WHO Global Air Quality Guidelines 2021

Setting ambitious goals for air quality to protect public health

May 16, 2023

Dr. Tom Luben, U.S. EPA

What are the WHO Air Quality Guidelines?

- Based on extensive scientific evidence, the AQGs identify the levels of air quality necessary to **protect public health worldwide.**
- They provide recommendations on **air quality guidelines levels** (and interim targets) for **$PM_{2.5}$ and PM_{10}**, **O_3**, **NO_2**, **SO_2** and **CO,** and qualitative good practice statements for certain types of particulate matter.
- Guideline levels can be used as an **evidence-informed reference** to help decision-makers in setting legally binding standards and goals for air quality management.
- They are an **instrument to design effective measures** to achieve reduction of air pollution, and therefore, to protect human health.

WHO Global Air Quality Guidelines 2021

Setting ambitious goals to reduce air pollution

What is new in the AQGs?

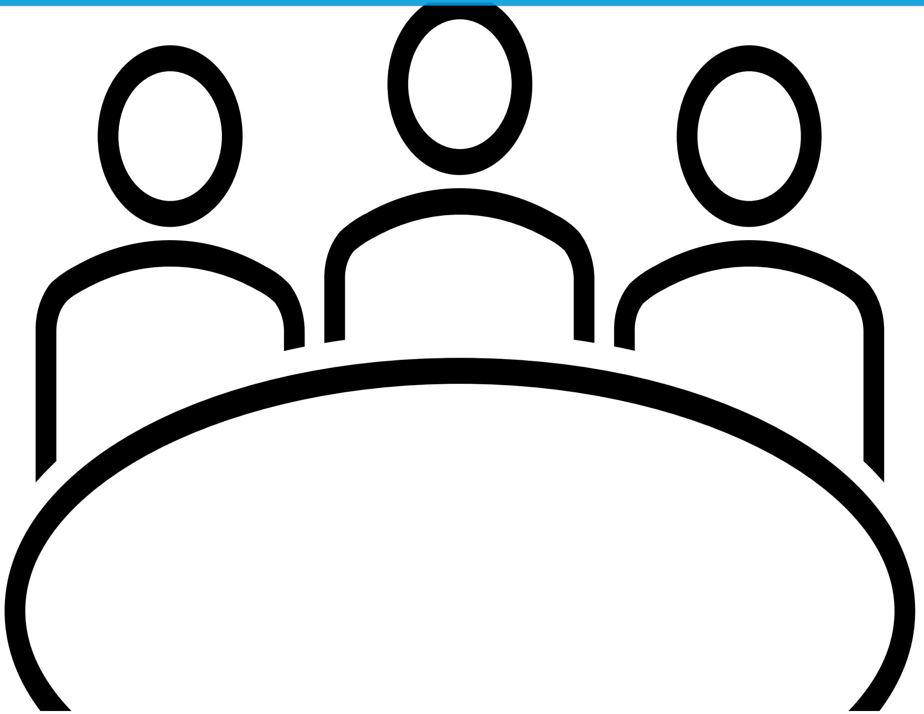
Why are the AQGs so important for health?

How were these guidelines developed?

How can these guidelines be used?

What can countries do with them?

How were these guidelines developed?



Guideline development

Main steps

1. Systematic review process
2. Grading the evidence
3. Developing recommendations

Involved Groups

Systematic Review Team

- External Review Group

Guideline Development Group

- External Review Group

WHO Steering Group

The scope of the AQGs

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Selection of pollutants

Scoping the guidelines involved the selection of air pollutants, and the critical health outcomes for each air pollutant in relation to durations of exposure.

The guideline development group (GDG) considered different criteria

The GDG decided to develop AQGs levels (with interim targets) for particulate matter PM_{10} and $PM_{2.5}$, O_3, NO_2, SO_2 and CO, and good practice statements for black/elemental carbon, ultrafine particles and sand & duststorms

What the AQGs are not/do not include

- The WHO AQGs are not legally binding. They are a set of recommendations, which may serve a reference for setting standards or policies
- They do not apply to occupational settings, but all others (including outdoor and indoor)
- They do not include recommendations about joint effects of multiple exposures.
- They do not address specific recommendations on policies and interventions because these are largely context specific
- They do not cover all air pollutants, but all previous WHO guidelines not updated remain valid

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Systematic reviews of evidence

Short-term exposure to O_3, NO_2 and SO_2 and asthma

Long-term exposure to O_3 and NO_2 and all-cause and cause-specific mortality

Long-term exposure to PM and all-cause and cause-specific mortality

Short-term exposure to SO_2 and all-cause and cause-specific mortality

Short-term exposure to CO and ischaemic heart disease

Short-term exposure to PM, NO_2 and O_3 and all-cause and cause-specific mortality

https://www.sciencedirect.com/journal/environment-international/special-issue/10MTC4W8FXJ

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GRADE - the framework to assess the quality of the evidence for WHO guidelines

