WHO ambient air quality database

2022 update

Status report

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Introduction

This document describes the latest WHO database on ambient air quality. Since 2011, WHO has been compiling and publishing ground measurements of air quality and, specifically, the annual mean concentrations of particulate matter with a diameter ≤ 2.5 µm ($PM_{2.5}$) and ≤ 10 µm (PM_{10}). The objective – beyond summarizing the current state of air quality – is to collect data on air quality that could be used to derive robust estimates of population exposure for studies of the burden of disease analysis due to ambient air pollution *(1, 2)*. The database thus fulfils part of WHO's custodial role for indicators 11.6.2 (Air quality in cities) and 3.9.1 (Mortality from air pollution) of the Sustainable Development Goals.

The recent update of the WHO air quality guidelines, a set of evidence-based recommendations for limit values of specific air pollutants, provides clear evidence of the damage that air pollution inflicts on human health, at even lower concentrations than previously recognized. The guidelines recommend new air quality levels to protect the health of populations, and reducing the levels of key air pollutants will also contribute to slowing climate change *(3)*. Pollutants for which new guidelines for annual mean have been set are $PM_{2.5}$, with guideline value half the previous one, PM_{10}, which is decreased by 25%, and that for nitrogen dioxide (NO_2), which is four times lower than the previous guideline (Table 1).

Table 1. Recommended levels and interim targets (in µg/m^3) for an annual averaging time

Pollutant	Interim target				AQG (2021)	AQG (2005)
	1	2	3	4		
$PM_{2.5}$	35	25	15	*10*	**5**	10
PM_{10}	70	50	30	*20*	**15**	20
NO_2	*40*	30	20		**10**	40

AQG: WHO air quality guidelines.

The new guidelines are designed to help countries achieve air quality that protects public health. They have been welcomed by the health community, medical societies and patient organizations *(4)*. The guidelines are not legally binding but serve as benchmarks to guide countries in deriving national air quality standards. As indicated in a recent report by the United Nations Environment Programme, "there is no common legal framework for Ambient Air Quality Standards (AAQS) globally and that effective enforcement of AAQS remains a significant legal challenge. Many countries lack legislation that sets AAQS or requires air quality monitoring and only a few address transboundary air pollution" *(5)*.

In its previous versions (2011, 2014, 2016 and 2018), the database contained data only on particulate matter ($PM_{2.5}$ and PM_{10}). Data on NO_2 are included in this fifth update.

The early focus on PM reflected its worldwide ubiquity, and it is the most widely used indicator for assessing the health effects of exposure to air pollution. PM originates from many different sources, such as transport, power plants, agriculture, waste burning, industry and natural sources *(6)*. PM may be emitted directly or may be a product of chemical processes in the atmosphere, where it may be transported over long distances. A consequence of the latter is transboundary PM, which makes it even more difficult to control local air quality *(7)*. PM can penetrate deep into the lung and enter the bloodstream, causing cardiovascular, cerebrovascular (stroke) and respiratory diseases *(8)*. There is emerging evidence that PM also affects other organs and diseases *(9, 10)*.

NO_2 originates primarily from anthropogenic fuel combustion (e.g. from traffic) and is especially common in urban areas. Exposure to NO_2 is associated with respiratory disease (including asthma), with symptoms such as coughing, wheezing and difficulty in breathing and more hospital admissions and visits to emergency rooms *(11)*; it may also contribute to the development of asthma *(12)* and increase susceptibility to respiratory infections *(13)*. This pollutant is also correlated with carbon dioxide and contributes to the formation of ozone and $PM_{2.5}$; therefore, any reduction in NO_2 can have co-benefits for health and the climate.

Availability of data

The 2022 version of the WHO ambient air quality database includes annual means for PM_{10}, $PM_{2.5}$ and NO_2 for the years between 2010 and 2019 and it covers 6743 human settlements in 117 countries worldwide.

The settlements range in size from < 100 to > 30 million inhabitants. As more than 50% of the settlements have over 50 000 inhabitants and are designated as urban centres or cities by the United Nations Statistical Commission *(14)* (Table 2), the database is often referred to as an "urban air quality database". However, > 25% of settlements covered in the database have fewer than 15 000 residents, and a limited proportion (mostly in Europe) have fewer than 1500 inhabitants. These town and rural settlements may, however, be located near larger urban agglomerations.

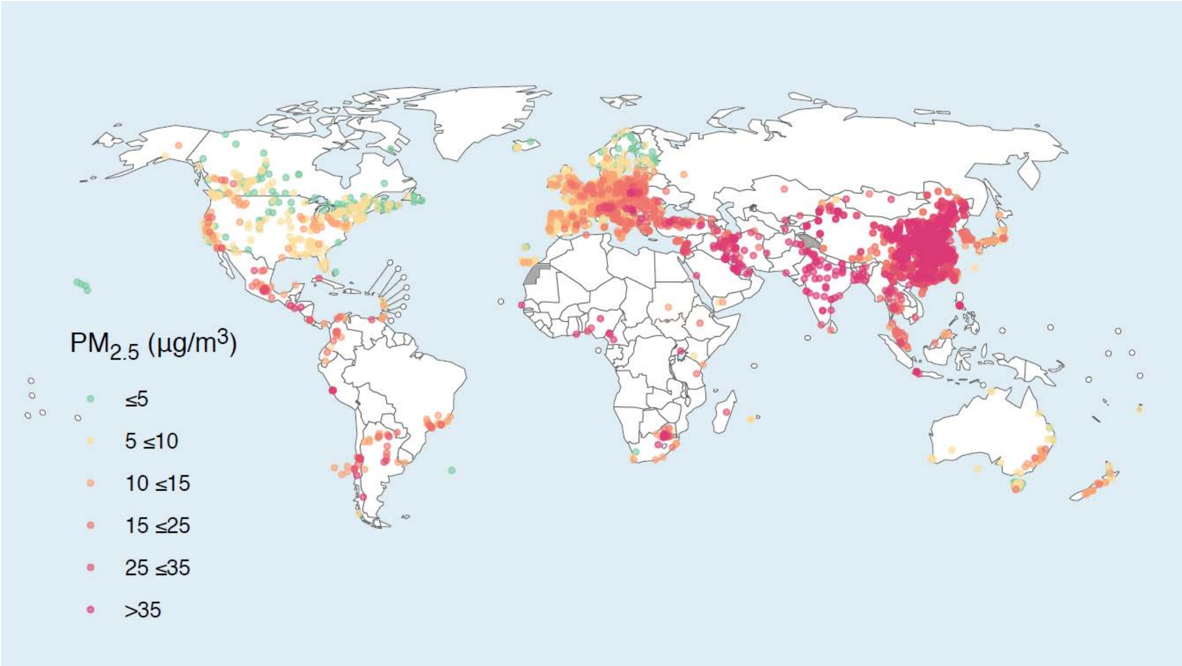
Table 2. Distribution of settlements size

% Observations in settlements smaller than listed in the next columns	**Settlement size** with PM_{10}, $PM_{2.5}$ or NO_2 data
0	0
5	1 027
10	2 962
25	14 666
50	56 847
75	304 344
90	955 041
95	1 978 502
99	8 051 068
Mean settlement size	480 332
No. of settlements	6 743

For NO_2, data are available for 3976 human settlements in 74 countries. Most of the data for both pollutants were retrieved at monitoring stations and aggregated at city level. The settlements ranged in size from < 100 inhabitants to > 30 million, but most are urban (see Table 2) and are therefore referred to generally as "human settlements" or "towns and cities".

