED]

From: [REDACTED]
Sent: 24 November 2022 15:37
To: [REDACTED]
Cc: ETC <ETC@planninginspectorate.gov.uk>
Subject: RE: Calder Valley Skip Hire Limited – Environmental Permit Appeal – Reference APP/EPR/603 CORRECTION Please use this once.
Importance: High

[REDACTED]

I do not understand why you are asking this.

I am making a representation on the current position to the Planning Inspectorate who are managing the appeal process. I copied you in as a representative of the regulating authority and as the party who is, I understand, responsible for ensuring the public have access to the documents in advance of the Hearing. Documents being available

to public objectors only on the day of the Hearing is clearly not acceptable in my view, particularly when they are so detailed.

I am also flagging what appears to be a change to the permit application to PINS for the same reason.

Kind Regards

■

From: [REDACTED]
Sent: 24 November 2022 15:15
To: [REDACTED]
[REDACTED]
Subject: RE: Calder Valley Skip Hire Limited – Environmental Permit Appeal – Reference APP/EPR/603
CORRECTION Please use this once.

[REDACTED]

You have not copied [REDACTED] into this e-mail.

Have you e-mailed him separately?

The inspectorate has asked that a complete set of papers be made available at the Hearing, both in hard copy and electronic format. That will happen.

[REDACTED]
[REDACTED]
[REDACTED]
[REDACTED]
[REDACTED]
[REDACTED]
[REDACTED]
[REDACTED]
[REDACTED]

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From: [REDACTED]
Sent: 24 November 2022 14:36
To: [REDACTED]
Cc: [REDACTED]
Subject: RE: Calder Valley Skip Hire Limited – Environmental Permit Appeal – Reference APP/EPR/603
CORRECTION Please use this once.
Importance: High

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Dear Sirs,

You are aware I have been copied a hearing bundle of documents from [REDACTED]
as of Mid day 24th November these are as yet unavailable to the public.

With reference to the draft permit I have received, there appears to be a late change from the original application.

On the draft permit, the SWIP is described now as "Small Waste Co-incineration Plant" not an "incineration plant"

In the publicly available document on the CMBC web site submitted by RPS on behalf of CVSH (Schedule 13 SWIP Permit Application dated 5th August 2020) it says at point 2.1.8.....", the SWIP has been assessed against thresholds set out for incineration rather than co-incineration"

At this late stage are the existing documents and application appropriate or is this a material change and in fact requires a new application?

Also I am concerned that a complete set of hearing documents which includes the objections made by the public and comments from consultees has still not been made available to the general public. However it is clear that the Appellant has had these documents now for some time. I do not consider that this meets with the requirements under the regulations or natural justice.

I do not think that the Hearing should take place unless the public have had a chance to see the response from the Appellant and the other objections. Sending them to me is not sufficient. I do not act as a representative of the general public in this matter in any formal capacity.

Kind regards

[REDACTED]

From: [REDACTED]
Sent: 16 November 2022 14:09
To: [REDACTED]
[REDACTED]
Subject: RE: Calder Valley Skip Hire Limited – Environmental Permit Appeal – Reference APP/EPR/603
CORRECTION Please use this once.

Dear Sir,

Thank you for your email.

I understand the Council (copied in) will be updating the website before the hearing and will also be providing a paper copy of the evidence for interested parties at the event itself for ease of reference.

Kind regards,

[REDACTED]

From: [REDACTED]
Sent: 16 November 2022 13:55
To: [REDACTED]
Cc: ETC <ETC@planninginspectorate.gov.uk>; [REDACTED]
[REDACTED]
Subject: RE: Calder Valley Skip Hire Limited – Environmental Permit Appeal – Reference APP/EPR/603
CORRECTION Please use this once.
Importance: High

Hello

I hope you can help me?

I believe the deadline for objections and the responses by the Appellant and Calderdale Council(CMBC) falls this week.

As you know, the Hearing is 29 & 30 November .

In order to prepare for that can you let me know how to obtain/view copies of all the documents additional to those on the CMBC web site? I believe this new evidence is important for consideration and would appreciate your assistance in obtaining this.

A Link to currently available documents at Calderdale Metropolitan Council (13)

[CMBC EP APPEAL](#)

Many thanks

[REDACTED]

From: [REDACTED]
Sent: 26 October 2022 11:43
To: [REDACTED]
Subject: RE: Calder Valley Skip Hire Limited – Environmental Permit Appeal – Reference APP/EPR/603 CORRECTION Please use this once.

Thank you – the case officer will be in touch shortly.

Kind Regards

[REDACTED]

From: [REDACTED]
Sent: 25 October 2022 17:38
To: ETC <ETC@planninginspectorate.gov.uk>
Cc: [REDACTED]
Subject: RE: Calder Valley Skip Hire Limited – Environmental Permit Appeal – Reference APP/EPR/603 CORRECTION Please use this once.

Dear Sir/Madam

Please find enclosed my Objection to the Environmental Appeal, I attach a PDF objection which also contains the supporting documents .

The previous version had an incorrect reference in the email heading and the document – I have corrected this and hope you will be able to correctly assign this.

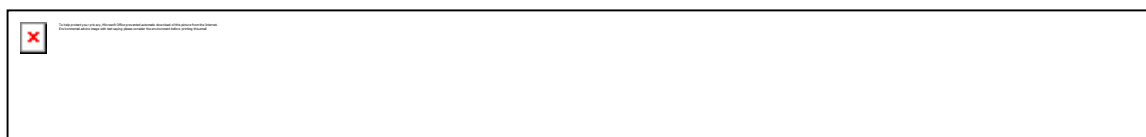
If there is anything unclear I hope you will let me know and I would still appreciate confirmation of receipt and if possible the dates for the Hearing and the name of the Inspector when assigned.

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DPC:76616c646f72



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Objection to Application by CVSH for Permit to Operate a Small Waste Co-Incineration Plant. Reference APP/EPR/603 4 Feb 2023

This objection is to the permit to operate a co-incineration plant 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 no information on the Incinerator itself, or the heat exchanger, or the final exhaust filter. There seems to be no provision for the storage of the fuel oil required to fire this co-incinerator. This must be in a suitable tank and appropriately bunded in case of leaks, especially as it is close to the river and liable to flooding.

The only reference to equipment specification is in the Permit application, reference Schedule 13, Appendix D Technical Documents 18-1000.pdf Inciner8 System Overview CEMS.pdf pollution-control-systems. pdf Zuccato Sk ZE-200-LT 190320 EN.pdf. I have been unable to find these documents in the appeal documentation.

As this is an assembly of essentially 4 machines to make a single unit, the Incinerator (Inciner8 or model 18-100), the heat exchanger, the flue gas filter, and the Triogenic ORC engine. (Arguably the Dryer is also part of this machine as it is integral to the operation of the co-incinerator.) Under HSE guidance this becomes "In situ manufacture or assembly of equipment and plant" (<https://www.hse.gov.uk/work-equipment-machinery/machine-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. This in turn means that the entire installation should be assessed by a competent body who can apply the CE or UKCA mark on the entire installation as it has now become a single new machine. Note that putting two CE or UKCA marked machines together does not automatically make the whole machine compliant, (CE plus CE does not equal CE) it must be assessed as an assembly. To comply for CE or UKCA marking the machine must also comply with the EMC directive as a whole as the individual components may interfere with each other and render the installation non compliant. The basic information for CE or UKCA marking is in the HSE Guide at <https://www.hse.gov.uk/work-equipment-machinery/uk-market.pdf>.

In order to comply with the above the entire installation must be assessed and a technical file detailing all tests and certificates for EMC compliance, safety devices etc. risk assessments, positions of EPO and EMO switches etc. is created by a competent body and then the CE or UKCA mark applied. This machine cannot be legally run until the above has been completed irrespective of any permits that Calderdale issue.

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? 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? 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 which it currently does not. Until it is assessed as a complete assembly by a recognised competent body, no guarantees can be given with respect to emissions, safety or performance, all of which form part of the permit to operate.

The efficiency of the plant is also part of the permit and this is not possible to calculate as some of the heat is used to run the ORC (which does not appear to be connected to the Electricity grid) and some is used for the "dryer" . Is this useful energy? During the night the dryer cannot be used, but the co-incinerator will be running. Is this heat just wasted? This installation looks more like an "incinerator" than a proper "co-incinerator" as a lot of the so called recovered heat will not actually be recovered.

To Summarise. This whole installation seems to be an assembly of bits 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. The entire assembly requires CE or UKCA compliance and mark, depending on timing, now that is post Brexit. All technical information contained in the specification for the equipment in the application is provided as bald statements without any reference to competent or certified bodies, therefore all calculations, models and conclusions with respect to this application are based on uncertified information.

I have spent 40 years running my own business installing and modifying equipment, during which I have worked for British Nuclear Fuels, Atomic Weapons Establishment, Rolls Royce Aero Engines, Texas Instruments, Philips Semiconductors, Motorola, National Semiconductors, Intel, Seagate disc Drives, British Aerospace, Equipment Support Company, plus numerous others, including working on CE marking American Equipment for use in the UK before Brexit.

[REDACTED] [REDACTED] [REDACTED] [REDACTED]

[REDACTED] [REDACTED]

[REDACTED]

From: [REDACTED]
Sent: 02 February 2021 19:23
To: [REDACTED]
Cc: [REDACTED]
Subject: Re: CVSH consultant report

Follow Up Flag: Follow up
Flag Status: Flagged

Hi [REDACTED]

Thank you for your email.

The first sentence of the condition clearly is something to be determined by planning – ie CVSH are required to submit evidence and we should confirm that this is done.

On the second part, there would need to be a check regularly by either the Environment agency or another competent person/authority. I am concerned that this is the basis upon which CVSH got Planning permission and yet it seems like it will now just be waved through. It needs managing and ownership in partnership with a competent body. Have the Environment Agency been asked of their view on this?

The condition must be reviewed regularly as part of the condition. The Inspectors condition said “

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.
”

How will we have any idea if they are in compliance if we are not monitoring it? This is one of the reasons why so many residents are opposed to the incinerator. The company has been the subject of hundreds of complaints over several years and there is a feeling that the authorities are just not on top of it at all. There is no trust that conditions will be adhered to or that the authorities will pick them up on it if they don't.

I would like my comments recording as part of the consultation on the discharge of the condition please. It should not be classed as discharged until there are proper plans in place as to how we will monitor it.

Regards
[REDACTED]

From: [REDACTED]
Sent: 02 February 2021 11:38
To: [REDACTED]
Cc: [REDACTED]
Subject: RE: CVSH consultant report

Good morning [REDACTED]

I was just in the process of replying to your email from yesterday, so I'll roll them into one. I have pasted the condition below as an aide memoir.

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.

My understanding is that the Inspector believed the condition was necessary because he would not have granted planning permission for an incinerator that was not R1 compliant. Whilst, I understand this reasoning, it is a little problematic because it blurs the roles of Planning and Permitting legislation, which does in turn make it difficult to manage expectations around the Local Planning Authority's longer term role post-determination of the condition.

Whilst the condition requires ongoing compliance, as is normal for planning conditions, I don't believe that it creates a requirement for proactive monitoring by the Council. As with any planning condition (1000s of which are added to permissions every year), we would investigate if evidence emerged of non-compliance. In this instance the SWIP would (if the Permit is granted) be subject to ongoing control by the Permitting Authority, who are equipped with the legal powers and expertise to ensure that it operates correctly.

Ultimately Planning could in theory become involved in enforcement activity if a breach of the condition is identified; however, from the perspective of operational efficiency and effectiveness it is best that we maintain the distinctive rolls of the different arms of the Council.

I hope that this explanation makes sense – please come back to me if you have any further queries. I have copied Andrew in because it overlaps with his responsibilities around Environmental Health.

Kind regards

██████████

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Calderdale Metropolitan Borough Council

Annual Status Report 2022

Bureau Veritas

June 2022

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2022 Air Quality Annual Status Report (ASR)

In fulfilment of Part IV of the Environment Act 1995
Local Air Quality Management

Date: June 2022

Information	Calderdale MBC Details
Local Authority Officer	
Department	Environmental Health
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Report Reference Number	CMBC.ASR.22
Date	June 2022

Executive Summary: Air Quality in Our Area

Air Quality in Calderdale

Air pollution is associated with a number of adverse health impacts. It is recognised as a contributing factor in the onset of heart disease and cancer. Additionally, air pollution particularly affects the most vulnerable in society: children, the elderly, and those with existing heart and lung conditions. There is also often a strong correlation with equalities issues because areas with poor air quality are also often less affluent areas^{1,2}.

The mortality burden of air pollution within the UK is equivalent to 28,000 to 36,000 deaths at typical ages³, with a total estimated healthcare cost to the NHS and social care of £157 million in 2017⁴.

In Calderdale, the air quality is generally good, owing to the large amount of rural land. However, there are some areas where the NO₂ annual mean objective is exceeded, as vehicle emissions are trapped in the small space created by buildings near roads ('street canyons'). Currently, Calderdale has eight Air Quality Management Areas (AQMA), all of which have been declared alongside major roads in response to exceedances of the annual mean objective for NO₂. The most recent AQMA (Calderdale No.8 New Bank) was declared on 26th February 2020 along the A58 at New Bank. Additional information including further assessment reports is available on Calderdale Metropolitan Borough Council's [AQMA page](#).

In 2021, the measured concentration of NO₂ increased within five of the eight AQMAS, and is likely reflective of the increased travel activity relative to 2020, when there was more COVID-19 restrictions. Indeed, compared to 2019 when travel activity was at pre-pandemic levels, the concentrations in 2021 within the eight AQMA is lower in all but one AQMA. Therefore, excluding the 2020 COVID-19 impacts, the concentrations within AQMA is

¹ Public Health England. Air Quality: A Briefing for Directors of Public Health, 2017

² Defra. Air quality and social deprivation in the UK: an environmental inequalities analysis, 2006

³ Defra. Air quality appraisal: damage cost guidance, July 2021

⁴ Public Health England. Estimation of costs to the NHS and social care due to the health impacts of air pollution: summary report, May 2018

decreasing. However, it should be noted that some COVID-19 restrictions were still in place at the start of 2021 and could likely have impacted pollutant concentrations.

Actions to Improve Air Quality

Whilst air quality has improved significantly in recent decades, and will continue to improve due to national policy decisions, there are some areas where local action is needed to improve air quality further.

The 2019 Clean Air Strategy⁵ sets out the case for action, with goals to reduce exposure to harmful pollutants. The Road to Zero⁶ sets out the approach to reduce exhaust emissions from road transport through a number of mechanisms; this is extremely important given that the majority of Air Quality Management Areas (AQMAs) are designated due to elevated concentrations heavily influenced by transport emissions.

Calderdale Metropolitan Borough Council's 2019 Air Quality Action Plan (AQAP) outlines a number of key actions that are being undertaken to tackle sources of air pollution. A source appointment exercise (carried out in 2017) identified that road traffic was the main source of air pollution within the eight declared AQMAs. Therefore, the main focus points include:

- Promoting low emission transport by encouraging the uptake and use of ultra-low emission vehicles (ULEVs).
- Facilitating the use of public transport by increasing the interconnectivity of the transport hub to control urban traffic congestion, prioritising public transport.
- Encouraging active travel by improving infrastructure (i.e. developing cycleways).
- Promoting the use of alternative fuels by providing electrical vehicle (EV) charging points and offering incentives such as discounted parking for EVs.
- Providing accessible information to the public to influence behaviour change.

Transport and infrastructure projects feature prominently within the 2019 AQAP, as road traffic is the main source of pollution within the borough (particularly in AQMAs). As vehicle standards are beyond the control of Calderdale Metropolitan Borough Council, the AQAP is designed to influence other aspects of the road transport system. For example, the primary

⁵ Defra. Clean Air Strategy, 2019

⁶ DfT. The Road to Zero: Next steps towards cleaner road transport and delivering our Industrial Strategy, July 2018

focus is on enhancing infrastructure that will reduce congestion, improve the flow of traffic and encourage people to use a more active form of travel (i.e. walking/cycling). Therefore, the AQAP directly targets road traffic, which is the main source of pollution in each AQMA.

Conclusions and Priorities

During 2021, the annual mean NO₂ concentration increased at 30 diffusion tube sites, the majority of which are in AQMAs. As road traffic is the main source of air pollution in the eight AQMAs, this is likely reflective of the increased travel activity compared to 2020 when there were more COVID-19 restrictions in place. Indeed, compared to 2019 (not impacted by COVID-19), the NO₂ annual mean is lower in 2021 in each of the AQMAs, except for AQMA No.1 (Salterhebble). The maximum annual mean NO₂ concentration was 53.2 µg/m³ (before distance correction) at site LV-NBN, which is within AQMA No.8 (New Bank). Based upon the latest monitoring, Calderdale Metropolitan Borough Council do not plan to revoke any of the eight AQMAs. The PM₁₀ and PM_{2.5} monitoring completed within the borough continues to show compliance with the relevant annual mean and short-term objectives. Therefore, the NO₂ annual mean continues to be the primary concern.

In order to tackle the exceedance of the NO₂ annual mean objective of 40 µg/m³, the 2019 AQAP mainly focuses on methods to reduce vehicle emissions. One key priority is to bid for funding to install EV charging points that facilitate the use of ULEVs. Calderdale Metropolitan Borough Council are therefore committed to actively finding ways to encourage a more active form of travel that reduces the dependence on private vehicle use. By promoting travel alternatives, the NO₂ annual mean concentration within AQMAs should start to decrease.

Local Engagement and How to get Involved

Calderdale Metropolitan Borough Council are committed to raising the awareness of the impacts of poor air quality with the public. For example, improvements to public engagement are underway, ranging from web page improvements to making live monitoring data publicly available. As well as raising awareness, Calderdale Metropolitan Borough Council intend to involve public engagement into policy decisions that impact upon travel. Indeed, Priority 4 in the 2019 AQAP is to encourage public engagement and interest through improved communication and community involvement. Calderdale libraries obtained funding for a project named 'Something in the Air?' which, in partnership with local organisations and academic researchers, aims to educate the public on the impacts of air pollution. The project

involves the public in air quality issues in an attempt to make them think more deeply and consider the changes they could make. The focus of the initial project was to engage members of the public in the Sowerby Bridge (AQMA No.2) area, however following the success of the project, this is to move to the town of Hebden Bridge (AQMA No.3) in 2022.

Local Responsibilities and Commitment

This ASR was prepared by the Bureau Veritas on behalf of Calderdale Metropolitan Borough Council with the support and agreement of the following officers and departments:

[REDACTED]

[REDACTED]

[REDACTED]

Environmental Health & Community Protection Team

This ASR has been approved by:

[REDACTED]

[REDACTED]

If you have any comments on this ASR please send them to [REDACTED] at:

Town Hall, Crossley Street, Halifax, West Yorkshire, HX1 1UJ

[REDACTED]

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1 Local Air Quality Management

This report provides an overview of air quality in Calderdale during 2021. It fulfils the requirements of Local Air Quality Management (LAQM) as set out in Part IV of the Environment Act (1995) and the relevant Policy and Technical Guidance documents.

The LAQM process places an obligation on all local authorities to regularly review and assess air quality in their areas, and to determine whether or not the air quality objectives are likely to be achieved. Where an exceedance is considered likely the local authority must declare an Air Quality Management Area (AQMA) and prepare an Air Quality Action Plan (AQAP) setting out the measures it intends to put in place in pursuit of the objectives. This Annual Status Report (ASR) is an annual requirement showing the strategies employed by Calderdale Metropolitan Borough Council to improve air quality and any progress that has been made.

The statutory air quality objectives applicable to LAQM in England are presented in Table E.1.

2 Actions to Improve Air Quality

2.1 Air Quality Management Areas

Air Quality Management Areas (AQMA) are declared when there is an exceedance or likely exceedance of an air quality objective. After declaration, the authority should prepare an Air Quality Action Plan (AQAP) within 12 months setting out measures it intends to put in place in pursuit of compliance with the objectives.

A summary of AQMA declared by Calderdale Metropolitan Borough Council can be found in Table 2.1. The table presents a description of the eight AQMA that are currently designated within Calderdale. Appendix D: Maps of Monitoring Locations and AQMA provides maps of the AQMA and also the air quality monitoring locations in relation to the AQMA. The air quality objectives pertinent to the current AQMA designations is for the NO₂ annual mean.

Table 2.1 – Declared Air Quality Management Areas

AQMA Name	Date of Declaration	Pollutants and Air Quality Objectives	One Line Description	Is air quality in the AQMA influenced by roads controlled by National Highways?	Level of Exceedance: Declaration	Level of Exceedance: Current Year	Name and Date of AQAP Publication	Web Link to AQAP
Calderdale No. 1 Salterhebble	Declared October 2005, amended April 2014	NO ₂ Annual Mean	Stretch of the A629 south of Dryclough Lane	YES	46 µg/m ³	53.1 µg/m ³	AQAP 2019	AQAP 2019
Calderdale No.2 Sowerby Bridge	Declared July 2006	NO ₂ Annual Mean	A58 through central Sowerby Bridge	YES	53 µg/m ³	37.0 µg/m ³	AQAP 2019	AQAP 2019
Calderdale No.3 Hebden Bridge	Declared August 2006	NO ₂ Annual Mean	A646 through town centre	YES	48 µg/m ³	42.6 µg/m ³	AQAP 2019	AQAP 2019
Calderdale No.4 Luddendenfoot	Declared July 2007, amended March 2014	NO ₂ Annual Mean	A646 through town centre	YES	50 µg/m ³	32.0 µg/m ³	AQAP 2019	AQAP 2019
Calderdale No.5 Stump Cross	Declared July 2007	NO ₂ Annual Mean	A58 at junction of Leeds Road and Bradford Road	YES	58 µg/m ³	32.3 µg/m ³	AQAP 2019	AQAP 2019
Calderdale No.6 Brighouse	Declared July 2007, amended March 2014	NO ₂ Annual Mean	Encircling town centre	YES	51 µg/m ³	43.6 µg/m ³	AQAP 2019	AQAP 2019
Calderdale No.7 Hipperholme	Declared March 2014	NO ₂ Annual Mean	A58 Leeds Road close to junction with Brighouse Road	YES	47 µg/m ³	42.3 µg/m ³	AQAP 2019	AQAP 2019
Calderdale No.8 New Bank	Declared February 2020	NO ₂ Annual Mean	A58 east of Halifax town centre	YES	42 µg/m ³	53.2 µg/m ³	AQAP 2019	AQAP 2019

☒ Calderdale Metropolitan Borough Council confirm the information on UK-Air regarding their AQMAs is up to date.

☒ Calderdale Metropolitan Borough Council confirm that all current AQAPs have been submitted to Defra.

2.2 Progress and Impact of Measures to address Air Quality in Calderdale

Defra's appraisal of last year's ASR concluded:

"Calderdale Metropolitan Borough Council have reviewed their AQMA designations. Whilst AQMAs 4 and 5 are now compliant and have been for two and four consecutive years respectively, the Council are not considering revocation at this time. If these AQMAs continue to show low concentrations (less than 36 $\mu\text{g}/\text{m}^3$), the Council should consider revocation. The Mytholmroyd area has seen exceedances in past years but did not exceed in 2020. The Council are not declaring an AQMA here but are instead monitoring closely. The Councils review of AQMAs is supported, and an update is expected in the 2022 ASR".

- Although the maximum NO₂ annual mean concentration in AQMA No.4 (32.0 $\mu\text{g}/\text{m}^3$) and No.5 (32.3 $\mu\text{g}/\text{m}^3$) is below the air quality objective in 2021, there is currently no plans by Calderdale Metropolitan Borough Council to revoke these AQMAs. This is owing to the unprecedented reductions caused by COVID-19 restrictions. However, this will be considered over the next year. The NO₂ annual mean limit was also not exceeded in the Mytholmroyd area, therefore no AQMA is to be declared in this area.

"The report mentions a planning application and a new access route identified as potential new or changed sources of pollution in the borough. This is encouraged, and the next ASR should provide an update to this".

- The NO₂ annual mean concentration at the five diffusion tubes in the Mytholmroyd area was lower in 2021 than in 2020, suggesting that the new access route has eased congestion (i.e. less stopping and starting of vehicles).

"Trends have been presented, with a robust comparison to the air quality objective. The Council have also discussed how COVID-19, and flooding as a result of Storms Ciara and Dennis, have impacted road traffic and pollution within the Borough. This analysis demonstrates the Councils commitment to understanding trends within the Borough and is commended".

- Both long-term (2017-2021) and short-term (2020-2021) trends have been discussed in the 2022 ASR, whilst making reference to the relevant air quality objectives.

"Graphs displaying trends in pollutant concentrations have been included to support the reports trend analysis. However, annual mean NO₂ results from the three continuous

monitors (AQS2, 3 and 4) have not been presented. It would be beneficial to include this for completeness in future reports”.

- Automatic data has been presented and graphed, relative to the 5-year trend.

“Table 2.2 is missing information regarding funding status and cost of measures”.

- Information on the funding status of each measure to improve air quality has been included in the 2022 ASR.

“AQC1, 2 and 3 appears to be one triplicate (three tubes are one location) as the OS grid reference coordinates are the same. However, results for each tube have been presented individually. This is a possible source of confusion and should be clarified. If AQC1, 2 and 3 is a single triplicate location, an average of the three diffusion tubes would suffice”.

- AQC1, 2 and 3 has been classified as a triplicate location in the diffusion tube data processing tool (DTDPT), and therefore an average of the three tubes is provided.

“A local bias adjustment factor has been calculated and applied to the monitoring data. The national bias adjustment factor could be presented for comparison”.

- Both the national and local bias adjustment factor are presented in the 2022 ASR, with a justification provided for which was used to bias adjust the diffusion tube data.

Calderdale Metropolitan Borough Council has taken forward a number of direct measures during the current reporting year of 2021 in pursuit of improving local air quality. Details of all measures completed, in progress or planned are set out in Table 2.2. 29 measures are included within Table 2.2, with the type of measure and the progress Calderdale Metropolitan Borough Council have made during the reporting year of 2021 presented. Where there have been, or continue to be, barriers restricting the implementation of the measure, these are also presented within Table 2.2. More detail on these measures can be found in their respective Action Plans (see [Calderdale 2019 Air Quality Action Plan](#)).

Key completed measures are:

- **Travel Alternatives:** Installation of EV charging points at 10 locations, including Bethel Street car park in Brighouse, Market Place car park in Hebden Bridge and West Street car park in Sowerby Bridge. Over 70 cycle storage facilities (stands, shelters and lockers) have been installed across the borough, with the majority in key areas such as AQMAs (i.e. in Brighouse, Hebden Bridge and Sowerby Bridge).
- **Public Information:** Live automatic monitoring data is now available online, freely accessible to members of the public.

- School Streets: Introduced at over 10 schools in July 2020 as part of an initial trial, with more added in 2021 (i.e. Trinity Academy, effective from 28th June 2021).

Calderdale Metropolitan Borough Council expects the following measures to be completed over the course of the next reporting year:

- The 'Clean Air for All in Calderdale' strategy (currently in draft format), with strategies to be agreed. This strategy was formed following the completion of the 2021 ASR.
- The 'Active Calderdale' campaign which promotes alternative forms of travel.

Calderdale Metropolitan Borough Council's priorities for the coming year are:

- Priority 1: Promoting alternatives to private vehicle use, recognising the contribution of diesel vehicles and bidding for ULEV funding whenever possible.
- Priority 2: Improving the transport network infrastructure, as set out in Calderdale Metropolitan Borough Council's Transport Strategy and Local Plan.
- Priority 3: Developing awareness of impacts and remedies, and integrating the priorities of other strategies and frameworks, such as public health (active travel), sustainability (carbon reduction strategy) and local planning (sustainable development).
- Priority 4: Encouraging public engagement and interest through improved communication and community involvement.

Alongside the four priorities listed in the AQAP, Calderdale Metropolitan Borough Council aim to obtain funding via the West Yorkshire Low Emissions Strategy (WYLES) group for initiatives that will help reduce air pollution.

Progress on implementing some of the measures has been slower than expected due to COVID-19. This is because staff were absent due to either contracting COVID-19 or being allocated with COVID-19 duties. Calderdale Metropolitan Borough Council are however committed to progressing these measures during the current reporting year.