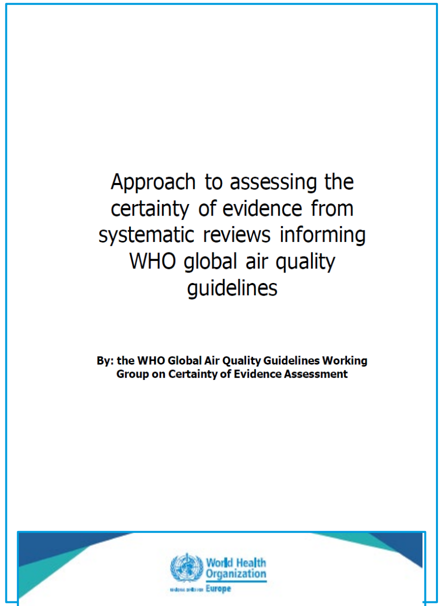
Reflects the confidence that the estimates of an effect are adequate to support a particular decision/recommendation

Implemented to evaluate evidence in support of formulation of clinical guidelines

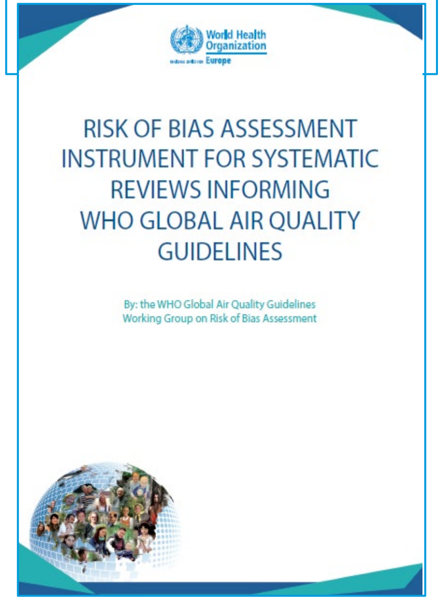
Randomised study design rated as of high quality at the outset

Several factors assessed for downgrading and upgrading the certainty of evidence

- Designed specifically to assess the certainty of the evidence from the systematic reviews commissioned to inform the update of WHO AQGs
- Guided systematic review team on the use of GRADE criteria for observational studies of exposure
- The ratings were subsequently used in the process of deriving AQG levels
- Extensively discussed at the GDG meetings, pilot tested by the systematic review team and improved iteratively


Approach to assessing the certainty of evidence from systematic reviews informing WHO global air quality guidelines

By: the WHO Global Air Quality Guidelines Working Group on Certainty of Evidence Assessment


World Health Organization
Europe

RISK OF BIAS ASSESSMENT INSTRUMENT FOR SYSTEMATIC REVIEWS INFORMING WHO GLOBAL AIR QUALITY GUIDELINES

By: the WHO Global Air Quality Guidelines Working Group on Risk of Bias Assessment

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From evidence to recommendations

Eight step procedure to move from the evidence in systematic reviews to AQG levels

Long-term AQG levels

Means of lowest 5th percentiles of study population distributions.

After evaluating the certainty of evidence at those low exposure levels and comparing these values across critical health outcomes, the AQG level was set.

Short-term AQG levels

Slight modifications on steps 2 and 3.

99th percentiles of distributions of 24-h mean concentrations matching the long-term AQG levels.

If a long-term AQG level was not set for a given pollutant (SO_2 and CO), its specified and justified low concentration.

The recent database of the MCC Collaborative Research Network was used for calculation of ratios of percentiles of daily concentrations to annual means.

From evidence to recommendations in a nutshell

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Eight step procedure to move from the evidence in systematic reviews to AQG levels

1. RR estimates and CRF
2. The lowest level of exposure measured
3. Minimal relevant increase in health outcome
4. Starting point for AQG determination
5. Compare the AQG level across critical health outcomes (cause-specific mortality)
6. Certainty of the evidence
7. New evidence
8. Reconsider causality

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Three scenarios for short-term AQG levels

Scenario	Description
Scenario 1	Development of a short-term AQG level for a pollutant for which a long-term AQG level for the same outcome was developed (e.g. all-cause mortality)
Scenario 2	Development of a short-term AQG level for a pollutant for which a long-term AQG level was developed for another outcome (e.g. hospital admissions and emergency room visits related to asthma versus all-cause mortality)
Scenario 3	Development of a short-term AQG level for a pollutant for which no long-term AQG level was developed

Example: short-term AQG level for NO_2

- Scenario 1 (all-cause mortality + morbidity, daily hospital admissions for asthma)
- Ratio of 99th percentile of distributions of 24-h means to mean of distribution
- Mean equal to long-term AQG (10 μg/m^3)
- Ratio from MCC database: ~2.5
- Short-term AQG level: 25 μg/m^3
- Excess mortality and morbidity at a day at the short-term AQG level, relative to a day at the long-term AQG level: 1.1% (mortality) and 2.1% (morbidity) (based on RRs from systematic reviews)
  - Under compliance with the long-term AQG level, days with concentrations close to 25 μg/m^3 will be rare, most days will have much lower values, with close to half having concentrations below or far below the annual AQG level.
  - The health burden related to a few days with higher concentrations corresponds to a very small fraction of the total air pollution-related burden.