Fig. 1. Locations of settlements with data on (A) $PM_{2.5}$ and (B) PM_{10} concentrations, 2010–2019

A. $PM_{2.5}$



B. PM_{10}

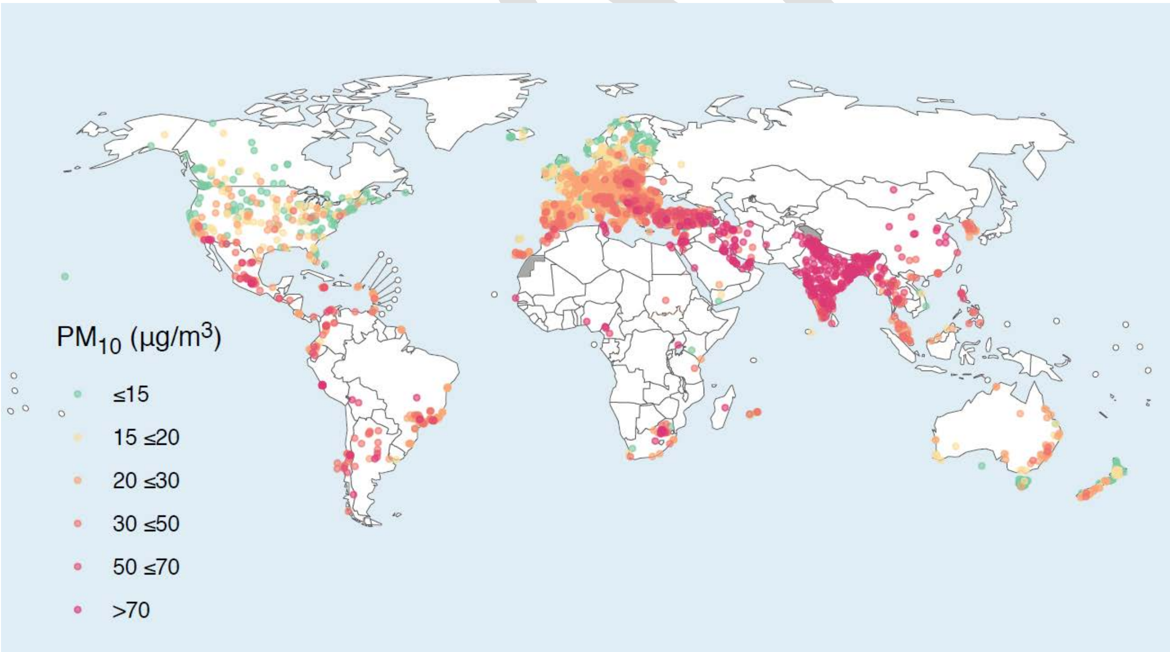
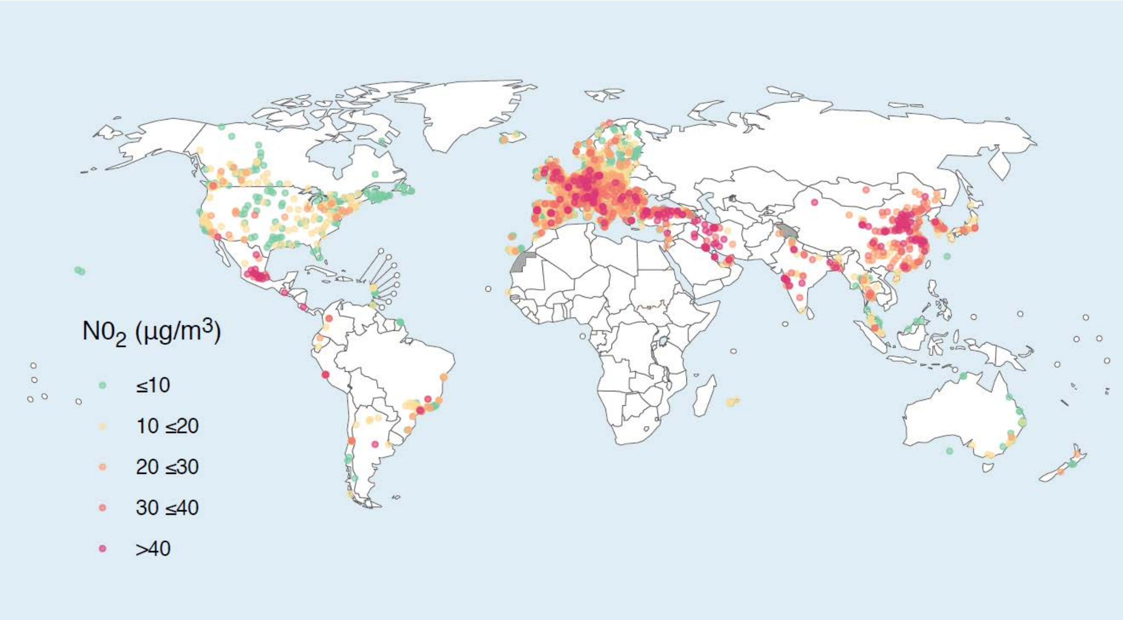


Fig. 1 shows that the coverage of ground measurements of $PM_{2.5}$ and PM_{10} is still not homogeneous around the globe. More ground measurements are generally found in high- and middle-income countries, in China, Europe, India and North America. A similar pattern is observed for NO_2 (Fig. 2), with greater densities of ground monitors in high- and middle-income countries.