Calderdale Metropolitan Borough Council anticipates that the measures stated below in Table 2.2 will achieve compliance in all of the eight AQMAs that are currently declared. This is owing to the fact that the measures are directed towards road traffic emissions, which is the main source of pollution in the AQMAs. Therefore, by implementing the measures in Table 2.2, the NO₂ annual mean should begin to comply with the air quality objective.

Table 2.2 – Progress on Measures to Improve Air Quality

Measure No.	Measure	Category	Classification	Year Measure Introduced	Estimated / Actual Completion Year	Organisations Involved	Funding Source	Defra AQ Grant Funding	Funding Status	Estimated Cost of Measure	Measure Status	Reduction in Pollutant / Emission from Measure	Key Performance Indicator	Progress to Date	Comments / Barriers to Implementation
AQAP 1 (1)	Achieve better understanding of local air quality, including monitoring and source appointment	Transport and Planning Infrastructure	Other	2009 – 2020	Ongoing	Calderdale MBC, neighbouring authorities, tools from Defra, WYCA	Calderdale MBC, neighbouring authorities, tools from Defra, WYCA	No	Partially funded	< £10k	Implementation	Neutral	Data collection	Monitoring contracts extended. Live data now on website air quality dashboard	Funding ended 2019
AQAP 1 (2)	Traffic flow and network improvements	Traffic Management	UTC, congestion management, traffic reduction	Current	Ongoing	CMBC, Highways England, neighbouring authorities, WYCA	CMBC, Highways England, neighbouring authorities, WYCA	No	Partially funded	< £10k	Implementation	Neutral	Improved traffic flows and reduced queue lengths at key network points	Implementation ongoing	Funding
AQAP 1 (3)	Urban Traffic Control (UTC) Improvements	Traffic Management	UTC, congestion management, traffic reduction	Current	To be included in major projects and corridor improvement plans. Further VMS included in Phase 4 scheme for A629	Calderdale MBC, neighbouring authorities	Calderdale MBC, neighbouring authorities	No	Not funded	< £10k	Implementation	Some reduction due to improved flows of traffic	Improved traffic flows and reduced queue lengths at key network points, less parking space hunting	Proposal to link all signals in centralised system (UTC) based in Leeds. Variable message Signs giving route-specific messages now established. Development of a new parking strategy commended. Draft strategy completed. APPY parking technology now in use in town centres.	Modified since original action plan
AQAP 1 (4)	Handling Emissions Data (Emissions Factor Toolkit)	Transport planning and infrastructure	Other	Current	Ongoing	Calderdale MBC, tools from Defra	Calderdale MBC, tools from Defra	No	Not funded	< £10k	Implementation	Neutral	Effectiveness of predictions	Informs annual status report	N/A
AQAP 2 (1)	Improve air quality web pages – access to live data	Public Information	Via the internet	2019	September 2019	Calderdale MBC	Calderdale MBC	No	Not funded	< £10k	Completed	Indirect, may influence behavioural change	Web traffic / customer satisfaction	Web pages updated – live data now online	N/A
AQAP 2 (2)	Clean Air Campaign	Public Information	Via the internet / social media / other	June 2019	Ongoing	Calderdale MBC	Calderdale MBC	No	Not funded	< £10k	Implementation	Moderate impact behaviour change	Social media analytics	Successful event including branded messaging launched in June 2019	N/A
AQAP 2 (3)	Investigate Freight Partnership	Freight and Delivery Management	Freight partnerships for city centre deliveries	2019 onwards	2021	Kirklees MBC, Calderdale MBC, Highways England	Kirklees MBC, Calderdale MBC, Highways England	No	Partially funded	< £10k	Planning	Significant improvements in longer term	Number of partners signed up	Preliminary work with operators	Resources to engage with potential partners
AQAP 3 (1)	Promote high occupancy travel	Transport Planning and Infrastructure	Strategic highways improvement, re-prioritising	Ongoing	Ongoing	Calderdale MBC, neighbouring authorities	Calderdale MBC, neighbouring authorities	No	Not funded	< £10k	Planning	Modest reduction in road emissions	Reduction in vehicle numbers	Campaign 2018	Resource and partner commitments
AQAP 3 (2)	Cycling infrastructure improvements and facilities	Promoting Travel Alternatives	Promotion of cycling	2018 onwards	Ongoing	Calderdale MBC	Calderdale MBC	No	Not funded	< £10k	Implementation	Significant improvements in longer term	Increases in numbers cycling and reduction in car use, kilometres of new cycle paths	Calderdale Cycling Forum (CCF) reports into the cabinet transport working party, CCF meets regularly made up of Calderdale cycle reps council officers, members, schools & other stakeholders. Upgrade of Upper Valley Towpath complete to Hebden Bridge – further work planned in Phase 2 to Todmorden is underway. Hebble Trail extension plan now developed. Now incorporated into the WYTF Phase 4	Funding and staffing resources. Land ownership

Measure No.	Measure	Category	Classification	Year Measure Introduced	Estimated / Actual Completion Year	Organisations Involved	Funding Source	Defra AQ Grant Funding	Funding Status	Estimated Cost of Measure	Measure Status	Reduction in Pollutant / Emission from Measure	Key Performance Indicator	Progress to Date	Comments / Barriers to Implementation
AQAP 3 (3)	Active Calderdale Campaign	Promoting Travel Alternatives	Intensive active travel campaign & infrastructure	Ongoing	2022	Calderdale MBC	Calderdale MBC	No	Not funded	< £10k	Implementation	Low impact on emissions, but reduced exposure	Increases in cycling and walking – most active borough in the North by 2024	Cycling infrastructure installed in key areas (Brighouse, Sowerby Bridge). LCWIP to be used in development	Commitment from communities
AQAP 3 (4)	Metro travel card pool scheme	Alternatives to Private Vehicle Use	Other	Ongoing	Ongoing	Calderdale MBC, Metro	Calderdale MBC, Metro	No	Partially funded	< £10k	Implementation	Low initial impact	Increase in public transport use, number of staff car journeys replaced	Calderdale's first LCWIP is complete (Halifax for Walking and Brighouse for cycling)	Further cards purchased 2018
AQAP 3 (5)	20pmh areas	Traffic Management	Reduction of speed limits, 20mph zones	2017	Completed 2017	Calderdale MBC	Calderdale MBC	No	Not funded	< £10k	Completed	Possible small reduction in road traffic emissions	Number of 20mph zones	Zones completed	Opportunities for further extension
AQAP 3 (6)	Car sharing promotion	Alternatives to Private Vehicle Use	Car & lift sharing schemes	2009 – 2020	Ongoing	Calderdale MBC	Calderdale MBC	No	Not funded	< £10k	Implementation	Small reduction, behaviour change	Reduced private car use, number of car sharing partners	Car sharing scheme up and running – featured in Clean Air Day 2018. Car club up and running for 5-years	Growing interest
AQAP 4 (1)	ULEV Procurement	Promoting Low Emission Transport	Company vehicle procurement – prioritising uptake of low emission vehicles	2023 onwards	After 2023	Calderdale MBC	Calderdale MBC	No	Not funded	< £10k	Implementation	Reduction in emissions around schools	Reduce number of petrol and diesel cars and increase number of chargers (% ULEV in vehicle fleet)	30 ULEVs ordered for Calderdale fleet. Project team set up to deliver EV charging infrastructure across multiple sites	Funding availability
AQAP 4 (2)	EV recharging provision	Promoting Low Emission Transport	Procuring alternative refuelling infrastructure to promote Low Emission Vehicles, EV recharging, gas fuel recharging	Current	Ongoing	Calderdale MBC, supported by OLEV etc.	Calderdale MBC, supported by OLEV etc.	No	Partially funded	< £10k	Implementation	Reduced vehicle emissions	Number of EV charging points	EV charging points installed in 10 locations (i.e. Brighouse, Hebden Bride and Sowerby Bridge)	Funding availability
AQAP 4 (3)	Retrofit school bus fleet	Promoting Low Emission Transport	Public vehicle procurement – promoting uptake of low emission vehicles	2017	Ongoing	Calderdale MBC, neighbouring authorities	Calderdale MBC, neighbouring authorities	No	Not funded	< £10k	Implementation	Reduced vehicle emissions	Proportion of fleet retrofitted	Implementation ongoing	N/A
AQAP 5 (1)	Travel plans	Promoting Travel Alternatives	Workplace travel planning	Current	Ongoing	Calderdale MBC, neighbouring authorities	Calderdale MBC, neighbouring authorities	No	Not funded	< £10k	Implementation	Potential moderate in long-term	Number of workplaces with travel plans	Planning condition for travel plans created	Enforcement
AQAP 5 (2)	School travel Plans	Promoting Travel Alternatives	School travel plans	2020 onwards	2020	Calderdale MBC, neighbouring authorities	Calderdale MBC, neighbouring authorities	No	Not funded	< £10k	Implementation	Mainly behavioural influence	Number of schools with travel plans	Plan completed pre 2019	Many schools not with Local Authority
AQAP 5 (3)	Local Plan Air Quality Policies	Policy Guidance and Development Control	Air quality planning and policy guidance	2017 onwards	2021	Calderdale MBC	Calderdale MBC	No	Not funded	< £10k	Implementation	Significant improvements in longer-term	Consistent approach to air quality in planning guidance	WYLES adopted and used. Currently being revised by WYLES delivery group	WYLES includes air quality guidance for developers
AQAP 5 (4)	Promote update of electric vehicles e.g. taxis	Promoting Low Emission Transport	Taxi emission incentives	2017 onwards	Ongoing	Calderdale MBC	Calderdale MBC	No	Not funded	< £10k	Implementation	Moderate, especially in town centres	Reduction in number of petrol and/or diesel taxis	1 operating further promotion in place	Engagement of licence trade
AQAP 5 (5)	Promote and support use of public transport and improve infrastructure	Promoting Low Emission Transport	Public vehicle procurement – promoting uptake of low emission vehicles	2018	2019	Calderdale MBC, WYCA	Calderdale MBC, WYCA	No	Partially funded	< £10k	Completed / Implementation	Potentially moderate in the longer term	Passenger journeys on public transport	Clean Bus Technology grants awarded and fleet being upgraded. Development of station at Elland included access and parking (delivery expected 2022/23). Implemented the community rail partnership to encourage more train travel.	Funding

Measure No.	Measure	Category	Classification	Year Measure Introduced	Estimated / Actual Completion Year	Organisations Involved	Funding Source	Defra AQ Grant Funding	Funding Status	Estimated Cost of Measure	Measure Status	Reduction in Pollutant / Emission from Measure	Key Performance Indicator	Progress to Date	Comments / Barriers to Implementation
AQAP 5 (6)	Promote good practices is domestic burning	Policy Guidance and Development Control	Other	Current	Ongoing	Calderdale MBC, Defra	Calderdale MBC, Defra	No	Partially funded	< £10k	Implementation	Significant local impact	Number of complaints about smoke from chimneys	Published on website	Enforcement
AQAP 6 (1)	Community renewable energy scheme	Promoting Low Emission Plant	Public procurement of stationary combustion sources	2019 onwards	Ongoing	Calderdale MBC	Calderdale MBC	No	Not funded	< £10k	Implementation	Significant improvements in longer term	Number of schemes approved	Feasibility modelling done	Funding
AQAP 6 (2)	Promote locally grown food, goods and services	Freight and Delivery Management	Other	2018 onwards	Ongoing	Calderdale MBC, local partners including 'Incredible Edible'	Calderdale MBC, local partners including 'Incredible Edible'	No	Partially funded	< £10k	Implementation	Significant improvements in longer term	Policies applied to all developments	Council policy agreed and land use for growing promoted	Ongoing community take up
AQAP 6 (3)	Improved energy efficiency	Other	Other			Calderdale MBC	Calderdale MBC	No	Not funded	< £10k	Implementation		Number of developments incorporating energy efficiency measures		N/A
AQAP 6 (4)	Compliance checks for environmental permit	Promoting Low Emission Plant	Environmental Permits	Current	Ongoing	Calderdale MBC, Environment Agency	Calderdale MBC, Environment Agency	No	Partially funded	< £10k	Implementation	Significant impact locally	Level of compliance with permit conditions	Part A1, A2, B and Schedule 9 and 13 permits in place	N/A
AQAP 6 (5)	Introduction of green screens	Transport/ Planning/ Infrastructure	Other	Current	Ongoing	Calderdale MBC	Calderdale MBC	No	Not funded	< £10k	Implementation	Moderate local impact	NO ₂ monitoring, protection of children in playground from NO ₂ and PM	First installation May 2019	Finance
AQAP 6 (6)	Pilot school road closure	Transport/ Planning/ Infrastructure	Other	Current	Ongoing	Calderdale MBC, schools	Calderdale MBC, schools	No	Not funded	< £10k	Completed/ Implementation	Significant local impact	Air quality monitored	12 in place – more in planning stages. 20% modal shift – following 12-month survey. Expansion around school areas to create Active Travel Neighbourhoods	Community support
AQAP 6 (7)	Tackle idling vehicles	Traffic Management	Congestion Management/Traffic Reduction	Current	Ongoing	Calderdale MBC	Calderdale MBC	No	Not funded	< £10k	Completed/ Implementation	Moderate local impact	Number of idling vehicles in key destinations	Confirming legal orders. Within AQMAs, buses given priority and removal of parked cars to improve the flow of traffic/reduce the stopping and starting of traffic on the key route network	Compliance and resource

2.3 PM_{2.5} – Local Authority Approach to Reducing Emissions and/or Concentrations

As detailed in Policy Guidance LAQM.PG16 (Chapter 7), local authorities are expected to work towards reducing emissions and/or concentrations of PM_{2.5} (particulate matter with an aerodynamic diameter of 2.5µm or less). There is clear evidence that PM_{2.5} has a significant impact on human health, including premature mortality, allergic reactions, and cardiovascular diseases.

Calderdale Metropolitan Borough Council is taking the following measures to address PM_{2.5}:

- **Biomass Combustion (including domestic wood burning):** Guidance is provided on the appropriate selection of fuels on Calderdale Metropolitan Borough Council's web pages, and support is provided to the information campaign by Defra surrounding domestic emissions. The latest announcement to phase out coal burning and other fuels has also been made available. A green waste collection service is also in operation to discourage the burning of garden waste. As large parts of Calderdale (especially urban areas) are covered by [Smoke Control Areas](#), households are advised on how to comply with these measures and where additional information can be obtained from.
- **Industrial Sources:** Calderdale Metropolitan Borough Council are engaging with local operators who hold environmental permits for combustion plant to ensure that emissions are within limits and, where possible, reduced even further. A number of premises burning waste below the permitted threshold have been identified, and advice is being provided on obtaining a U4 exemption and, more importantly, reducing the smoke emissions from their appliances. Calderdale Metropolitan Borough Council is also working with the Environment Agency to identify and regularise waste burning in the borough.
- **Public Information:** The public are informed by Calderdale Metropolitan Borough Council on less polluting ways of travel, in particular avoiding private vehicle use where possible. Encouraging the use of alternative modes of transport (i.e. walking and cycling) is hoped to assist in reducing fine particles from brake and tyre wear.

A Climate Change Operational Group has been formed within Calderdale Metropolitan Borough Council, alongside the Air Quality Operational Group to develop ideas that can be implemented to reduce the overall concentration of PM_{2.5} across the borough.

3 Air Quality Monitoring Data and Comparison with Air Quality Objectives and National Compliance

This section sets out the monitoring undertaken within 2021 by Calderdale Metropolitan Borough Council and how it compares with the relevant air quality objectives. In addition, monitoring results are presented for a five-year period between 2017 and 2021 to allow monitoring trends to be identified and discussed.

3.1 Summary of Monitoring Undertaken

3.1.1 Automatic Monitoring Sites

Calderdale Metropolitan Borough Council undertook automatic (continuous) monitoring at three sites during 2021. Table A.1 in Appendix A shows the details of the automatic monitoring sites. The [Dataworks page](#) presents automatic monitoring results for Calderdale. Maps showing the location of the monitoring sites with reference to the current AQMAs are provided in Appendix D. Further details on how the monitors are calibrated and how the data has been adjusted are included in Appendix C.

3.1.2 Non-Automatic Monitoring Sites

Calderdale Metropolitan Borough Council undertook non-automatic (i.e. passive) monitoring of NO₂ at 57 sites during 2021. One site is however a triplicate, resulting in 59 diffusion tubes being deployed each month – an increase from the 54 that made up the monitoring network in 2020. Table A.2 in Appendix A presents the details of the non-automatic sites. Maps showing the location of the monitoring sites are provided in Appendix D: Maps of Monitoring Locations and AQMAs. Further details on Quality Assurance/Quality Control (QA/QC) for the diffusion tubes, including bias adjustments and any other adjustments applied (e.g. annualisation and/or distance correction), are included in Appendix C.

The results presented from the passive diffusion tube monitoring network should however be treated with caution. This is because the maximum data capture at a single site was 35%, with diffusion tubes either not deployed or overexposed for a large part of the year, especially at the beginning (January – July and December). Therefore, only four months data has been used (August – November) and annualisation has been applied to all tubes.

3.2 Individual Pollutants

The air quality monitoring results presented in this section are, where relevant, adjusted for bias, annualisation (where the annual mean data capture is below 75% and greater than 25%), and distance correction. Further details on adjustments are provided in Appendix C.

3.2.1 Nitrogen Dioxide (NO₂)

Table A.3 and Table A.4 in Appendix A compare the ratified and adjusted monitored NO₂ annual mean concentrations for the past five years with the air quality objective of 40µg/m³. Note that the concentration data presented represents the concentration at the location of the monitoring site, following the application of bias adjustment and annualisation, as required (i.e. the values are exclusive of any consideration to fall-off with distance adjustment).

During 2021, the average NO₂ annual mean concentration increased in five of the eight AQMAs. Relative to 2020, the greatest change was seen in AQMA No.1 (Salterhebble), where the annual mean NO₂ concentration increased by 13%. As in 2020, the greatest average NO₂ annual mean concentration was in AQMA No.8 (New Bank) at 43.9 µg/m³, with a single diffusion tube (LV-NBN) measuring a NO₂ concentration as high as 53.2 µg/m³. However, following distance correction, this fell to below the air quality objective. With the exception of AQMA No.4 (Luddendenfoot) and AQMA No.5 (Stump Cross), all AQMAs had a diffusion tube site that exceeded, or was within 10% of, the NO₂ annual mean air quality objective of 40 µg/m³. Outside of AQMAs, the NO₂ annual mean objective was exceeded at two sites (LV-AT: 41.5 µg/m³ and NB-GL: 43.5 µg/m³). No AQMA is however needed to be declared as these tubes are not located in areas of relevant exposure, as following distance correction the NO₂ annual mean concentrations were 31.6 µg/m³ (LV-AT) and 26.7 µg/m³ (NB-GL). Across the three automatic monitoring sites in Calderdale, an NO₂ annual mean concentration of 35.5 µg/m³ (AQS2), 32.8 µg/m³ (AQS3) and 33.0 µg/m³ (AQS4) were recorded in 2021. Relative to the previous reporting year, this is an average increase of approximately 4 µg/m³, and is likely reflective of the increased travel activity, with less COVID-19 restrictions in 2021 than there were in 2020.

For diffusion tubes, the full 2021 dataset of monthly mean values is provided in Appendix B. Note that the concentration data presented in Table B.1 includes distance corrected values, only where relevant.

Table A.5 in Appendix A compares the ratified continuous monitored NO₂ hourly mean concentrations for the past five years with the air quality objective of 200µg/m³, not to be exceeded more than 18 times per year.

No single diffusion tube site recorded a concentration greater than 60 µg/m³, indicating that the 1-hr mean objective of 200 µg/m³ (not to be exceeded more than 18 times per year) was not likely to be breached at these sites. Indeed, this is supported by the three automatic monitoring stations, that recorded zero 1-hr means greater than 200 µg/m³, with a maximum NO₂ 1-hr mean being 155 µg/m³ (AQS2), 166 µg/m³ (AQS3) and 159 µg/m³ (AQS4).

3.2.2 Particulate Matter (PM₁₀)

Table A.6 in Appendix A: Monitoring Results compares the ratified and adjusted monitored PM₁₀ annual mean concentrations for the past five years with the air quality objective of 40µg/m³.

The PM₁₀ monitoring site (AQS4), situated within AQMA No.2 (Sowerby Bridge), recorded an annual mean PM₁₀ concentration of 24.5 µg/m³. This follows the trend of the last five years, where the PM₁₀ concentration has been relatively stable at around 24 – 26 µg/m³.

Table A.7 in Appendix A compares the ratified continuous monitored PM₁₀ daily mean concentrations for the past five years with the air quality objective of 50µg/m³, not to be exceeded more than 35 times per year.

The 24-hr (daily) limit of 50 µg/m³ was exceeded 11 times in 2021, which is significantly lower than the 20 times which the daily air quality limit for PM₁₀ was breached in 2020.

3.2.3 Particulate Matter (PM_{2.5})

Table A.8 in Appendix A presents the ratified and adjusted monitored PM_{2.5} annual mean concentrations for the past five years.

PM_{2.5} is measured by the two remaining automatic monitoring stations (AQS2 and AQS3) that do not record PM₁₀. An annual mean PM_{2.5} concentration of 10.0 µg/m³ and 8.5 µg/m³ was recorded at site AQS2 and AQS3, respectively. The concentration at the Huddersfield Road site (AQS2) was higher than that recorded in 2020 (9.6 µg/m³), whilst that recorded at the Hebden Bridge site (AQS3) was lower than the concentration in 2020 (11.0 µg/m³).

Appendix A: Monitoring Results

Table A.1 – Details of Automatic Monitoring Sites

Site ID	Site Name	Site Type	X OS Grid Ref (Easting)	Y OS Grid Ref (Northing)	Pollutants Monitored	In AQMA? Which AQMA?	Monitoring Technique	Distance to Relevant Exposure (m) ⁽¹⁾	Distance to kerb of nearest road (m) ⁽²⁾	Inlet Height (m)
AQS2	Huddersfield Road	Roadside	409485	423430	NO ₂ , PM _{2.5}	YES; AQMA No.1 (Salterhebble)	Chemiluminescent; BAM	N/A	3	1.5
AQS3	Hebden Bridge	Roadside	398990	427210	NO ₂ , PM _{2.5}	YES; AQMA No.3 (Hebden Bridge)	Chemiluminescent; BAM	N/A	3	1.5
AQS4	Sowerby Bridge	Roadside	406075	423615	NO ₂ , PM ₁₀	YES; AQMA No.2 (Sowerby Bridge)	Chemiluminescent; BAM	N/A	3	1.5

Notes:

(1) 0m if the monitoring site is at a location of exposure (e.g. installed on the façade of a residential property).

(2) N/A if not applicable

Table A.2 – Details of Non-Automatic Monitoring Sites

Diffusion Tube ID	Site Name	Site Type	X OS Grid Ref (Easting)	Y OS Grid Ref (Northing)	Pollutants Monitored	In AQMA? Which AQMA?	Distance to Relevant Exposure (m) ⁽¹⁾	Distance to kerb of nearest road (m) ⁽²⁾	Tube Co-located with a Continuous Analyser?	Tube Height (m)
AQ21	AQ21	Roadside	409822	423167	NO ₂	Yes: AQMA No.1 (Salterhebble)	2.0	2.0	No	2.5
AQC1, AQC2, AQC3	AQC1, AQC2, AQC3	Roadside	409485	423431	NO ₂	Yes: AQMA No.1 (Salterhebble)	2.0	2.0	Yes	1.5
CRH1	CRH1	Roadside	409767	423011	NO ₂	Yes: AQMA No.1 (Salterhebble)	0.0	2.0	No	2.5
SB1	SB1	Roadside	406135	423639	NO ₂	Yes: AQMA No.2 (Sowerby Bridge)	0.0	2.0	No	2.5
SB15	SB15	Roadside	406707	423824	NO ₂	Yes: AQMA No.2 (Sowerby Bridge)	1.0	2.0	No	2.0
SB16	SB16	Roadside	406638	423836	NO ₂	Yes: AQMA No.2 (Sowerby Bridge)	0.0	2.0	No	2.5
SB22	SB22	Roadside	405823	423395	NO ₂	Yes: AQMA No.2 (Sowerby Bridge)	0.0	2.0	No	2.0
SB3	SB3	Roadside	405961	423571	NO ₂	Yes: AQMA No.2 (Sowerby Bridge)	0.0	2.0	No	2.5
SB-AQ	SB-AQ	Roadside	406075	423615	NO ₂	Yes: AQMA No.2 (Sowerby Bridge)	0.5	1.5	Yes	2.0
BS1 HB	BS1 HB	Roadside	398990	427210	NO ₂	Yes: AQMA No.3 (Hebden Bridge)	8.0	3.0	Yes	1.5
HB6	HB6	Roadside	399502	427041	NO ₂	Yes: AQMA No.3 (Hebden Bridge)	0.0	4.0	No	2.0
HQ1	HQ1	Roadside	398794	427237	NO ₂	Yes: AQMA No.3 (Hebden Bridge)	0.0	3.0	No	2.0
HQ9	HQ9	Roadside	399236	427176	NO ₂	Yes: AQMA No.3 (Hebden Bridge)	0.0	2.0	No	2.5
LF1	LF1	Roadside	403810	424977	NO ₂	Yes: AQMA No.4 (Luddendenfoot)	0.0	2.0	No	2.5
LF2	LF2	Roadside	403738	425110	NO ₂	Yes: AQMA No.4 (Luddendenfoot)	0.0	1.0	No	2.5

Diffusion Tube ID	Site Name	Site Type	X OS Grid Ref (Easting)	Y OS Grid Ref (Northing)	Pollutants Monitored	In AQMA? Which AQMA?	Distance to Relevant Exposure (m) ⁽¹⁾	Distance to kerb of nearest road (m) ⁽²⁾	Tube Co-located with a Continuous Analyser?	Tube Height (m)
SC5	SC5	Roadside	410823	426265	NO ₂	Yes: AQMA No.5 (Stump Cross)	0.0	3.0	No	3.0
BE2	BE2	Roadside	414385	422457	NO ₂	Yes: AQMA No.6 (Brighouse)	0.0	2.0	No	2.5
BE4	BE4	Roadside	414478	422692	NO ₂	Yes: AQMA No.6 (Brighouse)	0.0	1.0	No	2.5
BH3	BH3	Roadside	414671	422740	NO ₂	Yes: AQMA No.6 (Brighouse)	3.0	1.5	No	2.5
HXR1	HXR1	Roadside	414218	422957	NO ₂	Yes: AQMA No.6 (Brighouse)	0.0	4.0	No	2.0
LV-BRD	LV-BRD	Roadside	414683	423155	NO ₂	Yes: AQMA No.6 (Brighouse)	5.0	2.0	No	2.0
WR2	WR2	Roadside	415090	422817	NO ₂	Yes: AQMA No.6 (Brighouse)	0.0	4.0	No	2.5
HH-1A	HH-1A	Roadside	412593	425497	NO ₂	Yes: AQMA No.7 (Hipperholme)	0.0	1.5	No	2.5
HH-LT	HH-LT	Roadside	412450	425435	NO ₂	Yes: AQMA No.7 (Hipperholme)	0.0	3.0	No	2.5
HH-TC	HH-TC	Roadside	412718	425556	NO ₂	Yes: AQMA No.7 (Hipperholme)	5.0	1.5	No	2.5
LV-NBN	LV-NBN	Roadside	409715	425754	NO ₂	Yes: AQMA No.8 (New Bank)	40.0	1.0	No	2.5
LV-NBS	LV-NBS	Roadside	409708	425737	NO ₂	Yes: AQMA No.8 (New Bank)	25.0	2.0	No	2.5
LV-NBX	LV-NBX	Roadside	409602	425797	NO ₂	Yes: AQMA No.8 (New Bank)	30.0	1.0	No	2.5
NB-GR	NB-GR	Roadside	409957	425642	NO ₂	Yes: AQMA No.8 (New Bank)	4.0	3.0	No	2.0
NB-NB1	NB-NB1	Roadside	409663	425740	NO ₂	Yes: AQMA No.8 (New Bank)	2.0	2.0	No	2.5
AQ20	AQ20	Roadside	409483	423337	NO ₂	No	0.0	5.0	No	2.0
AT-BR	AT-BR	Suburban	411514	419548	NO ₂	No	6.0	1.0	No	2.0
AT-MR	AT-MR	Roadside	411581	419373	NO ₂	No	10.0	0.5	No	2.5

Diffusion Tube ID	Site Name	Site Type	X OS Grid Ref (Easting)	Y OS Grid Ref (Northing)	Pollutants Monitored	In AQMA? Which AQMA?	Distance to Relevant Exposure (m) ⁽¹⁾	Distance to kerb of nearest road (m) ⁽²⁾	Tube Co-located with a Continuous Analyser?	Tube Height (m)
CL1	CL1	Roadside	413261	420686	NO ₂	No	0.0	2.0	No	2.5
HTAH	HTAH	Suburban	411494	419594	NO ₂	No	0.0	2.0	No	2.0
LV-62E	LV-62E	Roadside	416717	422113	NO ₂	No	25.0	4.0	No	2.5
LV-62W	LV-62W	Roadside	416172	422282	NO ₂	No	6.0	3.0	No	2.5
LV-AT	LV-AT	Roadside	411533	419358	NO ₂	No	14.0	4.0	No	2.5
LV-EWB	LV-EWB	Roadside	410104	421516	NO ₂	No	250.0	1.0	No	2.5
LV-LEE	LV-LEE	Roadside	417698	420709	NO ₂	No	200.0	3.0	No	2.0
LV-SAA	LV-SAA	Roadside	411201	419429	NO ₂	No	11.0	0.0	No	2.5
LV-SCA	LV-SCA	Roadside	405911	416597	NO ₂	No	150.0	10.0	No	1.0
MY01	MY01	Roadside	401431	425995	NO ₂	No	0.0	1.0	No	2.5
MY02	MY02	Urban Background	401275	426046	NO ₂	No	20.0	10.0	No	2.5
MY03	MY03	Roadside	401204	426041	NO ₂	No	0.0	2.0	No	2.5
MY-04	MY-04	Roadside	401059	426179	NO ₂	No	12.0	2.0	No	2.5
MY-05	MY-05	Roadside	401040	426186	NO ₂	No	19.0	2.0	No	2.5
NB-GL	NB-GL	Roadside	410367	425975	NO ₂	No	17.0	2.0	No	2.5
SB23	SB23	Roadside	405701	423223	NO ₂	No	3.0	1.5	No	2.5
WV-SR1	WV-SR1	Roadside	409598	421167	NO ₂	No	0.0	2.0	No	2.5
WV-SR2	WV-SR2	Roadside	409608	421160	NO ₂	No	3.0	2.0	No	2.5
SB40	SB40	Roadside	405814	422611	NO ₂	No	35.0	0.5	No	2.0
SB41	SB41	Roadside	405727	422878	NO ₂	No	5.0	0.0	No	2.0
SB42	SB42	Roadside	404938	422699	NO ₂	No	10.0	2.0	No	2.0
SB43	SB43	Roadside	405082	422999	NO ₂	No	8.0	1.5	No	2.0
SB44	SB44	Roadside	405234	423022	NO ₂	No	30.0	0.0	No	2.0
SB45	SB45	Roadside	405780	423349	NO ₂	No	20.0	1.5	No	2.0

Notes:

(1) 0m if the monitoring site is at a location of exposure (e.g. installed on the façade of a residential property).

