SAVE PEEL HALL
TOO LATE WHEN IT'S GONE

Proof of Evidence

Vol 4 - Air Quality

Produced by Jim Sullivan

Rule 6 Party

Peel Hall - APP/ M0655/W/17/3178530

Contents

My name is Jim Sullivan. I have lived in the area since 1987. I would like to speak about air quality

1. Introduction

1.1 This evidence is concerned with air quality as it impacts on both the proposed build area and the surrounding area. We shall consider the air quality impacts of the proposed development on a child living within the urban area adjoining the site.

The site at Peel Hall is at the intersection of two Air Quality Management Areas (AQMAs). These are areas which breach WHO international guidelines for concentrations of harmful particulates and/or gases. The appellant's evidence asserts that, at the traffic flows modelled, the level of harmful gases and particulates within the occupied section of the site will not breach WHO thresholds and will have 'negligible' impact on existing air quality levels.

1.2 There are significant weaknesses in the air quality modelling undertaken by the appellant:

a) The road traffic model which underpins the air quality model is based on inadequate monitoring (please see Traffic PoE for detail) and relies on assumptions about future trends in traffic – particularly HDVs – which are unsound. This, in turn, undermines the air quality modelling, which completely relies on the road traffic model
b) The settings for the air quality model have not been provided in sufficient detail to either verify or challenge the model
c) The plan is in direct opposition to Warrington's Air Quality Action Plan, as detailed below
d) The model used by Satnam explicitly excludes impact on air quality from site traffic, even though this is accepted to be at high volumes over a 10 year period. HGV movements related to site traffic are missing in their entirety from Satnam's predicted future traffic levels

2. Key reasons for objection on air quality grounds

a) This is an unusually sensitive site. Several existing homes already fall within one of the Air Quality Management Areas, with many families currently living in or very close to the 'red zone' – ie locations which currently breach the WHO threshold for dangerous levels of air pollution. These families are at current and persistent risk of ill health and premature death. The development at Peel Hall will exacerbate these conditions, leading to an increased probability of air-quality induced illness and premature death
b) The modelling carried out by Miller Goodall is based on inadequate road traffic modelling (see 'Road Traffic Modelling' below). Without accurate and rigorous traffic modelling it is not possible to accurately estimate the impact of the additional c. 3,000 vehicles on air quality both within the site and in the Air Quality Management Areas. The appellant's claim that impact on air quality would be 'negligible' is therefore unproven, given the weaknesses in the traffic modelling
c) Impact to health caused by construction activity is shown by the appellant's consultants to have a Medium to High risk to human health. Within an existing Air Quality Management Area, where the local population's respiratory health is already compromised, this is an even more significant finding. The directly affected population is approximately 35,000 people

whose homes directly border the site ie Orford, Poplars & Hulme and Poulton North Wards. The development is currently estimated to last for 10 years

d) We note that the construction traffic impact on NOx and particulate pollution has not been included in the modelling, on an assumption that this will have negligible impact. This is not a safe assumption, particularly in such a sensitive site

e) There is no safe level of air pollution. Both particulates and NOx pollution cause harm and premature death at levels well below the current WHO threshold levels which have been cited in the appellant's documentation. Some of the relevant independent, peer reviewed medical and scientific evidence is summarised in the following paper: https://onlinelibrary.wiley.com/doi/full/10.1111/1753-6405.12264 This evidence unequivocally shows that **any** level of increased air pollution brings increased harm to health and increased risk of death

3. Previous Inspector's Report

3.1 We would highlight a number of comments made in Mr Schofield's 2018 report, as these remain relevant. We would note that whilst the Judicial Review quashed the decision letter, this does not invalidate the previous Inspectors' Report which was compiled after examining the evidence.

Paragraph numbers below relate to the 2018 inspectors' report.

> 13.2 At the start of the Inquiry, one of my main considerations was: "whether the appeal scheme would provide appropriate living conditions for future occupiers, with regard to highway noise and air quality".
>
> 13.3 Such matters, should, in my view, be addressed before the reserved matters stage, so that there is a clear basis on which to take forward detailed design. This would certainly seem prudent given the site's proximity to the M62.
>
> 13.4 Nonetheless, on the basis of all that I heard, and having regard to what became a joint position between the main parties on this matter, it appears that these considerations could be addressed satisfactorily by condition (notwithstanding my overall conclusions on the wider issue of air quality). Even so, I do not regard this position as ideal, and feel obligated to reiterate the strong proviso that I made at the Inquiry. That is to say, any mitigation in relation to noise and air quality should be addressed through building situation and orientation rather than through such means as non-opening windows and mechanical ventilation. Others may form a different view, but I do not consider that such mechanisms can be regarded as conducive to the provision of optimum living conditions for future residents.

3.2 IR13.55 to 13.67 – makes clear that 'There is no real dispute that the appellant's initial air quality work had some failings' and details these failings including specifically: 13.66 The evidence provided lacks clarity in a number of areas, with some conclusions being presented absent the necessary supporting detail. In addition, given my doubts about some of the transport modelling work from which parts of the air quality work appears to derive, precaution is warranted. 13.67 Thus, I conclude that, overall, the appeal proposal has failed to demonstrate that it would not give rise to an adverse impact upon local air quality. It would conflict with Core Strategy policy QE6, and relevant paragraphs of the Framework, the requirements of which are set out above.

3.3 There can be no doubt that the evidence submitted to the previous PI was deficient and that despite ample opportunity at that time the applicant was unable to correct these failings. The Judicial Review that led to the re-opening of this PI was not related to air quality and **it is against natural justice that the applicant has been given a second bite of the cherry when additional evidence should have been gathered to support a completely new planning application**.

3.4 It is clear that with respect to both noise and air quality, Mr Schofield's comments have not been taken into consideration in this – only slightly revised - application. The appellant continues to rely on people choosing to live in a state of permanent lockdown in order to mitigate noise and air quality impacts, rather than designing a reasonable site which more effectively addresses these concerns through design. Rather than a resubmitted appeal, what is required is a fresh planning application with fresh design parameters which address the very serious issues identified.

4. Health impact of air pollution

4.1 Defra (https://uk-air.defra.gov.uk/air-pollution/effects) highlights the impact of poor air quality:

Pollutant	Health effects at very high levels
Nitrogen Dioxide, Sulphur Dioxide, Ozone	These gases irritate the airways of the lungs, increasing the symptoms of those suffering from lung diseases
Particles	Fine particles can be carried deep into the lungs where they can cause inflammation and a worsening of heart and lung diseases
Carbon Monoxide	This gas prevents the uptake of oxygen by the blood. This can lead to a significant reduction in the supply of oxygen to the heart, particularly in people suffering from heart disease

4.2 The World Health Organisation https://www.who.int/airpollution/ambient/health-impacts/en/ notes that:

> "Ambient (outdoor air pollution) is a major cause of death and disease globally. The health effects range from increased hospital admissions and emergency room visits, to increased risk of premature death.
>
> An estimated 4.2 million premature deaths globally are linked to ambient air pollution, mainly from heart disease, stroke, chronic obstructive pulmonary disease, lung cancer, and acute respiratory infections in children.
>
> Worldwide ambient air pollution accounts for:
>
> - 29% of all deaths and disease from lung cancer
> - 17% of all deaths and disease from acute lower respiratory infection
> - 24% of all deaths from stroke
> - 25% of all deaths and disease from ischaemic heart disease
> - 43% of all deaths and disease from chronic obstructive pulmonary disease
>
> Pollutants with the strongest evidence for public health concern, include particulate matter (PM), ozone (O3), nitrogen dioxide (NO2) and sulphur dioxide (SO2).
>
> The health risks associated with particulate matter of less than 10 and 2.5 microns in diameter (PM10 and PM2.5) are especially well documented. PM is capable of penetrating deep into lung passageways and entering the bloodstream causing cardiovascular, cerebrovascular and respiratory impacts. In 2013, it was classified as a cause of lung cancer by WHO's International Agency for Research on Cancer (IARC). It is also the most widely used indicator to assess the health effects from exposure to ambient air pollution.
>
> In children and adults, both short- and long-term exposure to ambient air pollution can lead to reduced lung function, respiratory infections and aggravated asthma. Maternal exposure to ambient air pollution is associated with adverse birth outcomes, such as low birth weight, pre-term birth and small gestational age births. Emerging evidence also suggests ambient air

pollution may affect diabetes and neurological development in children. Considering the precise death and disability toll from many of the conditions mentioned are not currently quantified in current estimates, with growing evidence, the burden of disease from ambient air pollution is expected to greatly increase”

4.3 Air pollution affects the health and quality of life of people living in Warrington daily. It aggravates breathing conditions and increases the risk of asthma attacks leading to more hospital admissions. Prolonged exposure can cause serious medical conditions, such as cancer, heart attacks and strokes. While we are all affected, those who are the most vulnerable in our society are more at risk, especially children and older people. Exposure to air pollution can cause children to develop breathing conditions and stunted lungs. There is also a growing body of research linking air pollution to other illnesses, including diabetes, developmental problems for children and suggested links to dementia.

4.4 Legal firm Client Earth have repeatedly proven in the courts that the UK government is failing in its legal duty to protect us from toxic air pollution and that local authorities are doing too little too late. The legal action has forced Government to produce two new air quality plans. But apart from the failings of central Government, local government is not acting fast enough. Developments like Peel Hall are why we’re still breathing illegally dirty air in Warrington. Approval of this polluting new development rather than one based on active travel will condemn existing and future residents to more disease, death and a poorer quality of life than if it is refused.

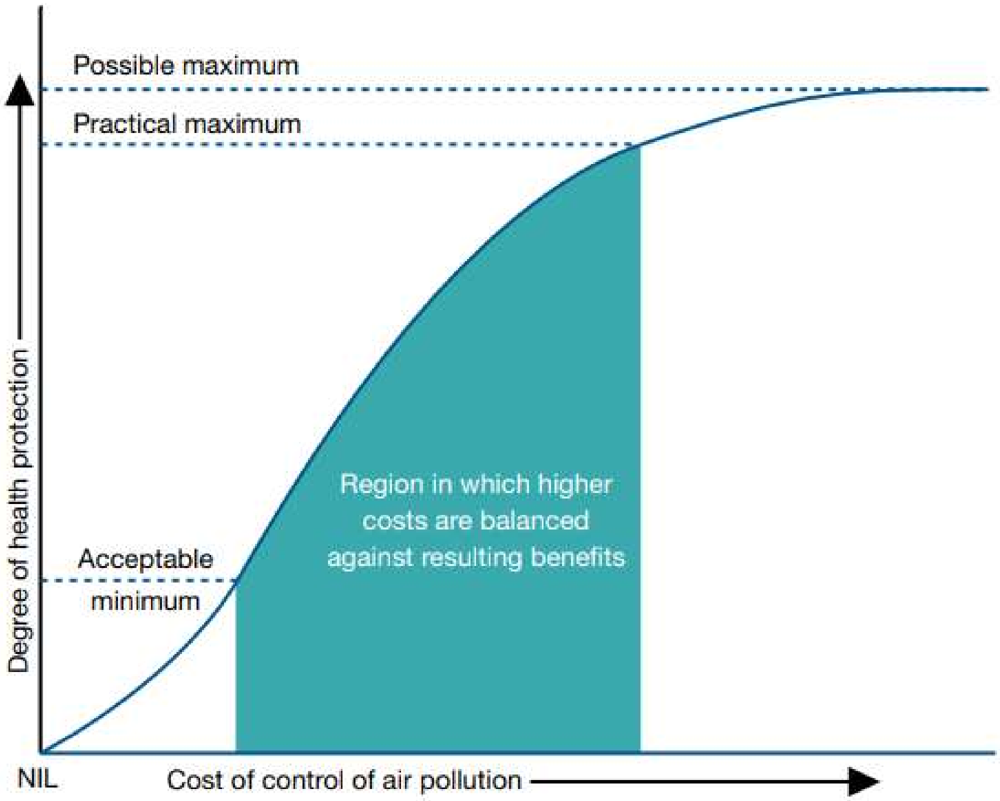
4.5 Given this context, the very high population density in the surrounding urban area and the car-dependent nature of the site, it should be clear that this development would cause and exacerbate a range of serious health problems in a large population.

It is particularly reckless to locate a care home in such an area.

5. There is no safe level of air pollution

5.1 As shown in numerous studies, the international thresholds which have been referenced in the appeal documents do not indicate **safe** levels of air pollution. Whilst these levels are informed by research they are also arbitrary in the sense that they seek to find a point on a continuous scale of harmfulness which is politically acceptable, as the following graphic from *Evolution of WHO Air Quality Guidelines* (Appendix 1) illustrates:

Fig. 2. Schematic representation of degree of health protection as a function of cost of air pollution control



Source: WHO (1972). Reproduced with permission.

5.2 The WHO guidelines therefore define an arbitrary level of harmful concentrations against arbitrarily defined time durations. These thresholds would be expected to continue to change over time, in much the way that they have since the first WHO guidelines were published in 1958.

5.3 For example, in 1958 the WHO recommended threshold for oxides of nitrogen was 500µg/m^3 at any one time and 150 µg/m^3 per 24 hour average. Current WHO guidelines for NO_2 are 40 µg/m^3 annual mean and 200 µg/m^3 per 1-hour mean – a much stricter standard, even allowing for the slightly different definitions ('oxides of nitrogen' includes NO_2 but also other oxides. The appellant's calculations, using the Defra calculator, give NOx values slightly less than 1.5 times NO_2

values across the site). Thus a standard of 500µg/m^3 in 1958 becomes a standard of <60 µg/m^3 in 2020.

5.4 We would expect standards to continue to become much stricter in future, and would note that this development will be in place for at least a century. The appellant makes reference to electric charging points but makes no explicit, quantifiable defined commitment to fund these. It should be anticipated that levels of traffic-related pollution will improve over time. So, too, will our expectations of air quality – as they have over the past 60 years, as shown by the WHO guidelines.

5.5 Clearly, homes are needed and therefore building must take place somewhere. What makes this site so ill-suited to development?

a) The sensitivity of the site (discussed in sections 6 and 7 below). This is the key point; the health of a significant population is already impacted by poor air quality, and this development would worsen that situation

This is supported by two related issues:

b) The car-dependent nature of the site, which is in opposition to principles of sustainable development
c) The access difficulties which mean that any increase in traffic within this road network will exacerbate existing congestion, in turn worsening air pollution from existing traffic in addition to the new journeys caused by the development

6. Air Quality Action Plan

6.1 This is a highly sensitive site, which is subject to an Air Quality Action Plan (AQAP). The proposed development breaches four of the five priorities in this AQAP.

6.2 Quoting from the appellant's submission:

"The AQAP describes the key priorities for Warrington Borough Council as;

Priority 1 – Reduce traffic volume and improve flows

Priority 2 - Reduce emissions from HGVs and LGVs

Priority 3 – Reduce emissions from bus and public transport including taxis

Priority 4 – Reduce exposure for those who are most vulnerable

Priority 5 – Ensure that future development is designed to reduce exposure and improve air quality"

6.3 **Priority 1** – Reduce traffic volume and improve flows

This site is landlocked and has very challenging access arrangements. 1,200 dwellings, a care home and a 2,000 m^2 retail outlet would generate significant additional levels of additional car usage, much of which can only access the site by passing through one of the AQMAs ie traffic volume in the AQMA would be **increased** rather than reduced.

Traffic *flows* would also be worsened because of the access arrangements. Traffic from the site would be required to exit via inappropriate, congested and very narrow routes. This traffic would also worsen the existing congestion in the area.