Fig. 2. Locations of settlements with data on NO_2 concentrations, 2010–2019



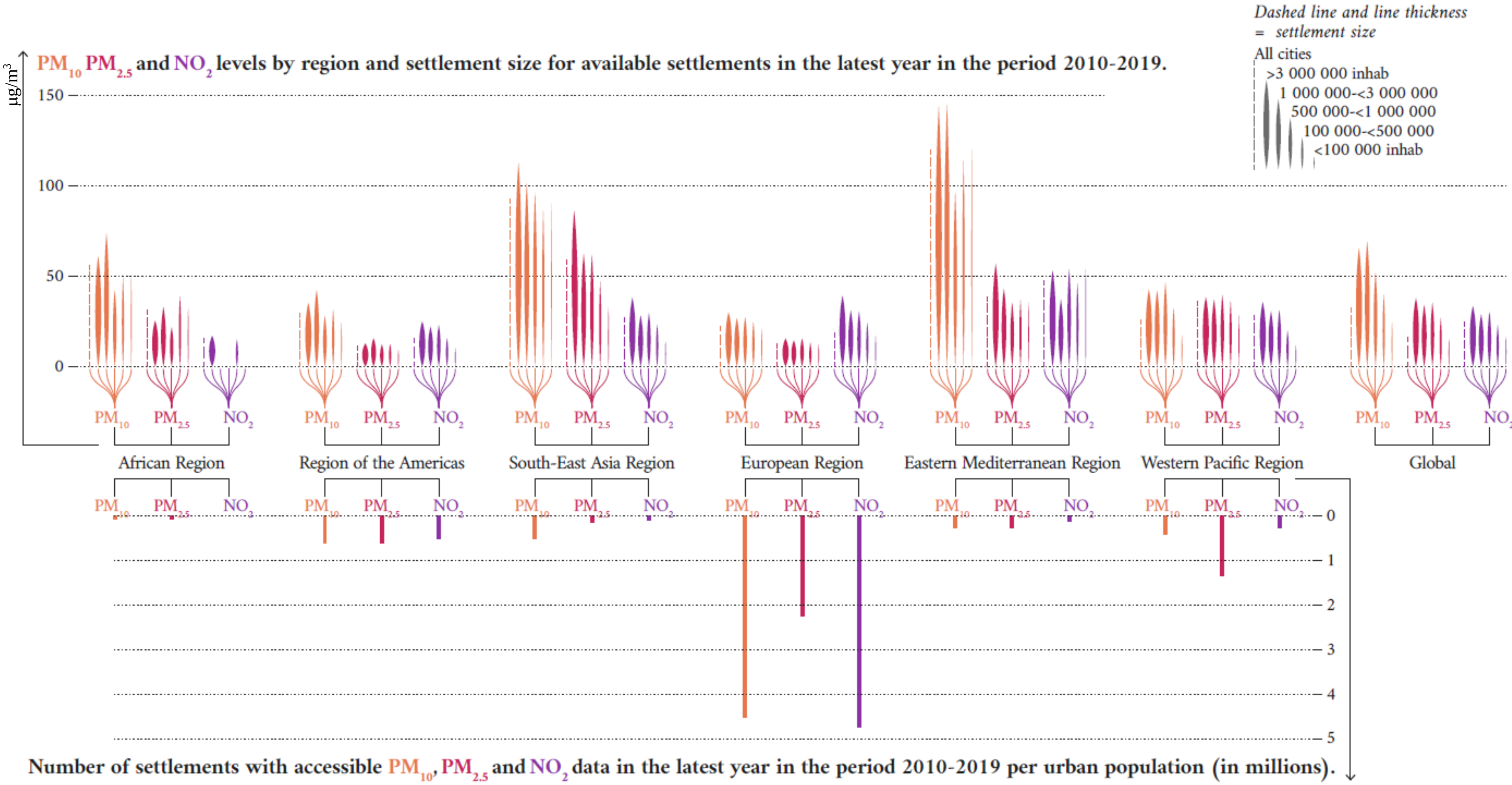
The regional distribution documented in the database and the number of settlements for which data were available are shown in Table 3 and Fig. 3, respectively.

Table 3. Total numbers of human settlements in the database, 2022 version, by region

WHO region and classification by income [a]	No. *of settlements*	No. *of countries with data*	*Total number of countries*
WHO region			
African	59	12	47
Americas	781	22	35
South-East Asia	398	9	11
European	3 654	48	53
Eastern Mediterranean	158	14	21
Western Pacific	1 693	12	27
Income level [a]			
High	4 226	51	57
Low and middle	2 517	66	145
Total	6 743	117	194

[a] See Annex 1 for regional groupings.

Fig. 3. PM_{10}, $PM_{2.5}$ and NO_2 annual means and data accessibility, by region and settlement size



As $PM_{2.5}$ measurements can be used to estimate health impacts directly, they are of particular interest as compared to PM_{10}. $PM_{2.5}$ is measured widely in high-income countries (HIC), and, while $PM_{2.5}$ measurements are still not available in many low- and middle-income countries (LMIC), there have been improvements in the past few years. When $PM_{2.5}$ measurements are not available, PM_{10} measurements should be converted to $PM_{2.5}$ for estimation of health impacts.

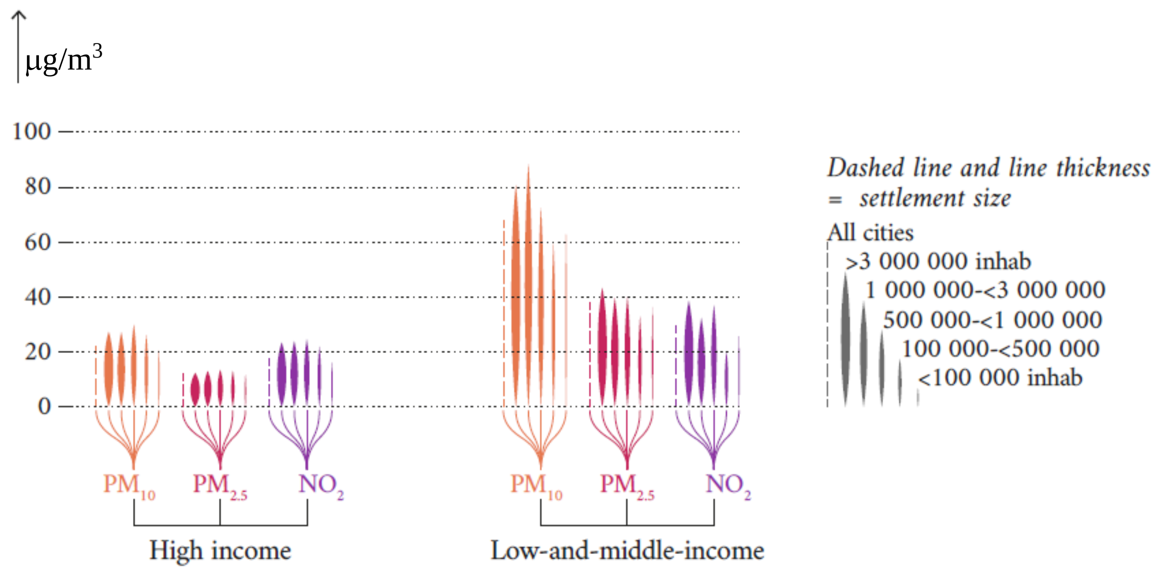
Summary of data

The database can be consulted on the WHO website at:

www.who.int/data/gho/data/themes/air-pollution/who-air-quality-database.

An overview of PM_{10}, $PM_{2.5}$ and NO_2 levels in the WHO regions and in selected cities is presented in Figs 3 –5 and in Annex 2.

Fig. 4. PM_{10} , $PM_{2.5}$ and NO_2 annual means by income level and settlement size, for settlements for which data were available in the latest year between 2010 and 2019



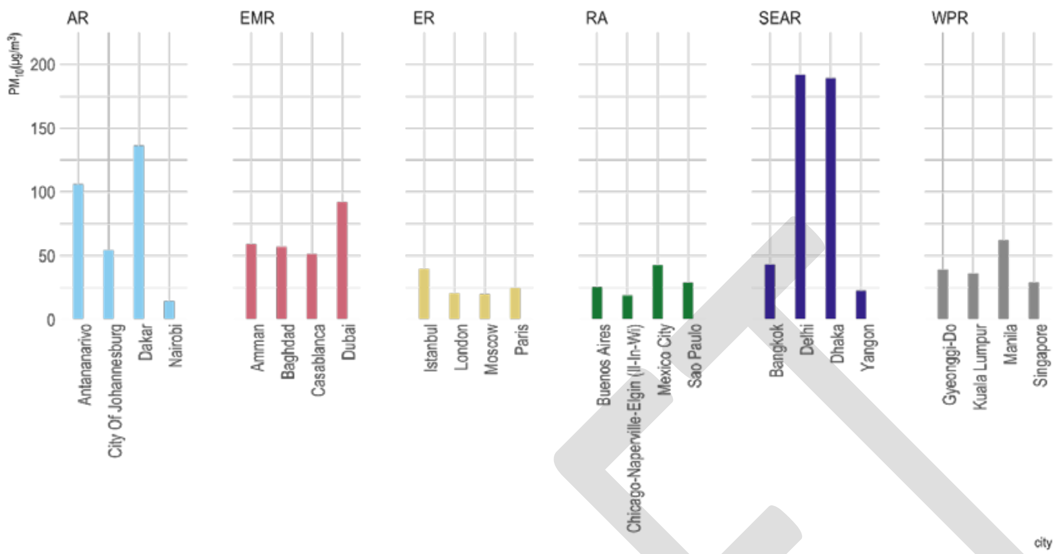
Comparison of $PM_{2.5}$ and PM_{10} levels by income group shows greater exposure in LMIC than in the world as a whole, by a factor of about 3 in comparison with HIC (Fig. 4 and Table A1).