(2) N/A if not applicable.

Table A.3 – Annual Mean NO₂ Monitoring Results: Automatic Monitoring (µg/m³)

Site ID	X OS Grid Ref (Easting)	Y OS Grid Ref (Northing)	Site Type	Valid Data Capture for Monitoring Period (%) ⁽¹⁾	Valid Data Capture 2021 (%) ⁽²⁾	2017	2018	2019	2020	2021
AQS2	409485	423430	Roadside	97	97	-	38.6	39.7	32.1	35.5
AQS3	398990	427210	Roadside	84	84	-	35.0	34.3	26.7	32.8
AQS4	406075	423615	Roadside	99	99	-	38.1	36.0	29.6	33.0

☒ Annualisation has been conducted where data capture is <75% and >25% in line with LAQM.TG16.

☒ Reported concentrations are those at the location of the monitoring site (annualised, as required), i.e. prior to any fall-off with distance correction.

Notes:

The annual mean concentrations are presented as µg/m³.

Exceedances of the NO₂ annual mean objective of 40µg/m³ are shown in **bold**.

All means have been “annualised” as per LAQM.TG16 if valid data capture for the full calendar year is less than 75%. See Appendix C for details.

Concentrations are those at the location of monitoring and not those following any fall-off with distance adjustment.

(1) Data capture for the monitoring period, in cases where monitoring was only carried out for part of the year.

(2) Data capture for the full calendar year (e.g. if monitoring was carried out for 6 months, the maximum data capture for the full calendar year is 50%).

Table A.4 – Annual Mean NO₂ Monitoring Results: Non-Automatic Monitoring (µg/m³)

Diffusion Tube ID	X OS Grid Ref (Easting)	Y OS Grid Ref (Northing)	Site Type	Valid Data Capture for Monitoring Period (%) ⁽¹⁾	Valid Data Capture 2021 (%) ⁽²⁾	2017	2018	2019	2020	2021
AQ21	409822	423167	Roadside	35.4	35.4	48.0	45.0	44.0	43.0	53.1
AQC1, AQC2, AQC3	409485	423431	Roadside	35.4	35.4	41.7	36.0	39.3	32.8	37.1
CRH1	409767	423011	Roadside	35.4	35.4	52.0	52.0	42.0	38.4	38.9
SB1	406135	423639	Roadside	35.4	35.4	45.0	46.0	42.0	40.2	37.0
SB15	406707	423824	Roadside	35.4	35.4	37.0	34.0	34.0	27.9	30.6
SB16	406638	423836	Roadside	27.2	27.2	38.0	40.0	36.0	31.2	25.4
SB22	405823	423395	Roadside	35.4	35.4	42.0	45.0	40.0	34.1	33.5
SB3	405961	423571	Roadside	35.4	35.4	40.0	43.0	35.0	35.9	37.0
SB-AQ	406075	423615	Roadside	35.4	35.4	-	-	-	33.5	31.6
BS1 HB	398990	427210	Roadside	35.4	35.4	38.0	37.0	33.0	29.7	30.5
HB6	399502	427041	Roadside	35.4	35.4	35.0	31.0	30.0	26.0	28.5
HQ1	398794	427237	Roadside	35.4	35.4	50.0	46.0	44.0	38.4	42.6
HQ9	399236	427176	Roadside	35.4	35.4	36.0	39.0	35.0	29.9	29.8
LF1	403810	424977	Roadside	35.4	35.4	39.0	41.0	34.0	33.9	32.0
LF2	403738	425110	Roadside	35.4	35.4	35.0	34.0	29.0	26.3	27.2
SC5	410823	426265	Roadside	35.4	35.4	38.0	39.0	35.0	34.1	32.3
BE2	414385	422457	Roadside	35.4	35.4	38.0	37.0	35.0	31.8	36.5
BE4	414478	422692	Roadside	35.4	35.4	47.0	45.0	42.0	33.6	43.2
BH3	414671	422740	Roadside	35.4	35.4	46.0	42.0	43.0	38.2	42.7
HXR1	414218	422957	Roadside	35.4	35.4	49.0	49.0	42.0	43.0	43.6
LV-BRD	414683	423155	Roadside	35.4	35.4	31.0	28.0	27.0	23.4	24.1
WR2	415090	422817	Roadside	35.4	35.4	38.0	36.0	33.0	30.9	31.1
HH-1A	412593	425497	Roadside	35.4	35.4	-	-	-	31.8	31.5

Diffusion Tube ID	X OS Grid Ref (Easting)	Y OS Grid Ref (Northing)	Site Type	Valid Data Capture for Monitoring Period (%) ⁽¹⁾	Valid Data Capture 2021 (%) ⁽²⁾	2017	2018	2019	2020	2021
HH-LT	412450	425435	Roadside	35.4	35.4	51.0	48.0	41.0	40.7	42.3
HH-TC	412718	425556	Roadside	35.4	35.4	36.0	35.0	33.0	26.0	27.7
LV-NBN	409715	425754	Roadside	35.4	35.4	66.0	64.0	55.0	53.5	53.2
LV-NBS	409708	425737	Roadside	35.4	35.4	42.0	44.0	41.0	34.0	40.7
LV-NBX	409602	425797	Roadside	35.4	35.4	43.0	39.0	39.0	36.3	36.9
NB-GR	409957	425642	Roadside	35.4	35.4	53.0	53.0	46.0	49.4	51.9
NB-NB1	409663	425740	Roadside	35.4	35.4	44.0	42.0	40.0	35.2	36.6
AQ20	409483	423337	Roadside	35.4	35.4	24.0	24.0	22.0	18.7	18.5
AT-BR	411514	419548	Suburban	35.4	35.4	35.0	30.0	28.0	20.4	23.4
AT-MR	411581	419373	Roadside	35.4	35.4	34.0	27.0	25.0	19.9	23.9
CL1	413261	420686	Roadside	27.2	27.2	34.0	33.0	29.0	27.0	28.2
HTAH	411494	419594	Suburban	27.5	27.5	35.0	31.0	27.0	21.1	26.3
LV-62E	416717	422113	Roadside	35.4	35.4	40.0	38.0	36.0	32.2	31.8
LV-62W	416172	422282	Roadside	35.4	35.4	40.0	40.0	37.0	30.4	39.2
LV-AT	411533	419358	Roadside	35.4	35.4	47.0	47.0	45.0	34.7	41.5
LV-EWB	410104	421516	Roadside	35.4	35.4	27.0	27.0	27.0	21.2	19.8
LV-LEE	417698	420709	Roadside	35.4	35.4	32.0	30.0	27.0	25.0	26.9
LV-SAA	411201	419429	Roadside	35.4	35.4	33.0	30.0	25.0	23.7	22.4
LV-SCA	405911	416597	Roadside	35.4	35.4	48.0	46.0	37.0	33.6	37.1
MY01	401431	425995	Roadside	35.4	35.4	28.0	52.0	44.0	35.6	33.7
MY02	401275	426046	Urban Background	35.4	35.4	42.0	24.0	21.0	18.8	14.9
MY03	401204	426041	Roadside	35.4	35.4	-	42.0	39.0	34.8	32.4
MY-04	401059	426179	Roadside	35.4	35.4	-	29.0	27.0	23.5	20.6
MY-05	401040	426186	Roadside	27.2	27.2	-	33.0	28.0	24.9	22.4
NB-GL	410367	425975	Roadside	27.5	27.5	57.0	52.0	49.0	47.6	43.5
SB23	405701	423223	Roadside	35.4	35.4	-	-	-	23.4	23.4

Diffusion Tube ID	X OS Grid Ref (Easting)	Y OS Grid Ref (Northing)	Site Type	Valid Data Capture for Monitoring Period (%) ⁽¹⁾	Valid Data Capture 2021 (%) ⁽²⁾	2017	2018	2019	2020	2021
WV-SR1	409598	421167	Roadside	35.4	35.4	39.0	38.0	38.0	32.8	33.2
WV-SR2	409608	421160	Roadside	35.4	35.4	29.0	31.0	28.0	25.7	22.9
SB40	405814	422611	Roadside	27.5	27.5	-	-	-	-	7.9
SB41	405727	422878	Roadside	27.5	27.5	-	-	-	-	7.9
SB42	404938	422699	Roadside	27.5	27.5	-	-	-	-	23.0
SB43	405082	422999	Roadside	27.5	27.5	-	-	-	-	9.0
SB44	405234	423022	Roadside	27.5	27.5	-	-	-	-	11.5
SB45	405780	423349	Roadside	27.5	27.5	-	-	-	-	27.3

☒ Annualisation has been conducted where data capture is <75% and >25% in line with LAQM.TG16.

☒ Diffusion tube data has been bias adjusted.

☒ Reported concentrations are those at the location of the monitoring site (bias adjusted and annualised, as required), i.e. prior to any fall-off with distance correction.

Notes:

The annual mean concentrations are presented as $\mu\text{g}/\text{m}^3$.

Exceedances of the NO₂ annual mean objective of 40 $\mu\text{g}/\text{m}^3$ are shown in **bold**.

NO₂ annual means exceeding 60 $\mu\text{g}/\text{m}^3$, indicating a potential exceedance of the NO₂ 1-hour mean objective are shown in **bold and underlined**.

Means for diffusion tubes have been corrected for bias. All means have been “annualised” as per LAQM.TG16 if valid data capture for the full calendar year is less than 75%. See Appendix C for details.

Concentrations are those at the location of monitoring and not those following any fall-off with distance adjustment.

(1) Data capture for the monitoring period, in cases where monitoring was only carried out for part of the year.

(2) Data capture for the full calendar year (e.g. if monitoring was carried out for 6 months, the maximum data capture for the full calendar year is 50%).

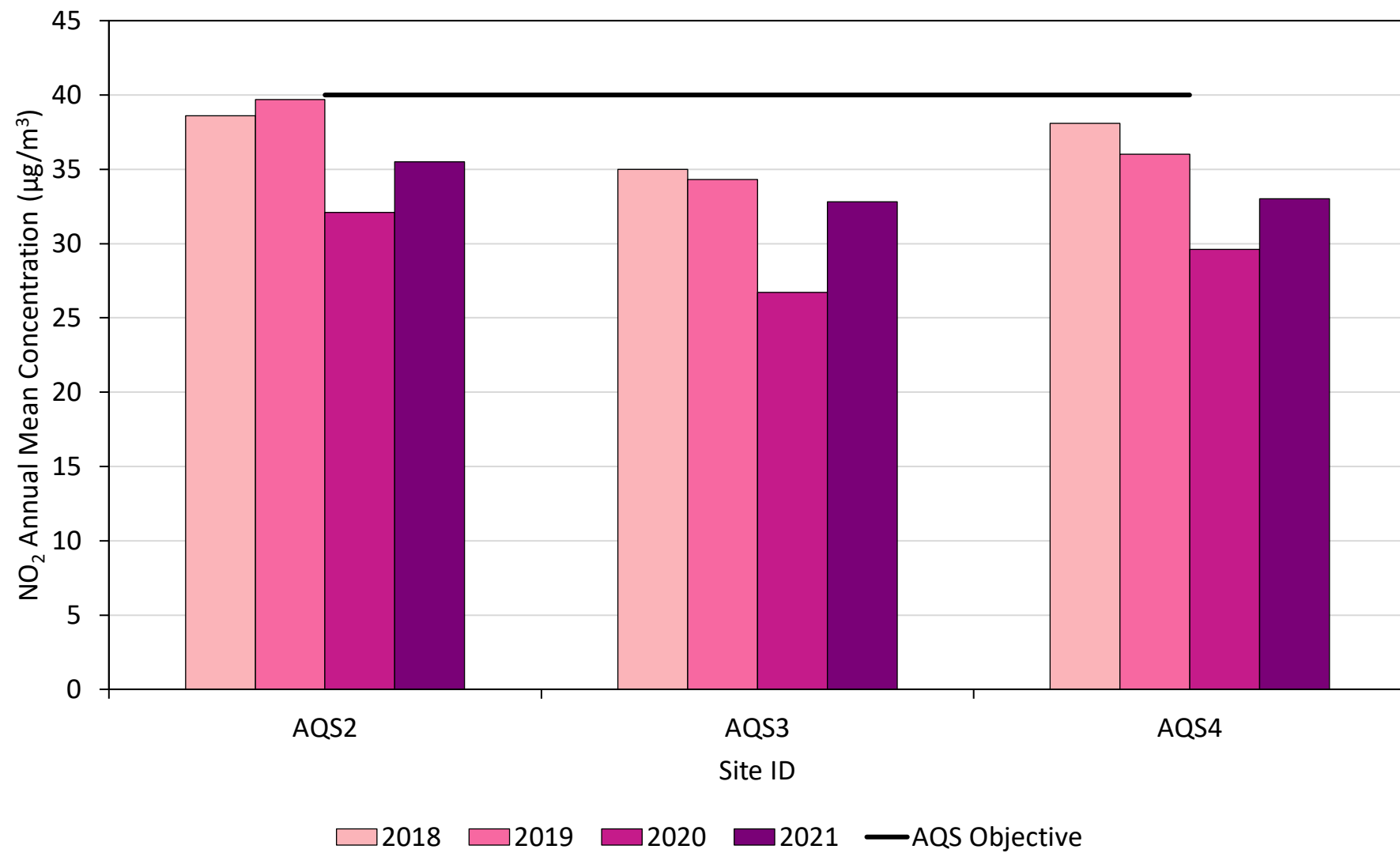
Figure A.1 – Trends in Annual Mean NO₂ Concentrations (Automatic Monitoring)

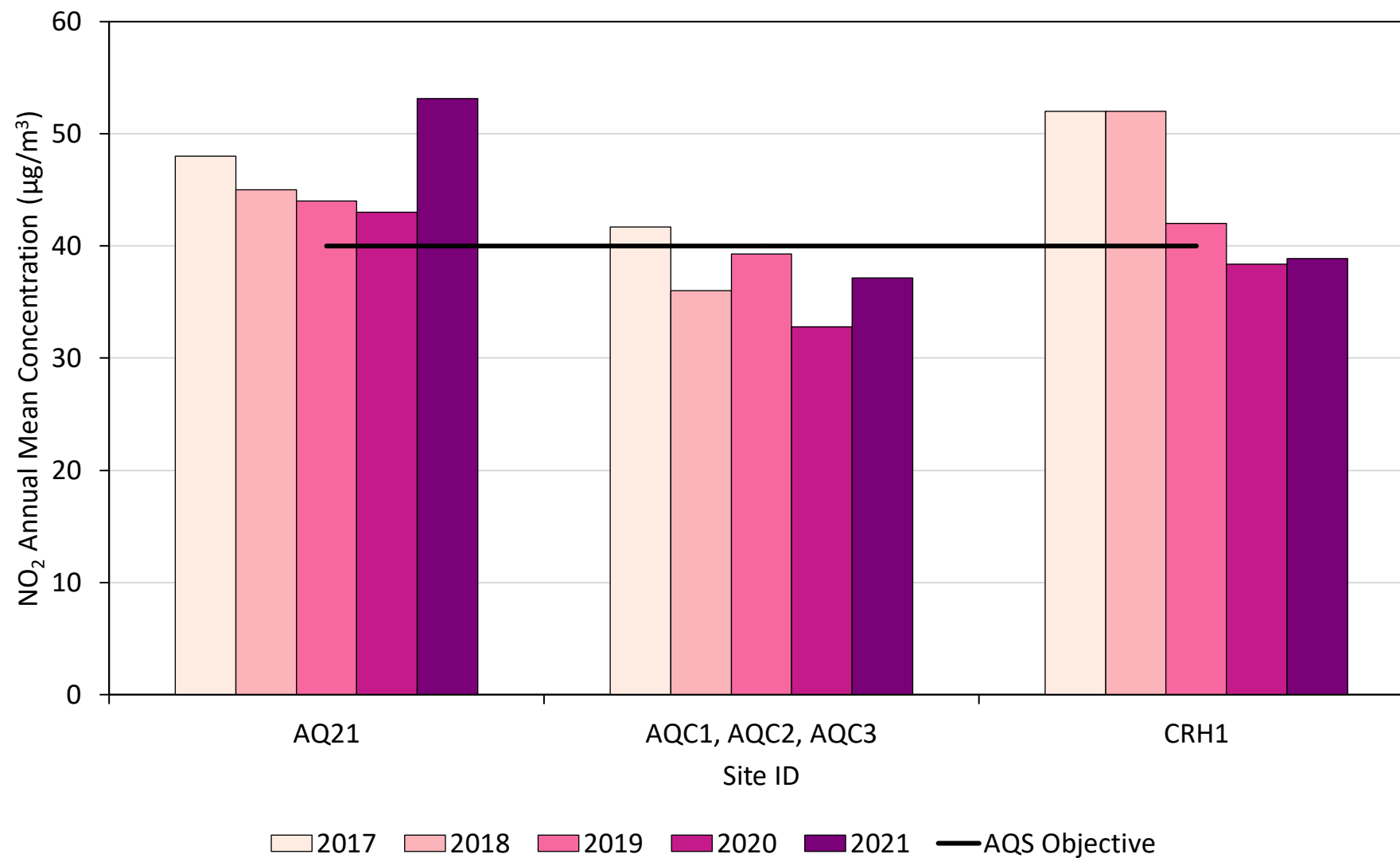
Figure A.2 – Trends in Annual Mean NO₂ Concentrations at Salterhebble (AQMA No.1)

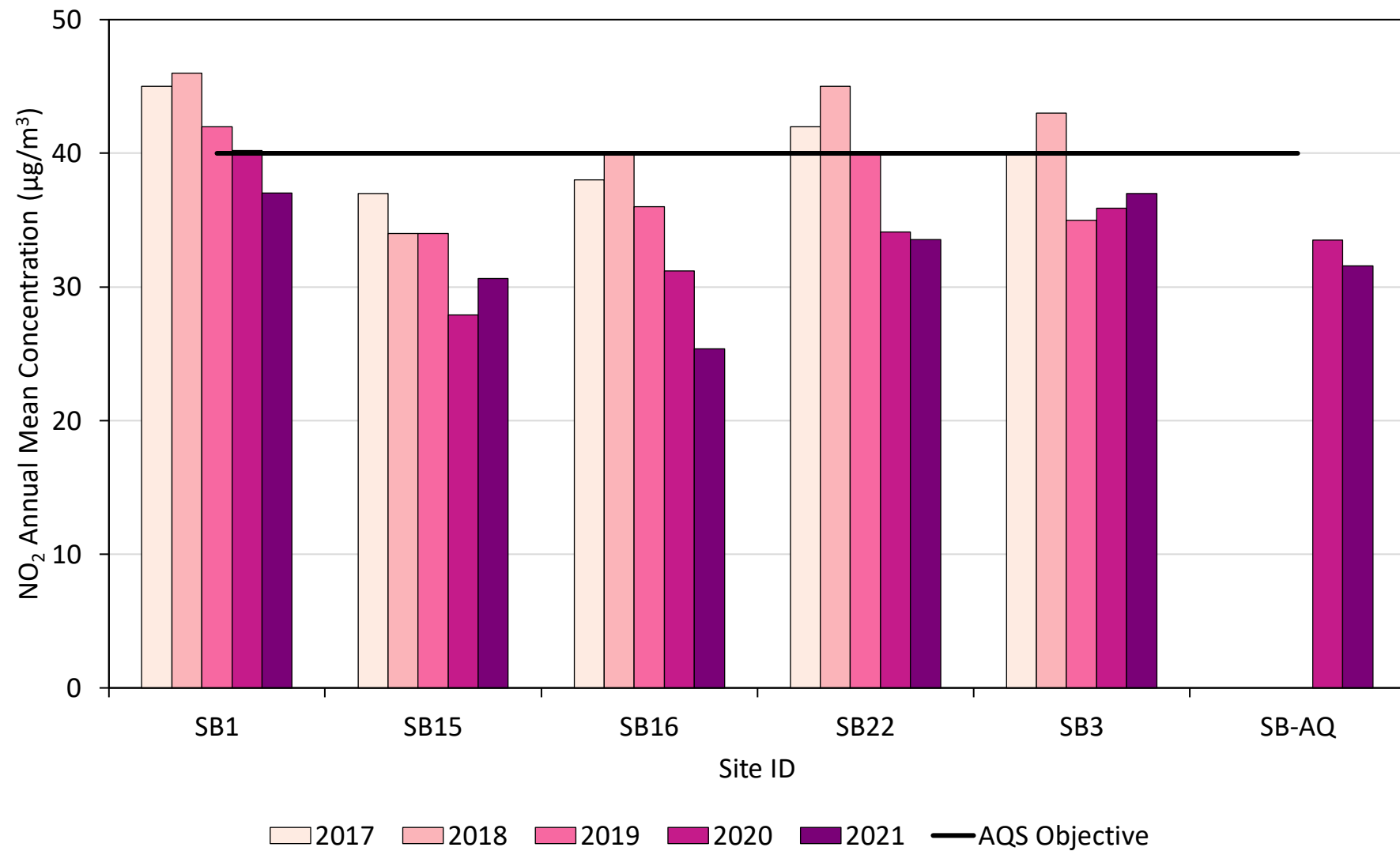
Figure A.3 – Trends in Annual Mean NO₂ Concentrations at Sowerby Bridge (AQMA No.2)

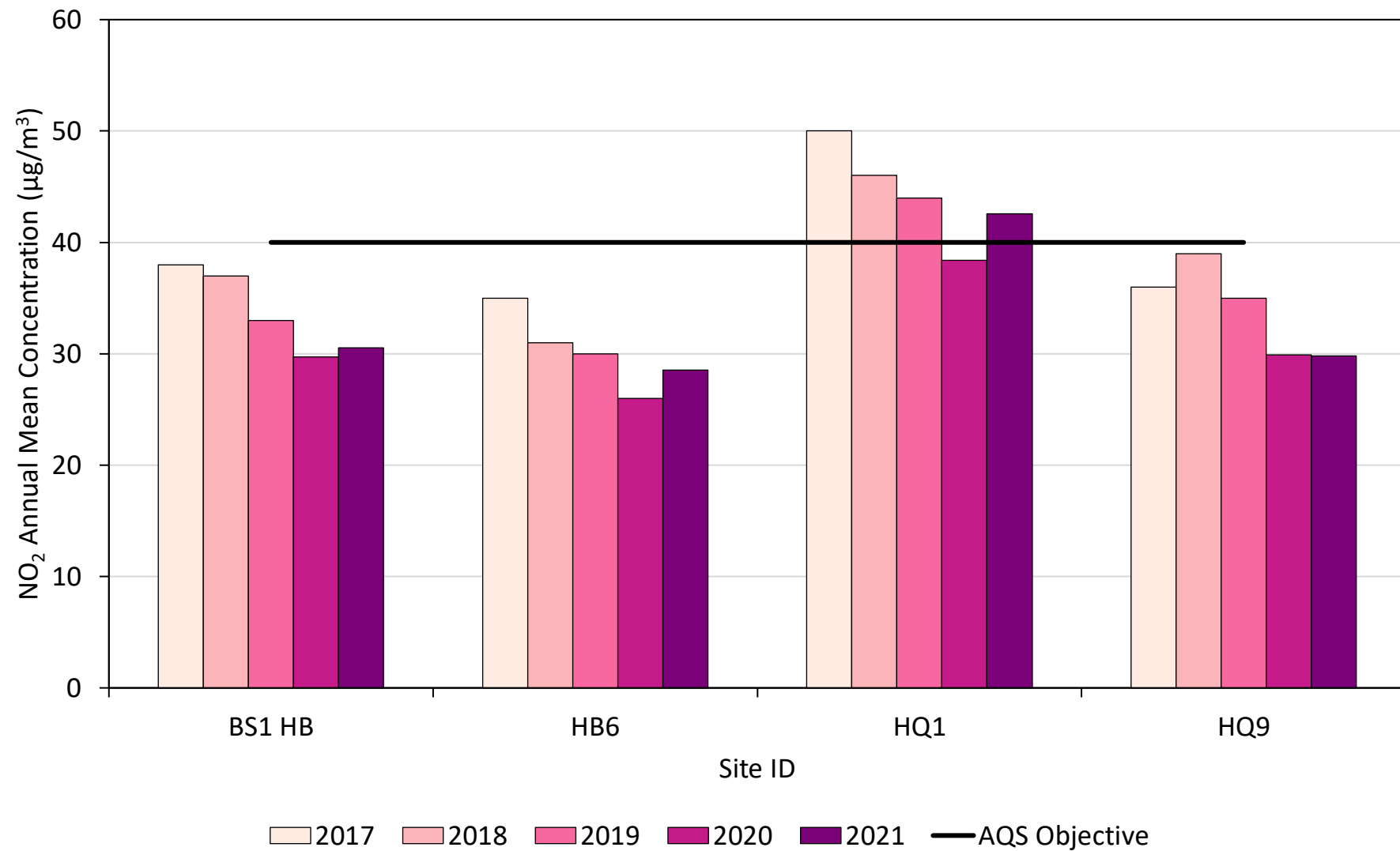
Figure A.4 – Trends in Annual Mean NO₂ Concentrations at Hebden Bridge (AQMA No.3)