Example: Short-term NO_2 Exposure

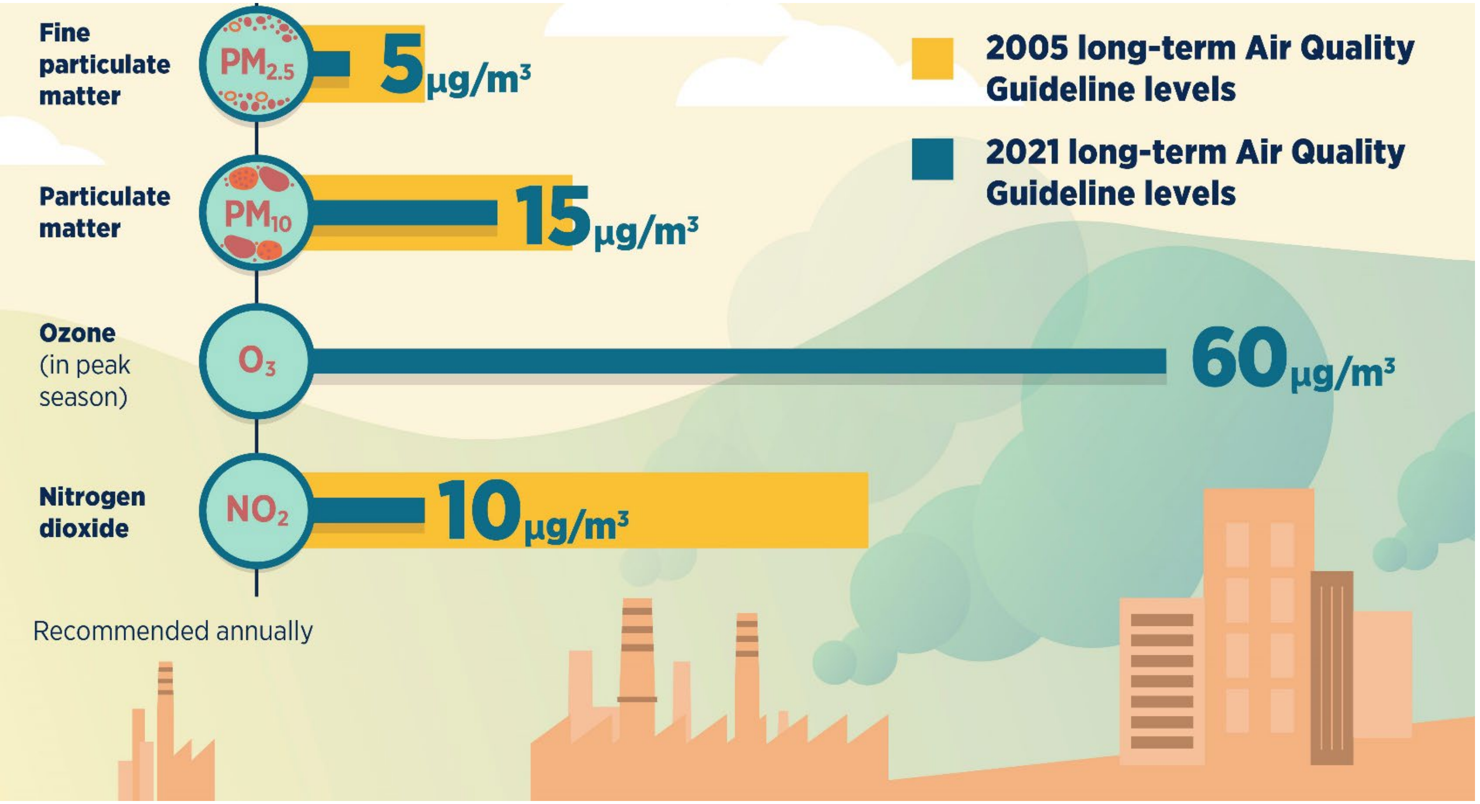
Step	Description
Step 1	Assess RR estimates and, when available, CRF for each critical health outcome per pollutant as provided by the systematic review.
Step 2	Determine the lowest level of exposure measured in the studies included in the systematic review or in the subset of studies in the systematic review that estimate risk at this lowest level. For individual studies that used statistical models to evaluate the shape of the CRF, ensure that the lowest level of exposure is associated with a monotonic increase of the CRF curve
Step 3	Determine the minimal relevant increase in health outcomes
Step 4	Determine the starting point for AQG level determination as the long-term concentration of pollutant from which the minimal relevant amount of the health outcome will result
Step 5	Compare the AQG levels for a specific pollutant across critical health outcomes. Take as the final AQG level the lowest AQG level found for any of the critical health outcomes
Step 6	Assess the certainty of the evidence at low levels of exposure. The adapted GRADE assessment is for the entire body of evidence, not the subset of studies conducted at the lowest exposure levels. The evidence provided by these latter studies needs to be discussed, starting from the RoB assessment that was conducted at individual study level
Step 7	Consider new relevant evidence not included in the systematic reviews in a qualitative or, where possible, quantitative manner
Step 8	Reconsider causality of associations between pollutants and outcomes, taking into account whether or not associations have been classified as causal or likely causal in recent reviews by authoritative bodies

-For short-term AQG levels for $PM_{2.5}$, PM_{10}, O_3 and NO_2, a comparison was made between health outcome at the 99th% of daily distributions corresponding to a distribution with the long-term AQG levels.