The site is poorly located for public transport:

a) Bus utilisation in the surrounding area is low and declining
b) Any extension of bus services into Peel Hall would tangibly extend current journey times, making the bus a less appealing service; it seems likely that any take-up by residents at Peel Hall would be offset by existing users abandoning the bus
c) The Memorandum of Understanding between the appellant and Warrington's Own Buses is for 5 years only, with a break option after 3 years. This does not provide certainty of public transport even for the build phase, let alone steady state thereafter
d) The current 20/21 services are notoriously long, serving Cinnamon Brow and Orford before reaching the town centre. Residents from Gorse Covert currently face a journey of up to 58 minutes to reach the town centre – a distance of only 6.3 miles. By car this would take 15 minutes. Residents in Cinnamon Brow along Enfield Park face a journey time of up to 30 minutes – 4.3 miles. By car this journey would take 10/13 minutes. To extend this service by say, 15 minutes to serve Peel Hall, some passengers face a one-way journey into town of more than an hour – even longer when waiting time is added on. A return journey into town could take up to two and a half hours.
e) Central Station is 2.99 km away from the nearest point in the site as the crow flies, and 3.83 km away from the furthest point as the crow flies. Padgate station is 1.87 km as the crow

flies from the nearest point on the site; 3.1 km away as the crow flies at the furthest point. Actual journey distances would be markedly higher than these distances.

f) The appellant suggests that residents would cycle to these railway stations. This seems unlikely to take place at sufficient volume to impact positively on air quality. Current levels of cycling are low, possibly because of the extremely busy roads which serve the area. The appellant's own traffic survey recorded 0.266 % of vehicles as bicycles (please see table below, taken from the appellant's traffic survey). This is so low as to be considered negligible and reflects the poor support for cycling in the existing road network. It is of little relevance if the site itself has good cycle paths if the roads which then connect the site to railway stations are, themselves, unsafe or otherwise unappealing for cyclists.

g) We note the appellant's suggestion to address some of the parked car issues in Poplars Avenue. We would note that low cycle takeup was recorded by the appellant on **every** road they surveyed, which would suggest that mitigations in Poplars Avenue alone would not address the root causes of low cycling takeup.

h) "Between 2010/2011 to 2015/16 there has been a decline in bus patronage from 11.5 million to 6.6 million journeys per year. This is nearly a 43% drop in patronage and vastly exceeds the 10% decrease in patronage observed across the North West region over the same time period". Source: Warrington LTP4 Evidence Base Review.

i) Traffic flows would be severely hampered by the access arrangements. Traffic will need to enter and leave the site via inadequate and already congested road networks. This will inevitably increase emissions. The appellant has not been able to find an answer to this problem since their first planning application; we may assume that this is because the problem is, indeed, intractable – the nature of the site simply makes it unsuitable for additional traffic.

6.4 **Journeys by cycle** as a proportion of total journeys recorded during the appellant's traffic survey are shown below:

	TOTAL CYCLE	**TOTAL JOURNEYS**
J1	21	3,763
J2	3	75
J3	6	2,293
J4	60	4,589
J5	16	2,055
J6	0	158
J7	11	9,878
J8	12	7,967
J9 Saturday	19	22,598
J9	9	11,129
J10	12	2,740
J11	37	2,693
J12	16	4,398
J13	26	3,256
J14	4	10,414
J15	20	15,623
J16	27	12,730
J17	18	2,669
TOTALS	**317**	**119,028**

Only 0.266% of journeys were undertaken by bicycle.

6.5 **Priority 2** – Reduce emissions from HGVs and LGVs

The construction phase is acknowledged by the appellant to involve high levels of HGV traffic throughout the 10 year+ construction phase. Quite apart from the major disruption to local traffic flows – with resultant increases in emissions from existing vehicles – which this would cause, the HGVs themselves would introduce additions to air pollution and congestion for at least 10 years. Note that the appellant has chosen not to model the impact of this traffic at all (12.8.1).

HGVs and LGVs will also be required to support a 2,000 m2 retail facility. This is clearly a challenging location for such a unit, given that access can only be achieved through the populated urban network. We note that the air quality model assumes a reduction in HDVs between start and completion of the build, despite the planned developments at Parkside and the next phase of the Omega site development.

This is simply illogical and is discussed further below.

6.6 **Priority 3** – Reduce emissions from bus and public transport including taxis

Public transport provision is solely based on conventional diesel buses which produce high amounts of oxides of nitrogen and particulate, the two key pollutants in poor air quality. While the number of buses would be low, the absence of bus priority and indicative timetables suggests that vehicle speeds would be low with a consequent increase in pollution. There are no plans to fund electric or alternative fuel buses. In addition, where public transport is unattractive, taxi use tends to be higher for households without access to cars. These will also be almost entirely diesel powered and add to pollution for new and existing residents.

6.7 **Priority 4** – Reduce exposure to those who are most vulnerable

This development is at the intersection of Warrington's two AQMAs. Very large numbers of people live within these areas of poor air quality, the majority in Orford and Poplars & Hulme Wards. Some statistics regarding these Wards are therefore relevant:

- 20.8% of children in Orford Ward and 24.3% of children in Poplars & Hulme Ward qualify for free school meals, against a Warrington average of 11.1%
- Male life expectancy (77.8 years Orford, 75.1 years Poplars & Hulme) is significantly lower than the Warrington average (78.8 years)
- Female life expectancy (81.2 years Orford, 79.8 years Poplars & Hulme) is slightly lower than the Warrington average (81.8 years)

6.8 Consider an 8 year-old child growing up in Orford or Poplars & Hulme. Children here already experience poorer health outcomes than children in most parts of Warrington and, indeed, England. Poor air quality is one of the factors disadvantaging children in this area. The development would have the following impacts for such a child:

- Increased air pollution in a ward already badly affected by vehicular pollution
- Increased road congestion over at least the next 10 years due to construction traffic, and further congestion caused by additional vehicles relating to residents and business located at the site. This congestion will, in turn, lead to raised pollution levels
- Road safety issues related to the site construction traffic. These would continue *at least* until she reaches adulthood
- Other impairments not covered in this evidence (such as school overcrowding due to phasing of additional provision, GP availability etc)

6.9 This proposed development would impair the life chances of children growing up in Orford or Poplars & Hulme in many ways, not least because their already poor health and life expectancy would be further worsened.

6.10 The proposal also includes the location of a care home within the site, exposed to existing poor air quality which can only worsen following the development of this site. This is directly counter to Priority 4 of Warrington's AQAP.

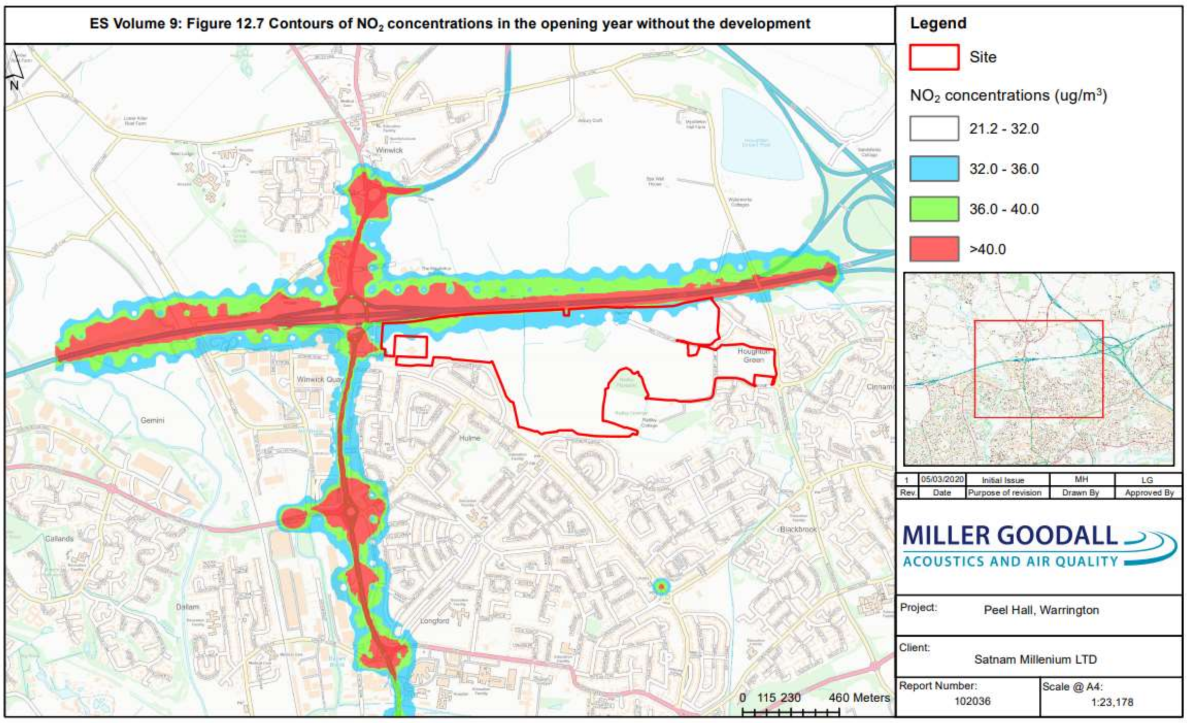
6.11 **Priority 5** - Ensure that future development is designed to reduce exposure and improve air quality

There is literally no commitment to air quality improvement at any point in this proposed development. There is an unquantified reference to electric charging points, though these would only mitigate the impact of around 3,000 extra vehicles rather than reducing net exposure to air pollution. The site's location means that residents will be significantly dependent on cars. Public transport usage and cycling will be negligible, as they are in the surrounding urban area.

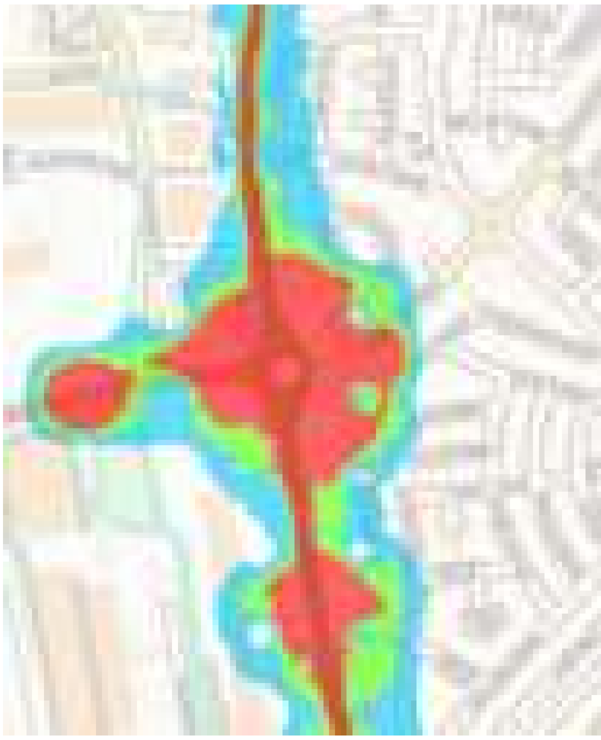
6.12 **It is clear that the proposed development is in direct opposition to Warrington's Air Quality Action Plan.**

7. Many hundreds of people are significantly affected by poor air quality bordering this site

7.1 The following map shows the current Air Quality Management Areas:

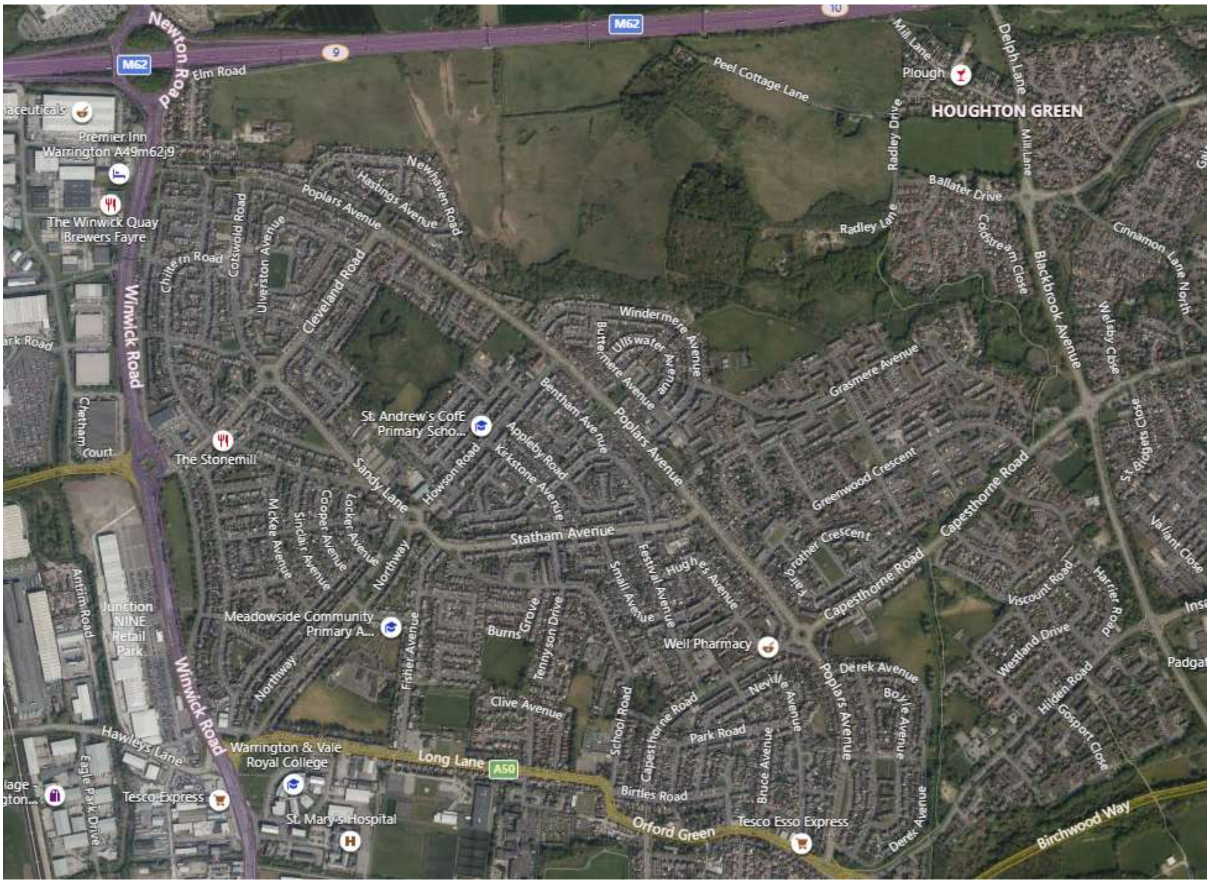


7.2 If we zoom in on just one part of the red zone and look at the population density, we can see that very large numbers of people already live and travel within an area which falls outside nationally-mandated air quality levels:



7.3 Orford and Poplars & Hulme Wards are the wards most directly impacted by current air quality issues. These two wards have a combined population of 24,603.

A fuller picture of the area bounded by the two AQMAs and the density of population bounded by them can be seen in the following image:



7.4 The appellant's claim that air quality will be unaffected by filling in the green part of this map with further high density housing is, clearly, incorrect. It may be the case that air quality levels within the Peel Hall site itself fall largely within WHO guidelines. Nevertheless, even if that were the case it would not change the fact that air quality in this landlocked area, bounded as it is by the M62 and A49 – two AQMAs – would worsen. This would have significant health implications for a population of 40,000 people when the site is fully occupied.