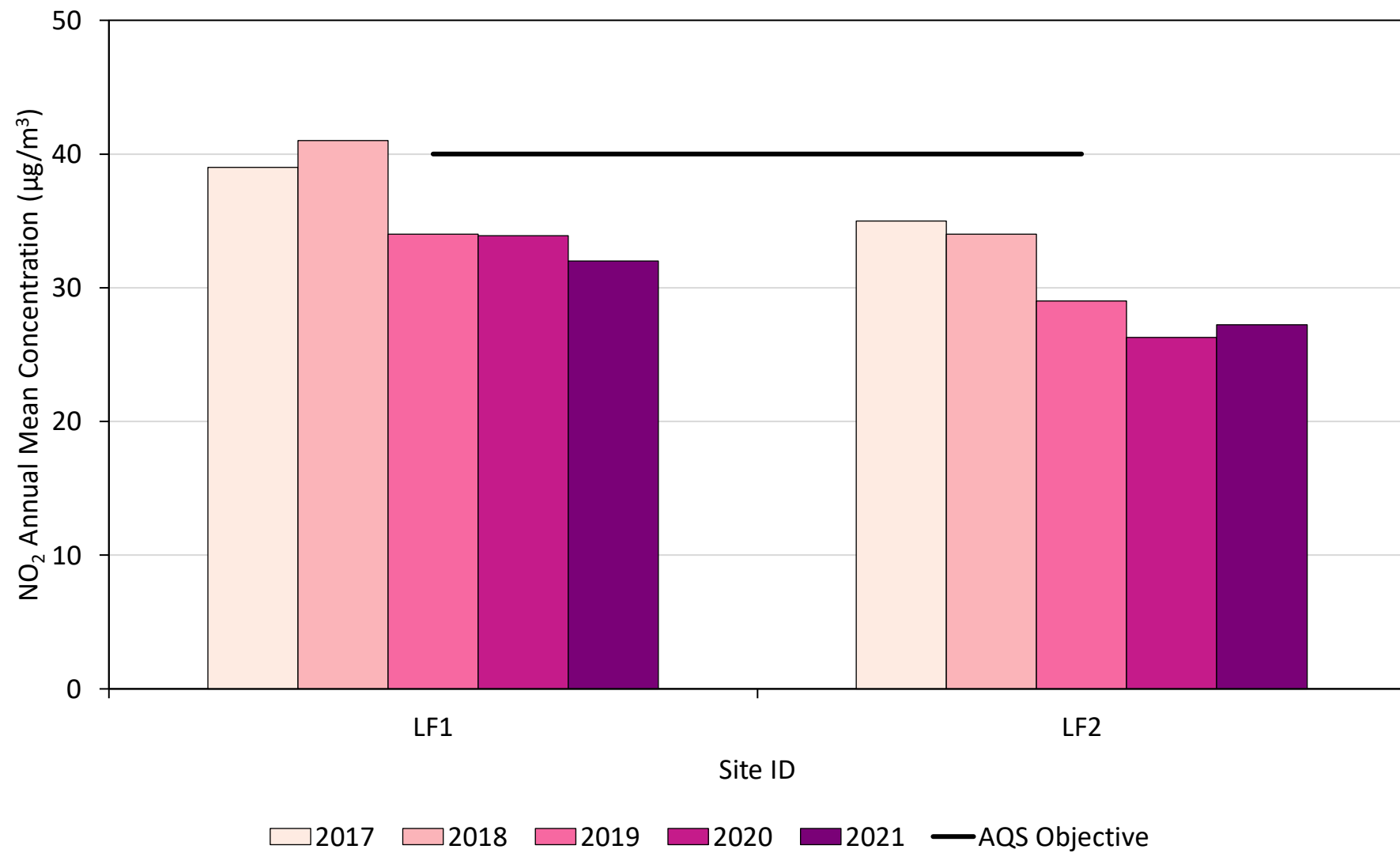
Figure A.5 – Trends in Annual Mean NO₂ Concentrations at Luddendenfoot (AQMA No.4)

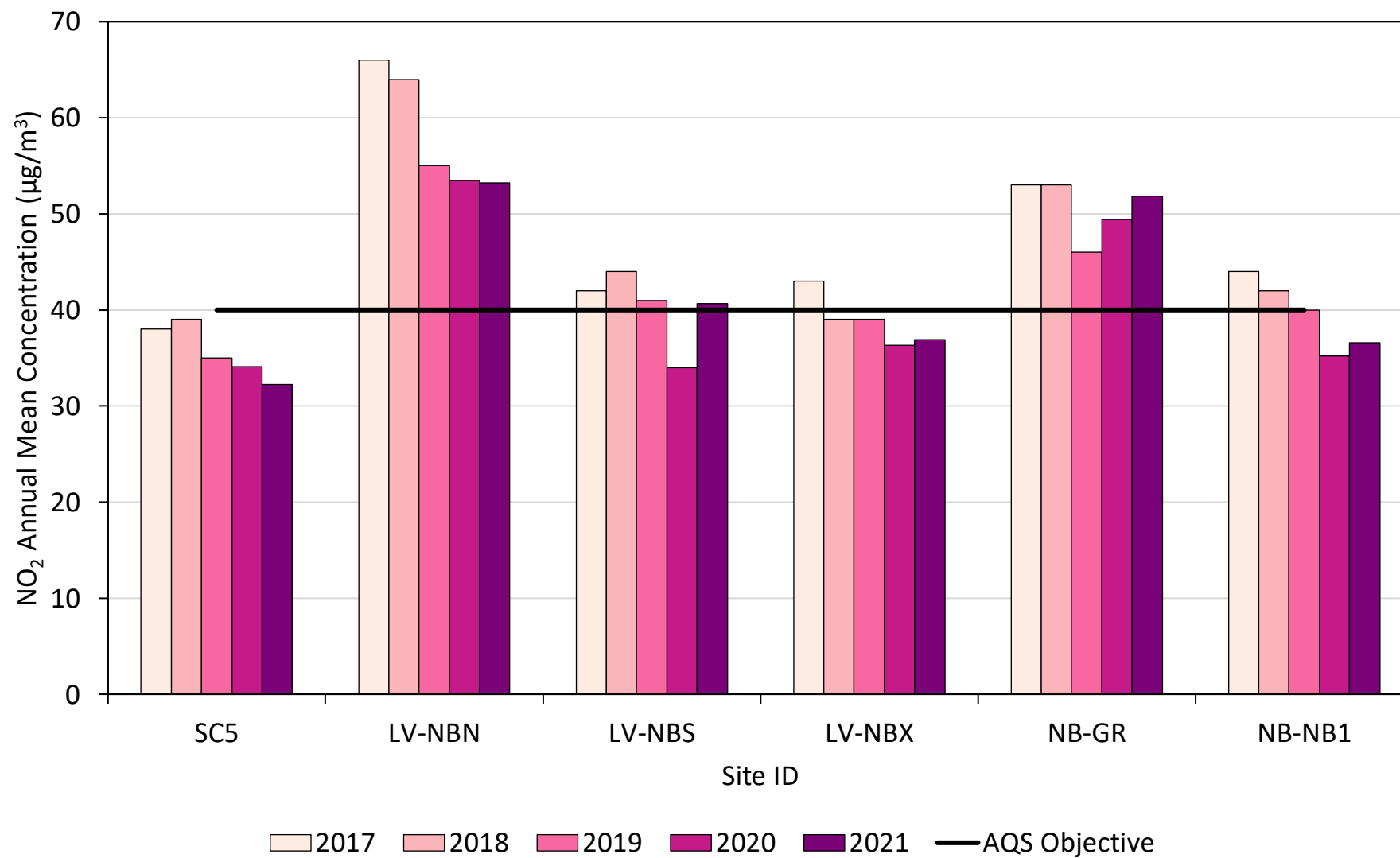
Figure A.6 – Trends in Annual Mean NO₂ Concentrations at Stump Cross (AQMA No.5) & New Bank (AQMA No.8)

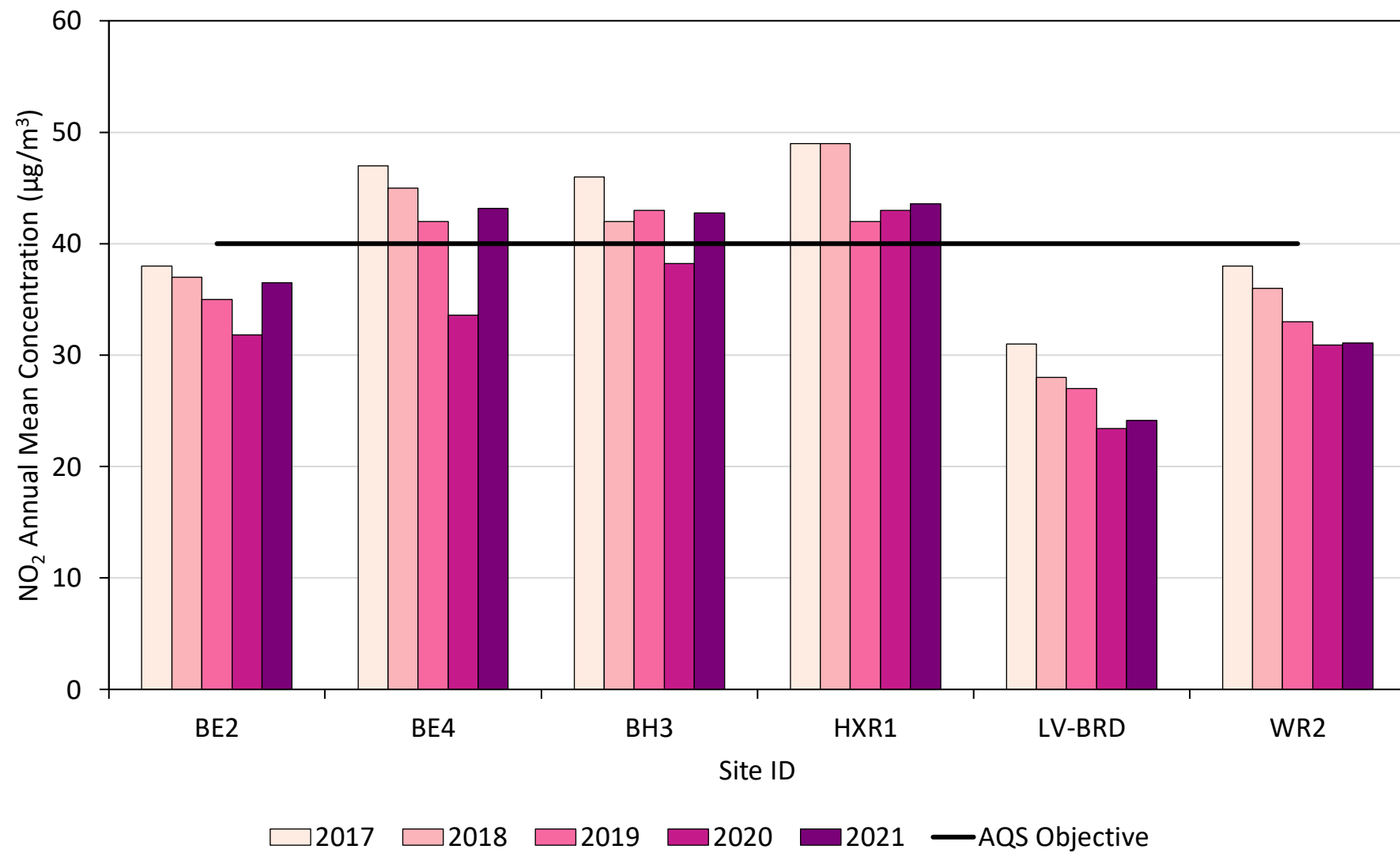
Figure A.7 – Trends in Annual Mean NO₂ Concentrations at Brighouse (AQMA No.6)

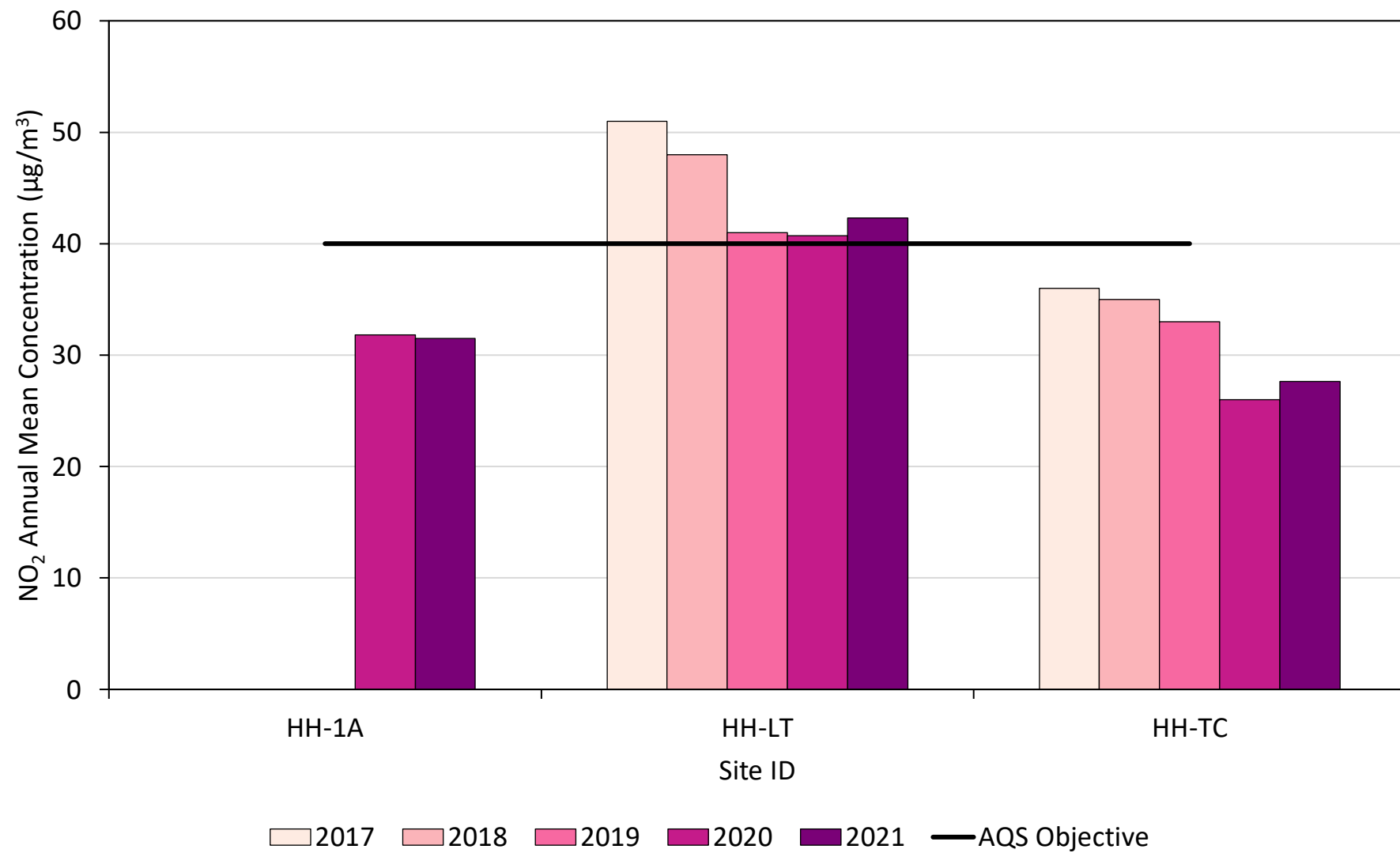
Figure A.8 – Trends in Annual Mean NO₂ Concentrations at Hipperholme (AQMA No.7)

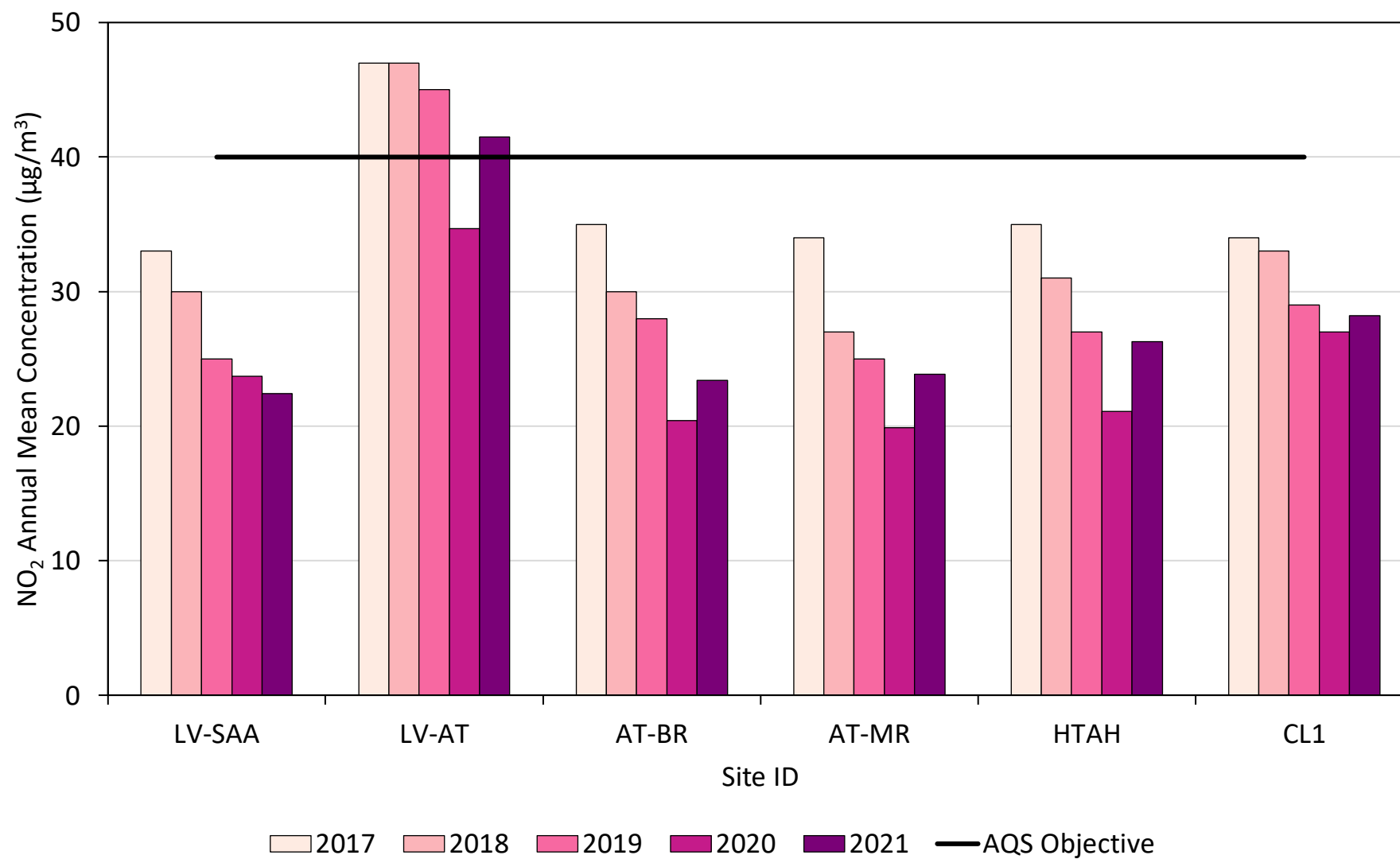
Figure A.9 – Trends in Annual Mean NO₂ Concentrations Outside of AQMAs (Ainley Top & Rastrick)

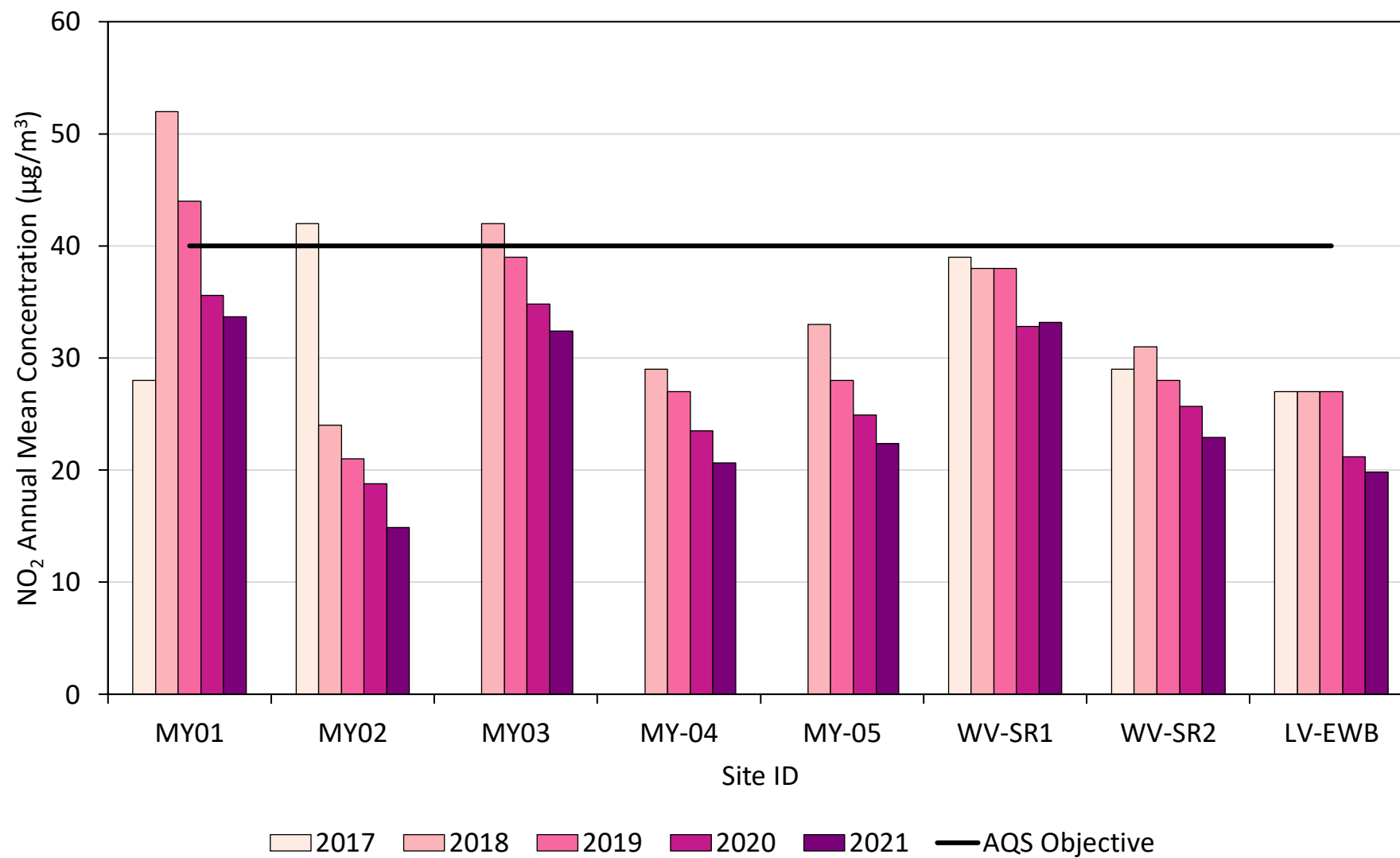
Figure A.10 – Trends in Annual Mean NO₂ Concentrations Outside of AQMAs (Mytholmroyd & West Vale)

Figure A.11 – Trends in Annual Mean NO₂ Concentrations Outside of AQMAs (Salterhebble, Brighouse South, Scammonden & New Bank)

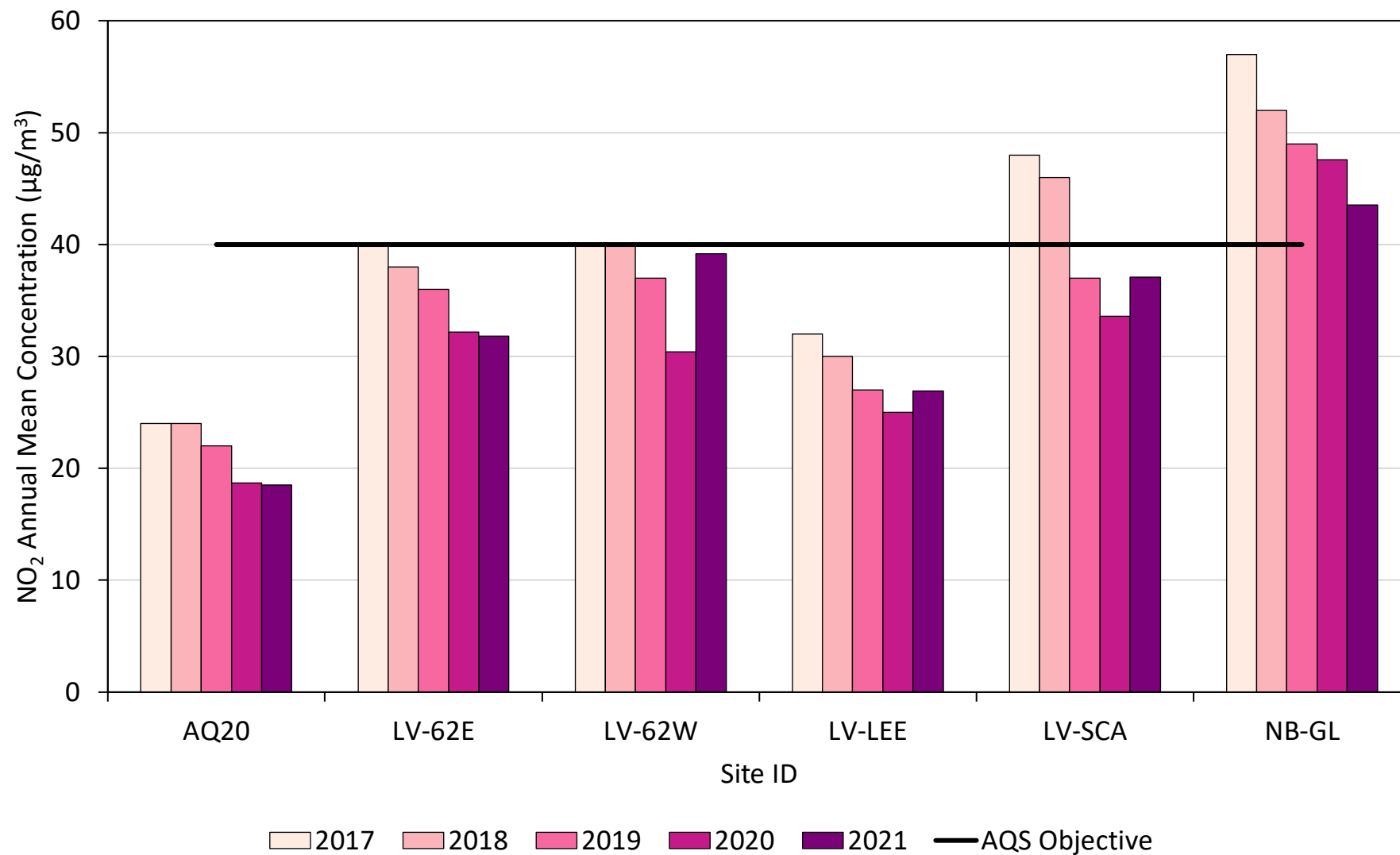


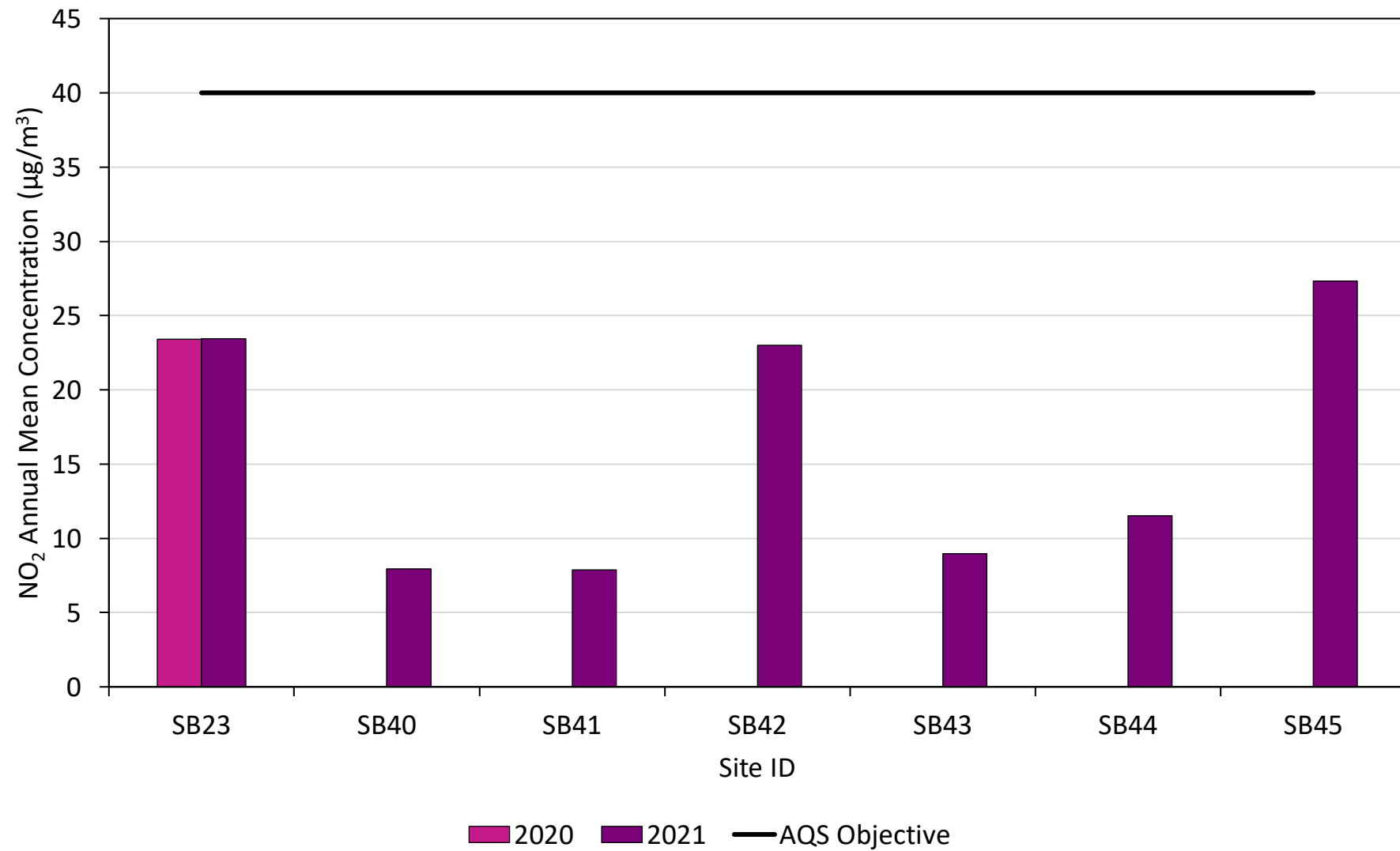
Figure A.12 – Trends in Annual Mean NO₂ Concentrations Outside of AQMAs (Sowerby Bridge)

Table A.5 – 1-Hour Mean NO₂ Monitoring Results, Number of 1-Hour Means > 200µg/m³

Site ID	X OS Grid Ref (Easting)	Y OS Grid Ref (Northing)	Site Type	Valid Data Capture for Monitoring Period (%) ⁽¹⁾	Valid Data Capture 2021 (%) ⁽²⁾	2017	2018	2019	2020	2021
AQS2	409485	423430	Roadside	97	97	0	4	4 (133.7)	0	0
AQS3	398990	427210	Roadside	84	84	0	0	0	0 (98.8)	0 (99.6)
AQS4	406075	423615	Roadside	99	99	0	1	1	0	0

Notes:

Results are presented as the number of 1-hour periods where concentrations greater than 200µg/m³ have been recorded.