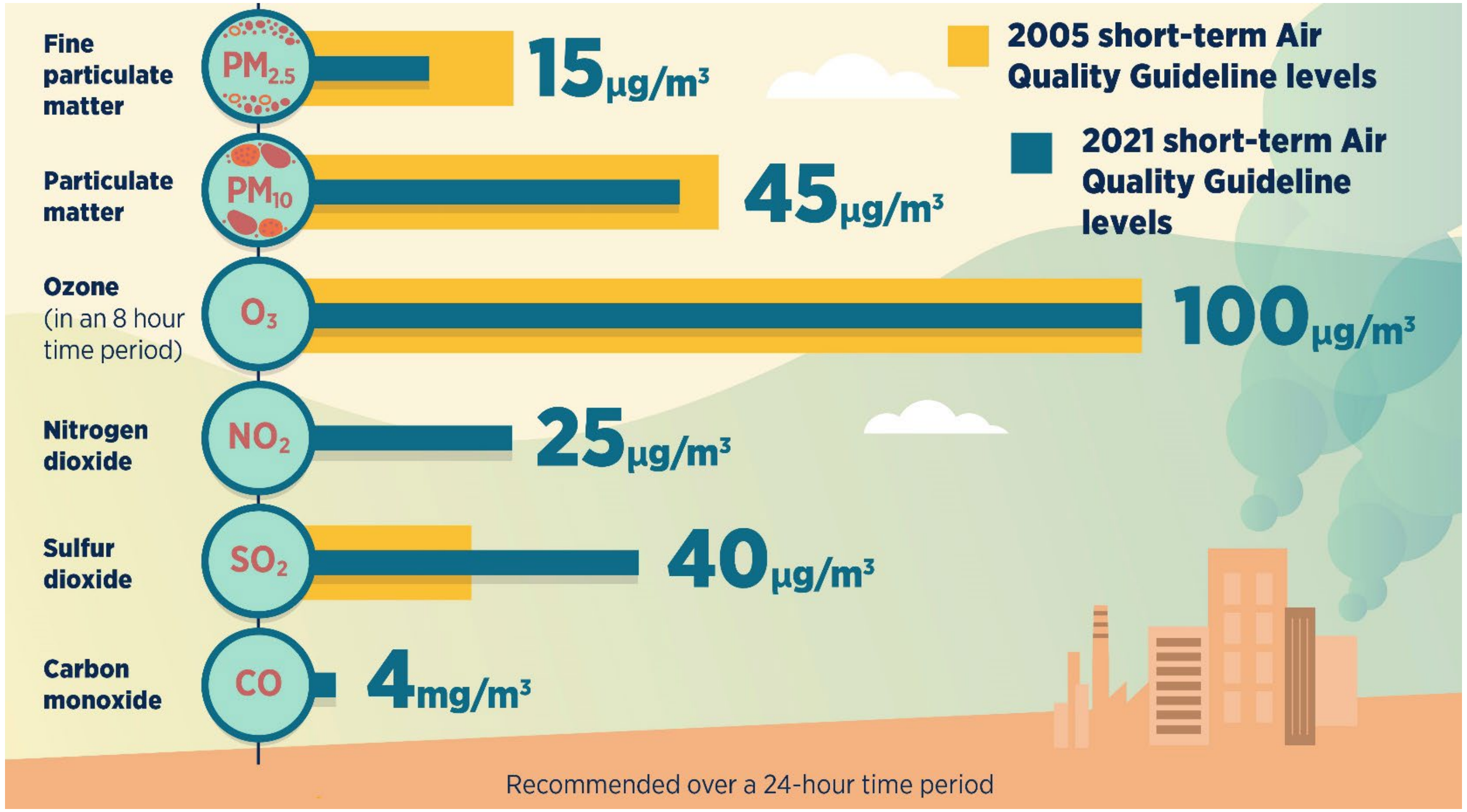
-Ratio of 2.5 between 99^{th}% of daily concentrations and annual mean NO_2 concentrations observed across multiple locations (Liu et al. 2019)

-Ratio of ~2.5 between the 99th% and annual mean, of 10 µg/m^3,= 25 µg/m^3

Long-term AQG levels



Short-term AQG levels



What the AQGs provide…

Summary of recommended AQG levels and interim targets

Pollutant	Averaging time	IT1	IT2	IT3	IT4	AQG level
$PM_{2.5}$, µg/m³	Annual	35	25	15	*10*	5
$PM_{2.5}$, µg/m³	24-hour[a]	75	50	37.5	*25*	15
PM_{10}, µg/m³	Annual	70	50	30	*20*	15
PM_{10}, µg/m³	24-hour[a]	150	100	75	*50*	45
O_3, µg/m³	Peak season[b]	100	70	–	–	60
O_3, µg/m³	8-hour[a]	160	120	–	–	100
NO_2, µg/m³	Annual	*40*	30	20	–	10
NO_2, µg/m³	24-hour[a]	120	50	–	–	25
SO_2, µg/m³	24-hour[a]	125	50	–	–	40
CO, mg/m³	24-hour[a]	7	–	–	–	4

Air quality guideline levels for both long- and short-term exposure in relation to critical health outcomes.