A different pattern is observed for NO_2 levels, HIC and LMIC reporting more homogeneous concentrations than global averages (Fig. 4*)*. Overall, the NO_2 concentrations in LMIC were only about 1.5 times higher than in HIC. It is noteworthy to mention that only 37 % of settlements that recorded air quality levels were in LMIC.

PM_{10} levels were above the global average in the Eastern Mediterranean and South-East Asia regions in human settlements of all sizes (Fig. 3) and were six to eight times the AQG. These regions receive large quantities of desert dust particles. The pattern of $PM_{2.5}$ levels is similar, although the African and Western Pacific regions had levels that were nearly five times the AQG (Fig. 3). Modelled estimates of $PM_{2.5}$ supplemented by satellite data reflected similar regional patterns *(15, 16)*.

Fig. 5. PM_{10} (A) and NO_2 (B) annual means in selected cities by region for which data were available in the latest year between 2017 and 2019

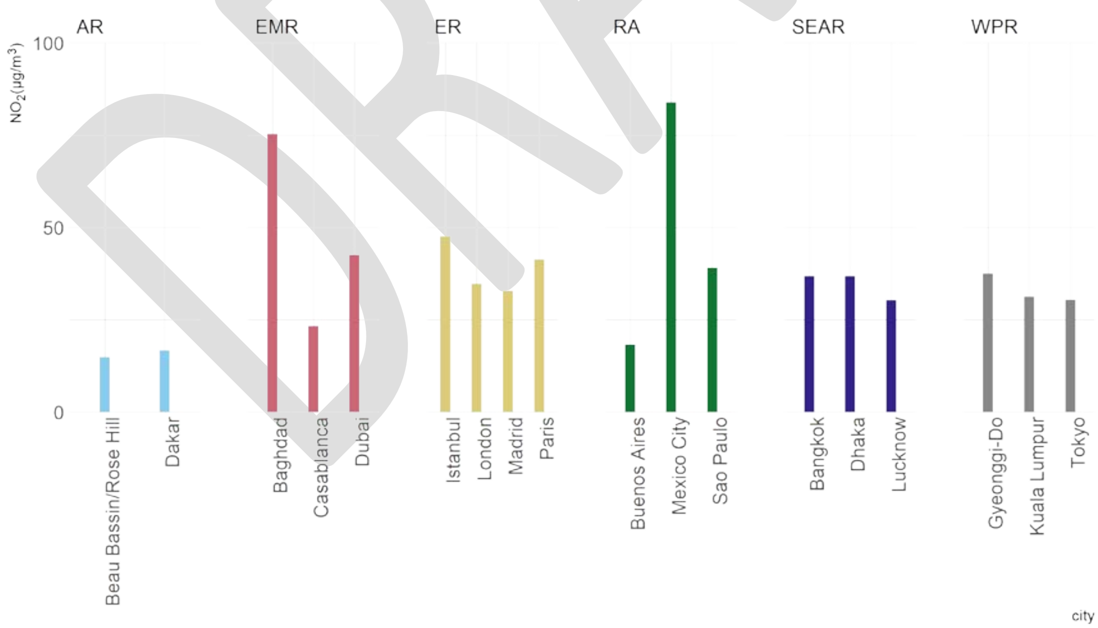
(A)



AFR: African Region; AMR: Region of the Americas; EMR: Eastern Mediterranean Region; EUR: European Region; SEAR: South-East Asia Region; WPR: Western Pacific Region.

Selection criteria: For the latest year of measurement, but not older than 2017, for each city included in the database, the largest city in each country in a region was selected.

(B)



AFR: African Region; AMR: Region of the Americas; EMR: Eastern Mediterranean Region; EUR: European Region; SEAR: South-East Asia Region; WPR: Western Pacific Region.

Selection criteria: For the latest year of measurement, but not older than 2017, for each city included in the database, the largest city in each country in a region was selected.

A similar pattern was observed for annual average NO_2 concentrations, settlements in the Eastern Mediterranean Region having higher concentrations than the global average, while all the other regions had lower, homogeneous levels (Fig. 3). The lowest levels of PM were observed in Europe and the lowest levels of NO_2 in the Americas (as data from Africa are limited, regional interpretation is difficult). While PM_{10} levels varied widely by region, NO_2 levels appeared to be more homogeneous. Modelled estimates of global NO_2 reported recently *(12)* indicate that the highest concentrations occur in the most populated regions of the world.

With regard to exposure levels in human settlements of different sizes, the NO_2 concentration tended to increase with settlement size, which might reflect larger emissions from traffic *(17)*, whereas the highest PM concentrations were found in settlements that varied in size from 500 000 to 3 million inhabitants.

The homogeneity of NO_2 concentrations in different regions and may be due to the local nature of the sources of NO_2 and its reactive chemical nature.

It is interesting to focus also on PM_{10} and NO_2 concentration in the most populous cities, with size ranging from 1 million to 26 million habitants (Fig. 5). The annual levels of PM_{10} and NO_2 varied widely by city size and income level in a given region. This is probably because the data from each city were not for the same year, temporal coverage or spatial coverage. While the data for each city indicate the air quality in the region, they are not comparable with those for other cities in the same region and even less so with those for other regions.

A comparison of the levels in mega-cities in the 2018 and 2022 versions of the database showed that the annual mean PM concentrations are relatively constant, only a few cities (e.g., Delhi) having improved their air quality. The mega-cities that recorded high PM_{10} concentrations, such as Beijing, Delhi and Dhaka, also had elevated NO_2 concentrations (data not shown).