Exceedances of the NO₂ 1-hour mean objective (200µg/m³ not to be exceeded more than 18 times/year) are shown in **bold**.

If the period of valid data is less than 85%, the 99.8th percentile of 1-hour means is provided in brackets.

(1) Data capture for the monitoring period, in cases where monitoring was only carried out for part of the year.

(2) Data capture for the full calendar year (e.g. if monitoring was carried out for 6 months, the maximum data capture for the full calendar year is 50%).

Table A.6 – Annual Mean PM₁₀ Monitoring Results (µg/m³)

Site ID	X OS Grid Ref (Easting)	Y OS Grid Ref (Northing)	Site Type	Valid Data Capture for Monitoring Period (%) ⁽¹⁾	Valid Data Capture 2021 (%) ⁽²⁾	2017	2018	2019	2020	2021
AQS4	406075	423615	Roadside	80	80	23.0	25.0	24.0	26.4	24.5

☒ **Annualisation has been conducted where data capture is <75% and >25% in line with LAQM.TG16.**

Notes:

The annual mean concentrations are presented as µg/m³.

Exceedances of the PM₁₀ annual mean objective of 40µg/m³ are shown in **bold**.

All means have been “annualised” as per LAQM.TG16 if valid data capture for the full calendar year is less than 75%. See Appendix C for details.

(1) Data capture for the monitoring period, in cases where monitoring was only carried out for part of the year.

(2) Data capture for the full calendar year (e.g. if monitoring was carried out for 6 months, the maximum data capture for the full calendar year is 50%).

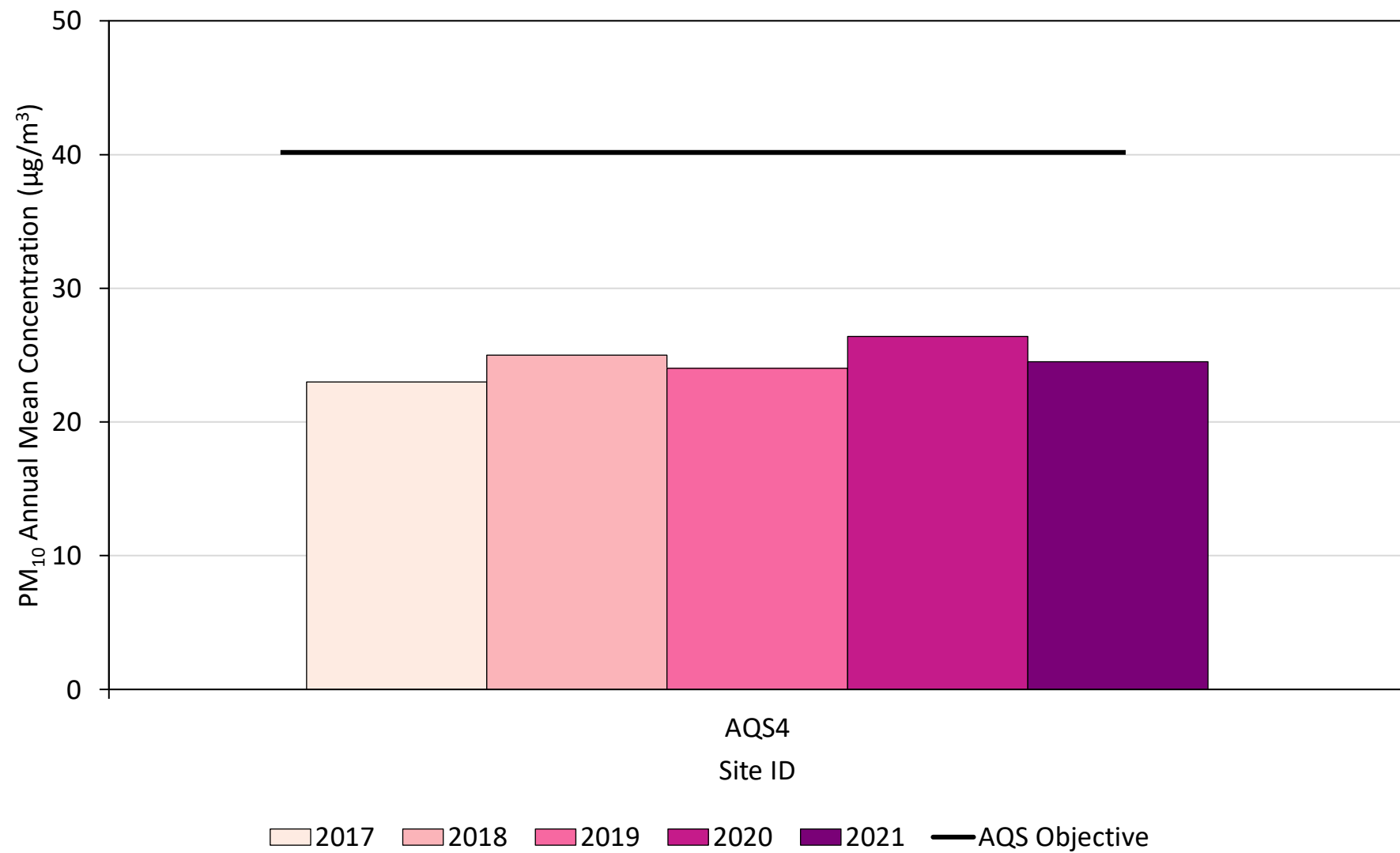
Figure A.13 – Trends in Annual Mean PM₁₀ Concentrations

Table A.7 – 24-Hour Mean PM₁₀ Monitoring Results, Number of PM₁₀ 24-Hour Means > 50µg/m³

Site ID	X OS Grid Ref (Easting)	Y OS Grid Ref (Northing)	Site Type	Valid Data Capture for Monitoring Period (%) ⁽¹⁾	Valid Data Capture 2021 (%) ⁽²⁾	2017	2018	2019	2020	2021
AQS4	406075	423615	Roadside	80	80	8	12	19	20	11 (42)

Notes:

Results are presented as the number of 24-hour periods where daily mean concentrations greater than 50µg/m³ have been recorded.

Exceedances of the PM₁₀ 24-hour mean objective (50µg/m³ not to be exceeded more than 35 times/year) are shown in **bold**.

If the period of valid data is less than 85%, the 90.4th percentile of 24-hour means is provided in brackets.

(1) Data capture for the monitoring period, in cases where monitoring was only carried out for part of the year.

(2) Data capture for the full calendar year (e.g. if monitoring was carried out for 6 months, the maximum data capture for the full calendar year is 50%).

Table A.8 – Annual Mean PM_{2.5} Monitoring Results (µg/m³)

Site ID	X OS Grid Ref (Easting)	Y OS Grid Ref (Northing)	Site Type	Valid Data Capture for Monitoring Period (%) ⁽¹⁾	Valid Data Capture 2021 (%) ⁽²⁾	2017	2018	2019	2020	2021
AQS2	409485	423430	Roadside	80	80	13	13	11	9.6	10.0
AQS3	398990	427210	Roadside	80	80	15	17	20	11.0	8.5

☒ **Annualisation has been conducted where data capture is <75% and >25% in line with LAQM.TG16.**

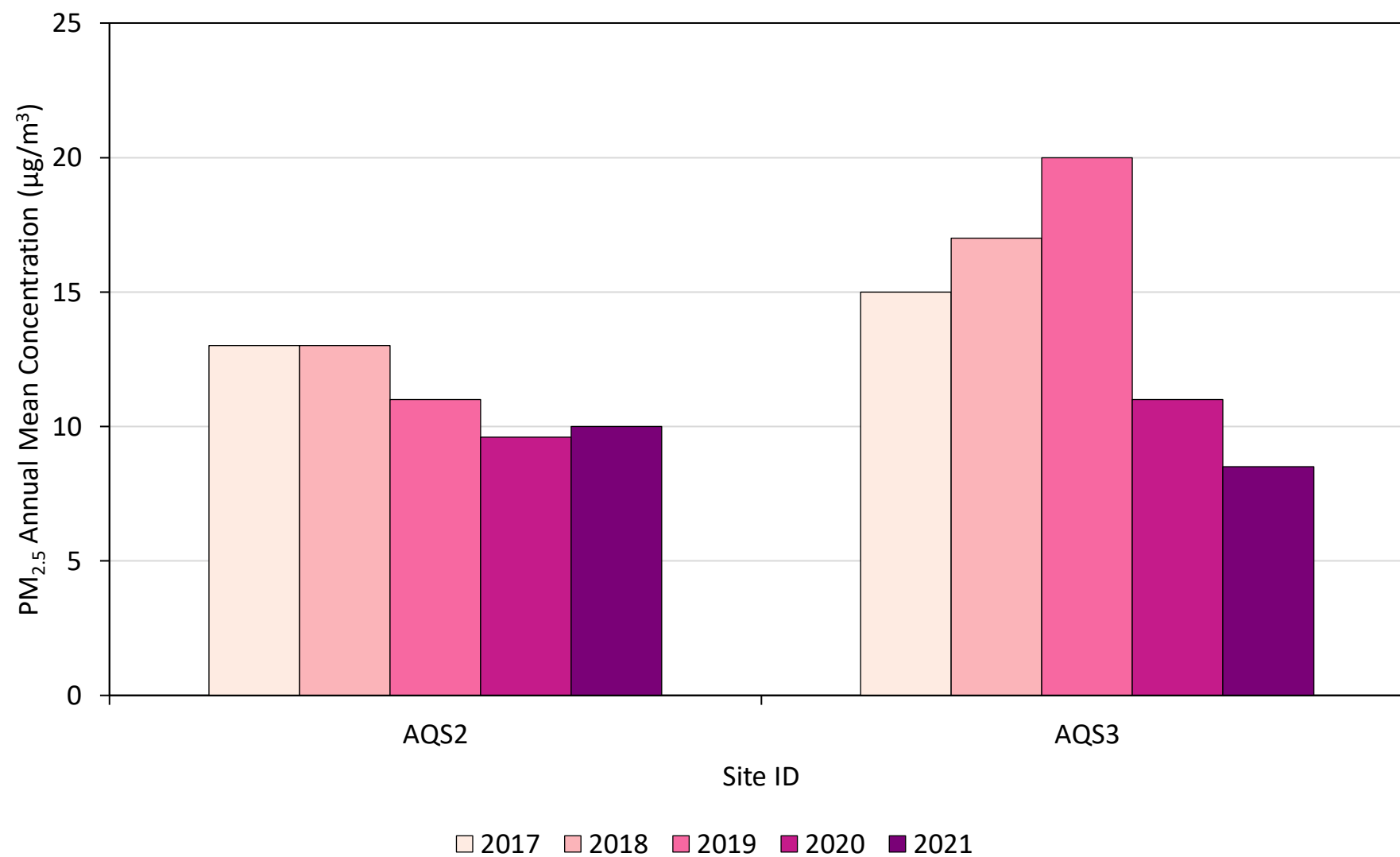
Notes:

The annual mean concentrations are presented as µg/m³.

All means have been “annualised” as per LAQM.TG16 if valid data capture for the full calendar year is less than 75%. See Appendix C for details.

(1) Data capture for the monitoring period, in cases where monitoring was only carried out for part of the year.

(2) Data capture for the full calendar year (e.g. if monitoring was carried out for 6 months, the maximum data capture for the full calendar year is 50%).

Figure A.14 – Trends in Annual Mean PM_{2.5} Concentrations

Appendix B: Full Monthly Diffusion Tube Results for 2021

Table B.1 – NO₂ 2021 Diffusion Tube Results (µg/m³)

DT ID	X OS Grid Ref (Easting)	Y OS Grid Ref (Northing)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Time-Weighted Annual Mean			Comment
															Raw Data	Annualised and Bias Adjusted (0.78)	Distance Corrected to Nearest Exposure	
AQ21	409822	423167								55.6	67.0	69.4	77.3		66.4	53.1	46.6	
AQC1	409485	423431								39.2	42.1	43.4	52.9					Triplicate Site with AQC1, AQC2 and AQC3 - Annual data provided for AQC3 only.
AQC2	409485	423431								39.8	47.0	51.3	56.7					Triplicate Site with AQC1, AQC2 and AQC3 - Annual data provided for AQC3 only.
AQC3	409485	423431								43.0	45.5	49.9	52.0		46.4	37.1	33.3	Triplicate Site with AQC1, AQC2 and AQC3 - Annual data provided for AQC3 only.
CRH1	409767	423011								42.4	46.7	50.2	57.0		48.6	38.9		
SB1	406135	423639								36.9	51.5	49.0	51.1		46.3	37.0		
SB15	406707	423824								33.9	35.9	41.3	43.4		38.3	30.6		
SB16	406638	423836								20.7	37.6		38.6		31.1	25.4		
SB22	405823	423395								40.3	41.0	44.4	42.5		41.9	33.5		
SB3	405961	423571								44.5	47.7	46.2	47.2		46.2	37.0		
SB-AQ	406075	423615								34.4	43.7	41.7	39.9		39.5	31.6		
BS1 HB	398990	427210								36.3	35.6	41.3	40.0		38.2	30.5		
HB6	399502	427041								32.2	33.9	35.8	41.8		35.7	28.5		
HQ1	398794	427237								43.0	48.3	59.7	65.1		53.2	42.6		
HQ9	399236	427176								34.1	36.8	38.1	41.0		37.2	29.8		
LF1	403810	424977								38.6	40.1	43.5	38.3		40.0	32.0		
LF2	403738	425110								26.3	34.3	36.7	41.5		34.1	27.2		
SC5	410823	426265								44.1	39.3	33.8	42.8		40.3	32.3		
BE2	414385	422457								41.0	46.0	49.7	47.3		45.6	36.5		
BE4	414478	422692								43.1	54.3	59.1	63.1		54.0	43.2		
BH3	414671	422740								46.5	49.1	58.1	62.2		53.4	42.7	36.2	
HXR1	414218	422957								54.5	53.8	56.2	53.3		54.5	43.6		
LV-BRD	414683	423155								25.7	30.2	34.0	32.2		30.2	24.1		
WR2	415090	422817								31.1	37.3	43.0	46.7		38.9	31.1		
HH-1A	412593	425497								36.1	43.1	42.7	36.7		39.3	31.5		
HH-LT	412450	425435								41.7	55.5	54.5	63.7		52.9	42.3		
HH-TC	412718	425556								32.0	33.3	34.7	39.1		34.6	27.7		
LV-NBN	409715	425754								63.3	72.8	61.1	70.2		66.5	53.2	24.9	
LV-NBS	409708	425737								45.9	50.7	53.1	55.4		50.9	40.7	25.3	
LV-NBX	409602	425797								41.3	44.6	48.2	51.9		46.1	36.9	22.0	
NB-GR	409957	425642								62.6	61.3	64.8	71.3		64.8	51.9	43.9	
NB-NB1	409663	425740								43.3	50.3	53.8	36.4		45.7	36.6	33.1	
AQ20	409483	423337								20.7	21.9	23.6	27.2		23.2	18.5		
AT-BR	411514	419548								26.3	27.6	30.3	33.8		29.3	23.4		
AT-MR	411581	419373								22.9	28.6	31.9	38.2		29.8	23.9		
CL1	413261	420686								35.1	32.5		35.9		34.6	28.2		
HTAH	411494	419594								30.5		32.2	37.0		33.0	26.3		
LV-62E	416717	422113								35.4	37.1	40.0	47.9		39.8	31.8		

DT ID	X OS Grid Ref (Easting)	Y OS Grid Ref (Northing)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Time-Weighted Annual Mean			Comment
															Raw Data	Annualised and Bias Adjusted (0.78)	Distance Corrected to Nearest Exposure	
LV-62W	416172	422282								37.5	64.5	47.6	50.6		49.0	39.2	33.5	
LV-AT	411533	419358								51.2	49.2	47.3	60.0		51.9	41.5	31.6	
LV-EWB	410104	421516								24.0	24.7	25.2	25.6		24.8	19.8		
LV-LEE	417698	420709								25.9	34.6	36.2	40.6		33.7	26.9		
LV-SAA	411201	419429								27.0	26.6	26.8	32.1		28.0	22.4		
LV-SCA	405911	416597								38.1	55.4	43.1	51.9		46.4	37.1		
MY01	401431	425995								34.3	42.7	46.5	47.5		42.1	33.7		
MY02	401275	426046								12.8	18.8	21.1	23.6		18.6	14.9		
MY03	401204	426041								35.9	41.8	44.3	41.6		40.5	32.4		
MY-04	401059	426179								20.5	25.9	25.4	33.1		25.8	20.6		
MY-05	401040	426186								22.7	28.5	28.7			26.2	22.4		
NB-GL	410367	425975								48.9		62.6	54.2		54.6	43.5	26.7	
SB23	405701	423223								25.5	28.2	29.4	35.3		29.3	23.4		
WV-SR1	409598	421167								29.6	44.9	45.4	50.1		41.5	33.2		
WV-SR2	409608	421160								21.6	31.2	31.7	32.6		28.7	22.9		
SB40	405814	422611								7.4		10.8	12.5		10.0	7.9		
SB41	405727	422878								7.7		9.8	12.8		9.9	7.9		
SB42	404938	422699								20.7		33.6	34.9		28.8	23.0		
SB43	405082	422999								8.3		13.1	13.3		11.2	9.0		
SB44	405234	423022								9.4		17.1	18.5		14.4	11.5		
SB45	405780	423349								29.8		36.8	37.7		34.3	27.3		

☒ All erroneous data has been removed from the NO₂ diffusion tube dataset presented in Table B.1.

☒ Annualisation has been conducted where data capture is <75% and >25% in line with LAQM.TG16.

☐ Local bias adjustment factor used.

☒ National bias adjustment factor used.

☒ Where applicable, data has been distance corrected for relevant exposure in the final column.

☒ Calderdale Metropolitan Borough Council confirm that all 2021 diffusion tube data has been uploaded to the Diffusion Tube Data Entry System.

Notes:

Exceedances of the NO₂ annual mean objective of 40µg/m³ are shown in **bold**.

NO₂ annual means exceeding 60µg/m³, indicating a potential exceedance of the NO₂ 1-hour mean objective are shown in **bold and underlined**.

See Appendix C for details on bias adjustment and annualisation.

Table B.2 – NO₂ June 2021 (Excluded) Diffusion Tube Results (µg/m³)

DT ID	X OS Grid Ref (Easting)	Y OS Grid Ref (Northing)	June
AQ21	409822	423167	54.8
AQC1	409485	423431	38.7
AQC2	409485	423431	41.4
AQC3	409485	423431	40.7
CRH1	409767	423011	45.3
SB1	406135	423639	44.5
SB15	406707	423824	-
SB16	406638	423836	34.4
SB22	405823	423395	25.9
SB3	405961	423571	45.0
SB-AQ	406075	423615	42.3
BS1 HB	398990	427210	28.0
HB6	399502	427041	31.3
HQ1	398794	427237	38.0
HQ9	399236	427176	35.6
LF1	403810	424977	40.1
LF2	403738	425110	28.9
SC5	410823	426265	39.9
BE2	414385	422457	36.0
BE4	414478	422692	34.6
BH3	414671	422740	40.4
HXR1	414218	422957	39.8
LV-BRD	414683	423155	23.9
WR2	415090	422817	28.5
HH-1A	412593	425497	35.6
HH-LT	412450	425435	43.8
HH-TC	412718	425556	25.7
LV-NBN	409715	425754	62.1
LV-NBS	409708	425737	41.8
LV-NBX	409602	425797	32.9
NB-GR	409957	425642	58.3
NB-NB1	409663	425740	23.9

DT ID	X OS Grid Ref (Easting)	Y OS Grid Ref (Northing)	June
AQ20	409483	423337	20.7
AT-BR	411514	419548	24.4
AT-MR	411581	419373	19.0
CL1	413261	420686	31.4
HTAH	411494	419594	28.6
LV-62E	416717	422113	36.5
LV-62W	416172	422282	28.7
LV-AT	411533	419358	46.7
LV-EWB	410104	421516	21.3
LV-LEE	417698	420709	28.0
LV-SAA	411201	419429	23.0
LV-SCA	405911	416597	27.8
MY01	401431	425995	33.6
MY02	401275	426046	11.9
MY03	401204	426041	35.4
MY-04	401059	426179	19.2
MY-05	401040	426186	22.6
NB-GL	410367	425975	49.2
SB23	405701	423223	22.1
WV-SR1	409598	421167	37.3
WV-SR2	409608	421160	30.0
SB40	405814	422611	-
SB41	405727	422878	-
SB42	404938	422699	-
SB43	405082	422999	-
SB44	405234	423022	-
SB45	405780	423349	-

Notes:

June values were excluded from the annual mean calculation as they were exposed beyond the 4-5 week recommendation of TG.16.

Appendix C: Supporting Technical Information / Air Quality Monitoring Data QA/QC

New or Changed Sources Identified Within Calderdale During 2021

Calderdale Metropolitan Borough Council has not identified any new sources relating to air quality within the reporting year of 2021. However, to ensure that any new development would not adversely impact air pollution, an air quality assessment was requested for the following planning applications:

- 21/00985/MIN: North Westerly extension to the currently operational Pasture House Quarry.
- 21/00839/FUL: Installation of a battery storage facility (7 battery containers along with 6 inverters, a switchgear container and a DNO substation).
- 21/00662/FUL: The proposed installation of a replacement MCPD compliant, natural gas fired CHP to generate electricity approximately 3.2 MW of electricity following the proposed decommissioning of the existing CHP currently operating at the site.
- 21/00207/FUL: Proposed amendment to contours for final restoration scheme at Clockface Quarry.
- 21/00017/LAA: Elland access package - construction of x2 pedestrian and cycleway bridges in Elland and West Vale.
- 20/01310/WAM: Change of use of existing buildings to install bio mass boilers to be fuelled by waste wood and associated processing of wood chip and timber material for fuel.
- 20/00907/FUL: Installation of three identical 295 kW biomass boilers and the development of a plant room to house boiler plant and heat exchange equipment.

Additional Air Quality Works Undertaken by Calderdale Metropolitan Borough Council During 2021

Calderdale Metropolitan Borough Council has not completed any additional works within the reporting year of 2021.

QA/QC of Diffusion Tube Monitoring

The diffusion tubes are supplied and analysed by SOCOTEC Didcot using the 50% TEA (triethanolamine) in acetone preparation method. SOCOTEC Didcot, a UKAS accredited laboratory, participate in the AIR-PT scheme for NO₂ diffusion tube analysis and Annual Field Intercomparison Exercise. These provide strict criteria relating to performance that participating laboratories must meet, thereby ensuring that the reported NO₂ concentrations are of a high calibre. In the first round of results during 2021, running from January – March (AIR-PT AR042), SOCOTEC Didcot were awarded a score of 100% – the percentage score is an indication of the results deemed satisfactory based upon the z-score of $< \pm 2$. At the time of writing this report, the AIR-PT results for April – December 2021 were not available.

For all observations in 2021, the precision of NO₂ diffusion tubes supplied by SOCOTEC Didcot was classified as ‘good’ for all but three. The precision is an indication of the laboratory’s performance and consistency in both the preparation, analysis and handling of the diffusion tubes. Full details of the precision summary results are available [here](#).

During 2021, the diffusion tubes were not deployed in line with the monitoring calendar, owing primarily to staff shortages caused by COVID-19 absences. As a result, there is no diffusion tube data for the first half of the monitoring period (January – May, and July). The diffusion tubes for June were overexposed beyond the recommended 4-5 weeks, and therefore the data has been excluded (but is shown in Table B.2 for complete transparency). In the latter half of the year (i.e. August onwards), there was less disruption to the changing of diffusion tubes, hence there is a more continual set of data between August – November.

Diffusion Tube Annualisation

Owing to the disruption caused by staff shortages, all diffusion tube sites were required to be annualised during 2021, with data capture ranging from 27% to 35%. Annualisation was carried out in accordance with TG.16 by calculating an average annualisation factor from four background monitoring sites within a 50-mile radius. The background monitoring sites used are all part of the Automatic Urban and Rural Network (AURN); Dewsbury Ashworth Grove, Leeds Centre, Manchester Piccadilly and Barnsley Gawber. Results of the calculations, including the average annualisation factor, are provided in Table C.3.