Interim targets to guide reduction efforts for the achievement of the air quality guideline levels.

Good practice statements in the management of certain types of particulate matter for which evidence is insufficient to derive quantitative air quality guideline levels, but points to their health relevance.

How can the updated AQGs be used?

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AS AN EVIDENCE-INFORMED TOOL

The AQGs are an evidence-informed tool for decision-makers to guide legislation and policies, to reduce levels of air pollutants and decrease the health burden that results from air pollution exposure worldwide.

Everybody has a role to play

TO STIMULATE RESEARCH

Air pollution researchers and academics can use it to help identify critical data gaps that future research agendas could address to better protect the population from the harmful effects of air pollution.

FOR CLIMATE ACTION

Efforts to improve air quality can enhance climate change mitigation, and climate change mitigation efforts can, in turn, improve air quality. All this enhance people's health.

AQGs are a power tool for climate action

What can countries do with the AQGs?

Key points

- Countries can **use the AQGs as a tool** to guide, drive and support the selection and adoption of measures to reduce exposure to air pollution:
    - Establish or ***update their legally binding air quality standards and develop policies***.
    - ***Strengthening multisectoral cooperation*** at national, regional, and international levels, and advocating for air quality.
    - Taking effective steps to ***reduce health inequities*** related to air pollution.
- Actions to reduce air pollution require cooperation of various sectors and stakeholders.
- Health sector is crucial in raising awareness, gathering evidence, advising people on how to mitigate impacts, and joining advocacy efforts.

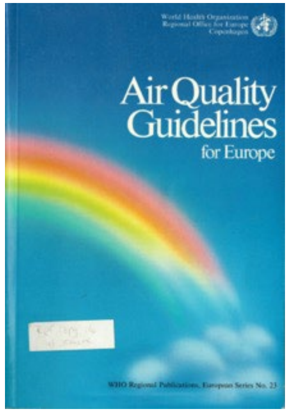
Dr. Tom Luben
U.S Environmental Protection Agency
Luben.tom@epa.gov

Thank You!

WHO global air quality guidelines. Particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. Geneva: World Health Organization; 2021. Licence: CC BY-NC-SA 3.0 IGO.
https://apps.who.int/iris/handle/10665/345329
https://www.who.int/news/item/22-09-2021-new-who-global-air-quality-guidelines-aim-to-save-millions-of-lives-from-air-pollution

Supplemental Slides

WHO Air Quality Guidelines



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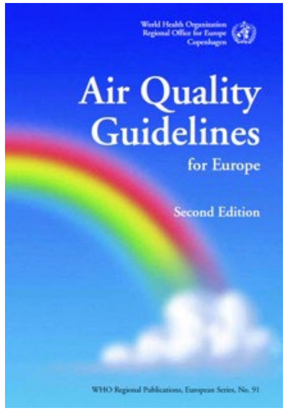

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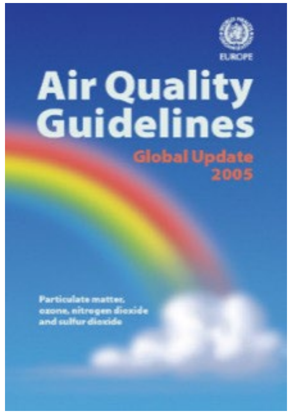