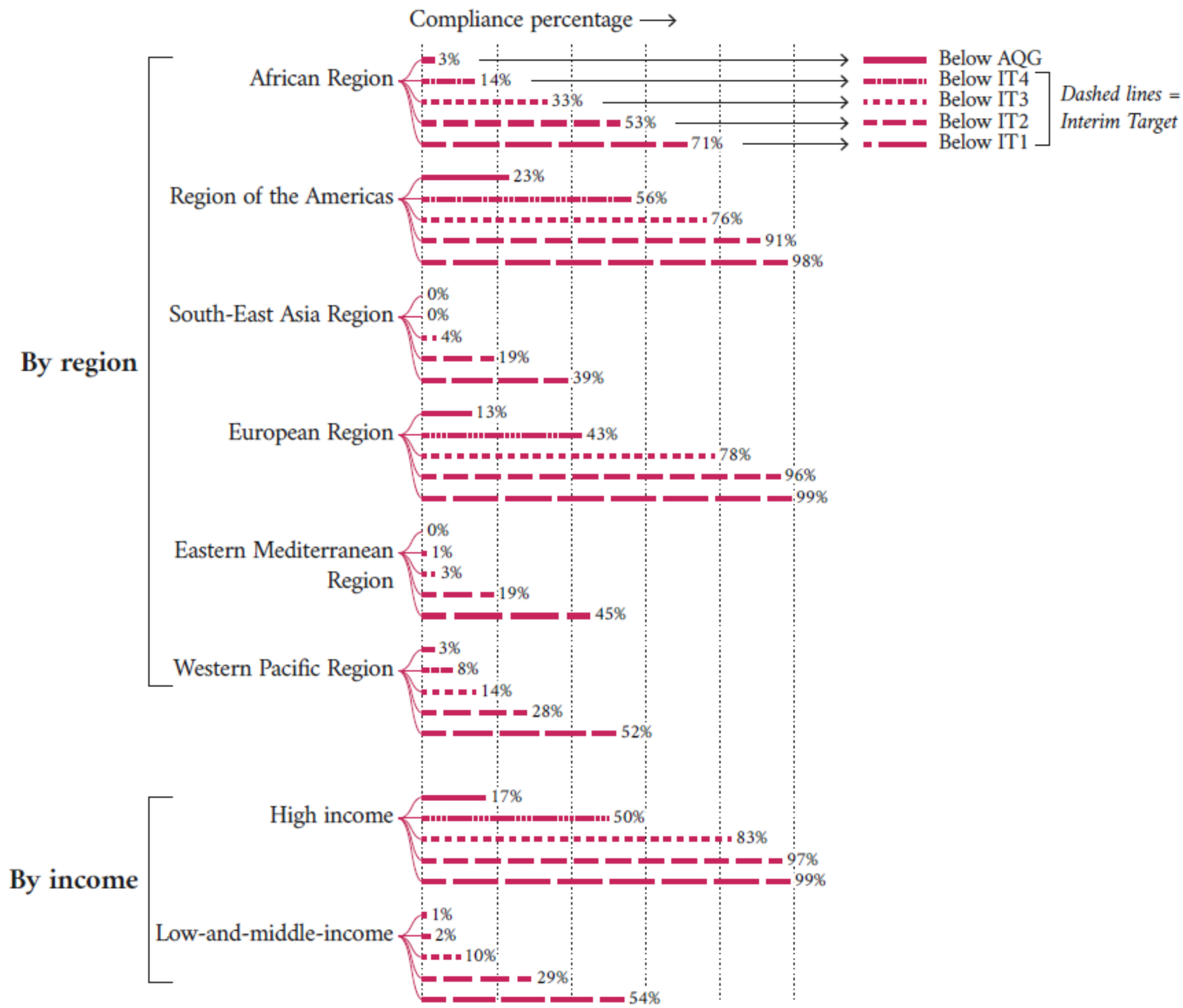
Compliance with the WHO air quality guidelines

Figs. 6 and 7 show the regional percentages of settlements with measurements of PM_{10} or $PM_{2.5}$ and NO_2 that experienced air pollution levels that met the WHO AQG, i.e., annual mean values of 10 $\mu g/m^3$ for NO_2, 15 $\mu g/m^3$ for PM_{10} and 5 $\mu g/m^3$ for $PM_{2.5}$ (see Table 1).

Globally, only the population of 10% of the assessed settlements was exposed to annual mean levels of PM_{10} or $PM_{2.5}$ that complied with the AQG (Fig. 6). The proportion increased to 31% for interim target (IT) 4 (i.e., IT-4: 20 $\mu g/m^3$ for PM_{10} and 10 $\mu g/m^3$ for $PM_{2.5}$) of the AQG, 54% for IT 3 (30 $\mu g/m^3$ for PM_{10} and 15 $\mu g/m^3$ for $PM_{2.5}$), 70% for IT 2 (50 $\mu g/m^3$ for PM_{10} and 25 $\mu g/m^3$ for $PM_{2.5}$) and 81% for IT 1 (70 $\mu g/m^3$ for PM_{10} and 35 $\mu g/m^3$ for $PM_{2.5}$).

For NO_2, only the population of 23% of the assessed settlements was exposed to annual mean levels that complied with AQG levels (Fig. 7). The proportion increased to 59% for IT 3 (20 $\mu g/m^3$), 83% for IT 2 (30 $\mu g/m^3$) and 95% for IT 1 (40 $\mu g/m^3$). The Region of the Americas recorded the best compliance with the WHO AQG for NO_2, 36% of cities recorded air quality levels below those set by the AQG, followed by the Europe. Interestingly, NO_2 compliance with AQG is more homogenous across geographical and income regions as compared to PM.

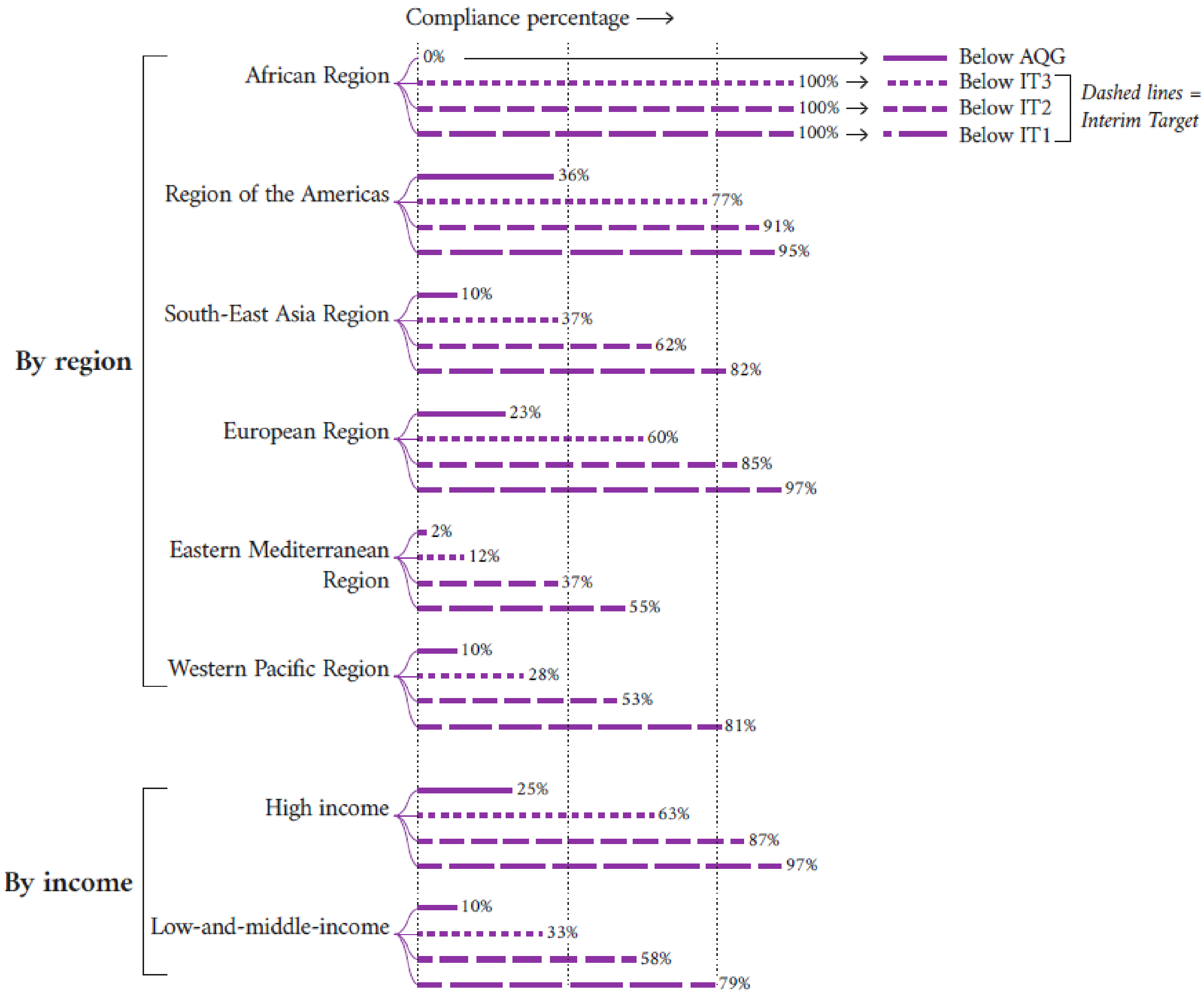
Fig. 6. Percentage of settlements assessed that complied with the WHO air quality guidelines and interim targets for annual mean PM



AQG: WHO air quality guidelines. IT: interim target; PM: particulate matter.