Diffusion Tube Bias Adjustment Factors

The diffusion tube data presented within the 2022 ASR have been corrected for bias using an adjustment factor. Bias represents the overall tendency of the diffusion tubes to under or

over-read relative to the reference chemiluminescence analyser. LAQM.TG16 provides guidance with regard to the application of a bias adjustment factor to correct diffusion tube monitoring. Triplicate co-location studies can be used to determine a local bias factor based on the comparison of diffusion tube results with data taken from NO_x/NO₂ continuous analysers. Alternatively, the national database of diffusion tube co-location surveys provides bias factors for the relevant laboratory and preparation method.

Calderdale Metropolitan Borough Council have applied a national bias adjustment factor of 0.78 to the 2021 monitoring data. A summary of bias adjustment factors used by Calderdale Metropolitan Borough Council over the past five years is presented in Table C.1.

A co-location study is carried out at the Huddersfield Road (AQS2) automatic monitoring station, where three diffusion tubes (AQC1, AQC2 and AQC3) are co-located within 30cm of the monitoring inlet. The local bias adjustment factor was calculated at 0.74 as shown in Table C.2. However, owing to the poor data capture of these three sites (35%), the more conservative national factor of 0.78 (spreadsheet 03/22) was used to bias adjust the data.

Table C.1 – Bias Adjustment Factor

Monitoring Year	Local or National	If National, Version of National Spreadsheet	Adjustment Factor
2021	National	03/22	0.78
2020	Local	-	0.87
2019	National	03/19	0.80
2018	National	03/18	0.78
2017	Local	-	0.84

Table C.2 – Local Bias Adjustment Calculation

	Local Bias Adjustment Input 1
Periods used to calculate bias	4
Bias Factor A	0.74 (0.72 – 0.77)
Bias Factor B	35% (30% - 40%)
Diffusion Tube Mean (µg/m ³)	46.9
Mean CV (Precision)	6%
Automatic Mean (µg/m ³)	34.8
Data Capture	100%
Adjusted Tube Mean (µg/m ³)	35 (34 – 36)

Notes:

Although not used to bias adjust the 2021 data, the results of the co-location study as presented for transparency.

NO₂ Fall-off with Distance from the Road

Wherever possible, monitoring locations are representative of exposure. However, where this is not possible, the NO₂ concentration at the nearest location relevant for exposure has been estimated using the Diffusion Tube Data Processing Tool/NO₂ fall-off with distance calculator available on the LAQM Support website. Where appropriate, non-automatic annual mean NO₂ concentrations corrected for distance are presented in Table B.1.

The NO₂ annual mean concentration was corrected for distance to relevant exposure at 11 diffusion tube sites in 2021. These sites were subject to such calculation as the annual mean concentration was greater than 36 µg/m³ and the monitoring site is not located at a point of relevant exposure. Site LV-SCA was not distance corrected as the diffusion tube is over 150m to the nearest point of relevant exposure and therefore an accurate estimation could not be achieved. A summary is provided in Table C.4.

QA/QC of Automatic Monitoring

The three automatic monitors are covered by a maintenance and callout contract, allowing six monthly maintenance visits and callouts for any instrument faults. Each site is visited every two weeks by a contractor to routinely monitor and detect any faults whilst checking the instrument nitrogen oxide span and zeros. Data from all three automatic monitoring sites is collected using WinAQMS and Airodis software, then checked for erroneous readings and backed up to Calderdale Metropolitan Borough Council's secure network. The raw values are checked for inconsistencies before using the span and zero values obtained on site each week to scale the data. Calderdale Metropolitan Borough Council's 2021 automatic air quality monitoring site data has been ratified by Air Quality Data Management to the LAQM TG.16 standards.

PM₁₀ and PM_{2.5} Monitoring Adjustment

Measurements of particulate matter are made using a beta attenuation monitor (BAM) with the appropriate inlets for PM₁₀ and PM_{2.5} and the data is collected using the same system as the NO₂ analysers. The BAM tape is changed by Council staff when required. Sections of the record where there is a consistent amount of missing data may need to be removed from the data as they are likely to be affected by instrument faults (something which is not normally detected during routine checks). Similarly, a period of known instrument faults is also removed. Once the data is in a suitable format, it can be imported into the open source

software package “openair”. Calderdale Metropolitan Borough Council has chosen to use “openair” primarily due to the range of analysis tools and ease of data manipulation.

Automatic Monitoring Annualisation

All automatic monitoring locations within Calderdale recorded data capture of greater than 75% therefore it was not required to annualise any monitoring data. In addition, any sites with a data capture below 25% do not require annualisation.

NO₂ Fall-off with Distance from the Road

No automatic NO₂ monitoring locations within Calderdale required distance correction during 2021.

Table C.3 – Annualisation Summary (concentrations presented in $\mu\text{g}/\text{m}^3$)

Site ID	Annualisation Factor Dewsbury Ashworth Grove	Annualisation Factor Leeds Centre	Annualisation Factor Manchester Piccadilly	Annualisation Factor Barnsley Gawber	Average Annualisation Factor	Raw Data Time- Weighted Annual Mean	Annualised Data Time- Weighted Annual Mean	Comments
AQ21	1.0559	0.9538	0.9723	1.1203	1.0256	66.4	68.1	
AQC1	1.0559	0.9538	0.9723	1.1203	1.0256	-	-	Triplicate Site with AQC1, AQC2 and AQC3 - Annual data provided for AQC3 only.
AQC2	1.0559	0.9538	0.9723	1.1203	1.0256	-	-	Triplicate Site with AQC1, AQC2 and AQC3 - Annual data provided for AQC3 only.
AQC3	1.0559	0.9538	0.9723	1.1203	1.0256	46.4	47.6	Triplicate Site with AQC1, AQC2 and AQC3 - Annual data provided for AQC3 only.
CRH1	1.0559	0.9538	0.9723	1.1203	1.0256	48.6	49.8	
SB1	1.0559	0.9538	0.9723	1.1203	1.0256	46.3	47.5	
SB15	1.0559	0.9538	0.9723	1.1203	1.0256	38.3	39.3	
SB16	1.0872	0.9978	0.9867	1.1132	1.0462	31.1	32.5	
SB22	1.0559	0.9538	0.9723	1.1203	1.0256	41.9	43.0	
SB3	1.0559	0.9538	0.9723	1.1203	1.0256	46.2	47.4	
SB-AQ	1.0559	0.9538	0.9723	1.1203	1.0256	39.5	40.5	
BS1 HB	1.0559	0.9538	0.9723	1.1203	1.0256	38.2	39.1	
HB6	1.0559	0.9538	0.9723	1.1203	1.0256	35.7	36.6	
HQ1	1.0559	0.9538	0.9723	1.1203	1.0256	53.2	54.6	
HQ9	1.0559	0.9538	0.9723	1.1203	1.0256	37.2	38.2	
LF1	1.0559	0.9538	0.9723	1.1203	1.0256	40.0	41.0	
LF2	1.0559	0.9538	0.9723	1.1203	1.0256	34.1	34.9	
SC5	1.0559	0.9538	0.9723	1.1203	1.0256	40.3	41.4	
BE2	1.0559	0.9538	0.9723	1.1203	1.0256	45.6	46.8	
BE4	1.0559	0.9538	0.9723	1.1203	1.0256	54.0	55.4	
BH3	1.0559	0.9538	0.9723	1.1203	1.0256	53.4	54.8	
HXR1	1.0559	0.9538	0.9723	1.1203	1.0256	54.5	55.9	
LV-BRD	1.0559	0.9538	0.9723	1.1203	1.0256	30.2	30.9	
WR2	1.0559	0.9538	0.9723	1.1203	1.0256	38.9	39.9	
HH-1A	1.0559	0.9538	0.9723	1.1203	1.0256	39.3	40.4	

Site ID	Annualisation Factor Dewsbury Ashworth Grove	Annualisation Factor Leeds Centre	Annualisation Factor Manchester Piccadilly	Annualisation Factor Barnsley Gawber	Average Annualisation Factor	Raw Data Time- Weighted Annual Mean	Annualised Data Time- Weighted Annual Mean	Comments
HH-LT	1.0559	0.9538	0.9723	1.1203	1.0256	52.9	54.2	
HH-TC	1.0559	0.9538	0.9723	1.1203	1.0256	34.6	35.5	
LV-NBN	1.0559	0.9538	0.9723	1.1203	1.0256	66.5	68.2	
LV-NBS	1.0559	0.9538	0.9723	1.1203	1.0256	50.9	52.2	
LV-NBX	1.0559	0.9538	0.9723	1.1203	1.0256	46.1	47.3	
NB-GR	1.0559	0.9538	0.9723	1.1203	1.0256	64.8	66.5	
NB-NB1	1.0559	0.9538	0.9723	1.1203	1.0256	45.7	46.9	
AQ20	1.0559	0.9538	0.9723	1.1203	1.0256	23.2	23.7	
AT-BR	1.0559	0.9538	0.9723	1.1203	1.0256	29.3	30.0	
AT-MR	1.0559	0.9538	0.9723	1.1203	1.0256	29.8	30.6	
CL1	1.0872	0.9978	0.9867	1.1132	1.0462	34.6	36.2	
HTAH	1.0522	0.9523	0.9516	1.1326	1.0222	33.0	33.7	
LV-62E	1.0559	0.9538	0.9723	1.1203	1.0256	39.8	40.8	
LV-62W	1.0559	0.9538	0.9723	1.1203	1.0256	49.0	50.2	
LV-AT	1.0559	0.9538	0.9723	1.1203	1.0256	51.9	53.2	
LV-EWB	1.0559	0.9538	0.9723	1.1203	1.0256	24.8	25.4	
LV-LEE	1.0559	0.9538	0.9723	1.1203	1.0256	33.7	34.5	
LV-SAA	1.0559	0.9538	0.9723	1.1203	1.0256	28.0	28.8	
LV-SCA	1.0559	0.9538	0.9723	1.1203	1.0256	46.4	47.5	
MY01	1.0559	0.9538	0.9723	1.1203	1.0256	42.1	43.2	
MY02	1.0559	0.9538	0.9723	1.1203	1.0256	18.6	19.1	
MY03	1.0559	0.9538	0.9723	1.1203	1.0256	40.5	41.5	
MY-04	1.0559	0.9538	0.9723	1.1203	1.0256	25.8	26.4	
MY-05	1.1005	1.0117	1.0768	1.1863	1.0938	26.2	28.7	
NB-GL	1.0522	0.9523	0.9516	1.1326	1.0222	54.6	55.8	
SB23	1.0559	0.9538	0.9723	1.1203	1.0256	29.3	30.0	
WV-SR1	1.0559	0.9538	0.9723	1.1203	1.0256	41.5	42.5	
WV-SR2	1.0559	0.9538	0.9723	1.1203	1.0256	28.7	29.4	
SB40	1.0522	0.9523	0.9516	1.1326	1.0222	10.0	10.2	
SB41	1.0522	0.9523	0.9516	1.1326	1.0222	9.9	10.1	
SB42	1.0522	0.9523	0.9516	1.1326	1.0222	28.8	29.5	
SB43	1.0522	0.9523	0.9516	1.1326	1.0222	11.2	11.5	
SB44	1.0522	0.9523	0.9516	1.1326	1.0222	14.4	14.8	
SB45	1.0522	0.9523	0.9516	1.1326	1.0222	34.3	35.0	

Table C.4 – NO₂ Fall off With Distance Calculations (concentrations presented in µg/m³)

Site ID	Distance (m): Monitoring Site to Kerb	Distance (m): Receptor to Kerb	Monitored Concentration (Annualised and Bias Adjusted)	Background Concentration	Concentration Predicted at Receptor	Comments
AQ21	2.0	4.0	53.1	13.2	46.6	Predicted concentration at Receptor above AQS objective.
AQC1, AQC2, AQC3	2.0	4.0	37.1	13.2	33.3	
BH3	1.5	4.5	42.7	15.4	36.2	Predicted concentration at Receptor within 10% the AQS objective.
LV-NBN	1.0	41.0	53.2	15.4	24.9	
LV-NBS	2.0	27.0	40.7	15.4	25.3	
LV-NBX	1.0	31.0	36.9	15.4	22.0	
NB-GR	3.0	7.0	51.9	15.4	43.9	Predicted concentration at Receptor above AQS objective.
NB-NB1	2.0	4.0	36.6	15.4	33.1	
LV-62W	3.0	9.0	39.2	19.2	33.5	
LV-AT	4.0	18.0	41.5	18.0	31.6	
LV-SCA	10.0	160.0	37.1	-	-	Not distance corrected as site is over 150m from nearest point of relevant exposure.
NB-GL	2.0	19.0	43.5	11.6	26.7	

Appendix D: Maps of Monitoring Locations and AQMAs

Figure D.1 – Map of Non-Automatic & Automatic Monitoring Sites in Salterhebble (AQMA No.1)



Figure D.2 – Map of Non-Automatic & Automatic Monitoring Sites in Sowerby Bridge (AQMA No.2)



Figure D.3 – Map of Non-Automatic & Automatic Monitoring Sites in Hebden Bridge (AQMA No.3)

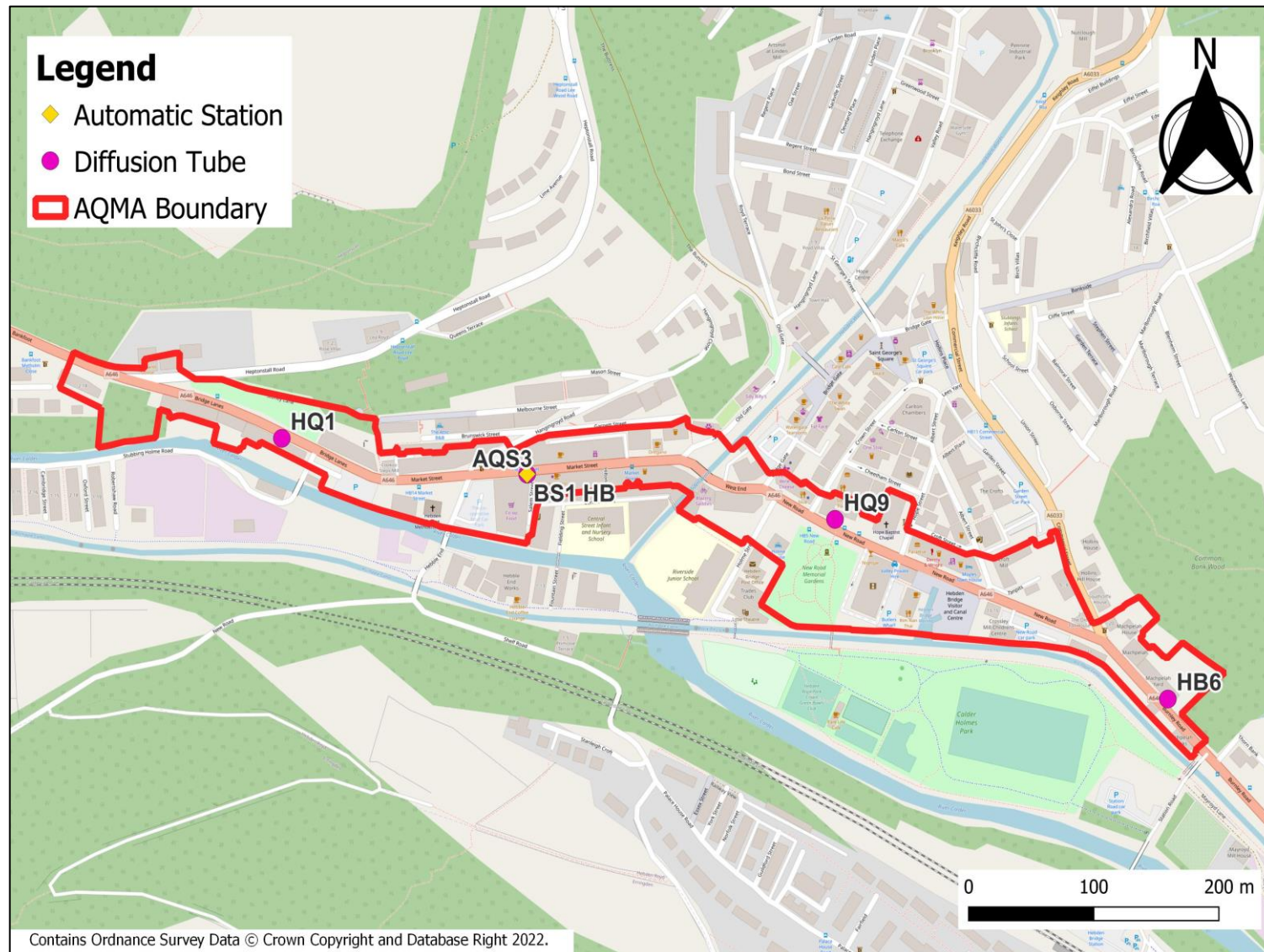


Figure D.4 – Map of Non-Automatic Monitoring Sites in Luddendenfoot (AQMA No.4)

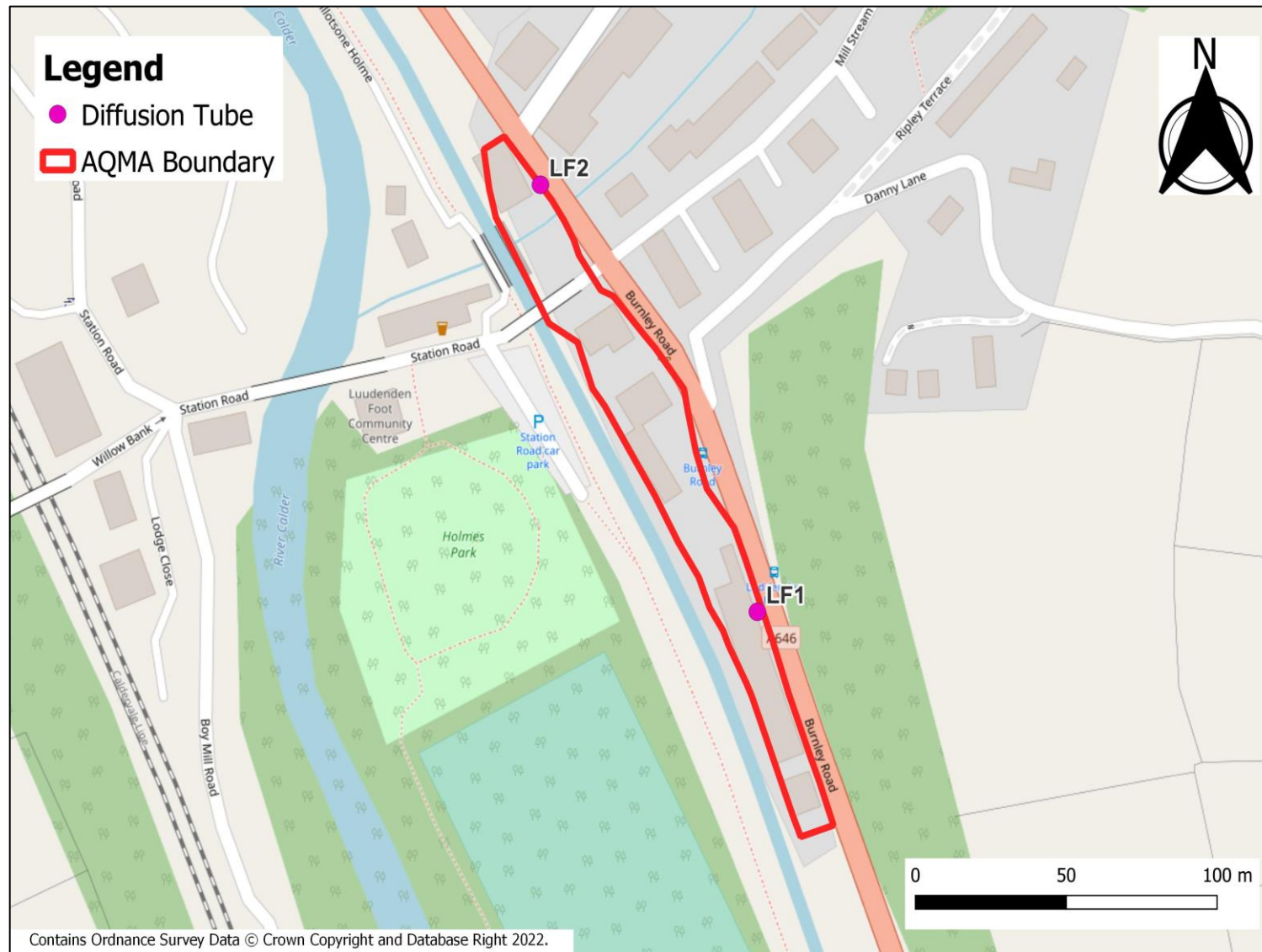


Figure D.5 – Map of Non-Automatic Monitoring Sites in Stump Cross (AQMA No.5) & New Bank (AQMA No.8)

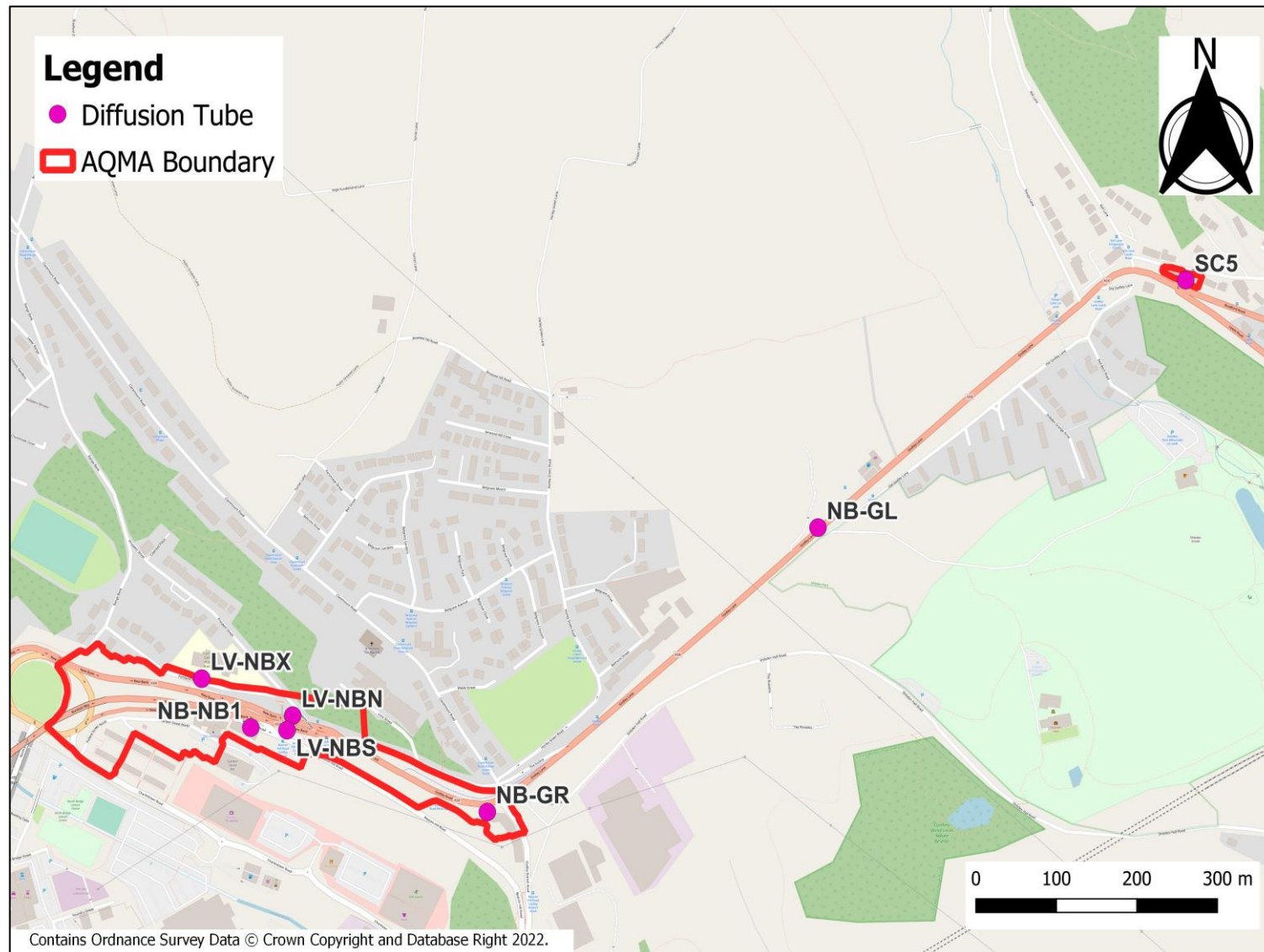


Figure D.6 – Map of Non-Automatic Monitoring Sites in Brighouse (AQMA No.6)

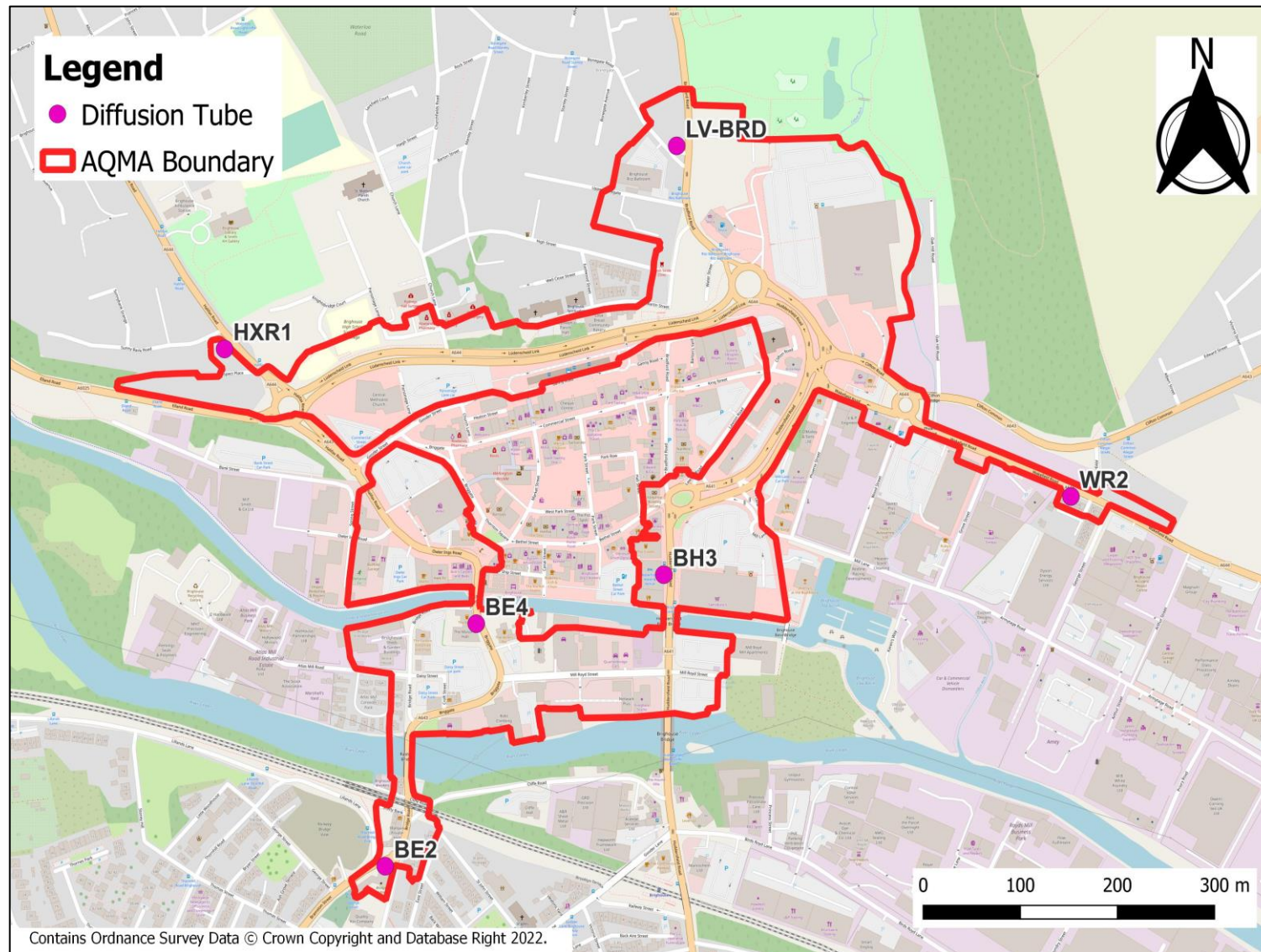


Figure D.7 – Map of Non-Automatic Monitoring Sites in Hipperholme (AQMA No.7)