7.5 The poor air quality in populated areas is shown in the appellant's published data:

Table 12.15 - Local Authority Annual Mean NO_2 Results – Diffusion Tubes

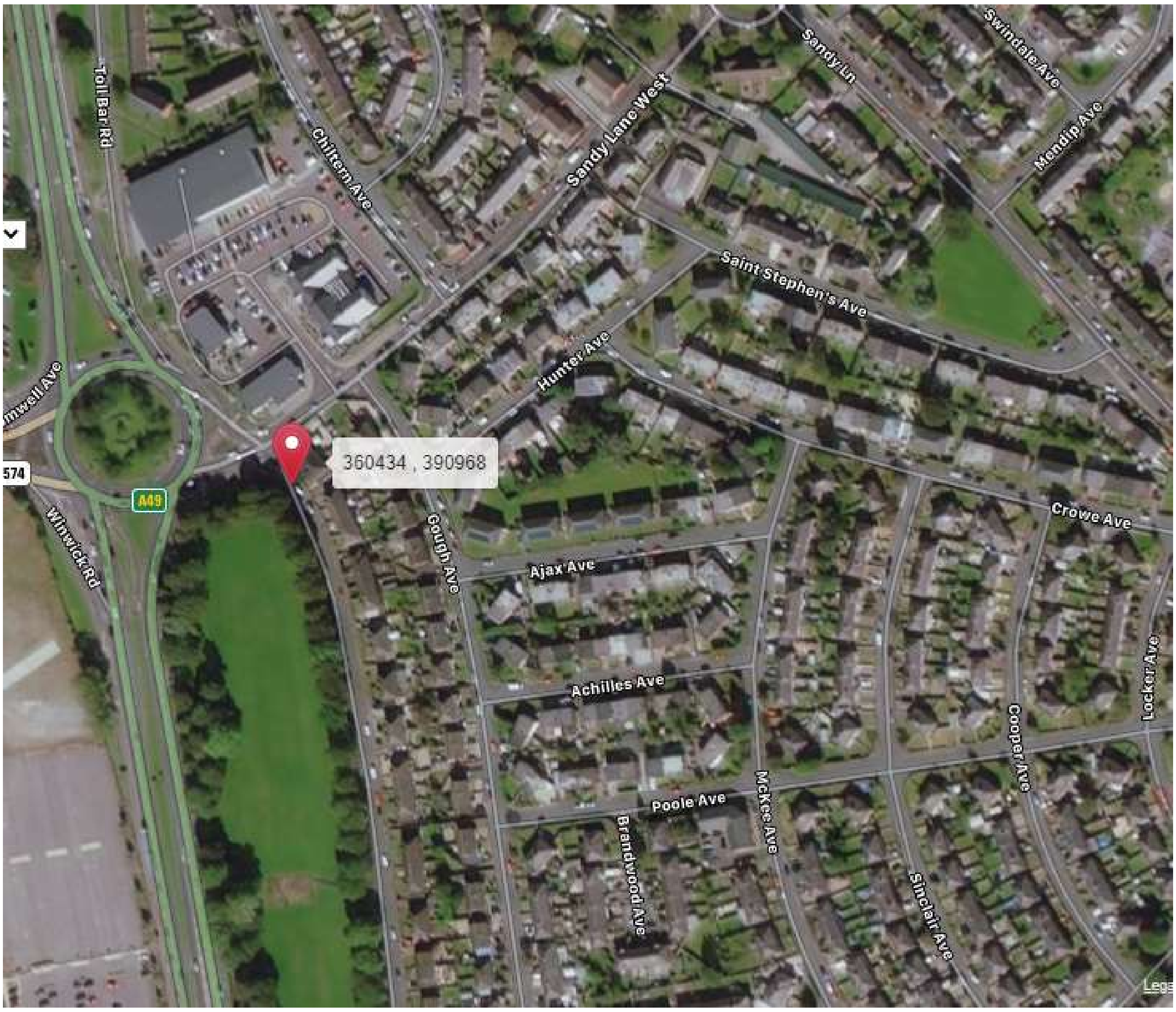
Site ID	Type of site	OS Grid reference	Level of nitrogen dioxide (µg/m^3) 2015	2016	2017	2018	Verification values 2018-19
WA123 M62 Radley Lane	Roadside	361655, 391914	-	-	-	29.7	25.0
WA95 Winwick Road 1	Roadside	360598, 389820	**39.5**	**39.9**	34.7	32.6	32.1
WA96 Winwick Road 2	Roadside	360484, 390416	**47.2**	**50**	**44.2**	**40.3**	39.3
WA112 Winwick Road 3	Roadside	360434, 390968	**52**	**55**	**49.3**	**43.9**	**41.9**

$_2$ is 40 µg/m^3

Note: Winwick Road 2 and 3 sites have persistently breached WHO guidelines for NO2, although site 2 was just within the current guideline at its latest reading.

7.6 The Winwick Road 2 site is at the junction of Winwick Road and Long Lane, a very densely-populated area. The location of the diffusion tube is shown in the following satellite image, which also illustrates the high population density at this location:

7.7 The Winwick Road 3 site is close to the junction of Winwick Road with Sandy Lane West, also a densely populated area. The location of the diffusion tube is shown in the following satellite image. Once again, this demonstrates NO2 emissions which breach WHO guidelines in an area of high population density:



8. Impact of construction on health

8.1 We note that no assessment or modelling has been undertaken with regard to vehicular pollution during the 10+ year construction process. We note, also, that the traffic modelling assumes a completed build by 2022 and takes no account of HGV movements. Given the already congested nature of the local road network and the scale of construction, these are remarkable omissions. The number of vehicle journeys will be significant and these will be large vehicles accessing a site which is wholly unsuited to such vehicles, due to its challenging access arrangements.

8.2 The appellant notes that: “The potential effects of construction traffic and combustion sources associated with the proposed development have been scoped out of this assessment”. This statement assumes that any risk to health in adjacent properties from vehicular emissions is negligible, even though these movements have not been included in the appellant’s model. This is unacceptable.

8.3 The access arrangements for construction traffic have not been set out, which is also unacceptable, given the nature of local road infrastructure.

As noted in Addendum 2 Volume 8:

- **Construction**: The total building volume to be constructed is >100,000m^3 . The dust emission magnitude for construction is, therefore, considered to be Large.
- **Earthworks**: The total site area is >10,000m^2 . The dust emission magnitude for earthworks is, therefore, considered to be Large.
- **Trackout**: It is assumed that there are likely to be more than 50 HDV outward movements in any one day. The dust emission magnitude for trackout is, therefore, considered to be Large

8.4 Some generic mitigations have been listed, **but no assessment has been made of the probable effectiveness of such mitigations in preventing negative impact on human health** in this densely-populated site. The risks to health from the construction phase are noted in the appellant's table below:

Table A12.5.2 Outcome of Defining the Sensitivity of the Area

Potential Impact	Sensitivity of the Surrounding Area			
	Demolition	Earthworks	Construction	Trackout
Dust Soiling	High	High	High	High
Human Health	Medium	Medium	Medium	Medium

Step 2C Risk of Impacts

The dust emission magnitude and sensitivity of the area were combined and the risk of impacts determined using the criteria detailed in **Table 12.6** to **Table 12.9 of Chapter 12.0**.

- Demolition – is considered to be **High** risk for dust soiling, **High** risk for human health;
- Earthworks – is considered to be **High** risk for dust soiling, **Medium** risk for human health;
- Construction – is considered to be **High** risk for dust soiling, **Medium** risk for human health; and
- Trackout activities – is considered to be **High** risk for dust soiling, **Medium** risk for human health.

A summary of the risks, before mitigation measures are applied, for dust soiling and human health are shown in **Table A12.5.3**

Table A12.5.3 Risk of Dust Impacts

Potential Impact	Dust Risk			
	Demolition	Earthworks	Construction	Trackout
Dust Soiling	High	High	High	High
Human Health	High	Medium	Medium	Medium

8.5 This is a 10 year construction plan generating significant levels of dust in a population which already suffers from the effects of chronic exposure to high levels of airborne pollutants. The appellant has listed a number of generic mitigations but has not committed to an agreed standard of dust control. This is unacceptable. As stated, the development imposes a significant additional risk to the health of the local population.

9. Road traffic modelling

9.1 The air quality model relies on the traffic modelling. As noted in the Traffic PoE, the scope and scale of traffic assessment is considered to be inadequate, with some key junctions assessed only on one day and the remainder assessed only for a single week. Notably, these were not heavy traffic weeks, and the omission of a home game Saturday was particularly indefensible.

9.2 Here are some of the predicted AADT figures for a number of key junctions, both with and without the development. This data was used by Miller Goodall in the development of the air quality model; the complete table can be found at Table A12.4.1 in ES Volume 9:

Table A12.4.1 Traffic Data

Link Number	Name	2019 Base Year/Verification				2022 Opening Year Without Development				2022 Opening Year With Development			
		AADT	LDV	HDV	%HDV	AADT	LGV	HDV	%HDV	AADT	LDV	HDV	%HDV
1 -	A49 Northbound (JunctionNINE Retail Park - Hawleys Lane)	21,417	20,417	1,000	4.7%	22,278	21,295	983	4.4%	22,744	21,759	985	4.3%
2 -	A49 Northbound (M62 - Birch Avenue)	22,019	21,003	1,016	4.6%	22,485	21,490	995	4.4%	22,843	21,848	995	4.4%
3 -	A49 Northbound (north of M62)	23,198	22,242	956	4.1%	24,102	23,165	937	3.9%	24,433	23,496	937	3.8%
4 -	A49 Northbound (parallel to Brendon Avenue - Sandy Lane West)	22,019	21,003	1,016	4.6%	22,485	21,490	995	4.4%	22,843	21,848	995	4.4%
5 -	A49 Northbound (Sandy Lane West - JunctionNINE Retail Park)	22,009	21,005	1,004	4.6%	22,806	21,822	984	4.3%	23,271	22,285	986	4.2%
6 -	A49 South of A50 (Northbound)	16,851	16,109	743	4.4%	17,563	16,835	728	4.1%	18,328	17,600	728	4.0%
7 -	A49 South of A50 (Southbound)	20,631	19,960	671	3.3%	21,522	20,863	659	3.1%	22,540	21,880	659	2.9%
8 -	A49 Southbound (JunctionNINE Retail Park - Hawleys Lane)	24,199	23,446	753	3.1%	23,960	23,238	722	3.0%	24,032	23,309	723	3.0%
9 -	A49 Southbound (M62 - Birch Avenue)	23,742	22,853	890	3.7%	24,466	23,594	872	3.6%	24,727	23,809	918	3.7%
10 -	A49 Southbound (north of M62)	22,025	21,150	875	4.0%	22,540	21,683	858	3.8%	22,838	21,981	858	3.8%
11 -	A49 Southbound (parallel to Brendon Avenue - Sandy Lane West)	23,742	22,853	890	3.7%	24,466	23,594	872	3.6%	24,727	23,809	918	3.7%
12 -	A49 Southbound (Sandy Lane West - JunctionNINE Retail Park)	23,813	23,068	745	3.1%	23,551	22,836	715	3.0%	23,620	22,904	716	3.0%
13 -	A49 Winwick Link Road	21,767	20,610	1,157	5.3%	22,672	21,539	1,134	5.0%	22,829	21,695	1,134	5.0%
14 -	A50 Long Lane	12,162	11,879	283	2.3%	12,379	12,107	271	2.2%	12,505	12,234	271	2.2%
15 -	A50 Orford Green	11,111	10,826	286	2.6%	11,106	10,824	282	2.5%	12,081	11,806	275	2.3%
16 -	Birch Avenue (Site entrance)	194	192	2	0.9%	203	201	2	0.8%	380	378	2	0.4%
17 -	Blackbrook Avenue (Ballater Dr - Capesthorne Rd)	6,573	6,547	26	0.4%	7,039	7,013	26	0.4%	11,707	11,681	25	0.2%
18 -	Blackbrook Avenue (Capesthorne Rd - Insall Rd)	6,543	6,502	41	0.6%	6,909	6,869	41	0.6%	9,794	9,750	44	0.4%

9.3 The assumptions which underpin this traffic model are not stated. This is a significant omission which calls into question the validity not only of the traffic model, but also of the air quality model which relies on these traffic projections. It is not possible to confirm or challenge the traffic modelling because the settings for the model have not been published.

9.4 There are good reasons to question these projected traffic levels:

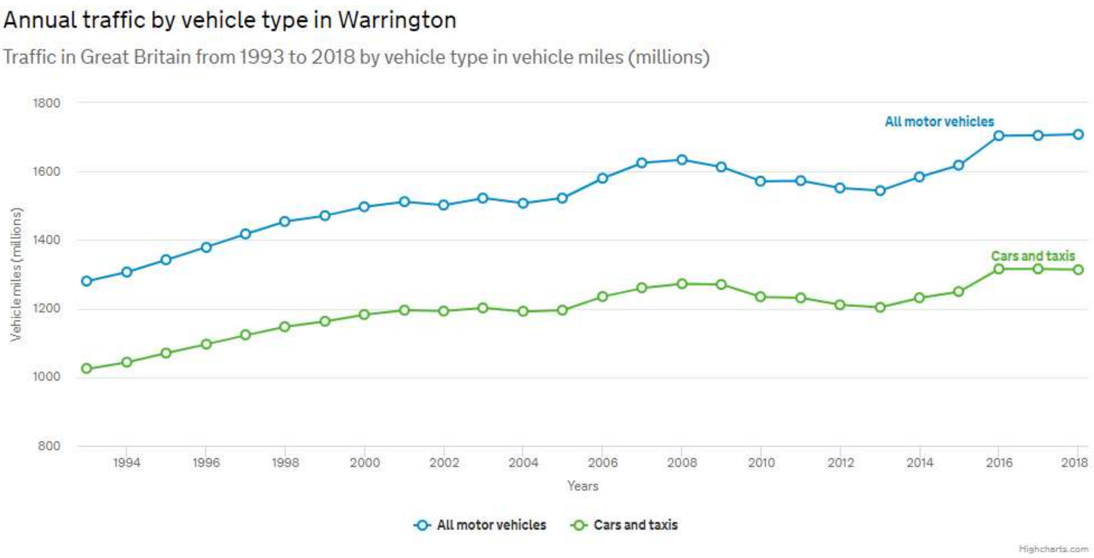
a) The model assumes a *reduction* in HDV journeys between 2019 and 2022 in the 'without development' option. This increases only marginally in the 'with development' option, resulting in an overall **reduction** in HDV journeys

b) The reduction in HDV journeys between 2019 and 2022 'without development' equates to 1.98% (Appendix 2 The reduction in HDV journeys between 2019 and 2022 'with development' equates to 1.64% (Appendix 2). No rationale is provided for these assumptions, which appear highly questionable given the underlying trend for *increased* traffic

c) The model takes no account of HDV journeys associated with the building works themselves. Table A12.5.1 of the appellant's report notes that "There are likely to be >50 HDV movements in any one day". This may not be a significant figure in the overall context of Warrington's traffic levels, but HDV movements of this magnitude through densely populated areas and focusing on the two AQMAs is significant – these are frequent movements of large, pollution-emitting vehicles in areas where large numbers of people live. Their absence from any air quality modelling is unacceptable

d) The model appears to take no account of HDV journeys associated with facilities within the development – care home, retail facility, school

9.5 The Department for Transport's traffic modelling for Warrington shows a slight year on year reduction from 2017 to 2018 (the latest dates available) for cars and taxis, and a slight *increase* in those years for HGVs. The data also shows a clear underlying trend for increase in traffic volumes for all vehicle types, which is unsurprising considering the continued population growth in the town:



https://roadtraffic.dft.gov.uk/local-authorities/74

9.6 It is, therefore, not credible to build a model on an assumption of a baseline *reduction* in HDV movements. The data used by Miller Goodall in their air quality modelling contradicts the most recent DfT data.

10. Conclusion

10.1 This is a highly sensitive site, bounded by two Air Quality Management Areas in an already congested and densely-populated location. The development would lead to an increase in car journeys, and therefore air pollution, and will inevitably lead to further illness and premature deaths.

10.2 The appellant's modelling indicates that the air quality levels at most areas within the site will meet national standards and that the impact of additional traffic on the existing population will be negligible. However, the model itself has not been provided – only contour maps of the outputs – and the model is therefore unavailable for analysis or challenge.