Note: For settlements for which both PM_{10} and $PM_{2.5}$ values were available, $PM_{2.5}$ values were used. Only the latest data available between 2010 and 2019 were used for the analysis.

Fig. 7. Percentage of settlements assessed that complied with the WHO air quality guidelines and interim targets for annual mean NO_2



AQG: WHO air quality guidelines. IT: interim target; NO_2: nitrogen dioxide.

Note : Only the latest data available between 2010 and 2019 were used for the analysis. For Africa, the analysis was based on few cities, hence the data may not be representative.

Methods

The database includes annual mean concentrations of PM_{10}, $PM_{2.5}$ and NO_2 based on ground measurements of these pollutants. It provides an average for a city or town as a whole rather than at individual stations. Most of the measurements were made between 2010 and 2019.

Data sources

The primary sources of data were official reports of countries sent to WHO upon request, official national and subnational reports and national and subnational websites that contain measurements of PM_{10} or $PM_{2.5}$ and ground measurements compiled in the framework of the Global Burden of Disease project *(18)*. For NO_2, ground measurements compiled for research by Larkin et al. in 2017 *(19)* were obtained. Measurements reported by the following regional networks were also used: Clean Air for Asia *(20)*, the Air quality e-reporting database of the European Environment Agency *(21)* for Europe and the AirNow Programme from the United States embassies and consulates *(22)*. If such official data were not available, values from peer-reviewed journals were used.

Types of data

Annual mean concentrations of particulate matter (PM_{10} or $PM_{2.5}$) and NO_2 derived from daily stationary measurements or data that could be aggregated into annual means, were used. In the absence of annual means, measurements over a more limited part of the year were used exceptionally to derivate the annual mean, if the different seasons were represented.

In order to present air quality data that represent human exposure, we used mainly urban measurements, comprising urban background, residential areas, commercial and mixed areas or rural areas and industrial areas close to urban settlements. Only data from stationary measurements, as opposed to mobile stations, were included. Air quality stations that covered particular “hot spots” and exclusively industrial areas were not included in the analysis, as such measurements often represent areas with the highest exposure and not mean population exposure. “Hot spots” were either designated as such in the original reports or were qualified as such because they were, e.g., near exceptionally busy roads. It should be noted that the omission of these measurements, might, however, have resulted in underestimates of the mean air pollution in a city.

When data from various sources were available for an urban area, only the latest, most reliable sources were used. For locations for which no new data were available, data from the previous version of the database were used.

We could not retrieve or use all the publicly available data of interest, because they were not in one of the four languages selected for the search (i.e., English, French, Portuguese and Spanish) or they provided incomplete information (such as the reference year or station coordinates). Data were used as presented in the original sources. The numbers of monitors cited do not necessarily correspond to the number of operational stations in a city but to the number of stations used to derive a long-term mean needed to assess the heath impact from human exposure to air pollution.

Search strategy

When official reporting from countries to WHO were not available, we screened the websites of national ministries of the environment and health and statistics offices for publicly available data

The web searches were conducted with the terms “air quality”, “air pollution”, “suspended particles”, “monitoring”, “PM10”, “PM2.5” and “NO2”. The languages chosen were English, French, Portuguese and Spanish.

Only measurements up to 2019 were included, although some late searches included 2020.

Data processing and reporting

When they were available, means for cities and towns reported in the original sources were included. When a mean was not provided, data from the eligible monitoring station in the city or town were averaged. As monitoring stations may be placed in locations that do not represent the level of background pollution, aggregation of their data may not necessarily represent mean air pollution in a city. This risk was partly mitigated by excluding data from monitoring stations located in hot spots, as stated above.

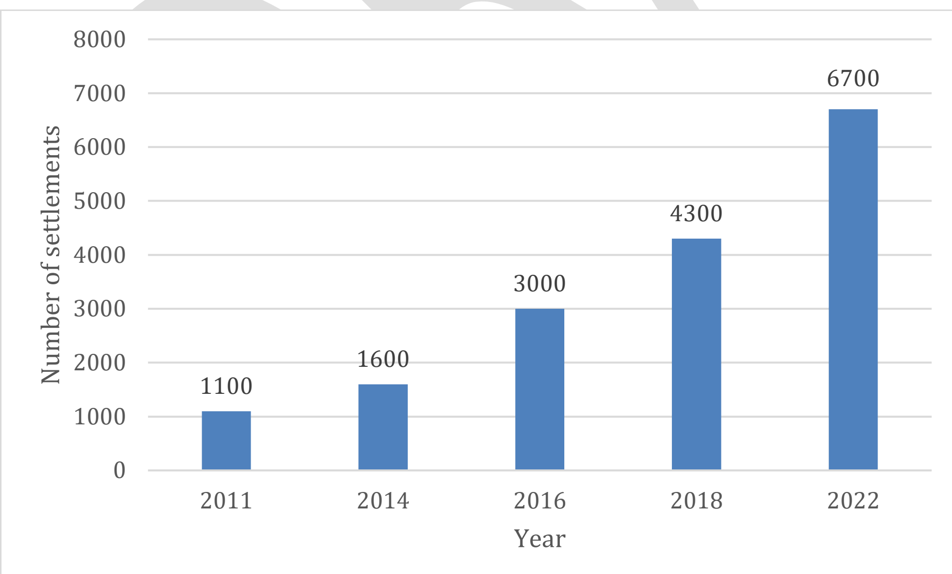
The population data used for weighting and for estimating the proportion of the population covered were derived from United Nations Population Statistics *(23)* (when available) for all the human settlements covered or census data from national statistics offices *(24)*.

The temporal coverage represents the number of days per year covered by measurements and any other range provided in the original sources. When data from several monitoring stations in one city or town were available, the average temporal coverage was used as the overall average. Although information on temporal coverage was not always available, the reporting agencies often set a threshold for the number of days covered before reporting the measurements from a station or used it to estimate the city mean.

Discussion

Since 2011, when WHO released the first database, the availability of data has increased dramatically. Fig. 8 shows the numbers of settlements for which PM measurements were available up to 2021. Within a decade, the number of cities and towns in which air quality is measured increased by approximatively six times. Additional ground monitors, especially in settlements with elevated concentrations of PM_{10} and $PM_{2.5}$ will be pivotal for monitoring the progress of national policies and interventions.

Fig. 8. Numbers of human settlements included in the WHO database, by year of release



The database is the result of collaborations among WHO, countries and academic institutions and has contributed considerably to improving estimates of exposure to particulate matter *(1, 2)*.

Addition of NO_2 measurements will contribute to (i) increasing awareness about this pollutant, which is often used as an effective proxy for anthropogenic fuel combustion, specifically from traffic and especially in urban settings; (ii) monitoring progress in policies to reduce exposure to air pollution; and (iii) improving work to derive estimates of global exposure to NO_2 *(12, 18, 25–27)*.