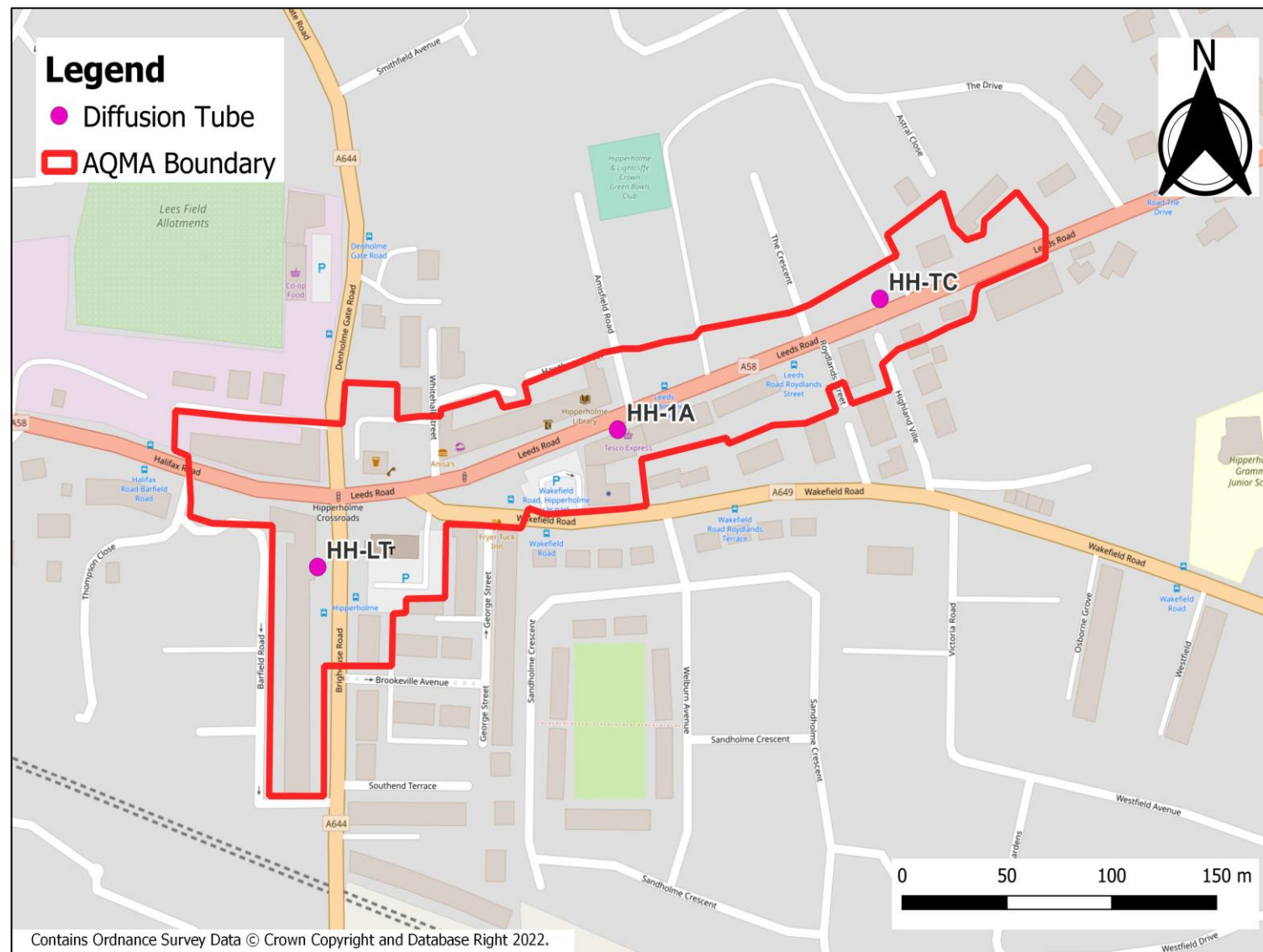


Figure D.8 – Map of Non-Automatic Monitoring Sites in Mytholmroyd

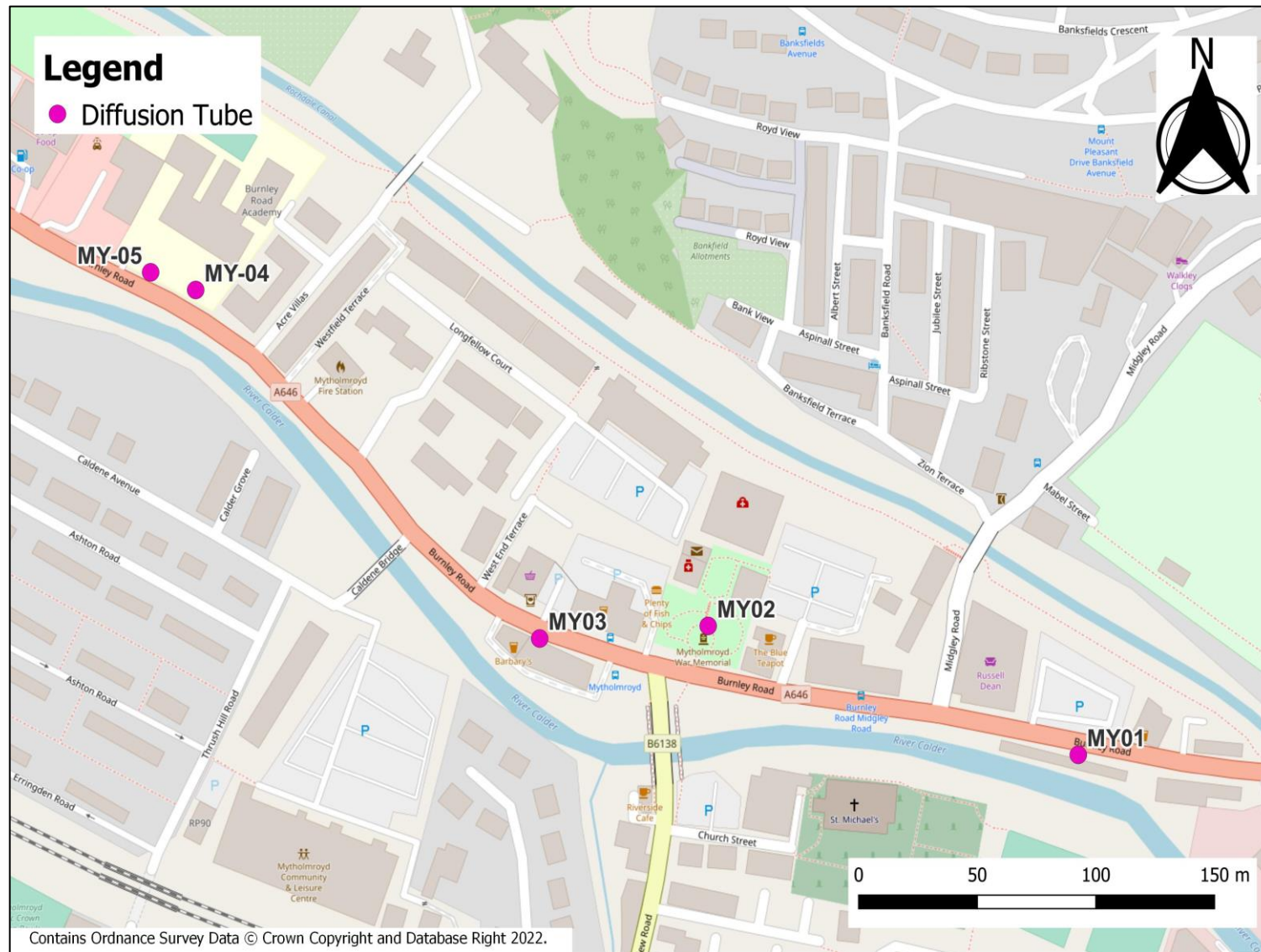


Figure D.9 – Map of Non-Automatic Monitoring Sites in West Vale, Ainley Top & Rastrick

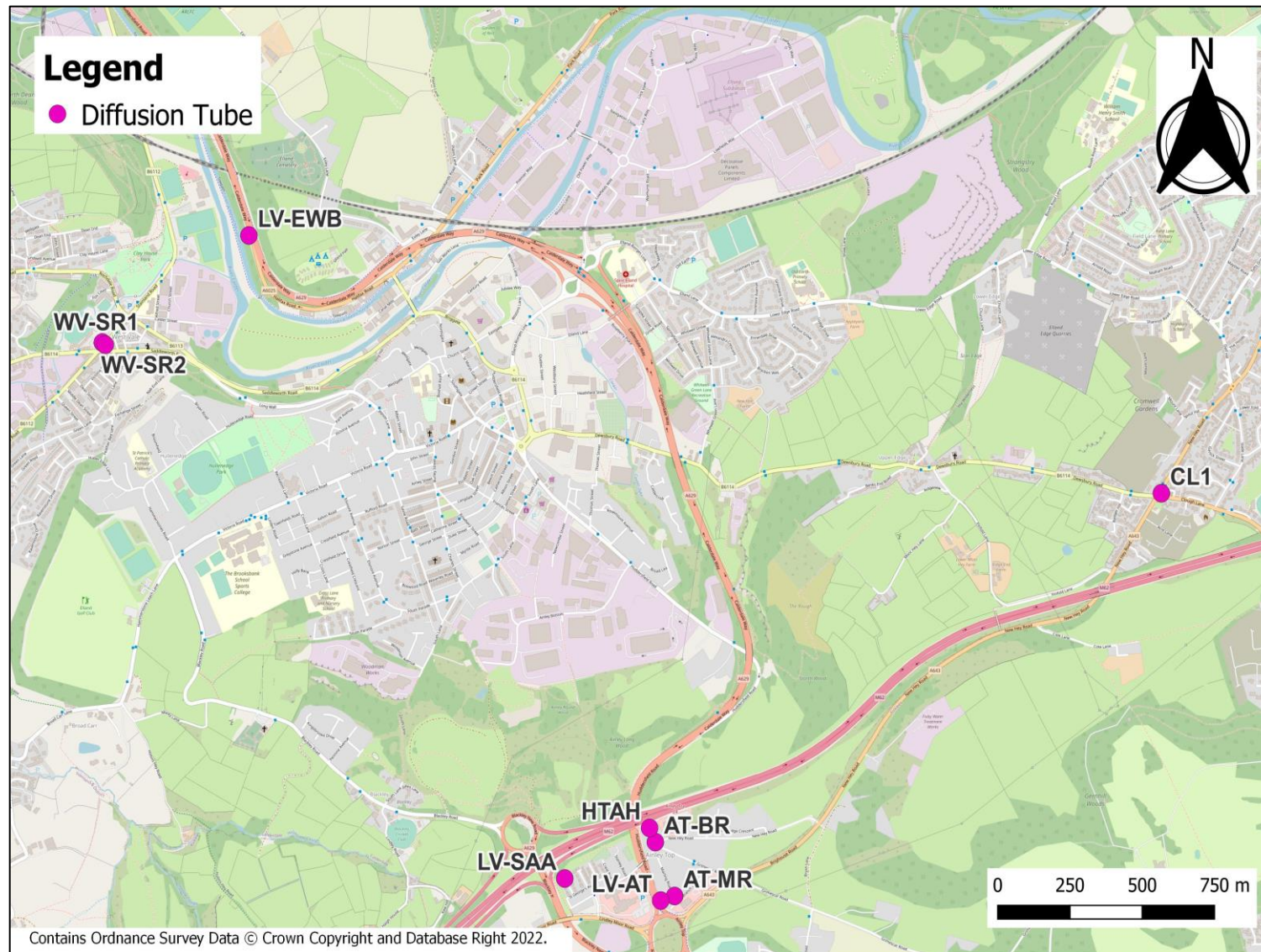


Figure D.10 – Map of Non-Automatic Monitoring Sites in Brighouse South & Cooper Bridge

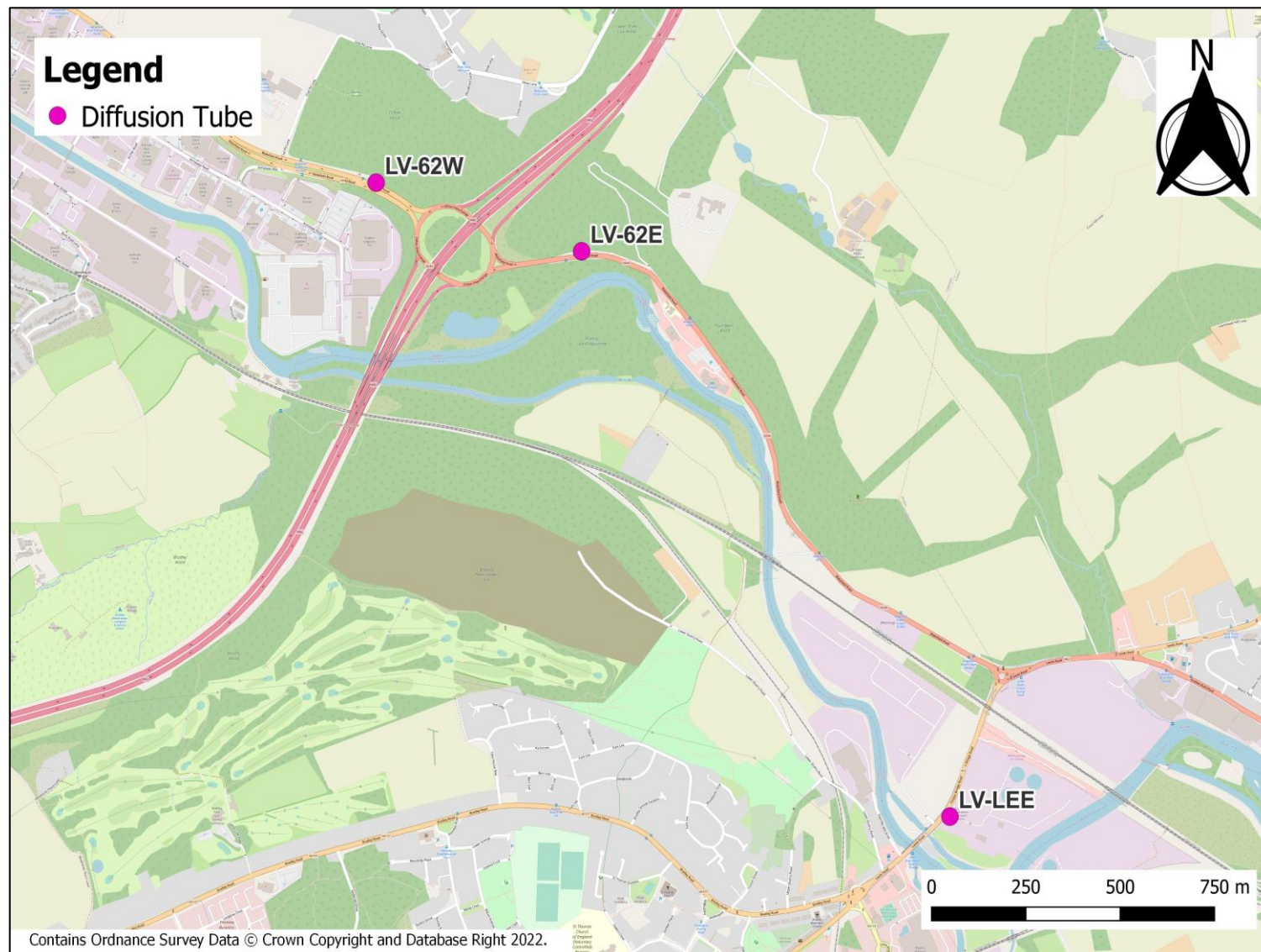


Figure D.11 – Map of Non-Automatic Monitoring Sites in Sowerby Bridge

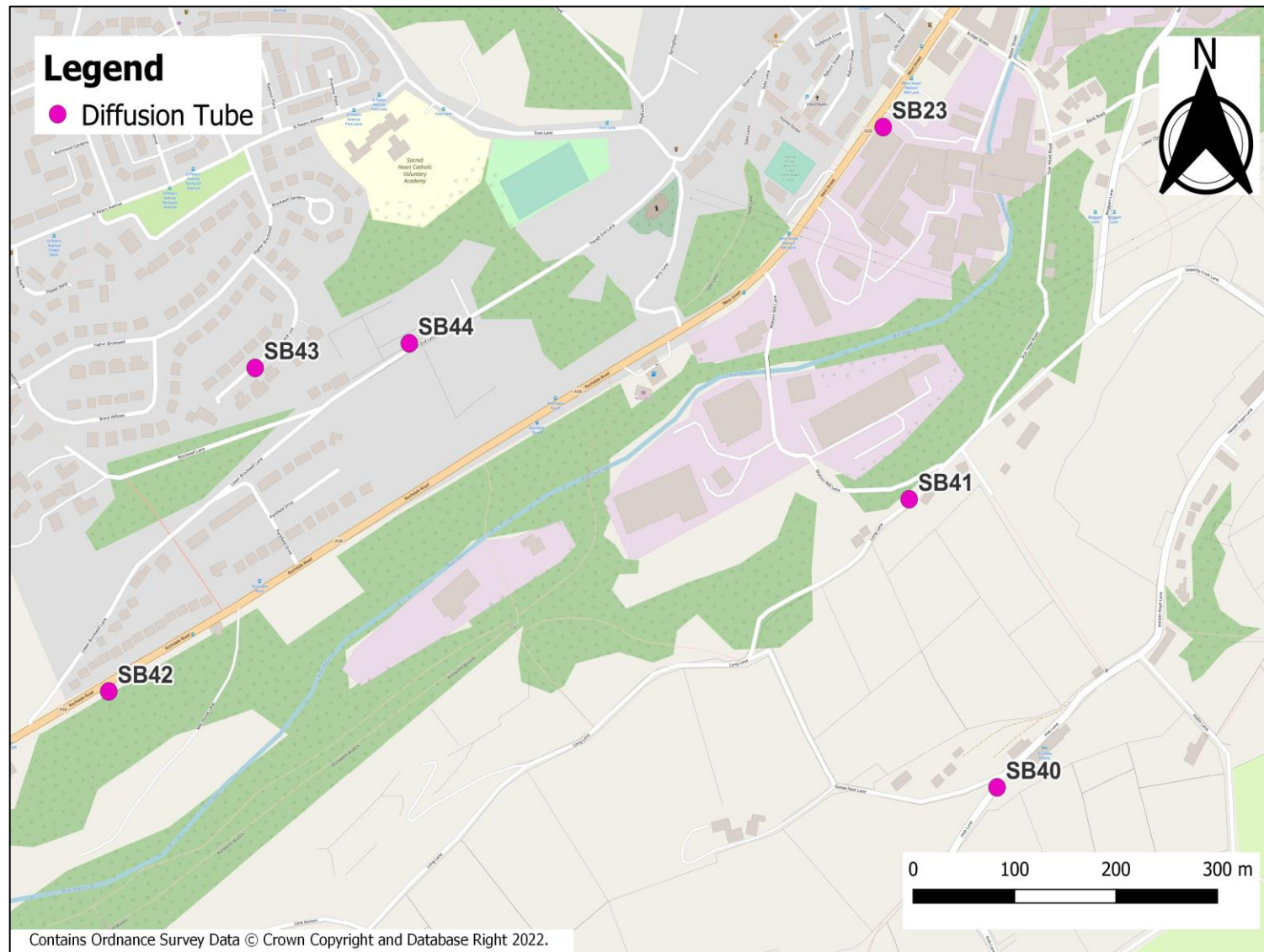
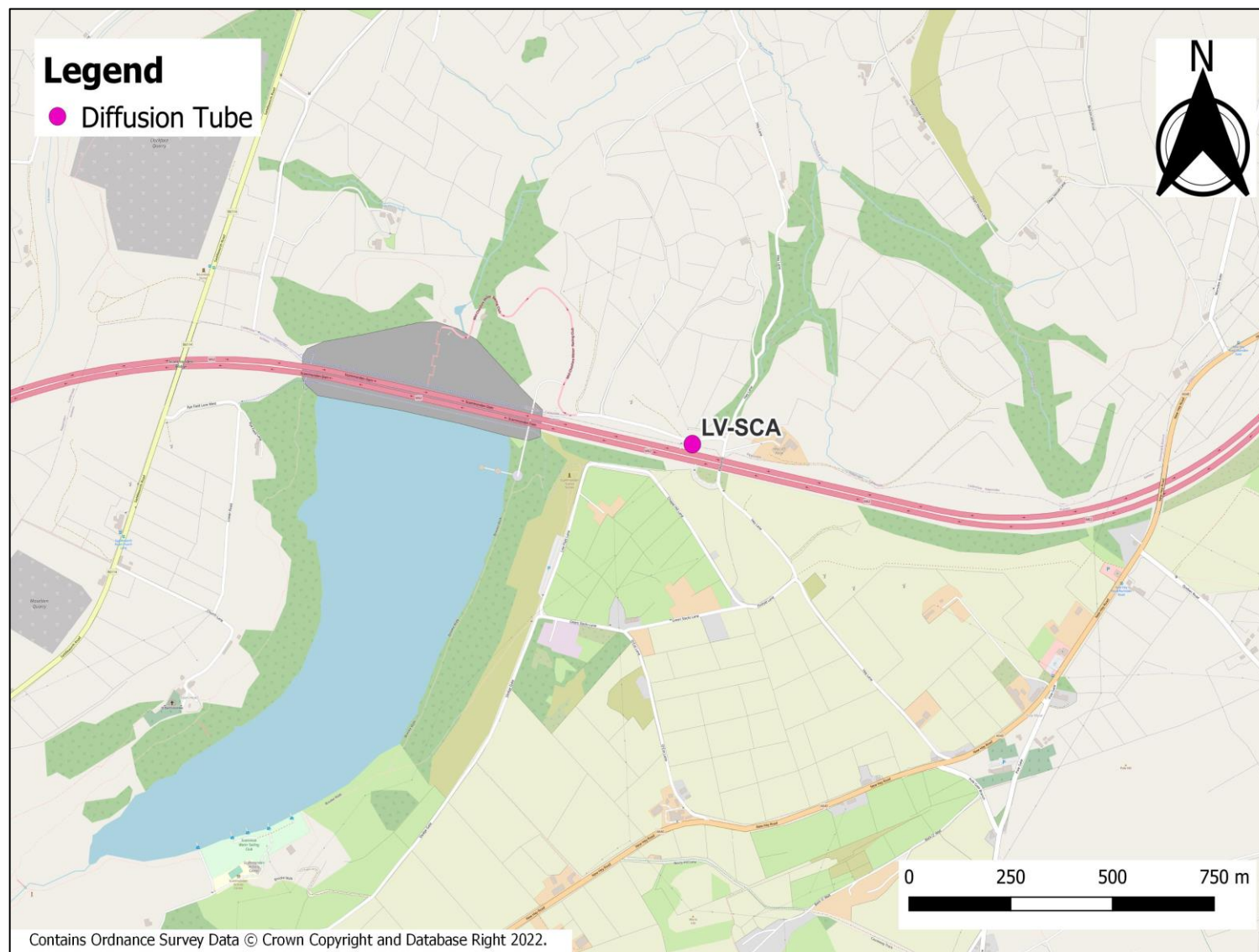


Figure D.12 – Map of Non-Automatic Monitoring Sites in Scammonden



Appendix E: Summary of Air Quality Objectives in England

Table E.1 – Air Quality Objectives in England⁷

Pollutant	Air Quality Objective: Concentration	Air Quality Objective: Measured as
Nitrogen Dioxide (NO ₂)	200µg/m ³ not to be exceeded more than 18 times a year	1-hour mean
Nitrogen Dioxide (NO ₂)	40µg/m ³	Annual mean
Particulate Matter (PM ₁₀)	50µg/m ³ , not to be exceeded more than 35 times a year	24-hour mean
Particulate Matter (PM ₁₀)	40µg/m ³	Annual mean
Sulphur Dioxide (SO ₂)	350µg/m ³ , not to be exceeded more than 24 times a year	1-hour mean
Sulphur Dioxide (SO ₂)	125µg/m ³ , not to be exceeded more than 3 times a year	24-hour mean
Sulphur Dioxide (SO ₂)	266µg/m ³ , not to be exceeded more than 35 times a year	15-minute mean

⁷ The units are in microgrammes of pollutant per cubic metre of air (µg/m³).

Glossary of Terms

Abbreviation	Description
AQAP	Air Quality Action Plan - A detailed description of measures, outcomes, achievement dates and implementation methods, showing how the local authority intends to achieve air quality limit values'
AQMA	Air Quality Management Area – An area where air pollutant concentrations exceed / are likely to exceed the relevant air quality objectives. AQMAs are declared for specific pollutants and objectives
ASR	Annual Status Report
AURN	Automatic Urban and Rural Network
Defra	Department for Environment, Food and Rural Affairs
DMRB	Design Manual for Roads and Bridges – Air quality screening tool produced by National Highways
EU	European Union
FDMS	Filter Dynamics Measurement System
LAQM	Local Air Quality Management
NO ₂	Nitrogen Dioxide
NO _x	Nitrogen Oxides
PM ₁₀	Airborne particulate matter with an aerodynamic diameter of 10µm or less
PM _{2.5}	Airborne particulate matter with an aerodynamic diameter of 2.5µm or less
QA/QC	Quality Assurance and Quality Control
SO ₂	Sulphur Dioxide

References

- Local Air Quality Management Technical Guidance LAQM.TG16. April 2021. Published by Defra in partnership with the Scottish Government, Welsh Assembly Government and Department of the Environment Northern Ireland.
- Local Air Quality Management Policy Guidance LAQM.PG16. May 2016. Published by Defra in partnership with the Scottish Government, Welsh Assembly Government and Department of the Environment Northern Ireland.
- Calderdale Air Quality Action Plan 2019. May 2019. Published by Calderdale Metropolitan Borough Council.

Borough Council of Calderdale

Environmental Permitting (England and Wales) Regulations 2016 (as amended)

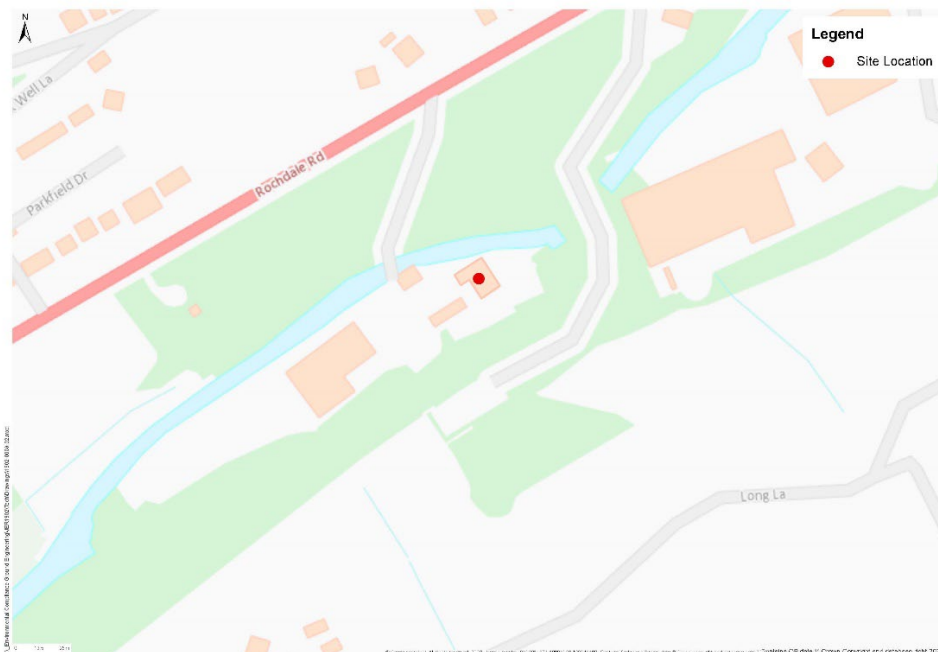
Schedule 13 Environmental Permit

Permit reference

Operator:	Calder Valley Skip Hire Ltd Belmont Industrial Estate Rochdale Road Sowerby Bridge HX6 3LL
Company Number:	03861770
Regulated facility:	Small Waste Co-incineration Plant Calder Valley Skip Hire Ltd Belmont Industrial Estate Rochdale Road Sowerby Bridge HX6 3LL

Permitted Activity: Operation of a small waste -incineration plant, being a waste co-incineration plant, as defined in the Regulations.