2006

since 2016

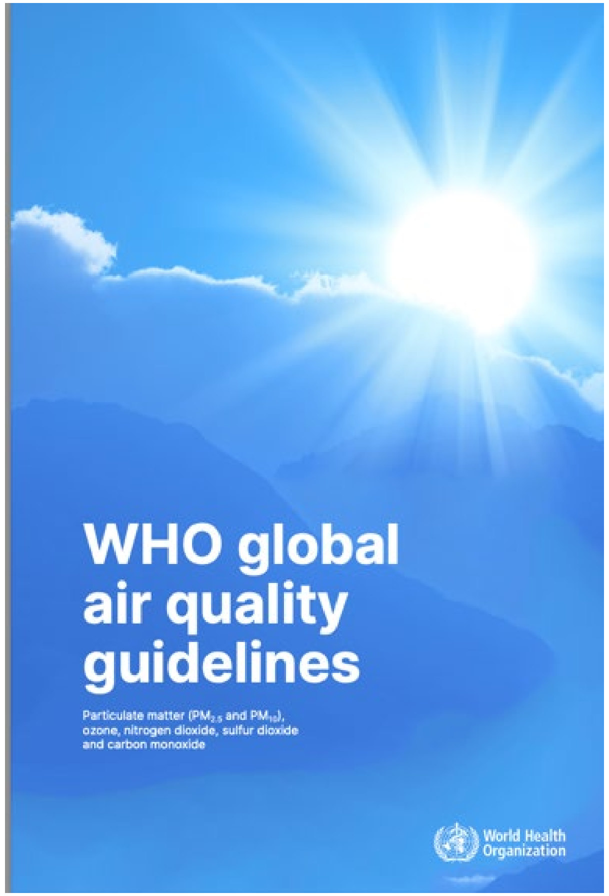
Robust public health recommendations

Support informed decision-making

Intended for worldwide use

Comprehensive assessment of the evidence

What is new in these AQGs 2021?



- Since the last 2005 global update, there has been a marked increase in the quality and quantity of evidence that shows how air pollution affects different aspects of health.
- There are also now clearer insights about sources of emissions and the contribution of air pollutants to the global burden of disease.
- For that reason, and after a systematic review of the accumulated evidence, **several of the updated AQG levels are now lower than 15 years ago.**
- New features include new AQG levels for peak-season O_3 and 24-h NO_2 and CO, as well as new interim targets.

How will WHO support this process?

- In the European Region 94% of countries have standards for at least one pollutant. AQGs can help to update standards and add more pollutants to the list.
- **WHO is ready to support Member States and the EU in implementing the guidelines**
- Science-policy dialogues within and among Member States and with sectors and stakeholders
- Advocacy to support the uptake of AQGs and how to apply them
- Capacity building in the health and other sectors

Systematic reviews of evidence

Pablo Orellano, Julieta Reynoso, Nancy Quaranta, Ariel Bardach, Agustin Ciapponi. *Short-term exposure to particulate matter (PM10 and PM2.5), nitrogen dioxide (NO2), and ozone (O3) and all-cause and cause-specific mortality: Systematic review and meta-analysis*

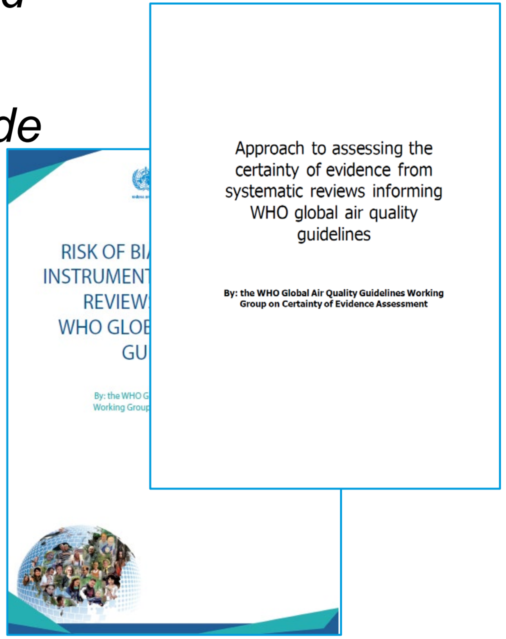
Kuan Ken Lee, Nicholas Spath, Mark R. Miller, Nicholas L. Mills, Anoop S.V. Shah. *Short-term exposure to carbon monoxide and myocardial infarction: A systematic review and meta-analysis.*

Jie Chen, Gerard Hoek. *Long-term exposure to PM and all-cause and cause-specific mortality: A systematic review and meta-analysis.*

Peijue Huangfu, Richard Atkinson. *Long-term exposure to NO2 and O3 and all-cause and respiratory mortality: A systematic review and meta-analysis*

Pablo Orellano, Julieta Reynoso, Nancy Quaranta. *Short-term exposure to sulphur dioxide (SO2) and all-cause and respiratory mortality: A systematic review and meta-analysis*

Xue-yan Zheng, Pablo Orellano, Hua-liang Lin, Mei Jiang, Wei-jie Guan. *Short-term exposure to ozone, nitrogen dioxide, and sulphur dioxide and emergency department visits and hospital admissions due to asthma: A systematic review and meta-analysis*



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GRADE adaptation in the context of an update of WHO AQGs