10.3 Reasons to reject the development on air quality grounds are summarised below:

a) The air quality model is based on an inadequate traffic model relying on an inadequate survey period and an unproven assumption of a general reduction in HDV movements
b) The traffic model is not defined sufficiently to enable it to be reproduced by a third party. This means that it is not susceptible to analysis or challenge
c) The air quality model is not defined sufficiently to enable it to be reproduced by a third party. This means that it is not susceptible to analysis or challenge
d) Existence of two AQMAs bordering the site define this as a sensitive site
e) The planned development is in direct opposition to the town's Air Quality Action Plan
f) Extremely high population density, already health-disadvantaged, which will be affected by the associated increase in air pollution
g) The site has been designed to be heavily dependent on car transport
h) The site's access arrangements will inevitably lead to increased traffic congestion in the surrounding road network, itself a contributory factor to air pollution. This will further impact on the AQMAs
i) The presence of a care home and 2,000 m^2 retail unit will add significantly to the number of journeys through the adjacent road network
j) The care home will expose a vulnerable cohort to the poor air quality already present in this area

10.4 This development will worsen an already serious position with regard to the impact of poor air quality on human health. It would not be overstating the case to say that human life is likely to be lost prematurely as a consequence of this worsening of air pollution in a densely-populated area. The scientific data is clear: air pollution at the levels already experienced in the urban area adjacent to the site are sufficient to cause illness and premature death.

11. Appendix 1

World Health Organization
REGIONAL OFFICE FOR Europe

EUROPEAN ENVIRONMENT
AND HEALTH PROCESS

Evolution of WHO air quality guidelines:

past, present and future

Abstract

This document summarizes key WHO publications in the field of air quality and health since the 1950s, which led to the development of the series of WHO air quality guidelines. It outlines the evolution of the scientific evidence on the health effects of air pollution and of its interpretation, supporting policy- and other decision-makers in setting outdoor and indoor air quality management strategies worldwide. Current WHO activities and their future directions in this field are also presented.

Keywords

AIR POLLUTION
AIR POLLUTANTS
ENVIRONMENTAL EXPOSURE
WORLD HEALTH ORGANIZATION
EUROPE

[redacted]

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Contributions of all the experts who participated in the development of key WHO publications in the field of air quality and health are gratefully acknowledged.

Abbreviations

AQGs	air quality guidelines
BaP	Benzo[a]pyrene
CO	carbon monoxide
CRF	concentration–response function
FEV	forced expiratory volume
FVC	forced vital capacity
GRADE	Grading of recommendations assessment, development and evaluation (framework)
HRAPIE	Health risks of air pollution in Europe (project)
ISO	International Organization for Standardization
NO_2	nitrogen dioxide
PM	particulate matter
PM_{10}	particulate matter with a diameter of 10 microns or less
$PM_{2.5}$	particulate matter with a diameter of 2.5 microns or less
REVIHAAP	Review of evidence on health aspects of air pollution (project)
SO_2	sulfur dioxide
SO_x	sulfur oxides
US EPA	United States Environmental Protection Agency
USSR	(former) Union of Soviet Socialist Republics

1. Introduction

Air pollution from both outdoor and indoor sources represents the single largest environmental risk to health globally. WHO estimates that more than 6 million premature deaths were caused by air pollution exposure in 2012 (WHO, 2014a; 2016a). The enormous burden of disease due to air pollution is increasingly being recognized by governments and institutions around the globe as a major public health concern.

In May 2015 the World Health Assembly, the decision-making body of WHO, adopted resolution WHA68.8 on health and the environment: addressing the health impact of air pollution, which urged Member States and WHO to redouble their efforts to protect populations from the health risks posed by air pollution. The resolution recognized for the first time the role of WHO air quality guidelines (AQGs) in providing guidance and recommendations for clean air that protect human health.

This report outlines WHO's trajectory on air quality and health, from its initial manuals and reports published as early as 1957 to the series of editions of AQGs that serve as a reference tool in developing ambient and indoor air quality management policies in many countries worldwide. It describes and provides critical commentary on the importance and key features of these documents, and highlights future directions and challenges of WHO's work in this area of increasing relevance to public health.

2. WHO publications on air quality and health before the AQGs (1958–1984)

2.1 *Air pollution* (WHO Technical Report Series, No. 157)

Air pollution (WHO, 1958) was published in the WHO Technical Report Series and was the first to deal with air pollution and its effects on health. It was written by a group of experts acting for the Expert Committee on Environmental Sanitation, which met in November 1957, which included members from Belgium, India, Italy, South Africa and the United States of America and representatives from the World Meteorological Organization.

The report was laudably concise: 26 pages providing an introduction to air pollution science, the sources of air pollutants, factors affecting ambient concentrations, methods of measuring concentrations of pollutants and effects on health. Emphasis was placed on smoke and sulfur dioxide (SO_2), photochemical generated smog (ozone, peroxyacids and peroxynitrates), secondary aerosols and hydrogen fluoride. The toxicological effects of individual pollutants were not discussed in any detail, although the photochemical pollutants were noted to cause effects ranging from lachrymation to pulmonary oedema. For SO_2, emphasis was placed on its irritant effects, recognized by the Committee as an adverse health effect. It was clearly appreciated that exposure to unusually high concentrations of air pollutants could damage health although, and very curiously, no mention was made of the Donora air pollution episode of 1948 or the London smog of 1952.

Box 1. Highlights of *Air pollution* (WHO, 1958)

- This was the first WHO publication that dealt with air pollution and health.
- The report represented the work of an expert group, an approach consistently used by WHO in this field in the years following 1957.
- The authors accepted that air pollutants could damage health, but categorized effects as (a) serious, when concentrations were unusually high, and (b) relatively minor and probably transient, consisting mainly of irritation of mucous membranes, at lower concentrations.
- For the first time, the case for air quality standards was considered briefly, although it was agreed that not enough data were available to allow standards designed to safeguard health to be set.
- An argument against standards was developed, based on possible inhibitory effects on industry.
- The terms *criteria*, *guidelines* and *guides* were not used; these appeared in subsequent reports.
- No mention was made of the potential carcinogenic effects of air pollutants.

2.2 *Air pollution* and other ancillary reports

Progress towards the WHO AQGs began in WHO Technical Report 157 described above, and continued with WHO Technical Reports 271 and 506 (see sections 2.3 and 2.4). In addition, between 1958 and 1972 WHO produced a number of additional interesting reports on air pollution (Barker et al., 1961; Katz, 1969; Lawther, Martin & Wilkins, 1962; WHO, 1963a; 1963b; 1968; 1970).

Of these ancillary reports, *Air pollution* (Barker et al., 1961) remains of significant interest. This 442-page report deals with many aspects of air pollution science in 15 substantial chapters and includes attractive colour plates showing the effects of air pollutants on plants. The report provided a historical review of atmospheric pollution and addressed the effects of air pollution on human health. It included reasonably detailed accounts of the Donora incident of 1948 and the London smog of 1952. Los Angeles smog was discussed in some detail, and short accounts were provided of what was then known of the effects on health of individual pollutants, including beryllium, manganese, fluorides, radioactive materials, insecticides, aero-allergens and carcinogens. One chapter, "Air pollution legislation: standards and enforcement", included a short review of the legislation enacted in the United Kingdom, the United States and the former USSR, with notes on the position in a selection of other countries. Only for the former Union of Soviet Socialist Republics (USSR) was a set of hygienic standards for urban air quoted from 1956 (reproduced in Table 1), expressed as "maximum permissible concentrations".

The list of compounds in Table 1 is as interesting for the compounds included – and those excluded – as for the standards themselves. No discussion of the derivation of the standards was provided, however.

Table 1. Maximum permissible pollution levels

Pollutant	Maximum permissible concentration (mg/m^3)	
	At any one time	24-hour average
Sulfur dioxide	0.5	0.15
Chlorine	0.1	0.03
Hydrogen sulfide	0.03	0.01
Carbon disulfide	0.5	0.15
Carbon dioxide[a]	6	2
Oxides of nitrogen	0.5	0.15
Non-toxic dusts	0.5	0.15
Soot	0.15	0.05
Phosphorus pentoxide	0.15	0.05
Manganese and compounds	0.03	0.01
Fluorine compounds	0.03	0.01
Sulfuric acid	0.3	0.1
Phenol	0.3	0.1
Arsenic (non-organic compounds, with the exception of arsine)	–	0.003
Lead and compounds (with the exception of lead tetraethyl)	–	0.0007
Metallic mercury	–	0.0003

[a] The authors of the current report note that carbon dioxide is presumably a misprint for carbon monoxide. The ambient concentration of carbon dioxide is 300 ppm; about 600 mg/m^3.

Source: Barker et al. (1961). Reproduced with permission.

2.3 *Atmospheric pollutants* (WHO Technical Report Series, No. 271)

Progress was made in the years following the publication of *Air pollution* and a number of additional reports and publications appeared on the subject: a monograph on air pollution (Barker et al., 1961), a report on a symposium on the epidemiology of air pollution (Lawther, Martin & Wilkins, 1962) and a paper surveying existing legislation on air pollution (WHO, 1963a). These provided the background against which a second meeting of experts was held in 1963. This group met as the WHO Expert Committee on Atmospheric Pollutants. Its members were drawn from Chile, France, Japan, South Africa, the United Kingdom of Great Britain and Northern Ireland, the United States and the USSR.

The resulting report, *Atmospheric pollutants* (WHO, 1964), was again concise, at 18 pages in all. Progress in developing legal instruments for the control of air pollution was noted and attention focused on technical methods for controlling it. These included control of emissions from motor vehicles, the use of liquid petroleum gas as a means of reducing hydrocarbon emissions and methods to reduce the use of coal and thus emissions of SO_2 and smoke. Increasing the use of electricity produced by "atomic power stations" and the use of natural gas were also mentioned. Further, a number of indirect means were advanced, such as improved traffic management, improved town planning, development of green belts and the introduction of "meteorological warning systems to allow temporary steps to reduce emissions of pollutants to be taken".

In discussing smoke and how it should be monitored, the group commented, providing forward-looking advice: "the object may be to measure blackness, particle mass or surface area of particles".

Atmospheric pollutants also reviewed the report of the WHO Interregional Symposium on Criteria for Air Quality and Methods of Measurement held in Geneva in 1963 (WHO, 1963b). As a result of the Symposium's deliberations, the terms *criteria* and *guides* for air quality were discussed and defined as follows.

- Criteria for guides to air quality are the tests which permit the determination of the nature and magnitude of the effects of air pollution on man and his environment.
- Guides to air quality are sets of concentrations and exposure times that are associated with effects of varying degrees of air pollution on man, animals, vegetation and the environment in general.

During the Symposium it was further suggested that guides to air quality for a given pollutant could be divided into four categories or levels. These were defined as the concentration and exposure times, which may vary for a given pollutant, at or above which:

- either no direct or indirect health effects occurred (level 1);
- likely irritation of the sensory organs or harmful effects on vegetation, visibility reduction or other adverse effects on the environment occurred (level 2);
- likely impairment of vital physiological functions or changes that may lead to chronic diseases or shortening of life occurred (level 3); or
- acute illness or death in susceptible groups of the population might occur (level 4).

Finally, it was highlighted that for some known pollutants it might not be possible to state concentrations and exposure times corresponding to all four of these levels because:

- the effects corresponding to one or more of the levels are not known;
- exposures producing effects corresponding to certain levels also produce more severe effects; or
- the present state of knowledge does not permit any valid quantitative assessment.

Box 2. Highlights of *Atmospheric pollutants* (WHO, 1964)

- The report called for international guides to air quality and requested that WHO take action to formulate these. This led, later, to the development of the first edition of the WHO AQGs (WHO Regional Office for Europe, 1987).
- The terms *criteria* and *guides* were first defined and introduced. In addition, guides were subdivided into four levels according to concentrations and exposure times in relation to increasing severity of effects on health and/or the environment.
- The report stated that some pollutants may have mutagenic effects, but it was concluded that too little was known about this subject to permit classification of such pollutants in the defined categories.
- For the first time it was accepted that long-term exposure to pollutants could induce chronic disease and shortening of life, and that lower concentrations could lead to more severe health effects than merely irritation.
- The term “threshold concentration” was not used but it seemed that, at least for non-mutagenic substances, the Committee accepted that such thresholds were likely to exist.
- The report concluded that it would be impossible to set internationally applicable emission standards, and that the prescription of such standards must be left to the discretion of individual governments or local authorities.

2.4 *Air quality criteria and guides for urban air pollutants* (WHO Technical Report Series, No. 506)

Air quality criteria and guides for urban air pollutants was produced in 1972 by an expert group with members drawn from Canada, Egypt, India, Japan, Sweden, Switzerland, the United States and the former USSR (WHO, 1972). It ran to 35 pages: again, a short report, which remains especially interesting in that – in addition to discussing a few common air pollutants in more detail than previous reports – it addressed the need to take into account the balance between health protection and the cost of lowering levels of air pollutants. WHO expert groups convened in the period 1957–1972 had few inhibitions about discussing methods for controlling levels of air pollutants, the likely costs of such methods and the need for “social decision-making”.

The report represented a significant step towards AQGs. It included short chapters dealing with sulfur oxides (SO_x) and suspended particles, carbon monoxide (CO), photochemical oxidants and nitrogen dioxide (NO_2), providing narrative reviews of the literature then available. Although no guidelines were formulated, the report provided the lowest ambient concentrations, defined in terms of specific averaging times, known to be associated with effects on health (i.e. guides, as defined in *Atmospheric pollutants* – see section 2.2). Much of the evidence is now very dated, but a few of the summary tables of interest are reproduced below.

Table 2 reflects substantial uncertainty and/or differences of opinion within the Committee’s conclusions (see table footnotes and the wide concentration ranges proposed for SO_2). By modern standards, the concentrations of SO_2 suggested seem very high: the upper figure was based on data collected in London (see Table 2, footnote b).

Table 2. Expected health effects of air pollution on selected population groups[a]

Pollutant	Excess mortality and hospital admissions	Worsening of patients with pulmonary disease	Respiratory symptoms	Visibility and/or human annoyance effects
SO_2[b]	500 μg/m³ (daily average)	500–250 μg/m³[c] (daily average)	100 μg/m³ (annual arithmetic mean)	80 μg/m³ (annual geometric mean)
Smoke[b]	500 μg/m³ (daily average)	250 μg/m³ (daily average)	100 μg/m³ (annual arithmetic mean)	80 μg/m³ (annual geometric mean)[d]

[a] The Committee specifically urged that this table should not be considered independently of the accompanying text: "a numerical value associated with a given effect does not mean that all exposed individuals will be thus affected. There is no valid information available that permits precise quantification of this risk. Usually, the proportion of the population that may be expected to be affected is small."

[b] British Standard Practice. [...] Values for sulfur dioxides and suspended particulates apply only in conjunction with each other. They may have to be adjusted when translated into terms of results obtained by other procedures.

[c] These values represent the differences of opinion within the Committee.

[d] Based on high-volume samplers.

Source: WHO (1972). Reproduced with permission.

The report's choice of a 4% concentration of carboxyhaemoglobin as a break point (Table 3) was agreed to be difficult and would nowadays be regarded as too high.

Table 3. CO concentrations required to reach 4% carboxyhaemoglobin levels[a]

Ambient CO[b]		Time (hours)
mg/m³	ppm	
29	25	24
35	30	8
117	100	1

[a] The Committee specifically urged that this table should not be considered independently of the accompanying text: "...the formulation of an air quality guide is fraught with difficulties... It can be seen that the time required to reach equilibrium depends to a large extent on whether the subject has acquired CO from smoking or other sources before exposure to ambient air..."