Location map: The location of the plant is shown in red below.



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Section 2 Emissions to water

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Section 4 Emission limits to air

Section 5 Monitoring of emissions to air

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Appendix B Provenance of Permit Conditions

Drawings and plans

Boundary plan of small waste co-incineration plant (adapted and annotated from the plans supplied by applicant)

Explanatory notes

Definitions

Unless otherwise specified, the definitions set out in the relevant Articles of Directive 2010/75/EU on industrial emissions (the Industrial Emissions Directive) (and in particular Article 3) and the definitions set out in the Environmental Permitting (England and Wales) Regulations 2016 (as amended) shall apply throughout this permit.

In addition

"The Regulator" means Calderdale Metropolitan Borough Council, the Borough Council of Calderdale.

"the Regulations" means the Environmental Permitting (England and Wales) Regulations 2016 (as amended).

"the Directive" means Directive 2010/75/EU on industrial emissions (integrated pollution prevention and control) 2010 as amended.

"The plant" and "the small waste co-incineration plant (SWCP)" and similar terms mean the small waste co-incineration plant for the combustion of non-hazardous waste, including waste storage areas, loading equipment and all associated equipment described in *the application*.

"Site", "on site" and similar terms shall be taken to refer to the site of the small waste co-incineration plant including all waste reception and storage areas, and the locations of processing activities. Note: all waste co-incineration activities must be undertaken within the small waste co-incineration plant building. The boundary of the site is shown in Plan S13/005/P1 and in drawing 'Permit Site Boundary Plan 1902-0002-01'.

"The application" means the application for an environmental permit made by the operator, on 6th August 2020 and duly made, including the appendices and supporting information together with supplementary information supplied on 16th October 2020 and further information provided for the permit re-determination in connection with that application supplied on 16th and 18th March 2020.

'Waste' means waste as defined in point 1 of Article 3 of Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste.

'Hazardous waste' means hazardous waste as defined in point 2 of Article 3 of Directive 2008/98/EC.

The application and supplementary information are held on the public register.

Other terms may be defined in the relevant section of the permit.

Schedules applied in this permit

This permit applies the following schedules to the Regulations:
Schedule 13 — small waste incineration plant.

Public register

The application, the permit and documents concerned with the determination of the application and subsequent reports and correspondence are held on the public register, a copy of which is available to view free of charge during office hours.

Parts of the application are referred to in the conditions of this permit and form part of the permit to the extent that they specify equipment and procedures that are to be complied with by virtue of the relevant permit conditions.

Application of conditions

Emission limits and monitoring requirements set out in Sections 1 to 8 apply to the small waste co-incineration plant.

The small waste co-incineration plant.

Waste of the types described in Table W1 is received by the SWCP site having been sorted at the adjacent permitted Waste Management Site. Waste fuel is loaded into a mechanical loader which feeds the primary combustion chamber of a i8-1000 small waste co-incinerator. Waste gases from the incinerate i8-1000 pass to air by a 12m stack after passing through the secondary combustion chamber and treatment in the abatement system. Emissions are monitored using MCERTS compliant equipment meeting the requirements of EN 14181. A fuller description of the small waste co-incineration plant is set out in the Schedule 13 permit application document and Appendix **D** to the application. These documents are held on the public register.

Record of changes to this permit		
Date	Change	Notes

Articles applied in this permit

Permit conditions are cross referenced against the relevant Articles of the Directive 2010/75/EU (Industrial Emissions Directive)

Article 7; action in event of accidents or incidents	Section 7
Article 8(2); action in the event of a breach of permit conditions	Section 7
Article 45(1); (2) and (4); permitted waste types	Section 1A
Article 46; control of emissions	Section 3
Article 47; action in case of breakdown	Section 7
Article 48(1) to (4); monitoring and recording requirements	Section 5
Article 49; determining compliance with emission limit values	Section 5
Article 50; operating conditions	Section 3
Article 52; delivery and reception of waste	Section 1B
Article 53; minimization, storage and transport of residues	Section 6

Start of permit conditions

Section 1a Permitted waste types

Condition 1.1 The operator shall use no other waste types in the small waste co-incineration plant than those set out in Table W1.

Table W1: Permitted non-hazardous waste types (refer to Condition 1.1)

Waste Code	Description	Detail	Permitted annual usage (tonnes per annum)
19 12 10	Refuse derived fuel	Sorted from adjacent permitted waste treatment site	10 000
Total			10 000

Condition 1.2 No hazardous waste shall be accepted at the small waste co-incineration plant.

Condition 1.3 Only the waste recovery operations identified in Table W2 shall be undertaken.

Table W2: Permitted Recovery and Disposal Activities (refer to Condition 1.3)

European R/D Code	Description of R/D Code	Limits of specified activity
R1	Use principally as a fuel or other means to generate energy.	Operation of a small waste incineration plant, being a waste co-incineration plant, as defined in the Regulations and as specified within Article 42 of the Directive including all waste co-incineration activities reception and storage of incoming RDF to treatment and discharge of emissions from the stack (S1) and temporary storage of residues prior to removal for off-site management.

Condition 1.4 The maximum input of waste that may be co-incinerated in the small waste co-incineration plant is 10 000 tonnes per annum, at a rate not exceeding two tonnes per hour.

Section 1 b Delivery and reception of waste

Condition 1.5 The precautions set out in Section 3.2 of the application, relating to the delivery and reception of waste, shall be used to ensure that the pollution of air, soil, surface water and groundwater shall be prevented or limited as far as practicable.

Condition 1.6 The precautions set out in Section 3.2 of the application relating to the delivery and reception of waste shall be used to ensure that negative effects on the environment, odours and noise, and direct risks to human health shall be prevented or limited as far as practicable.

Condition 1.7 The mass of each type of waste, according to the European Waste List established by Decision 2000/532/EC, shall be determined prior to accepting the waste on site, and recorded.

Section 2 Emissions to water

Condition 2.1 There shall be no discharges from the small waste co-incineration plant to surface water, sewer or groundwater.

Condition 2.2 Provision shall be made for an impervious collection area for contaminated water due to fire-fighting, to prevent the pollution of the land and water.

Condition 2.3 In the event of a fire in the small waste co-incineration plant building that uses firewater for firefighting polybooms or other barrier (as approved by the Fire and Rescue Service and the Regulator) shall be deployed across all entrances to the small waste co-incineration plant building to contain contaminated water from fire-fighting within the small waste co-incineration plant building. Contaminated water shall be tested prior to removal to an off-site approved treatment facility.

Section 3a Normal operating conditions

Condition 3.1 The operator shall not operate the small waste co-incineration plant unless the systems described in Section 3.3 of the application are functioning correctly.

Condition 3.2 The operator shall monitor the operation of the plant using the systems and equipment set out in Section 3.13 of the application, or an agreed equivalent.

Condition 3.3 Waste gases from the small waste co-incineration plant shall be discharged from the stack S1. The discharge height of the stack is 12m.

Condition 3.4 An automatic system shall be in place to stop waste feed into the primary combustion chamber if any continuous measurement shows that any emission limit value is exceeded due to disturbance or failure of the abatement equipment.

Condition 3.5 The heat recovery systems outlined in Section 4.2 of the application shall be used to ensure that heat is recovered as far as possible.

Condition 3.6 The small waste co-incineration plant shall be operated and controlled by a natural person who is competent to manage the plant. All operational staff at the plant shall receive the training referred to in documents set out in Section 5.3 of the application prior to commencing work at the plant. Records of the training shall be kept on site or at the operator's main offices.

Condition 3.7 The small waste co-incineration plant shall be operated in such a way that the gas resulting from the co-incineration of waste is raised 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.

Section 3b Permissible periods of abnormal operation

Condition 3.9 Waste shall not be charged, or shall cease to be charged, if:

- a) the temperature indicated by the temperature probe at the exit from the secondary combustion chamber is below, or falls below, 850°C; or
- b) any continuous emission limit value in Table T2 is exceeded, other than under "permissible periods of abnormal operation"; or
- c) the monitoring results required to demonstrate compliance with any continuous emission limit value in Table T2 are unavailable other than during "permissible periods of abnormal operation".

Condition 3.10 The operator shall record the beginning and the end of each permissible period of abnormal operation.

Condition 3.11 In the event of any permissible period of abnormal operation the operator shall restore normal operation of the failed equipment or replace the failed equipment at the earliest possible time.

Condition 3.12 Where, during permissible periods of abnormal operation, on an incineration line, any of the following situations arise, waste shall cease to be charged on that line until normal operation can be restored:

- a) continuous measurement shows that an emission exceeds any emission limit value in Table T2 due to disturbances or failures of the abatement systems, or continuous emission monitors or continuous effluent monitoring devices are out of service, as the case may be, for a total of 4 hours uninterrupted duration;
- b) the cumulative duration of permissible periods of abnormal operation over 1 calendar year has reached 60 hours.

Note: additional interpretation for Section 3b

"permissible periods of abnormal operation" means any technically unavoidable stoppages, disturbances, or failures of the abatement plant or the measurement devices other than continuous emission monitors for releases to air of particulates, TOC and/or CO, during which the concentrations in the discharges into air and the purified waste water of the regulated substances may exceed the normal emission limit values.

The end of the permissible period of abnormal operation means the earliest of the following:

- a) when the failed equipment is repaired and brought back into normal operation.
- b) when the operator initiates a shutdown of the waste combustion activity, as described in the application or as agreed in writing with the Regulator.
- c) when a period of four hours has elapsed from the start of the permissible period of abnormal operation.
- d) when, in any calendar year, an aggregate of 60 hours has been reached for permissible periods of abnormal operation.

Section 4 Emission limits to air

Condition 4.1 All emission limits shall be taken to be calculated at a temperature of 273.15K, a pressure of 101.3kPa, after correcting for the water content of the waste gases. The limits are standardised to 11% oxygen content for the parameters in Tables T1, T2 and Condition 4.3 and standardised to 6% oxygen for the parameter in Tables T3 and T4.

Condition 4.2 The emission limit values in Tables T1, T2, T3 and T4 shall apply to emissions from the small waste co-incineration plant through stack S1.

Note mg/Nm³ means milligrams of pollutant per metre cubed of gas measured at standard reference conditions and ng/Nm³ means nanograms of pollutant per metre cubed of gas measured at standard reference conditions (see Condition 4.1).

Table T1: Daily average emission limit values in mg/Nm³	
Total dust	10
Organic substances in the gas or vapour phase as total organic carbon (TOC)	10
Hydrogen chloride (HCl)	10
Sulphur dioxide (SO ₂)	50
Nitrogen monoxide (NO) and nitrogen dioxide (NO ₂) expressed as NO ₂	200

Table T2: Half-hourly average emission limit values in mg/Nm³	
Polluting substance	97 th percentile
Total dust	10
Organic substances in the gas or vapour phase as total organic carbon (TOC)	10
Hydrogen chloride (HCl)	10
Hydrogen fluoride (HF)	2
Sulphur dioxide (SO ₂)	50
Nitrogen monoxide (NO) and nitrogen dioxide (NO ₂) expressed as NO ₂	200

Table T3: Average emission limit values in mg/Nm³ for heavy metals over a sampling period of a minimum of 30 minutes and a maximum of 8 hours	
Cadmium and its compounds expressed as cadmium (Cd)	Total 0.05
Thallium and its compounds expressed as thallium (Tl)	
Mercury and its compounds expressed as mercury (Hg)	0.05
Antimony and its compounds expressed as antimony (Sb)	Total 0.05
Arsenic and its compounds expressed as arsenic (As)	
Lead and its compounds expressed as lead (Pb)	
Chromium and its compounds expressed as chromium (Cr)	
Cobalt and its compounds expressed as cobalt (Co)	
Copper and its compounds expressed as copper (Cu)	
Manganese and its compounds expressed as manganese (Mn)	
Nickel and its compounds expressed as nickel (Ni)	
Vanadium and its compounds expressed as vanadium (V)	

Table T4: Average emission limit values in ng/Nm³ for dioxins and furans at over a sampling period of a minimum of 6 hours and a maximum of 8 hours	
Dioxins and furans	0.1

Condition 4.3 The emission limits for carbon monoxide in the waste gases shall be, in mg/Nm³:

- (a) 50 as a daily average.
- (b) 100 as a half-hourly average.
- (c) 150 as a 10-minute average.

Section 5 Monitoring of emissions to air

Condition 5.1 Measurements for the determination of concentrations of polluting substances in waste gases from the small waste co-incineration plant shall be carried out in such a way that the samples are representative of the emissions. Sampling shall take place from points approved by the Regulator, before the plant is brought into operation, on the stack S1. The monitoring point shall meet the requirements of Environment Agency Monitoring Guidance Note TGN M1 "Sampling requirements for stack emission monitoring".

Condition 5.2 Sampling and analysis of polluting substances shall be carried out according to the standards set out in Tables T6 and T8. CEN standards or, where CEN standards are not available, to ISO or other national or international standards ensuring the provision of data of an equivalent scientific quality may be used, but prior written approval shall be sought from the Regulator in this event. Prior written approval shall be sought from the Regulator if sampling methods other than CEN standard methods are proposed.

Condition 5.3 The automated measuring systems described in Appendix D of the application shall be calibrated or, where appropriate, referenced, against CEN standard methods at least once each year.

Condition 5.4 For the daily emission level values, the 95% confidence intervals of individual results shall not exceed the percentages of the emission limit values in Table T5.

Table T5: percentages of emission limit values for condition 5.4	
Carbon monoxide (CO)	10%
Sulphur dioxide (SO ₂)	20%
Nitrogen dioxide (NO ₂)	20%
Total dust	30%
Total organic carbon (TOC)	30%
Hydrogen fluoride (HF)	40%
Hydrogen chloride (HCl)	40%

Condition 5.5 The measurements set out in Table T6 shall be carried out for air polluting substances.

Table T6: measurements for air polluting substances

Polluting substance	Method/standard	Type of monitoring
Oxides of nitrogen /NO _x)	BS EN 15267, parts 1-3	continuous
CO		
Total Dust		
Hydrogen chloride /HCl)		
Sulphur dioxide (SO ₂)		
Total organic carbon TOC		

Note: the requirement to continuously monitor for HF is omitted.

Condition 5.6 The measurements set out in Table T7 shall be made for the process operation parameters in that table.

Table T7: measurements of type of monitoring continuous process operation parameters

Process operation parameter	Type of monitoring
Temperature	Continuous
Oxygen concentration	
Pressure	
Moisture content of waste gas	

Condition 5.7 One measurement shall be made each three months of heavy metals, HF and dioxins and furans in waste gases during the first 12 months of operation of the plant. Thereafter, at the discretion of the Regulator, at least two measurements of these pollutants shall be made each year. Measurements shall be made using the methods specified in Table T8 and shall be made with the co-incineration plant operating under stable conditions.

Table T8: standards and methods for measurement of air polluting substances

Process operation parameter	Method/ standard
Cadmium & thallium and compounds (total)	BS EN 14385
Mercury and compounds	BS EN 13211
Sn, As, Pb, Cr, Co, Cu, Mn, Ni, V and compounds (total)	BS EN 14385
Dioxins, furans	BS EN 1948 Pts 1, 2, 3
Hydrogen Fluoride	BS ISO 15713

Condition 5.8 The following parameters shall be verified while the plant is operating under the most unfavourable conditions anticipated, within one month of the plant coming into service.

- (1) Residence time (secondary combustion chamber).
- (2) Minimum temperature of waste gases at the outlet from the secondary combustion chamber.
- (3) Oxygen content of waste gases at the outlet from the secondary combustion chamber.

Condition 5.9 In the case of periodic measurements, measured values shall not be adjusted to take account of the confidence intervals, but the uncertainty associated with the measurement shall be stated in the monitoring report to aid with determining compliance with the emission limit values.

Condition 5.10 The operator shall report their emissions monitoring data to the regulator within one month at the end of each quarter. All results shall be reported. The number of cumulative hours, where the half hour ELVs were exceeded for the quarter and for the year to date shall also be reported. Where monitoring is not in accordance with the main procedural requirements of the relevant standard, deviations shall be reported as well as an estimation of the error involved.

Condition 5.11 All monitoring results shall be recorded, processed and presented in such a way as to enable the regulator to verify compliance with the operating conditions and emission limit values which are included in this permit.

Condition 5.12 The regulator shall be notified, sufficiently in advance, of the monitoring exercise taking place to allow the regulator to witness the testing.

Section 6 Residues

Condition 6.1 The processes and procedures set out in Section 3.8 of the application shall be used to ensure that residues (bottom ash and air pollution control residues) are minimised in their amount and harmfulness and that, where appropriate, residues are recycled at an authorised third-party off-site facility.

Condition 6.2 Transport and intermediate storage of dry residues shall be carried out in such a way as to prevent dispersal of those residues in the environment. Dusty residues shall be stored in such a way as to prevent emissions of dust and particulate matter beyond the site boundary.

Condition 6.3 Appropriate tests shall be carried out to establish the physical and chemical characteristics and polluting potential of residues prior to determining the routes for disposal or recycling of those residues. The tests shall concern the total soluble fraction and heavy metals soluble fraction within the residues.

Condition 6.4 The small waste co-incineration plant shall be operated in such a way as to achieve a level of incineration such that the total organic carbon (TOC) content of bottom ashes from the primary combustion chamber is less than 3% or their loss on ignition (LOI) is less than 5% of the dry weight of the material.

Condition 6.5 Compliance with the limits of TOC or LOI in bottom ash stated in condition 6.4 shall be demonstrated by sampling and subsequent analysis of bottom ash samples in accordance with standard method BS EN 14899 every three months for the first twelve months from the date of this Permit and thereafter at a frequency determined by the regulator. More information on sampling can be found in Environment Agency publication TGN M4 "Guidelines for ash sampling and analysis".

Condition 6.6 Incinerator bottom ash shall be assessed in accordance with the Environment Agency's Technical Guidance WM3: "Waste Classification - Guidance on the classification and assessment of waste" (or the current equivalent guidance) and disposed of accordingly.

Section 7 Action in case of breakdown, accidents, incidents and breaches of permit conditions

Condition 7.1 In the event of any incident or accident significantly affecting the environment the operator shall

- (1) immediately inform the Regulator;
- (2) immediately take the steps set out in the documents 'Accident Management Plan', 'Fire Prevention Plan' and 'Environmental Management System for the Small Waste Co-incineration Plant' to limit the environmental consequences and to prevent further accidents or incidents;
- (3) take such complementary measures as required by the Regulator to limit the environmental consequences and to prevent further accidents and incidents.

Condition 7.2 In the event of any breach of permit conditions the operator shall

- (1) immediately inform the Regulator;
- (2) immediately take the measures required to ensure that compliance is restored in the shortest possible time;
- (3) take such complementary measures as required by the Regulator to restore compliance. The complementary measures shall include but are not limited to:
 - a) Agree with the regulator to investigate the issue.
 - b) Undertake the agreed investigation.
 - c) Adjust the process or activity to minimise those emissions.
 - d) If applicable re-test to demonstrate compliance as soon as possible.
 - e) Promptly record the events and actions taken.
 - f) Submit to the regulator the report and updates as agreed.

Condition 7.3 In the event of a breakdown the operator shall reduce or close down the operation of the plant as soon as practicable until normal operations can be restored.

Section 8 Records

Condition 8.1 The operator shall keep records as set out in Table T9, which shall be made available for inspection on request by the Regulator.

Table T9: Records		
Matter to be recorded	Type of record	Time to be retained for
Waste types and quantities accepted	Consignment notes including waste codes	Statutory period of 2 years
Monitoring of waste gases	Electronic records including all the parameters required by permit conditions	6 years
Abnormal conditions	All relevant records including paper reports, emails and other electronic records	1 year
Training	Training given to relevant staff, with dates and reviews	Period person is employed in the small waste co-incineration plant + 1 year
Maintenance	All relevant records including paper and electronic records	6 years
Energy performance	Quarterly electronic records of waste input, electrical output and heat output.	2 years

Section 9 Management

Condition 9.1 The operator shall manage and operate the small waste co-incineration plant in accordance with a written management system that identifies and minimises risks of pollution. The EMS shall include written systems covering, but not restricted to, the following areas:

- (1) Cleaning and maintenance, see condition 9.2
- (2) Training and plant operation, in accordance with condition 3.7
- (3) Waste acceptance criteria, in accordance with sections 1a and 1b
- (4) Bottom ash storage and disposal, in accordance with condition 6.2
- (5) Emission monitoring, in accordance with section 5
- (6) Plant failures and non-conformances, including the management of waste during plant down time, in accordance with sections 3b and 7
- (7) Accident prevention and management including fire prevention, in accordance with condition 7.1
- (8) Record keeping, in accordance with section 8

Condition 9.2 A schedule of preventative maintenance and cleaning for all items of plant and equipment and buildings which have a role in controlling emissions shall be implemented for the small waste co-incineration plant. Where applicable, manufacturers' recommendations shall be followed. Records of all such maintenance undertaken in accordance with the schedule shall be made and retained on site and made available to the regulator upon request.

Condition 9.3 In addition to the items listed in Table T9, condition 8.1, the following records shall be retained on site for a minimum of six years and made available to the regulator upon request:

- (1) All inspections both by external bodies and internal employees.
- (2) Maintenance including cleaning, maintenance undertaken by external contractors or internal personnel, particularly in relation to the maintenance schedule required by condition 9.2, and breakdowns.
- (3) Copies of manufacturers' operating manuals and internal operating procedures

Condition 9.4 Any person having duties that are or may be affected by the matters set out in this permit shall have convenient access to a copy of it kept at or near the place where those duties are carried out.

End of permit conditions

Signed _____

Date

An authorised officer of Calderdale Metropolitan Borough Council

Appendix A Permit determination timetables

Table A1 permit application determination		
Event	Date	Notes
Application received	06/08/2020	
Duly made	06/08/2020	
Schedule 5 notice served	18/09/2020	Response received 16/10/2020
Consultation start		
Consultation end	25/9/2020	
Responses considered	25/09/2020 to 8/1/2021	
Draft permit published	01/02/2021	
Permit refused/ granted	08/02/ 2021	
High Court Quashing Order	17/09/2021	
Notice of non-determination	23/05/2022	
Appeal against non-determination	26/05/2022	

Appendix B Provenance of Permit Conditions

The conditions in Sections 1 to 8 have been written to implement the requirements of Schedule 13 of the Regulations, taking into account information provided by the applicant. The requirements of Schedule 13 are framed in terms of articles of the recast Industrial Emissions Directive 2010/75/EU.

Table B1 permit conditions implementing Schedule 13 requirements		
Schedule 13 requirement	Subject	Conditions, notes
Article 5(1), 5(3)	granting a permit	Procedural
Article 7	regulator to require operator to take action in event of accidents or incidents	Section 7 Condition 7.1
Article 8(2)	regulator to require operator to take action in the event of a breach of permit conditions	Section 7 Condition 7.2
Article 9	greenhouse gases	Procedural
Article 42(1)	scope of chapter on waste incineration/ co-incineration (i.e., applicability to types of waste etc.)	Procedural
Article 43	definition of 'residue'	Procedural
Article 45(1), 45(2), 45(4)	(1)(a) permit conditions to include list of permitted waste types, total capacity of plant, limit values for emissions, sampling and measurement frequencies; (1)(f) limits on periods of higher emissions; (2) list of quantities of hazardous waste; (4) requirement to review permit conditions.	Section 1 Section 4 Section 3b Procedural
Article 46	control of emissions, and emission limits to air and water; prevention of accidental releases to air, land and water, including storage of contaminated rainwater in the event of spillage, fire; plant not to be run for more than 4 hours where emission limits not met.	Section 2 Condition 2.1 Section 3 (Condition 3.10) Section 4
Article 47	action in case of breakdown	Section 7 Condition 7.3
Article 48(1) 48(2) 48(3) 48(4)	monitoring and recording requirements	Section 2 Section 5 — point 2.3 of Part 6 of Annex VI has been applied.
Article 49	determining compliance with emission limit values	Procedural

Article 50	specifying operating conditions including temperature and residence times, automatic feed systems, interlocks	Section 3 — no Article 51 changes authorised.
Article 51(1) (2) (3)	authorising changes to operating conditions	
Article 52	requirements for delivery and reception of waste	Section 1
Article 53	minimisation, storage and transport of residues	Section 6
Article 54	substantial change definition	Adopted from IED
Article 55	information to be made available to the public	Procedural
Article 82(5), 82(6)	transitional arrangements	Procedural

Biomass is defined in 2010/75/EU.

Drawings and plans

Plan S13/005/P1 adapted from Permit Boundary Plan 1902-0002-01 and Drawing 1 JER1902-PER-001_D_200702_Emission Point Plan.

Plan S13/005/P1 showing the boundary of the small waste co-incineration plant (Green)



Documents referenced in this permit

Document name	Notes
Appendix A Application Form Appendix_A_Calder Valley Skip Hire Ltd S13 application form V1.pdf Calder Valley Skip Hire Ltd S13 application form V1 (signature removed)	
Appendix C Noise Assessment\Appendices Noise assessment.PDF NOISE REPORT-1211394.PDF Plus appendices to noise report	
Appendix D Technical Documents 18-1000.pdf Inciner8 System Overview CEMS.pdf pollution-control-systems. pdf Zuccato Sk ZE-200-LT 190320 EN.pdf	
Appendix E Air Quality Assessment AQ assessment.pdf	
Appendix F Residence Time Calculation Inciner818-1000 Residence Times 18.03.2020.pdf	
Appendix G Process flow diagram JER 1902 Calder Valley SWIP Process Flow Diagram.pdf	
Drawing 1 JER1902-PER-001_D_200702_EmissionPointPlan Drawing	
Drawing 2_9677_17_03C ii Layout Drawing	
Drawing 3_9677.17.35A Existing Drainage Drawing	
Additional Documents Submitted for the Permit Redetermination	
Drawing Revised Application Site Plan - Permit Boundary Plan 1902-0002-01	
Air Quality Response to AQC Review of Air Quality dated 15 March 2022	
Human Health Risk Assessment C98-P09-R01 Calder Valley HHRA February 2022	
Environmental Management System 220315 R JER1902 TH EMS Addendum for SWIP V2R1	
CFD Modelling CVSH SWIP CFD Flow Simulation Report 17.03.22	

Note: Appendix B of the application is a decision notice relating to planning appeals for the site.

Explanatory notes

These notes are not permit conditions. They are included so that the operator is aware of matters relevant to, but not part of, the permit. They reflect the statutes and statutory guidance in place at the date of issue of the permit and subsequent s.

1. This Permit is given in relation to the requirements of the Environmental Permitting (England and Wales) Regulations 2016 (as amended). It must not be taken to replace any responsibilities under workplace Health and Safety Regulations.
2. This Permit does not detract from any other statutory requirement, such as the need to obtain planning permission, building regulation approval, hazardous substances consent, discharge consents, waste disposal licence or any licence or consent from the Environment Agency.
3. The annual subsistence fee is due on 1 April each year. Failure to pay the fee will lead to revocation of the Permit.
4. The operator may apply for a variation to the conditions of this permit. A fee will be payable in certain cases.
5. The operator may surrender this permit in whole or in part if the small waste co-incineration plant ceases to operate. A fee will be payable, subject to applicable regulations.
6. The operator may, on joint application with another proposed operator, apply to transfer this permit to the proposed operator. A fee will be payable in this case.
7. Application forms and more information about environmental permitting can be found on Calderdale Metropolitan Borough Council's website www.calderdale.gov.uk
8. All enquiries and notifications made in relation to this Permit should be made to:

Calderdale Metropolitan Borough Council
Environmental Health
c/o Town Hall
Crossley Street
Halifax
HX1 1UJ

Tel: 01422 288001

[Email: environmental.health@calderdale.gov.uk](mailto:environmental.health@calderdale.gov.uk)

Incidents occurring outside office hours can be reported by telephoning 01422 288000 and asking for the Out of Hours Officer. In this case notification should also be sent by email to the address above.