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- Designed specifically to assess the certainty of the evidence from the systematic reviews commissioned to inform the update of WHO AQGs
- Guided systematic review team on the use of GRADE criteria for observational studies of exposure
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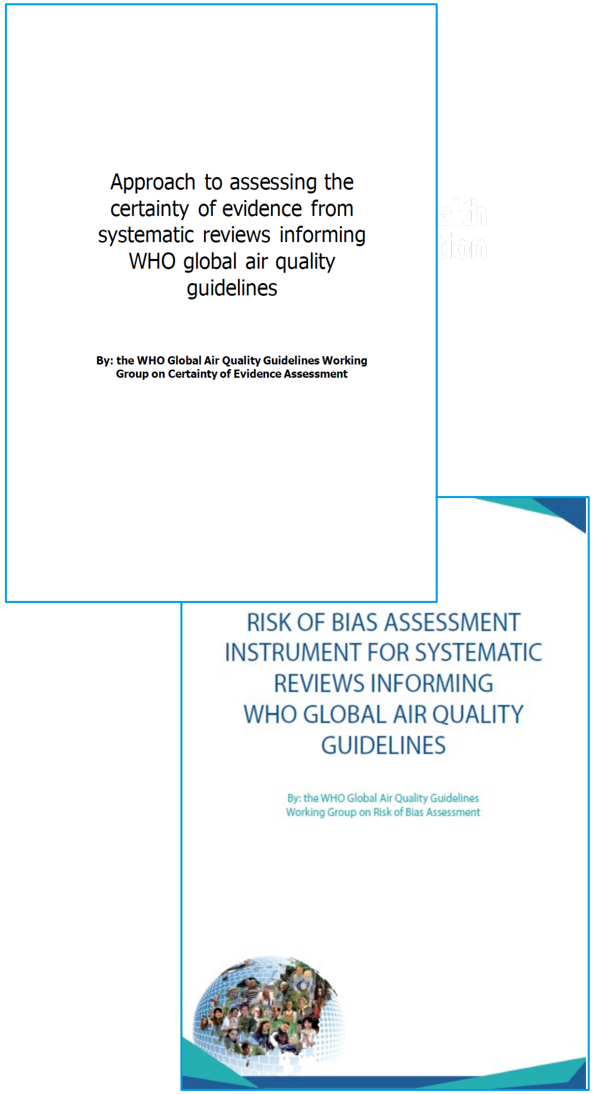

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- Start the rating of the certainty of the evidence for observational studies as moderate certainty evidence
- The certainty of the evidence from this level could be downgraded or upgraded, based on the criteria per GRADE domain
- Domains to be treated equally and independently
- Incorporation of some additional criteria to complement existing guidance

Steps in formulation of AQG levels

Step	Description
Step 1	Assess RR estimates and, when available, CRF for each critical health outcome per pollutant as provided by the systematic review.
Step 2	Determine the lowest level of exposure measured in the studies included in the systematic review or in the subset of studies in the systematic review that estimate risk at this lowest level. For individual studies that used statistical models to evaluate the shape of the CRF, ensure that the lowest level of exposure is associated with a monotonic increase of the CRF curve
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Step 7	Consider new relevant evidence not included in the systematic reviews in a qualitative or, where possible, quantitative manner
Step 8	Reconsider causality of associations between pollutants and outcomes, taking into account whether or not associations have been classified as causal or likely causal in recent reviews by authoritative bodies

Example: Long-term PM2.5 Exposure

Step 2. Determine the lowest level of exposure measured

"The five lowest levels reported or estimated in these studies were 3.0 μg/m^3 (Pinault et al. 2016), 3.2 μg/m^3 (Cakmak et al. 2018), 3.5 μg/m^3 (Pinault et al. 2017), 4.8 μg/m^3 (Villeneuve et al. 2015) and 6.7 μg/m^3 (Weichenthal et al. 2014). Weichenthal et al. (2014) found no effect. The Villeneuve et al. (2015) study provided no evidence of an effect of PM2.5 on all non-accidental mortality below 8 μg/m^3. The study by Di et al. (2017a) has the next lowest 5th percentile (7.1 μg/m^3) and the study by Hart et al. (2015) the next lowest (7.8 μg/m^3). The average $PM_{2.5}$ level across these five studies with the lowest exposure measurements … (disregarding the Villeneuve et al. (2015) and Weichenthal et al. (2014) studies) produced a mean of 4.9 μg/m^3 $PM_{2.5}$"

$$(3.0 + 3.2 + 3.5 + 7.1 + 7.8)/5 = 4.92$$

Table 3.2. Studies on long-term $PM_{2.5}$ exposure and all non-accidental mortality included in the systematic review by Chen & Hoek (2020), ordered by me(di)an concentration

Study	Me(di)an (μg/m^3)	SD	P5	P25	HR (95% CI)[a]
Pinault et al. (2016)	5.9	–	3.0[b]	4.2	1.26 (1.19–1.34)
Cakmak et al. (2018)	6.5	2.0	3.2[c]	–	1.16 (1.08–1.25)
Pinault et al. (2017)	7.1	–	3.5[b]	5.4	1.18 (1.15–1.21)
Weichenthal et al. (2014)	9.5	1.7	6.7[b]	–	0.95 (0.76–1.19)
Villeneuve et al. (2015)	9.5	3.5	4.8[b]	–	1.12 (1.05–1.20)
Di et al. (2017a)	11.5	2.9	7.1[b]	9.5	1.08 (1.08–1.09)
Parker, Kravets & Vaidyanathan (2018)	11.8	–	–	10.1	1.03 (0.99–1.08)
Bowe et al. (2018)	11.8	–	7.9[b]	10.2	1.08 (1.03–1.13)
Hart et al. (2015)	12.0	2.8	7.8[b]	10.2	1.13 (1.05–1.22)
Turner et al. (2016)	12.6	2.9	7.8[c]	–	1.07 (1.06–1.09)
Carey et al. (2013)	12.9	1.4	10.6[c]	–	1.11 (0.98–1.26)