[b] Light activity at sea level with initial "basal" values is assumed. Above 4% carboxyhaemoglobin levels there may be increased risk for patients with cardiovascular disease.

Source: WHO (1972). Reproduced with permission.

The concentrations recommended for photochemical oxidants (Table 4) are not very different from those discussed in the first edition of the WHO AQGs (WHO Regional Office for Europe, 1987). No guides for NO_2 were produced as the evidence available at that time was judged to be insufficient.

Table 4. Expected health effects of photochemical oxidants on vulnerable groups

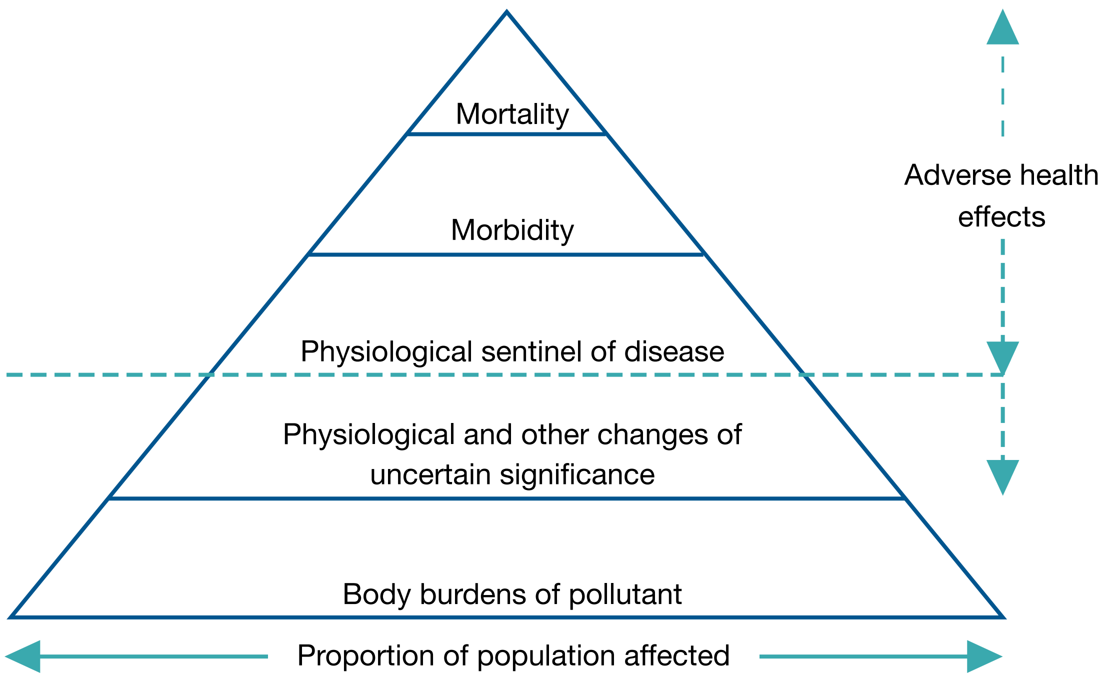
Increased mortality	Increased asthmatic attacks	Pulmonary dysfunction	Annoyance and eye irritation
Not reported to date	250 µg/m^3 [a] 1 hour	200 µg/m^3 1 hour	200 µg/m^3 1 hour

[a] Oxidant as measured by neutral buffered KI [potassium iodide] method and expressed as ozone.

Source: WHO (1972). Reproduced with permission.

From the perspective of 2016 perhaps the most interesting section of Air quality criteria and guides for urban air pollutants is section 6 on the administrative use of air quality criteria and guides. The authors introduced a diagram, reproduced here as Fig. 1.

Fig. 1. Schematic spectrum of biological response to pollutant exposure[a]



[a] Based on a diagram in United States Congress Document N° 92-241, 1972.

Source: WHO (1972). Reproduced with permission.

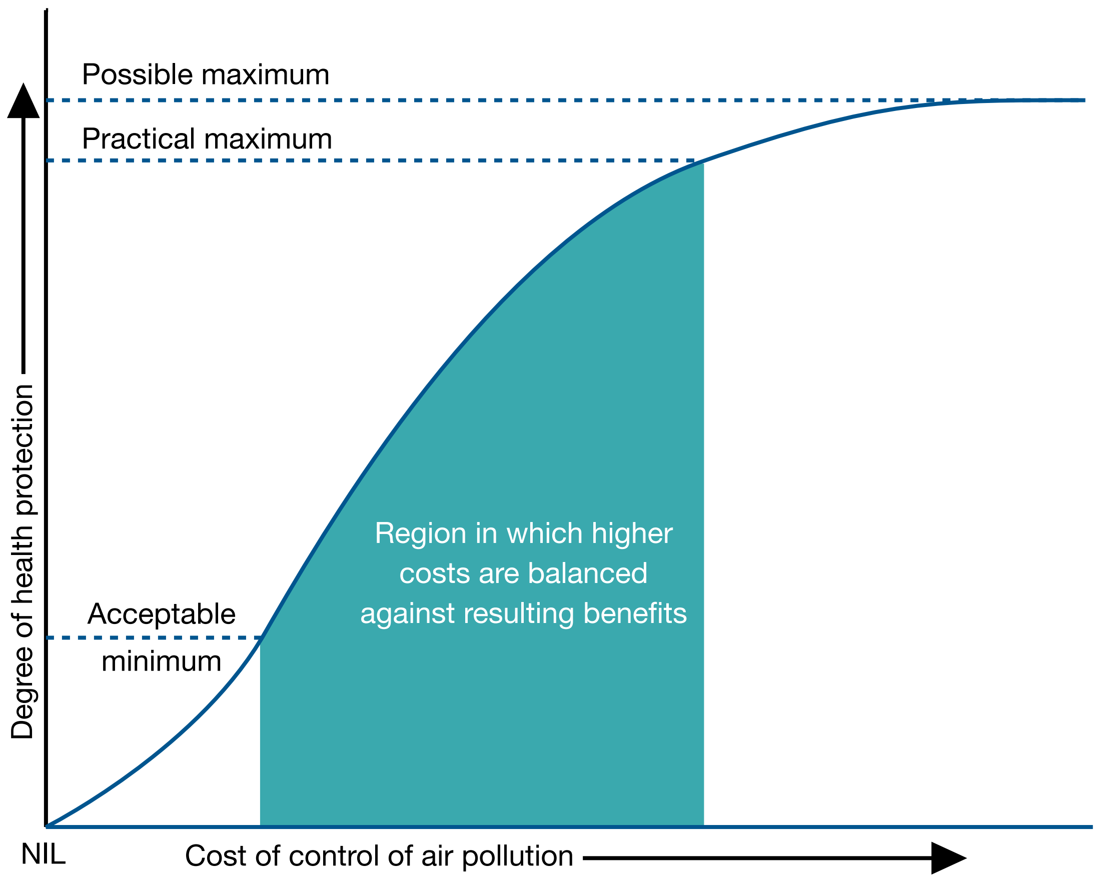
This was the first time this now well known triangle or pyramid had been used in WHO discussions of the effects on health of air pollutants. The authors agreed that a line could be drawn between concentrations likely and those not likely to produce adverse effects on health; however, they pointed out that the use of safety factors was advisable when using the guides as a basis for standards because of uncertainties about dose–response relationships. This approach was followed in later reports when guidelines were recommended. The implication that standards should be set at lower concentrations than the guides suggested in the report was clear. In discussing the size of safety factors the authors listed several elements they thought should be considered:

- political considerations, with an emphasis on cost–benefit calculations (this might be seen as controversial today);
- the significance and reliability of the data suggesting effects on health;
- the source of the data (for example, from studies in animals or in humans); and
- the nature of the effect against which protection is sought (for example, mortality or some lesser effect).

A definition of standards, taken from an earlier WHO report, was also provided: "Standards of environmental quality are guides that have been adopted by governments and other competent authorities and therefore have legal force. In some contexts, however, standards may include recommendations that need not be rigidly enforced" (WHO, 1970).

The same section, discussing health protection and air pollution control costs, introduced a diagram, presumably constructed by the authors as no source was provided, reproduced here as Fig. 2. This represents a clear and helpful piece of advice to anybody setting standards.

Fig. 2. Schematic representation of degree of health protection as a function of cost of air pollution control



Source: WHO (1972). Reproduced with permission.

The last section of the report was devoted to discussion of long-term goals. Members of the expert group argued that they had set criteria and guides for (some) urban air pollutants and that these could "be used by countries wishing to set air quality standards". It was accepted that these standards, especially when developed as short-term goals, might vary from country to country depending on "exposure conditions, the socioeconomic situation, and on the importance of other health problems". The expert group declined to provide such standards but pointed out that "severe effects are obviously to be avoided" and that "exposure to the air pollutants discussed in this report should be kept as low as possible". A rather stronger line was taken with regard to long-term goals, and in this context the following table was produced, emphasizing that these recommendations were subject to change as more data within different populations became available (see Table 5).

It is also interesting to note that the proposed long-term guide for ozone (8-hour average of 60 $\mu g/m^3$) is lower than later WHO recommendations. Indeed, it is lower than both the 150–200 $\mu g/m^3$ range proposed in the first edition of the WHO AQGs (WHO Regional Office for Europe, 1987) and the 100 $\mu g/m^3$ proposed in the 2005 WHO AQGs global update (WHO Regional Office for Europe, 2006a).

Table 5. Recommended long-term goals[a]

Pollutant	Measurement method	Limiting level
Sulfur oxides[b] – British Standard Procedure[c]	Annual mean 98% of observations[d] below	60 $\mu g/m^3$ 200 $\mu g/m^3$
Suspended particulates[b] – British Standard Procedure[c]	Annual mean 98% of observations[d] below	40 $\mu g/m^3$ 120 $\mu g/m^3$
Carbon monoxide – nondispersive infrared[c]	8-hour average 1-hour maximum	10 $\mu g/m^3$ 40 $\mu g/m^3$
Photochemical – oxidant as measured by neutral buffered KI method expressed as ozone	8-hour average 1-hour maximum	60 $\mu g/m^3$ 120 $\mu g/m^3$

[a] The Committee specifically urged that this table should not be considered independently of the accompanying text (see section 7.2 [of the original report]). [Note: the text that should accompany this table has been summarized by the authors in the current report.]

[b] Values for sulfur oxides and suspended particulates apply only in conjunction with one another.

[c] Methods are not those necessarily recommended but indicate those on which these units have been based. Where other methods are used an appropriate adjustment may be necessary.

[d] The permissible 2% of observations over this limit may not fall on consecutive days.

Source: WHO (1972). Reproduced with permission.

Box 3. Highlights of *Air quality criteria and guides for urban air pollutants* (WHO, 1972)

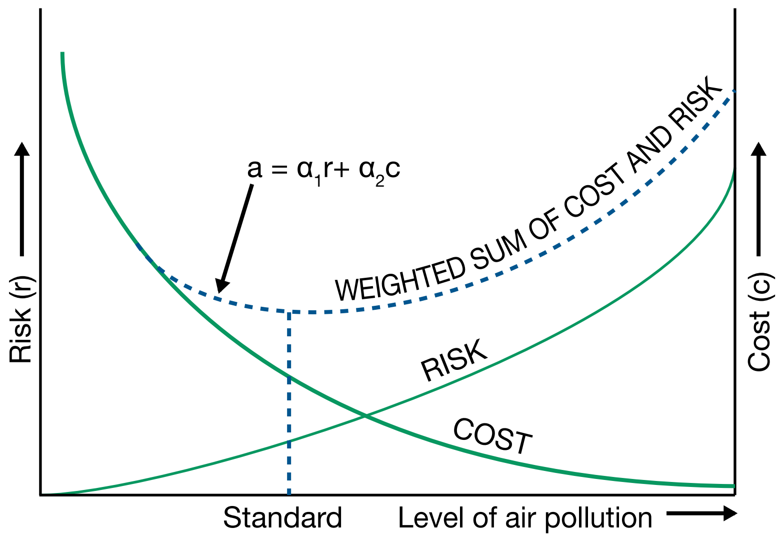
- Although guidelines were not proposed in the report, the lowest ambient concentrations defined in terms of specific averaging times known to be associated with effects on health (i.e. guides) were provided for SO_2, smoke, CO and photochemical oxidants.
- Hydrogen fluoride, radioactive materials, lead and other metals that had featured in earlier reports were excluded.
- The authors clearly stated that standards should be set at lower concentrations than the proposed guides; they suggested applying safety factors to account for uncertainties about dose–response relationships and other considerations left to regulatory authorities.
- The pyramid (or triangle) diagram of health effects due to exposure to air pollutants was used by WHO for the first time.
- The report concluded that WHO should publish critical reviews for each individual pollutant, which led to the inclusion of such reviews in the first edition of the WHO AQGs (WHO Regional Office for Europe, 1987).

2.5 *Manual on urban air quality management* (WHO Regional Publications, European Series, No. 1)

The *Manual on urban air quality management* (Suess & Craxford, 1976) remains a valuable contribution to the field. Two chapters are especially relevant to the current discussion: Chapter 4 on ambient air quality standards and their application and Chapter 6 on economic aspects of air pollution abatement. Air quality criteria and guides for urban air pollutants (see section 2.4) was reprinted as Chapter 3.

The advice on standard setting avoided too much focus on thresholds when considering responses at a population level. It proposed a trade-off between the costs and benefits of reducing levels of air pollutants, illustrated by a now well known graph reproduced here as Fig. 3.

Fig. 3. Derivation of ambient air quality standards



Source: Suess & Craxford (1976). Reproduced with permission.

The dotted line in Fig. 3 was derived by adding the cost line to the risk line and applying weighting factors: α_1 for risk and α_2 for cost. The author pointed out that the lowest point on the dotted line could be moved from left to right by adjusting the values given to α_1 and α_2. This point (where the standard could be set) was taken as the point of optimal balance between costs and reduction of risks. Decisions regarding the relative values of α_1 and α_2 should, it was suggested, be greatly dependent on "political climate and public opinion" and would involve a weighing of economic development and protection of health. The approach suggested was clearly based on the perception that WHO should not be providing air quality standards, but should be providing the evidence upon which such standards might be set and, very importantly, providing advice on how standards should be set.

2.6 *Glossary on air pollution* and the Environmental health criteria series

The period from 1976 to 1984 (when the planning meeting for the 1987 edition of the WHO AQGs was held) saw the publication of a number of very significant reviews on the effects of air pollutants on health. The WHO Regional Office for Europe published a *Glossary on air pollution* (1980). An initiative between WHO and the United Nations Environment Programme led to the establishment of the International Programme on Chemical Safety, and a series of documents entitled "Environmental health criteria" began to appear. These provided international, critical reviews of the effects of chemicals or combinations of chemicals and physical and biological agents on human health and the environment (WHO, 2016b). A number of these documents dealt with air pollutants.

3. WHO AQGs

Since the mid-1980s the WHO Regional Office for Europe has coordinated the development of a series of AQGs, widely used as reference tools to help policy-makers across the world in setting standards and goals for air quality management. Although methodologies and requirements have evolved over time, the WHO AQGs remain, in essence, manuals that provide evidence-based recommendations with the goal of protecting populations worldwide from the adverse health effects of air pollutants. Ensuring the necessary funding to conduct such work has never been easy. The support of Member States that use the WHO AQGs as a basis for policy development to improve public health is essential in order for this process to be continued.

Three editions of ambient AQGs have been published since 1987. These are intended to have a wide application in environmental decision-making, particularly in setting standards at a global level, despite the inclusion of the words "for Europe" on the cover of the first two editions.

Since 2006 WHO has worked on developing separate guidelines for indoor air quality and has published a series of three indoor-specific AQGs, providing health-based recommendations on selected air pollutants commonly found in indoor environments, biological agents (dampness and mould) and household fuel combustion.