Limitations of the database

The aim of the database is to compile ground measurements of annual mean concentrations of $PM_{2.5,}$ PM_{10} and NO_2. The database has several limitations, the main one being that comparison of data from different countries is limited because of:

- different locations of measurement stations;
- different measurement methods;
- different temporal coverage of certain measurements (If only part of a year is covered, the measurement may deviate significantly from the annual mean because of seasonal variations.);
- data from different countries were available for different years;
- possible inclusion of data that were not eligible for the database because of insufficient information for ensuring compliance;
- differences in the size of urban areas covered (For certain countries, only measurements for larger cities were found, whereas, for others, data for cities with only a few thousand inhabitants were available.);
- heterogeneity in the quality of measurements; and
- omission of data that could not yet be accessed because they were not in one of the four languages selected or were difficult to access.

Some of these limitations were discussed in a recent article, based on the 2016 version of the database *(28)*.

Prospects

Our past and current databases contain data from reference-grade monitors (or provided by country officials) in an attempt to rely on official data used for regulatory purposes. Countries have, however, shown growing interest in measuring and using data from alternative methods (i.e., other than standard reference grade monitors), such as those obtained with low-cost sensors (LCS), or estimates based on satellite data (or a combination thereof), particularly in regions in which there are no high-quality data. A common yet difficult question to answer is the reliability of these sensors.

In a recent report, the World Meteorological Organization *(29)* assessed several studies on the use of LCS and concluded that they are not yet suitable for replacing reference monitors but could complement them. In countries with at least some reference monitors, LCS could be added to the monitoring network to improve spatial coverage of air-quality monitoring. The importance of quality assurance and quality control of data from LCS should, however, be emphasized in order to reduce the uncertainty of the measurements. Data from LCS can be affected adversely by changes in humidity, temperature and the presence of other pollutants. In addition, LCS are susceptible to drifting baselines.

A meta-analysis of the scientific and grey literature also indicated that, while LCS could supplement air monitoring networks, more work is necessary before they could be used independently for monitoring source compliance *(30)*. An example of the use of LCS data to supplement data from reference monitors is that of the Meteorological Institute in The Netherlands; Mijling et al. *(31)* showed significantly better modelled concentrations of NO_2 on a fine spatial scale, although it was reported that the improvement was observed only when the LCS data were calibrated and validated with a reference monitor. Standard protocols for calibrating and validating LCS are available from the European Union *(32)* and the USA *(33)*. Environmental regulators and policy-makers who plan to include LCS in their monitoring networks should develop robust protocols for LCS calibration and validation to ensure that the data closely reflect those from a reference monitor. LCS are nevertheless being increasingly used, including to obtain real-time information and related indices of air quality *(34)*.

On the other end, satellite remote sensing has also dramatically improved in its ability to measure air quality *(35)*. The primary advantage of satellite data compared to ground measurements is their spatial coverage. Satellite data is available for the entire globe and can provide invaluable information on the level, composition and transportation of pollution but also on the changes over time. Health and air quality communities have increasingly been using satellite data, and this trend is expected to continue *(36, 37)*. Satellite data is already used to assess global air pollution exposure since years *(2, 38)* and an integral part of the modelling for SDG 11.6.2, Air quality in urban areas *(15, 39)*. The reliability of the satellite-based estimates of air pollutants concentration depends, to a large extent, on the availability of the ground monitoring data, which allows calibration of the estimates.

An expert group was set up recently to advise WHO on continuing assessment of exposure to air pollution *(40)*, and its recommendations will be used in future versions of this database.

Feedback, updating and improvement of the database

Countries, municipalities and their agencies that have relevant measurements are welcome to provide more recent or complete data in order to update or improve the database. Please contact us by writing to aqh_who@who.int.

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Annex 1. WHO regional groupings

Country	WHO region	World Bank income (2019)[a]
Afghanistan	Eastern Mediterranean	Low
Albania	European	Upper middle
Algeria	African	Lower middle
Andorra	European	High
Angola	African	Lower middle
Antigua and Barbuda	Americas	High
Argentina	Americas	Upper middle
Armenia	European	Upper middle
Australia	Western Pacific	High
Austria	European	High
Azerbaijan	European	Upper middle
Bahamas	Americas	High
Bahrain	Eastern Mediterranean	High
Bangladesh	South-East Asia	Lower middle
Barbados	Americas	High
Belarus	European	Upper middle
Belgium	European	High
Belize	Americas	Upper middle
Benin	African	Lower middle
Bhutan	South-East Asia	Lower middle
Bolivia (Plurinational State of)	Americas	Lower middle
Bosnia and Herzegovina	European	Upper middle
Botswana	African	Upper middle
Brazil	Americas	Upper middle
Brunei Darussalam	Western Pacific	High
Bulgaria	European	Upper middle
Burkina Faso	African	Low
Burundi	African	Low
Cabo Verde	African	Lower middle
Cambodia	Western Pacific	Lower middle
Cameroon	African	Lower middle
Canada	Americas	High
Central African Republic	African	Low
Chad	African	Low
Chile	Americas	High
China	Western Pacific	Upper middle
Colombia	Americas	Upper middle
Comoros	African	Lower middle

Country	WHO region	World Bank income (2019)[a]
Congo	African	Lower middle
Cook Islands	Western Pacific	Not applicable
Costa Rica	Americas	Upper middle
Côte d'Ivoire	African	Lower middle
Croatia	European	High
Cuba	Americas	Upper middle
Cyprus	European	High
Czechia	European	High
Democratic People’s Republic of Korea	South-East Asia	Low
Democratic Republic of the Congo	African	Low
Denmark	European	High
Djibouti	Eastern Mediterranean	Lower middle
Dominica	Americas	Upper middle
Dominican Republic	Americas	Upper middle
Ecuador	Americas	Upper middle
Egypt	Eastern Mediterranean	Lower middle
El Salvador	Americas	Lower middle
Equatorial Guinea	African	Upper middle
Eritrea	African	Low
Estonia	European	High
Eswatini	African	Lower middle
Ethiopia	African	Low
Fiji	Western Pacific	Upper middle
Finland	European	High
France	European	High
Gabon	African	Upper middle
Gambia	African	Low
Georgia	European	Upper middle
Germany	European	High
Ghana	African	Lower middle
Greece	European	High
Grenada	Americas	Upper middle
Guatemala	Americas	Upper middle
Guinea	African	Low
Guinea-Bissau	African	Low
Guyana	Americas	Upper middle
Haiti	Americas	Low
Honduras	Americas	Lower middle
Hungary	European	High
Iceland	European	High

Country	WHO region	World Bank income (2019)[a]
India	South-East Asia	Lower middle
Indonesia	South-East Asia	Upper middle
Iran (Islamic Republic of)	Eastern Mediterranean	Upper middle
Iraq	Eastern Mediterranean	Upper middle
Ireland	European	High
Israel	European	High
Italy	European	High
Jamaica	Americas	Upper middle
Japan	Western Pacific	High
Jordan	Eastern Mediterranean	Upper middle
Kazakhstan	European	Upper middle
Kenya	African	Lower middle
Kiribati	Western Pacific	Lower middle
Kuwait	Eastern Mediterranean	High
Kyrgyzstan	European	Lower middle
Lao People's Democratic Republic	Western Pacific	Lower middle
Latvia	European	High
Lebanon	Eastern Mediterranean	Upper middle
Lesotho	African	Lower middle
Liberia	African	Low
Libya	Eastern Mediterranean	Upper middle
Lithuania	European	High
Luxembourg	European	High
Madagascar	African	Low
Malawi	African	Low
Malaysia	Western Pacific	Upper middle
Maldives	South-East Asia	Upper middle
Mali	African	Low
Malta	European	High
Marshall Islands	Western Pacific	Upper middle
Mauritania	African	Lower middle
Mauritius	African	High
Mexico	Americas	Upper middle
Micronesia (Federated States of)	Western Pacific	Lower middle
Monaco	European	High
Mongolia	Western Pacific	Lower middle
Montenegro	European	Upper middle
Morocco	Eastern Mediterranean	Lower middle
Mozambique	African	Low
Myanmar	South-East Asia	Lower middle