Example: Long-term PM2.5 Exposure; C-R Function

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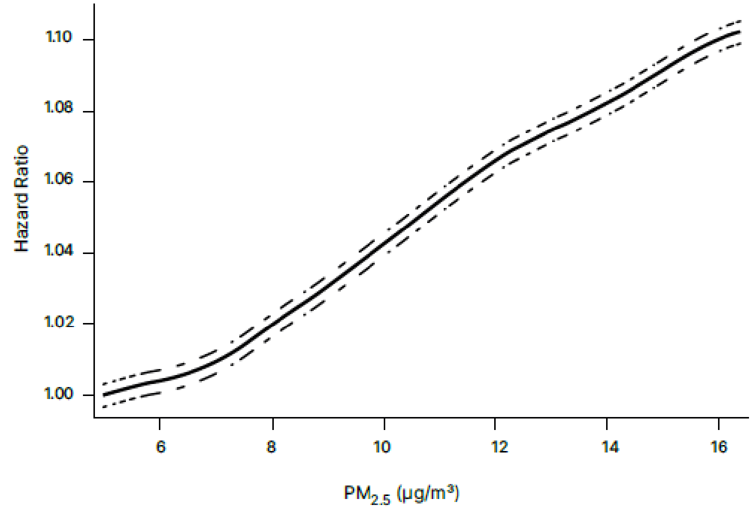
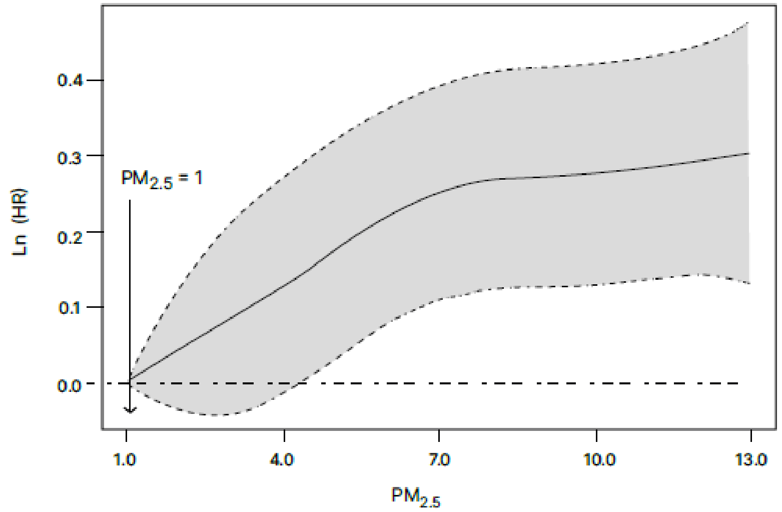
Fig. 3.4. CRF for long-term $PM_{2.5}$ exposure (μg/m³) and all non-accidental mortality



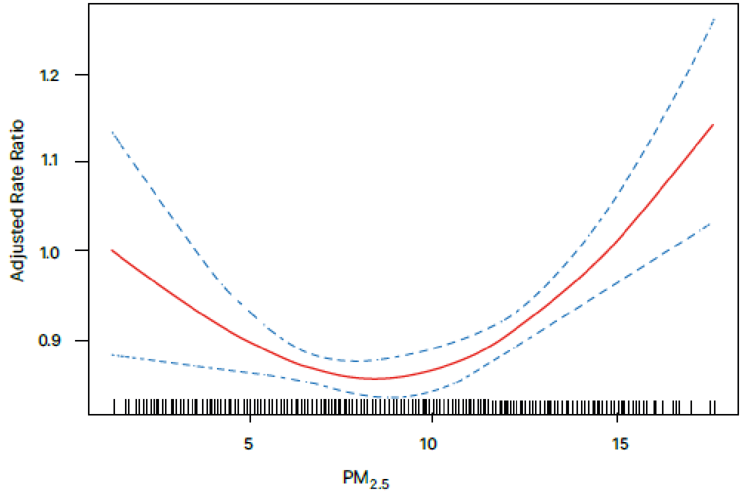
Source: reprinted from Di et al. (2017a) with permission from the Massachusetts Medical Society. Copyright © 2017 Massachusetts Medical Society.

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



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

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



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Example: Short-term SO_2 Exposure

Why is the 24-hour sulfur dioxide higher than the 2005 AQG?

The 24-hour AQG level for sulfur dioxide of 40 μg/m³ was recommended based on a new evaluation of the effects of short-term sulfur dioxide concentrations on all-cause and respiratory mortality. This AQG level is higher than the 2005 24-hour AQG level, **because a single, formal method was used that was the same for all 2021 short-term AQG levels**. No such formal method was applied to derive a guideline value in 2005.

In comparison, the recommended 24-hour AQG level of 40 μg/m³ is better motivated, and coherent with the approaches followed in the recommendations for short-term AQG levels for the other pollutants covered in this report.