3.1 *Air quality guidelines for Europe*

The first edition of *Air quality guidelines for Europe* was a complete, standalone manual on air pollution and health (WHO Regional Office for Europe, 1987). At that time the WHO regional Health for All strategy provided a stimulus and policy framework for this work, specifically through the target that "by 1995, all people of the Region should be effectively protected against recognized health risks from air pollution" (WHO Regional Office for Europe, 1985). Support for production of the guidelines and some of the funding was provided by the Netherlands, following the successful publication and uptake by end-users of the WHO guidelines for drinking-water quality (WHO, 1984). A project coordinator was appointed and a total of 12 meetings were held between early 1984 and November 1986, attended by many of the most distinguished experts in the air pollution field at that time, to produce a 426-page comprehensive report, which provided recommendations for 28 organic and inorganic chemical air pollutants.

A definition of an adverse health effect proposed by the United States Environmental Protection Agency (US EPA) was adopted: "any effect resulting in functional impairment and/or pathological lesions that may affect the performance of the whole organism or which contributes to a reduced ability to respond to an additional challenge" (US EPA, 1980). The AQGs were intended to provide a basis for "protecting public health from adverse effects of air pollutants and for eliminating, or reducing to a minimum, those contaminants of the air that are known or likely to be hazardous to human health and well-being" (WHO Regional Office for Europe, 1987). The authors clearly stated that "compliance with recommendations regarding guideline values does not guarantee the absolute exclusion of effects at levels below such values". They recognized the limitations in protection provided by adherence to the guidelines in sensitive groups of the population (especially those impaired by concurrent disease or other physiological limitations) and the uncertainties related to "combined exposure to various chemicals or exposure to the same chemical by multiple routes".

A clear distinction was drawn between guidelines and standards:

> It should be strongly emphasized that the guideline values are not to be regarded as standards in themselves. Before standards are adopted, the guideline values must be considered in the context of prevailing exposure levels and environmental, social, economic and cultural conditions. In certain circumstances there may be valid reasons to pursue policies which will result in pollutant concentrations above or below the guideline values.

In this regard, it was assumed that regulatory authorities would consider costs and other factors when using the AQGs as basis for setting standards, placing a heavy responsibility on regulators and exposing them to potential criticism if they proposed standards at higher concentrations than those recommended by the guidelines.

Different approaches were used to deal with carcinogenic and non-carcinogenic health end-points. In the case of genotoxic carcinogens, it was accepted that it was impossible to define a no-effect or threshold level of exposure and a risk assessment approach was adopted. A unit risk factor was calculated: this estimated the excess cancer risk likely to be imposed by lifetime exposure to the unit concentration (1 μg/m^3 was adopted for most of the compounds) of the chemical considered. The methodology used to derive guidelines for non-carcinogens involved the assumption that, in general, a threshold of effect could be identified. In these cases, an approach regarded as standard in toxicological practice was adopted. Either the lowest observed adverse effect level (generally preferred) or the no observed adverse effect level (in the case of irritant effects) was used as a starting-point to derive a numerical guideline value, after applying a series of protection factors (also referred to in the guidelines as safety or uncertainty factors). A priori, no method for agreeing on suitable protection factors was found and a range of factors was used; these represented the expert judgement of the scientists involved in the work. Such arbitrary judgements were based on considerations of extent and quality of the available evidence, the question of sensitive groups, the need to allow for possible inter-species variations in sensitivity when animal studies were used as a basis for the guideline and the reversibility, or otherwise, of the effects considered. As an example, when deriving guidelines for SO_2 and particulate matter (PM) (considered in the guidelines as a combined exposure), a protection factor of 2 was used in relation to morbidity and mortality, and a protection factor of 1.5 in the case of reductions in indices of lung function.

The AQGs summarized recommended individual air pollutant guideline values for 19 pollutants for non-carcinogenic effects (excluding sensory effects and annoyance reactions), reproduced in Table 6.

Table 6. Guideline values for individual substances based on effects other than cancer or odour/annoyance[a]

Substances	Time-weighted average	Averaging time	Chapter
Cadmium	1–5 ng/m^3 10–20 ng/m^3	1 year (rural areas) 1 year (urban areas)	19
Carbon disulfide	100 μg/m^3	24 hours	7
Carbon monoxide	100 mg/m^3 [b] 60 mg/m^3 [b] 30 mg/m^3 [b] 10 mg/m^3	15 minutes 30 minutes 1 hour 8 hours	20
1.2-Dichloroethane	0.7 mg/m^3	24 hours	8
Dichloromethane (Methylene chloride)	3 mg/m^3	24 hours	9
Formaldehyde	100 μg/m^3	30 minutes	10
Hydrogen sulfide	150 μg/m^3	24 hours	22
Lead	0.5–1.0 μg/m^3	1 year	23
Manganese	1 μg/m^3	1 year[c]	24
Mercury	1 μg/m^3 [d] (indoor air)	1 year	25
Nitrogen dioxide	400 μg/m^3 150 μg/m^3	1 hour 24 hour	27
Ozone	150–200 μg/m^3 100–120 μg/m^3	1 hour 8 hours	28
Styrene	800 μg/m^3	24 hours	12
Sulfur dioxide	500 μg/m^3 350 μg/m^3	10 minutes 1 hour	30
Sulfuric acid	–[e]	–	30
Tetrachloroethylene	5 mg/m^3	24 hours	13
Toluene	8 mg/m^3	24 hours	14
Trichloroethylene	1 mg/m^3	24 hours	15
Vanadium	1 μg/m^3	24 hours	31

[a] The Information from this table should not be used without reference to the rationale given in the chapters indicated.

[b] Exposure at these concentrations should be for no longer than the indicated times and should not be repeated within 8 hours.

[c] Due to respiratory irritancy, it would be desirable to have a short-term guideline, but the present data base does not permit such estimations.

[d] The guideline value is given only for indoor pollution; no guidance is given on outdoor concentrations (via deposition and entry into the food-chain) that might be of indirect relevance.

[e] See Chapter 30.

Note: when air levels in the general environment are orders of magnitude lower than the guideline values, present exposures are unlikely to present a health concern. Guideline values in those cases are directed only to specific release episodes or specific indoor pollution problems.

Source: WHO Regional Office for Europe (1987). Reproduced with permission.

Table 7 presents the unit risks estimated for seven carcinogenic air pollutants. For cadmium, lead and ozone, ranges rather than single figures were recommended as guidelines. Further, in the case of ozone it was stated that some studies had suggested that no threshold of effect could be identified; this led to the guidelines being set close to concentrations at which "significant" effects had been demonstrated. The use of a range rather than a single value recommendation for ozone may reflect the fact that high natural background concentrations for this pollutant are found in some areas.

Table 7. Carcinogenic risk estimates based on human studies[a]

Substances	IARC Group classification	Unit risk[b]	Site of tumour
Acrylonite	2A	2×10^{-5}	lung
Arsenic	1	4×10^{-3}	lung
Benzene	1	4×10^{-6}	blood (leukaemia)
Chromium (VI)	1	4×10^{-2}	lung
Nickel	2A	4×10^{-4}	lung
Polynuclear aromatic hydrocarbons (carcinogenic fraction)[c]	–	9×10^{-2}	lung
Vinyl chloride	1	1×10^{-6}	liver and other sites

[a] Calculated with average relative risk model.

[b] Cancer risk estimates for lifetime exposure to a concentration of 1 μg/m^3.

[c] Expressed as benzo[a]pyrene (based on benzo[a]pyrene concentration of 1 μg/m^3 in air as a component of benzene-soluble coke-oven emissions).

Source: WHO Regional Office for Europe (1987). Reproduced with permission.

Table 8 shows that SO_2 and PM were considered together in the guidelines – the latter expressed both in terms of black smoke as per reflectance assessment or total suspended/thoracic particles as per gravimetric assessment methods. The guideline values for this combination of pollutants were based on studies in areas affected by coal smoke pollution (such as London). This was the first time that gravimetric assessment methods for particles were recommended in a WHO publication on air pollution. The guidelines provided for

Table 8. Guideline values for combined exposure to sulfur dioxide and PM[a]

Length of exposure	Averaging time	Sulfur dioxide (μg/m^3)	Reflectance assessment: black smoke[b] (μg/m^3)	Gravimetric assessment	
				Total suspended particulates[c] (μg/m^3)	Thoracic particles[d] (μg/m^3)
Short term	24 hours	125	125	120[e]	70[e]
Long term	1 year	50	50	–	–

[a] No direct comparisons can be made between values for PM in the right- and left-hand sections of this table, since both the health indicators and the measurement methods differ. While numerically total suspended particulate/thoracic particle values are generally greater than those of black smoke, there is no consistent relationship between them, the ratio of one to the other varying widely from time to time and place to place, depending on the nature of the sources.

[b] Nominal μg/m^3 units, assessed by reflectance. Application of the black smoke value is recommended only in areas where coal smoke from domestic fires is the dominant component of the particulates. It does not necessarily apply where diesel smoke is an important contributor.

[c] Measurement by high-volume sampler, without any size selection.

[d] Equivalent values as for a sampler with International Organization for Standardization (ISO) thoracic particle characteristics (having 50% cut-off point at 10 μm): estimated from total suspended values using site-specific total suspended particulate/ISO thoracic particle ratios.

[e] Values to be regarded as tentative at this stage, being based on a single study (involving sulfur dioxide exposure also).

Source: WHO Regional Office for Europe (1987). Reproduced with permission.

thoracic particles (equivalent to PM with a diameter of 10 microns or less (PM_{10})) were extrapolated from figures for total suspended particles and were not based on studies in which PM_{10} had been measured. The possible effects of long-term exposure to PM were beginning to be recognized since they had first been suggested by Lawther (1961) as likely to be important – perhaps more important than the effects of occasional exposure to very high concentrations.

The AQGs also recommended measures to prevent pollutant-associated risks, such as conducting population exposure-related surveys or monitoring (for example, of lead deposition in dust and soil or of radon-daughter concentrations in buildings), and underscored from the beginning the need for an integrated view of air quality management that included eco-toxicological aspects. This last point was reflected in the final section of the guidelines on effects of inorganic substances on vegetation, which described the effects of nitrogen, ozone and other photochemical oxidants and SO_x on terrestrial vegetation.

Box 4. Highlights of *Air quality guidelines for Europe* (WHO Regional Office for Europe, 1987)

- This was the first edition of the WHO AQGs, providing recommendations in the form of numerical values/ranges or unit risk factors for a total of 28 air pollutants.
- The authors recognized the limitations and uncertainties in health protection provided by adherence to the guidelines, especially in the case of sensitive groups and because of multiple routes of exposure and simultaneous exposure to various chemicals.
- It was strongly emphasized that the guideline values should not be regarded as standards in themselves. The latter would be left to the judgement of regulatory authorities, who would need to consider economic, social and cultural factors when using the guidelines as a basis for setting standards.
- Sulfur and black smoke were considered together in providing recommendations, and for the first time WHO recommended the use of gravimetric methods for assessment of particle concentration in this field.
- An eco-toxicological dimension was also considered; guideline values for a few pollutants, SO_x, nitrogen oxides and ozone/photochemical oxidants, based on effects on terrestrial vegetation, were provided.

3.2 *Acute effects on health of smog episodes* (WHO Regional Publications, European Series, No. 43)

The WHO Regional Office for Europe published a report after a meeting held in late 1990 (WHO Regional Office for Europe, 1992); this may be regarded as ancillary to the development of the WHO AQGs. The main goals of the report were to produce advice on the likely short-term effects on health of acute and episodic exposures to both winter and summer smog and to advise on measures that could be taken to reduce such effects. This was the last of the WHO reports in this area that dealt with the effects of the combination of black smoke and SO_2 and photochemical oxidants as “winter/ summer smog”.

In the report participants in the expert group meeting, based on previous work conducted by the US EPA (Lippmann, 1988; 1989), sought to grade health effects observed at different concentrations of SO_2, PM and ozone according to the degree of severity of the outcomes, as reproduced in Table 9.

For ozone, the report also defined the proportion of the population likely to be affected at different concentrations (reproduced in Table 10).

Table 9. Gradation of acute lung function, symptomatic and other responses to air pollution exposure into different classes of adversity

Response	Gradation		
	Mild	Moderate	Severe/incapacitating
Change in FVC or FEV[a] symptoms	5–10% Mild to moderate cough	10–20% Mild to moderate cough, pain on deep inspiration, shortness of breath	20–40%/>40% Repeated/severe cough, moderate to severe pain on deep inspiration and shortness of breath; breathing distress
Limitation of activity	None	Few individuals choose to discontinue activity	Some/many individuals choose to discontinue activity

[a] Note added in the current report: FVC = forced vital capacity; FEV = forced expiratory volume.

Source: WHO Regional Office for Europe (1992). Reproduced with permission.

Table 10. Expected acute effects of photochemical smog on days characterized by maximum 1-hour average ozone concentrations, as indicated for children and non-smoking young adults on the basis of observations made in toxicological, clinical and epidemiological studies

Ozone level (μg/m³)	Eye, nose and throat irritation	Average FEV, decrement in active people outdoors		Imposed avoidance of time and activity outdoors	Respiratory inflammatory and clearance response, hyper-reactivity in active people outdoors	Respiratory symptoms (mainly in adults)	Overall classification
		Whole population	Most sensitive 10% of population				
<100	No effect	None	None	None	None	None	–
200	In few sensitive people	5%	10%	None	Mild	Some chest tightness, cough	Mild
300	< 30% of people	15%	30%	Some individuals	Moderate	Increased symptoms	Moderate
400	> 50% of people	25%	50%	Many individuals	Severe	Further increase of symptoms	Severe

Note: In large cities, scavenging of ozone may lead to relatively low concentrations of ozone. Under such circumstances, other indicators of summer-type smog may be more useful.

Source: WHO Regional Office for Europe (1992). Reproduced with permission.

Concerning measures to protect the general public, the advice focused on reducing exposure by limiting physical activity outdoors during smog episodes. Short-term abatement measures, such as traffic bans or temporary reductions in industrial emissions, were not thought likely to be very effective. The report stated that traffic bans would lead to extreme overloading of the public transport system, and that outdoor population exposure to pollutants was likely to increase as people waited for buses or trains, walked to stations and bus stops, or walked or bicycled to work. Instead, it recommended providing advance warnings of smog episodes. It suggested that the "physically active general population" should be especially targeted during periods when summer smog episodes were likely to occur (as these are associated with warm, sunny weather encouraging the population to spend more time outdoors). Those with cardiorespiratory disease should be targeted predominantly during periods when episodes of winter smog were likely to occur, based on knowledge from the London smog episodes in 1952 (see Barker et al. (1961), outlined in section 2.3 above). The report further concluded that long-term measures to reduce baseline levels of pollution represented the most sensible and effective preventive measure.

3.3 *Air quality guidelines for Europe, second edition*

Early in the 1990s it was already recognized that evidence of the effects of air pollutants on health was accumulating rapidly, and that the 1987 AQGs were in need of revision (Brunekreef, Dockery & Krzyzanowski, 1995). A second edition of the WHO AQGs was published in 2000 (WHO Regional Office for Europe, 2000), as a result of close cooperation with the International Programme on Chemical Safety. Funding was provided by the European Commission, the Netherlands and Sweden. Work began in 1993, and more than 100 experts participated in a total of 10 meetings that were summarized in a series of WHO reports. These advance drafts were used in the years previous to the publication of the second edition to support the development of the European Union's legally binding limit values in the framework of the air quality directives. As a result of this work, detailed guidelines covering 35 air pollutants were produced, including reviews of evidence for essentially the same pollutants discussed in the first edition of the WHO AQGs (WHO Regional Office for Europe, 1987), with a few additional ones (butadiene, polychlorinated biphenyls, dibenzodioxins and dibenzofurans, fluoride and platinum). With some exceptions where evaluations from the previous WHO AQGs were retained (including for acrylonitrile, carbon disulfide, 1,2-dichloroethane, vinyl chloride, asbestos, hydrogen sulfide and vanadium), updated reviews of evidence were prepared and used as a basis for recommending guideline values. The final hard-copy report provided only summaries of the available evidence, but the lengthy reviews were made available electronically as an interactive CD-ROM and, later, on the WHO website.