Country	WHO region	World Bank income (2019)[a]
Namibia	African	Upper middle
Nauru	Western Pacific	High
Nepal	South-East Asian	Lower middle
Netherlands	European	High
New Zealand	Western Pacific	High
Nicaragua	Americas	Lower middle
Niger	African	Low
Nigeria	African	Lower middle
Niue	Western Pacific	Not applicable
North Macedonia	European	Upper middle
Norway	European	High
Oman	Eastern Mediterranean	High
Pakistan	Eastern Mediterranean	Lower middle
Palau	Western Pacific	High
Panama	Americas	High
Papua New Guinea	Western Pacific	Lower middle
Paraguay	Americas	Upper middle
Peru	Americas	Upper middle
Philippines	Western Pacific	Lower middle
Poland	European	High
Portugal	European	High
Qatar	Eastern Mediterranean	High
Republic of Korea	Western Pacific	High
Republic of Moldova	European	Lower middle
Romania	European	High
Russian Federation	European	Upper middle
Rwanda	African	Low
Saint Kitts and Nevis	Americas	High
Saint Lucia	Americas	Upper middle
Saint Vincent and the Grenadines	Americas	Upper middle
Samoa	Western Pacific	Upper middle
San Marino	European	High
São Tome and Principe	African	Lower middle
Saudi Arabia	Eastern Mediterranean	High
Senegal	African	Lower middle
Serbia	European	Upper middle
Seychelles	African	High
Sierra Leone	African	Low
Singapore	Western Pacific	High
Slovakia	European	High

Country	WHO region	World Bank income (2019)[a]
Slovenia	European	High
Solomon Islands	Western Pacific	Lower middle
Somalia	Eastern Mediterranean	Low
South Africa	African	Upper middle
South Sudan	African	Low
Spain	European	High
Sri Lanka	South-East Asia	Lower middle
Sudan	Eastern Mediterranean	Low
Suriname	Americas	Upper middle
Sweden	European	High
Switzerland	European	High
Syrian Arab Republic	Eastern Mediterranean	Low
Tajikistan	European	Low
Thailand	South-East Asia	Upper middle
Timor-Leste	South-East Asia	Lower middle
Togo	African	Low
Tonga	Western Pacific	Upper middle
Trinidad and Tobago	Americas	High
Tunisia	Eastern Mediterranean	Lower middle
Turkey	European	Upper middle
Turkmenistan	European	Upper middle
Tuvalu	Western Pacific	Upper middle
Uganda	African	Low
Ukraine	European	Lower middle
United Arab Emirates	Eastern Mediterranean	High
United Kingdom of Great Britain and Northern Ireland	European	High
United Republic of Tanzania	African	Lower middle
United States of America	Americas	High
Uruguay	Americas	High
Uzbekistan	European	Lower middle
Vanuatu	Western Pacific	Lower middle
Venezuela (Bolivarian Republic of)	Americas	Upper middle
Viet Nam	Western Pacific	Lower middle
Yemen	Eastern Mediterranean	Low
Zambia	African	Lower middle
Zimbabwe	African	Lower middle

[a]World Bank country and lending groups (US$). Low: ≤ US$ 1035; lower middle income: US$ 1036-4045; upper middle income: US$ 4046–12 535; High: > US$ 12 535 (http://databank.worldbank.org/data/download/site-content/OGHIST.xlsx).

Annex 2. PM and NO_2 annual means by region, income and settlement size

Table A1. PM_{10}, $PM_{2.5}$ and NO_2 annual means by income level and settlement size, for settlements for which data were available in the latest year between 2010 and 2019 (in μg/m^3)

WHO region and classification by income	Settlement size (no. of inhabitants)	PM_{10}	$PM_{2.5}$	NO_2
WHO region				
African				
	< 100 000	50.0	32.1	NA
	100 000–< 500 000	49.3	38.9	14.9
	500 000–-< 1 000 000	42.2	21.8	NA
	1 000 000 –< 3 000 000	73.6	33.0	NA
	> 3 000 000	61.0	25.4	16.8
	all cities	56.3	31.1	15.9
Americas				
	< 100 000	24.2	9.1	10.1
	100 000–< 500 000	31.5	12.5	15.7
	500 000–< 1 000 000	27.7	12.3	23.0
	1 000 000–< 3 000 000	42.2	15.7	22.1
	> 3 000 000	35.2	12.9	25.0
	all cities	29.8	11.2	15.5
South-East Asia				
	< 100 000	90.2	32.3	13.9
	100 000–< 500 000	86.4	46.9	23.1
	500 000–< 1 000 000	96.3	62.0	29.6
	1 000 000–< 3 000 000	101.5	62.9	28.3
	> 3 000 000	112.7	86.3	38.1
	all cities	92.9	59.0	27.3
European				
	< 100 000	21.0	12.3	16.8
	100 000–< 500 000	24.9	13.4	24.4
	500 000–< 1 000 000	27.3	15.4	30.6
	1 000 000–< 3 000 000	27.0	14.6	31.3
	> 3 000 000	30.1	15.7	39.3
	all cities	22.0	12.8	18.5
Eastern Mediterranean				
	< 100 000	120.5	35.4	54.0
	100 000–< 500 000	114.3	36.7	46.1
	500 000–< 1 000 000	97.1	35.5	53.9
	1 000 000–< 3 000 000	145.3	43.0	37.3
	> 3 000 000	143.9	57.4	53.1
	all cities	120.2	38.9	47.5
Western Pacific				
	< 100 000	17.3	28.5	11.6
	100 000–< 500 000	32.4	36.3	19.9
	500 000–< 1 000 000	46.5	39.7	31.3
	1 000 000–< 3 000 000	41.9	37.3	30.6
	> 3 000 000	42.4	38.3	35.7
	all cities	26.0	36.3	28.5

Income level			
High income			
< 100 000	20.7	11.4	16.3
100 000–< 500 000	26.1	12.9	22.3
500 000–< 1 000 000	29.9	13.5	24.6
1 000 000–< 3 000 000	27.2	13.0	24.0
> 3 000 000	27.3	12.4	23.5
all cities	22.0	11.9	17.7
Low- and middle income			
< 100 000	59.4	32.9	19.9
< 100 000	62.8	36.2	25.8
500 000–< 1 000 000	72.5	40.1	37.1
1 000 000–< 3 000 000	88.4	39.6	32.4
> 3 000 000	80.7	43.3	38.7
all cities	68.0	37.9	29.4
World			
< 100 000	24.7	15.0	16.5
100 000–< 500 000	39.8	26.7	23.1
500 000–< 1 000 000	52.2	35.4	30.2
1 000 000–< 3 000 000	69.3	33.9	28.9
> 3 000 000	65.6	37.9	33.5
all cities	32.5	24.5	19.4

NA: not applicable.