For the first time, recommendations for PM were provided separately from those for SO_2. It was also recognized that the rapidly expanding database of time-series studies should be used for guideline development and, importantly, that these studies did not suggest clear thresholds of effect. The results pointed to a near linear relationship between the logarithm of pollutant concentrations (24-hour average concentrations of ozone and PM monitored as PM_{10} or PM with a diameter of 2.5 microns or less ($PM_{2.5}$)) and percentage changes in indices of effects on health, including daily mortality and admissions to hospital. Similar results were appearing with regard to SO_2 and NO_2; there was concern that NO_2 was acting as an index or surrogate for an urban mixture of air pollutants, and effects on health of low concentrations of NO_2 per se were questioned.

While conventional numerical guideline values were recommended for NO_2 and SO_2, a new approach was taken for $PM_{2.5}$ and PM_{10}, for both long- and short-term exposure. PM guidelines were provided as the slopes (in the form of relative risks) of the estimated concentration–response functions (CRFs) developed for several outcomes (reproduced in Tables 11 and 12). This allowed regulatory authorities to develop their own policies (by explicitly selecting a level of acceptable exposure and associated health risk) and to set standards by taking into account their local circumstances as regards ambient concentrations and socioeconomic factors.

Table 11. Summary of relative risk estimates for various end-points associated with a 10 μg/m³ increase in the concentration of PM_{10} or $PM_{2.5}$

End-point	Relative risk for $PM_{2.5}$ (95% confidence interval)	Relative risk for PM_{10} (95% confidence interval)
Bronchodilatator use	–	1.0305 (1.0201–1.0410)
Cough	–	1.0356 (1.0197–1.0518)
Lower respiratory symptoms	–	1.0324 (1.0185–1.0464)
Change in peak expiratory flow (relative to mean)	–	−0.13% (−0.17% to −0.09%)
Respiratory hospital admissions	–	1.0080 (1.0048–1.0112)
Mortality	1.015 (1.011–1.019)	1.0074 (1.0062–1.0086)

Note: The authors of the current report note that the table lacks specification that the numbers provided relate to short-term exposure.

Source: WHO Regional Office for Europe (2000). Reproduced with permission.

Table 12. Summary of relative risk estimates for effects of long-term exposure to particulate matter on the morbidity and mortality associated with a 10 μg/m³ increase in the concentration of $PM_{2.5}$ or PM_{10}

End-point	Relative risk for $PM_{2.5}$ (95% confidence interval)	Relative risk for PM_{10} (95% confidence interval)
Death	1.14 (1.04–1.24)	1.10 (1.03–1.18)
Death	1.07 (1.04–1.11)	–
Bronchitis	1.34 (0.94–1.99)	1.29 (0.96–1.83)
Percentage change in FEV1, children[a]	−1.9% (−3.1% to −0.6%)	−1.2% (−2.3% to −0.1%)
Percentage change in FEV1, adults	–	−1.0% (not available)

[a] [FEV in 1 second;] for $PM_{2.1}$ rather than $PM_{2.5}$

Source: WHO Regional Office for Europe (2000). Reproduced with permission.

This thinking did not represent a completely novel proposition; it had already been brought forward by WHO in 1972 (in *Air quality criteria and guides for urban air pollutants*, discussed in section 2.4). The same approach was developed for ozone, although for this pollutant an 8-hour average concentration of 120 μg/m³ was further recommended as a conventionally framed guideline. At this concentration it was agreed that "acute effects on public health are likely to be small", and a cautionary note was attached to this guideline, stating: "For those public health authorities that cannot accept such levels of health risk, an alternative is to select explicitly some other level of acceptable exposure and associated risk." In spite of general agreement among the experts about a lack of indication of any threshold below which adverse effects of PM or ozone would not be anticipated, not all participants in the development of the guidelines regarded this approach as a step forward. Indeed, some experts argued that in the absence of a conventional guideline, regulatory authorities would be unlikely to develop and implement vigorous policies designed to reduce ambient concentrations of air pollutants.

Finally, another notable change from the 1987 publication was the inclusion of a chapter on the use of the guidelines in protecting public health. This was based on a report from a WHO working group on guidance for setting air quality standards, which had met in Barcelona in 1997 (WHO Regional Office for Europe, 1998). The working group included senior officials from regulatory authorities. The report reflected their expertise and experience of policy-making by explaining that air quality standards should be defined in terms of:

- how and where air pollutants should be monitored for comparison with standards;
- how the measurements should be handled in a statistical sense;
- the date by which the standard should be met; and
- the acceptable level of exceedance of the standard – for example, in terms of percentage of days per year that should be allowed or, rather, not be regarded as a failure to meet the standard.

Other issues such as the need for involvement of stakeholders in standard development, the raising of public awareness and the need for cost–benefit analysis were also raised.

Box 5. Highlights of *Air quality guidelines for Europe, second edition* (WHO Regional Office for Europe, 2000)

- The second edition of the WHO AQGs provided recommendations in the form of numerical values/ranges and unit risk factors or CRFs for the pollutants included in the previous edition, in addition to butadiene, polychlorinated biphenyls, dibenzodioxins and dibenzofurans, fluoride and platinum. A separate section for indoor air pollutants (environmental tobacco smoke, man-made vitreous fibres and radon) was also provided.
- No new evaluations were conducted for acrylonitrile, carbon disulfide, 1,2-dichloroethane, vinyl chloride, asbestos, hydrogen sulfide and vanadium, for which the recommendations from the 1987 AQGs were retained.
- For the first time guidelines were provided separately for SO_2 and PM.
- CRFs for PM and for ozone were developed – pollutant concentrations associated with specific levels of health response among defined population subgroups. A numerical guideline was proposed for ozone, while for PM only estimated relative risks for different outcomes from the CRFs were provided.
- A chapter on the use of the guidelines in protecting public health was introduced in this edition, discussing several air quality management issues to be considered when guidelines are to be used for the development of legally enforceable standards.

3.4 *Air quality guidelines: global update 2005*

Air quality guidelines: global update 2005, published in 2006, was a substantially different report from the 1987 and 2000 AQGs, as it focused on just four classical air pollutants: PM, ozone, NO_2 and SO_2. These were selected on the basis of the conclusions of a WHO project called “Systematic review of health aspects of air pollution in Europe” (WHO Regional Office for Europe, 2004). WHO explicitly recognized that the fact that other pollutants – such as CO – were not included in the update reflected the limited resources available for the project.

The first part of this 484-page manual provided outstanding detailed reviews in nine chapters, written by recognized experts in the field, on air pollutants sources, concentrations and global trends, human exposure, health effects of susceptibility, environmental equity, health impact assessment, application of the guidelines in policy formulation and indoor air quality. The second part consisted of comprehensive health risk assessments of the four selected pollutants. The detail provided reflects the rapid expansion of research on these pollutants that occurred in the period 1995–2005.

As already stressed, a stern demand for guidelines framed in the conventional form was recognized and, in addition to concentration–effect relationships, numerical guideline values were now provided for PM, for both annual and 24-hour mean concentrations (reproduced in Tables 13 and 14).

Remarkably, the guideline values for NO_2 (40 μg/m^3 for annual mean and 200 μg/m^3 for 1-hour mean concentrations) remained at the same levels as those set in the second edition of the WHO AQGs (WHO Regional Office for Europe, 2000), despite many time-series studies that linked 24-hour average concentrations with effects on health. This decision reflected the residual concerns at that time that NO_2 per se might not have effects on health at ambient concentrations, and that it might be acting as a surrogate for other, not routinely measured, components of combustion-related pollution mixture.

Further, a new approach was introduced in this edition of the guidelines, as interim targets were proposed for levels of three of the air pollutants: PM, ozone and SO_2. These are pollutant concentrations associated with a specified decrease of mortality risk proposed as “incremental steps in progressive reduction of air pollution, and are intended for use in areas where pollution is high”. Interim targets were set on an arbitrary basis – other levels of effect might have been chosen – and they reflect the essence of benefit assessment based on linear concentration–response associations.

Table 13. AQGs and interim targets for PM: annual mean

Annual mean level	PM_{10} (μg/m^3)	$PM_{2.5}$ (μg/m^3)	Basis for the selected level
WHO interim target 1	70	35	These levels are estimated to be associated with about 15% higher long-term mortality than at AQG levels.
WHO interim target 2	50	25	In addition to other health benefits, these levels lower risk of premature mortality by approximately 6% (2–11%) compared to interim target 1.
WHO interim target 3	30	15	In addition to other health benefits, these levels lower risk of premature mortality by approximately another 6% (2–11%) compared to interim target 2 levels.
WHO AQGs	20	10	These are the lowest levels at which total, cardiopulmonary and lung cancer mortality have been shown to increase with more than 95% confidence in response to $PM_{2.5}$ in the ACS study (323).[a] The use of the $PM_{2.5}$ guideline is preferred.

[a] The authors of the current report note that reference 323 mentioned in the table is a misprint, as this should be reference 295 in the original guideline document: Pope CA et al. Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution. JAMA, 2002, 287:1132–1141.

Source: WHO Regional Office for Europe (2006a). Reproduced with permission.

Table 14. AQGs and interim targets for PM: 24-hour mean

24-hour mean level[a]	PM_{10} (μg/m³)	$PM_{2.5}$ (μg/m³)	Basis for the selected level
WHO interim target 1	150	75	Based on published risk coefficients from multicentre studies and meta-analyses (about 5% increase in short-term mortality over AQG)
WHO interim target 2	100	50	Based on published risk coefficients from multicentre studies and meta-analyses (about 2.5% increase in short-term mortality over AQG)
WHO interim target 3[b]	75	37.5	About 1.2% increase in short-term mortality over AQG
WHO AQGs	50	25	Based on relation between 24-hour and annual PM levels

[a] 99th percentile (3 days per year).

[b] For management purposes, based on annual average guideline values, the precise number to be determined on the basis of local frequency distribution of daily means.

Source: WHO Regional Office for Europe (2006a). Reproduced with permission.

As emphasized in the first edition of the WHO AQGs (WHO Regional Office for Europe, 1987), the text accompanying the numbers in the tables is an integral part of the recommendations, so the guideline values and interim targets must be interpreted alongside the text explaining the reasoning behind the numbers and indicating, sometimes simplifying, assumptions and caveats. As an example, the guidelines for annual mean concentrations of PM_{10} were derived from the results of epidemiological studies on $PM_{2.5}$ effects using a simple conversion formula: $PM_{10} = 2 \times PM_{2.5}$. Observations quoted in the supporting text, however, indicate that $PM_{2.5}$ makes up, in various locations and at certain times, 40–90% of PM_{10}.

As well as the full text with the evidence assessment, WHO published an executive summary of the guidelines in all official languages (WHO, 2016c). This contained a short introduction on the role of the guidelines in protecting public health, as well as the rationale on which the guidelines for each of the four air pollutants were based.

Chapter 9 of the guidelines focused on indoor air pollution, addressing the conditions prevalent in developing countries as a result of indoor combustion of solid fuels, and making some preliminary recommendations for WHO work to be conducted in this area, including a framework for the future development of WHO indoor AQGs. The topic of environmental equity was also addressed (Chapter 6): the unequal distribution of environmental exposure to air pollutants and associated health risks was recognized, and policy implications as well as future research needs discussed.

Although national standards set as a result of the AQGs update vary considerably from country to country, none were set at lower levels than the recommended WHO guidelines. Setting standards below WHO AQGs would be likely to raise complaints from industry about what might be seen as an overcautious approach, considering the common perception that WHO guidelines represent “safe” (or at least safe enough) levels of exposure, and that straining for lower levels simply penalizes industry without benefiting health. Such criticism might be avoided by framing guidelines as concentration–effect relationships, suggesting that every additional reduction in ambient concentrations would be linked with benefits to health.

Finally, the importance of risk communication in relation to air pollution was clearly stated at the end of Chapter 8. Communication of health risks associated with air pollution should be addressed not only to policy-makers but to a wider audience. Public opinion and perception of risk among the general public is viewed as an important factor in influencing decisions, in that "the political capability of decision-makers is directly proportional to the interests and concerns of their constituents". The use of air quality indexes and other tools to inform people about air quality and health was briefly discussed in this section.

Evidence of the effects of air pollutants on health has continued to grow in the years following the publication of the 2005 WHO AQGs global update. The report of an expert review led by the WHO Regional Office for Europe, published in 2013, supported the update's scientific conclusions that adverse health effects occur at air pollutant levels lower than those used to establish the guidelines (WHO Regional Office for Europe, 2013a). Considering the significant expansion of the evidence on air pollution health effects, including their better quantification and detection, the project recommended that WHO should initiate the process of developing new revisions to its ambient AQGs.

Box 6. Highlights of *Air quality guidelines: global update 2005* (WHO Regional Office for Europe, 2006a)

- This was the last WHO publication to date that provided numerical ambient AQGs for PM, ozone, NO_2 and SO_2.
- The same guideline values were retained from the second edition of the WHO AQGs (WHO Regional Office for Europe, 2000) for NO_2, and concentration–response estimates (relative risks) were presented for PM in addition to the guideline values.
- For the first time interim targets were proposed for PM, ozone and SO_2. These were pollutant concentrations associated with a specified increase of mortality risk over that expected at the guidelines level, intended to guide Member States – especially those with high levels of air pollution – in moving towards lower levels of population exposure to ambient air pollution.
- A chapter was devoted to indoor air quality and proposed a framework for the future development of WHO indoor AQGs. The topic of environmental equity was also discussed for the first time, documenting the unequal distribution of health risks due to air pollution within and among nations, and its possible underlying causes.
- The importance of risk communication to a wide range of stakeholders, including the general public, was also addressed and viewed as a necessary component in air quality management.

3.5 *WHO guidelines for indoor air quality*

One of the results of the expert discussions held during the preparation of the 2005 WHO AQGs global update (WHO Regional Office for Europe, 2006a) was the recommendation that WHO should initiate the process of developing WHO guidelines focusing on indoor air quality. Populations spend a substantial proportion of their time in indoor environments, and problems of indoor air pollution were increasingly recognized as important risk factors for human health, requiring different management approaches from those used for outdoor air pollution.

Following the initial plan established in a working group meeting held in Bonn, Germany, in 2006 (WHO Regional Office for Europe, 2006b), WHO developed indoor AQGs on selected chemical and biological contaminants of indoor air, as well as on household fuel combustion (WHO Regional Office for Europe, 2009; 2010; WHO, 2014b).

3.5.1 Dampness and mould

The first volume of *WHO guidelines for indoor air quality* focused on dampness and mould and was published in 2009, as a result of collaboration between the WHO Regional Office for Europe and WHO headquarters (WHO Regional Office for Europe, 2009). Funding was provided by the governments of Germany and the United Kingdom.

These guidelines addressed and reviewed the scientific evidence on health effects resulting from dampness, associate microbial growth and contamination of indoor spaces, considering both private and public spaces. Quantitative guidelines for specific biological agents could not be developed due to the complex nature of the exposure and associated uncertainties, however. Instead, a set of recommendations was provided addressing a number of defined indicators of health risk in indoor environments, such as persistent dampness and presence of mould in buildings – often as a result of insufficient moisture control and ventilation. This decision was based on the evidence showing that excess moisture on almost all indoor materials leads to growth of microbes – such as mould, fungi and bacteria – which subsequently emit spores, cells, fragments and volatile organic compounds into indoor air. Moreover, dampness initiates chemical or biological degradation of materials, which also pollutes indoor air. Dampness has been found to be a strong, consistent indicator of risk of asthma and respiratory symptoms (such as cough and wheeze) in epidemiological studies.

The objective of the guidelines was to raise general awareness and provide a tool for public health authorities on how to identify and reduce the health hazards associated with indoor exposure to biological agents. While they provided recommendations for indoor air quality management, focusing on prevention of persistent dampness and microbial growth on interior surfaces and building structures to minimize the occurrence of associated adverse health effects, they did not give instructions for achieving those objectives. The determination of specific methods to enforce these recommendations was left to the judgement of the competent authorities, allowing for considerations of technical feasibility, level of development, resources available or human capacities, among other factors.

3.5.2 Selected pollutants

The second volume of *WHO guidelines for indoor air quality*, on selected pollutants, was published in 2010 and supported by donations from the governments of Canada, France and the Netherlands (WHO Regional Office for Europe, 2010).

Guidelines were provided for nine indoor air pollutants: benzene, CO, formaldehyde, naphthalene, NO_2, polycyclic aromatic hydrocarbons, radon, trichloroethylene and tetrachloroethylene. The pollutants were selected by the working group of experts who met in 2006 to plan the development of the guidelines (WHO Regional Office for Europe, 2006b). They considered the presence of the pollutants in indoor environments in concentrations of concern for health, as well as the availability of toxicological, epidemiological and clinical data. Regarding indoor exposure to PM, which can be higher than outdoor exposure in the presence of an indoor source of PM, readers were referred to the guideline values on PM from the 2005 WHO AQGs global update (WHO Regional Office for Europe, 2006a), which relate to all environments. A synthesis of the guidelines provided for the nine selected indoor air pollutants is reproduced in Table 15.

The development of these guidelines adopted a similar approach to that used for the previous AQGs for individual air pollutants. A unit risk approach was taken for carcinogenic compounds, as in the 1987 and 2000 AQGs. Note that the recommended guideline values for NO2 remained identical to those recommended in the 2005 WHO AQGs global update (WHO Regional Office for Europe, 2006a), and it was stated that epidemiological studies provided no evidence of a threshold of effect.

Table 15. Summary of indoor AQGs for selected pollutants

Pollutant	Critical outcome(s) for guideline definition	Guidelines	Comments
Benzene	• Acute myeloid leukaemia (sufficient evidence on causality) • Genotoxicity	• No safe level of exposure can be recommended • Unit risk of leukaemia per 1 μg/m³ air concentration is 6 × 10–6 • The concentrations of airborne benzene associated with an excess lifetime risk of 1/10 000, 1/100 000 and 1/1 000 000 are 17, 1.7 and 0.17 μg/m³, respectively	–
Carbon monoxide	Acute exposure-related reduction of exercise tolerance and increase in symptoms of ischaemic heart disease (e.g. ST-segment changes)	• 15 minutes – 100 mg/m³ • 1 hour – 35 mg/m³ • 8 hours – 10 mg/m³ • 24 hours – 7 mg/m³	–
Formaldehyde	Sensory irritation	0.1 mg/m³ – 30-minute average	The guideline (valid for any 30-minute period) will also prevent effects on lung function as well as nasopharyngeal cancer and myeloid leukaemia
Naphthalene	Respiratory tract lesions leading to inflammation and malignancy in animal studies	0.01 mg/m³ – annual average	The long-term guideline is also assumed to prevent potential malignant effects in the airways
Nitrogen dioxide	Respiratory symptoms, bronchoconstriction, increased bronchial reactivity, airway inflammation and decreases in immune defence, leading to increased susceptibility to respiratory infection	• 200 μg/m³ – 1-hour average • 40 μg/m³ – annual average	No evidence for exposure threshold from epidemiological studies
Polycyclic aromatic hydrocarbons	Lung cancer	• No threshold can be determined and all indoor exposures are considered relevant to health • Unit risk for lung cancer for polycyclic aromatic hydrocarbon mixtures is estimated to be 8.7 × 10⁻⁵ per ng/m³ of Benzo[a]pyrene (BaP) • The corresponding concentrations for lifetime exposure to BaP producing excess lifetime cancer risks of 1/10 000, 1/100 000 and 1/1 000 000 are approximately 1.2, 0.12 and 0.012 ng/m³, respectively	BaP is taken as a marker of the polycyclic aromatic hydrocarbon mixture
Radon	Lung cancer Suggestive evidence of an association with other cancers, in particular leukaemia and cancers of the extrathoracic airways	• The excess lifetime risk of death from radon-induced lung cancer (by the age of 75 years) is estimated to be 0.6 × 10⁻⁵ per Bq/m³ for lifelong non-smokers and 15 × 10⁻⁵ per Bq/m³ for current smokers (15–24 cigarettes per day); among ex-smokers, the risk is intermediate, depending on time since smoking cessation • The radon concentrations associated with an excess lifetime risk of 1/100 and 1/1000 are 67 and 6.7 Bq/m³ for current smokers and 1670 and 167 Bq/m³ for lifelong non-smokers, respectively	WHO guidelines provide a comprehensive approach to the management of health risk related to radon
Trichloroethylene	Carcinogenicity (liver, kidney, bile duct and non-Hodgkin's lymphoma), with the assumption of genotoxicity	• Unit risk estimate of 4.3 × 10⁻⁷ per μg/m³ • The concentrations of airborne trichloroethylene associated with an excess lifetime cancer risk of 1:10 000, 1:100 000 and 1:1 000 000 are 230, 23 and 2.3 μg/m³, respectively	–
Tetrachloroethylene	Effects in the kidney indicative of early renal disease and impaired performance	0.25 mg/m³ – annual average	Carcinogenicity is not used as an end-point as there are no indications that tetrachloroethylene is genotoxic and there is uncertainty about the epidemiological evidence and the relevance to humans of the animal carcinogenicity data

Finally, the guidelines addressed measures to reduce the concentrations of air pollutants both outdoors and indoors. The main measure is controlling the primary factor that determines their presence in the air: the source(s) of emission. In indoor environments, in addition, secondary factors (dispersion and dilution) can also be controlled to some extent by, for example, ensuring adequately ventilated spaces or through the use of low-emission materials in buildings and appropriate devices and fuels for indoor combustion. This last point was addressed in detail in the third volume of *WHO guidelines for indoor air quality.*

3.5.3 Household fuel combustion

The *WHO guidelines for indoor air quality* on household fuel combustion were published in 2014, building on the 2005 WHO AQGs global update for PM and carbon monoxide (WHO, 2014b). The project was coordinated by WHO headquarters, and financial support for its completion was obtained from Canada, Germany, the Indian Council for Medical Research, the United Kingdom and the United Nations Foundation Global Alliance for Clean Cookstoves.

The evidence on health effects of indoor air pollution due to combustion of household fuels was reviewed, but the recommendations focused on the reduction of emission rates by targeting the determinants of contamination of indoor spaces, such as the use of certain fuels (coal and kerosene) and types of stoves. This approach was intended to facilitate interventions to improve indoor air quality and reduce health risks due to contamination of indoor spaces by combustion of household fuels, and to reduce safety problems associated with their use (such as burns, poisoning or house fires). The guidelines emphasized that local ambient air quality conditions had to be considered in achieving the proposed indoor AQGs, considering the infiltration of outdoor air into indoor environments.

These were the first AQGs developed following the procedures outlined in the first edition of the WHO handbook for guideline development, published in 2012. This provides guidance on the steps needed to ensure that WHO guidelines are of high methodological quality and are developed through a transparent, evidence-based decision-making process, to guarantee that the final guidelines are free from biases and meet public health needs (WHO, 2012). This handbook, for which a second edition was published in 2014 (WHO, 2014c), provides detailed instructions for guideline developers on the following topics:

- application of high-quality methodology for guideline development using systematic search strategies, synthesis and quality assessment of the best available evidence to support the recommendations;
- appropriate collection and management of experts' declared conflict of interest;
- expert group composition, including content experts, methodologists, target users and policy-makers, with gender and geographical balance;
- instructions for the management of group process to achieve consensus among experts;
- standards for a transparent decision-making process, taking into consideration potential harms and benefits, and end-user values and preferences;
- developing plans for implementing and adapting guidelines; and
- minimum standards for reporting.

4. Update of the WHO global AQGs

Between 2011 and 2013 the WHO Regional Office for Europe coordinated two international projects co-funded by the European Union: Review of evidence on health aspects of air pollution (REVIHAAP) and Health risks of air pollution in Europe (HRAPIE) (WHO Regional Office for Europe, 2013a; 2013b). REVIHAAP provided the European Commission and its stakeholders with evidence-based advice on the latest scientific aspects of air pollution and health in the form of answers (supported by extensive rationale) to a series of policy-relevant questions. This project was grounded on a review conducted by a group of experts of all air pollutants regulated in European directives 2008/50/EC and 2004/107/EC. The output of the second project, HRAPIE, was a technical report recommending CRFs for cost–benefit analysis for several mortality and morbidity effects associated with short- and long-term exposure to PM, ozone and NO_2.

Results from these two projects aimed to support the comprehensive review of European Union air quality policy in 2013. One of the specific expert recommendations from the REVIHAAP project, however, was that WHO should begin the process of revising the current AQGs for ambient air pollutants. This recommendation was based, inter alia, on the availability of a large amount of scientific information that had emerged since the last ambient AQGs were published in 2006, including findings revealing associations between ambient air pollutants and adverse health effects at concentrations lower than previously identified.

As a result, and in preparation for an update of the AQGs, a global consultation meeting was organized by the WHO Regional Office for Europe in 2015 to obtain expert advice on air pollutants and other issues relevant to be considered in the future guidelines. Experts discussed the latest available scientific evidence on the health effects of 32 ambient air pollutants for which WHO had developed AQGs in the past, as well as the occurrence and trends of these pollutants in ambient air. The topic of air quality interventions to reduce ambient air pollution and improve public health was also discussed as part of this consultation (WHO Regional Office for Europe, 2016). The conclusions of the expert consultation contributed to the scoping of the content of the next update of the WHO global AQGs.

The update of the WHO global AQGs thus initiated is so far receiving funding and in-kind support from the European Commission (Directorate-General for Environment) and the governments of Germany, Switzerland and the United States of America. It is expected that the next AQGs will provide updated numerical concentration limits and, where possible, an indication of the shape of the CRFs for PM_{10}, $PM_{2.5}$, ozone, NO_2, SO_2 and CO, for short- and/or long-term exposure. Further, a statement on the relationship between exposure to mineral dust of natural origin and health outcomes will also be developed, based on a review of the latest evidence.

The process of updating the WHO global AQGs will follow the requirements described in the second edition of the *WHO handbook for guideline development* (WHO, 2014c). It will face the challenge of ensuring a comprehensive systematic review of the enormous amount of new scientific evidence related to the topic of the guidelines. It will also need to use Grading of recommendations assessment, development and evaluation (GRADE), which is the methodological framework adopted by WHO to assess the quality of the body of evidence for guideline development (GRADE Working Group, 2016). This framework was initially developed in the context of clinical guidelines and interventions; it will therefore need to be adapted to the area of environmental health. This is a current topic of discussion and a work in progress by many experts in the field (Morgan et al., 2016).

The process will benefit from new available studies performed in various environmental, social and health conditions, and will face the challenge of integrating results from different geographical locations with heterogeneous levels and sources of air pollutants, in order to provide recommendations of global application.

The updated AQGs will also address, in general terms, air quality management and the importance of reducing emissions of harmful air pollutants, which is the most effective way to improve air quality and protect populations from the adverse health effects of air pollution. As their effectiveness is highly context dependent, however, no recommendations for specific air quality interventions will be developed in the updated guidelines.

Future issues of the AQGs may consider developing evidence-based recommendations on the effectiveness of available personal interventions to decrease individual exposure to ambient air pollutants and associated health effects, like the use of protective equipment (face masks, air filters and similar) or following certain behavioural recommendations in daily activities, such as reducing outdoor exercise during peaks of air pollution. Nevertheless, inclusion of these recommendations in the next update of the AQG will depend on the availability of additional resources.

5. Final remarks

WHO's work on air pollution and health, and in particular the various AQGs for ambient and indoor air pollutants, have made a most important contribution to the synthesis of the latest knowledge on the health effects of air pollutants. They have provided expert and detailed guidance to regulatory authorities since the publication of the first edition of the WHO AQGs (WHO Regional Office for Europe, 1987). It has repeatedly been stressed that the guidelines are not intended to be taken as recommendations for air quality standards per se, but rather as a rigorous scientific tool that can be used by regulatory authorities as a basis for setting standards, taking into account local sociopolitical and economic conditions and prevailing ambient concentrations of air pollutants. Cost–benefit analysis of various pollution reduction options is an increasingly common tool supporting development of air quality policies. The evaluation of evidence provided by the WHO guideline process, and not only the numerical guidelines, is an essential input to such analysis.

Achievement of clean outdoor and indoor air is recognized as a basic right, and WHO activities in the air pollution field for the past 60 years have contributed substantially in moving towards this goal. That such work should be continued is beyond doubt, especially considering recent data ranking air pollution among the top risks for mortality and lost years of healthy life globally, which affects everyone in developed and developing countries, in both urban and rural areas. This was recognized in the roadmap for an enhanced global response to the adverse health effects of air pollution, presented by WHO at the Sixty-ninth World Health Assembly (WHO, 2016d), in which further development of the AQGs is included as an element of "expanding the knowledge base" – one of the cornerstones of the global action.

Disclaimer: the views presented here reflect those of the authors and should not be taken as reflecting the views of WHO.

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The WHO Regional Office for Europe

The World Health Organization (WHO) is a specialized agency of the United Nations created in 1948 with the primary responsibility for international health matters and public health. The WHO Regional Office for Europe is one of six regional offices throughout the world, each with its own programme geared to the particular health conditions of the countries it serves.

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12. Appendix 2

2019	2022 without development	2022 with development	% reduction for 'without development' option
1000	983	985	1.70%
1016	995	995	2.07%
956	937	937	1.99%
1016	995	995	2.07%
1004	984	986	1.99%
743	728	728	2.02%
671	659	659	1.79%
753	722	723	4.12%
890	872	918	2.02%
875	858	858	1.94%
890	872	918	2.02%
745	715	716	4.03%
1157	1134	1134	1.99%
283	271	271	4.24%
286	282	275	1.40%
2	2	2	0.00%
26	26	25	0.00%
41	41	44	0.00%
188	187	187	0.53%
54	48	52	11.11%
78	78	79	0.00%
10	10	10	0.00%
138	136	136	1.45%
637	623	669	2.20%
33	32	32	3.03%
22	23	23	-4.55%
73	72	72	1.37%
129	127	126	1.55%
0	0	0	
0	0	0	
99	98	98	1.01%
101	99	96	1.98%
753	734	734	2.52%
0	0	0	
3244	3178	3178	2.03%
2164	2120	2120	2.03%
3407	3337	3337	2.05%
607	594	594	2.14%
444	435	435	2.03%
446	437	437	2.02%
846	829	829	2.01%
5716	5599	5599	2.05%
6115	5991	5991	2.03%
35	35	34	0.00%
33	32	32	3.03%
33	32	31	3.03%
4	4	4	0.00%
0	0	0	

2019	2022 without development	2022 with development	% reduction for 'without development' option	
57	56	55	1.75%	
62	61	61	1.61%	
364	357	357	1.92%	
16	22	21	-37.50%	
84	82	82	2.38%	
192	189	189	1.56%	
184	181	181	1.63%	
0	0	0		
269	270	270	-0.37%	
207	219	215	-5.80%	
0	0	0		
4	4	4	0.00%	
235	238	238	-1.28%	
71	76	77	-7.04%	
106	110	110	-3.77%	
404	396	396	1.98%	
40018	39227	39360	1.98%	1.64%