Exposure to ambient air pollution from particulate matter for 2016

Version 2 April 2018

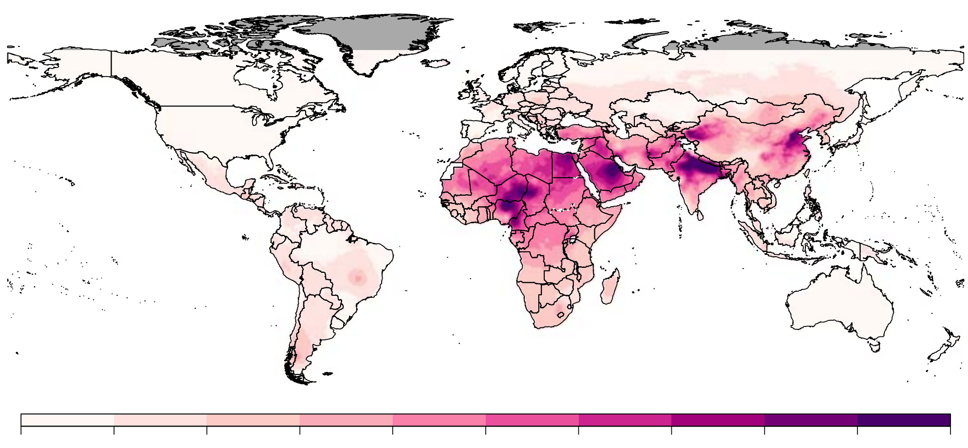
Summary of results

Exposure to particulate matter of a diameter equal or less than 2.5 µm ($PM_{2.5}$) has been modelled for the year 2016 to provide a comprehensive global coverage of estimates of air quality. The key parameter is the annual average concentration of $PM_{2.5}$, which is highly relevant for estimating health impacts.

Modelled exposure to $PM_{2.5}$ provides more comprehensive exposure information for countries than measured data that provide information only for a selection of towns and cities. A comprehensive set of estimated population exposures such as the one provided by the DIMAQ model is required when estimating the health impacts of ambient air pollution for a country.

Estimates of population exposure are required for all areas, including those that may not be covered by ground monitoring networks. Estimates of air quality, expressed in terms of average concentrations of $PM_{2.5}$ are now available for all regions of the world, including areas in which monitoring is not available (Figure 1). Modelled estimates of air quality can be downloaded and consulted interactively at www.who.int/airpollution/data.

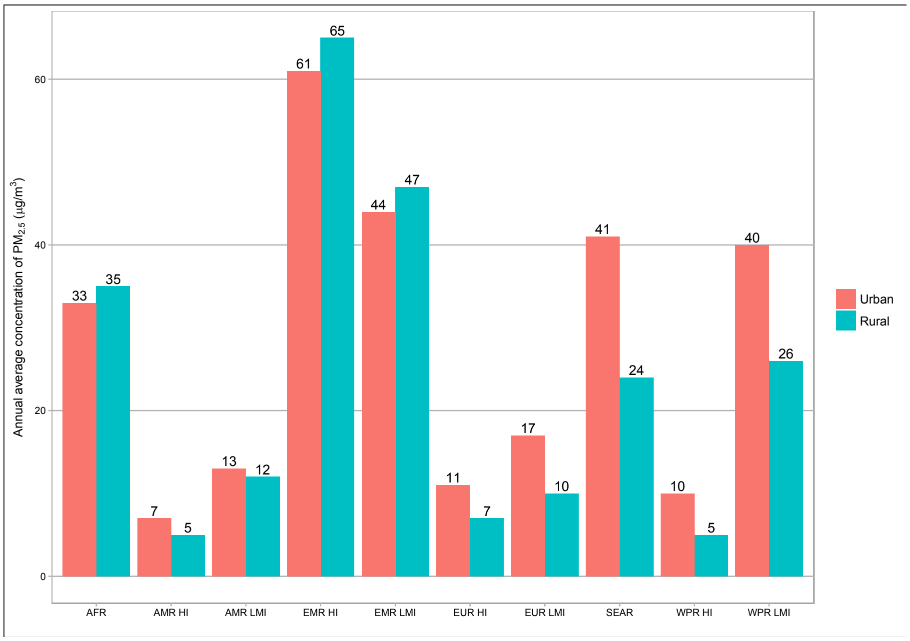
Figure 1: *Global map of annual average concentrations of ambient (outdoor) fine particulate matter ($PM_{2.5}$) in $\mu g/m^3$.*



In the majority of regions of the world, annual averages of air pollution are higher than the WHO air quality guideline (AQG) level of 10 µg/m^3, with particularly high exposures in the Eastern Mediterranean, South-East Asian and Western Pacific regions (Figure 2). Air pollution does not exclusively originate from human activity and can be greatly influenced by dust storms, particularly in areas close to deserts. This is partially illustrated in Figure 2, which shows modelled annual average $PM_{2.5}$ concentrations by area (rural/urban); and shows that rural areas in Africa and Eastern

Mediterranean regions have higher concentrations than urban ones. In the majority of regions however, as might be expected, concentrations in urban areas are higher than in rural areas (Figure 2) with the increase being particularly marked (over 1.5 times) in the South-East Asia and low- and middle-income Western Pacific regions.

Figure 2: *Annual average concentrations of ambient (outdoor) fine particulate matter air pollution ($PM_{2.5}$) in $\mu g/m^3$, by region – urban and rural areas, 2016.*

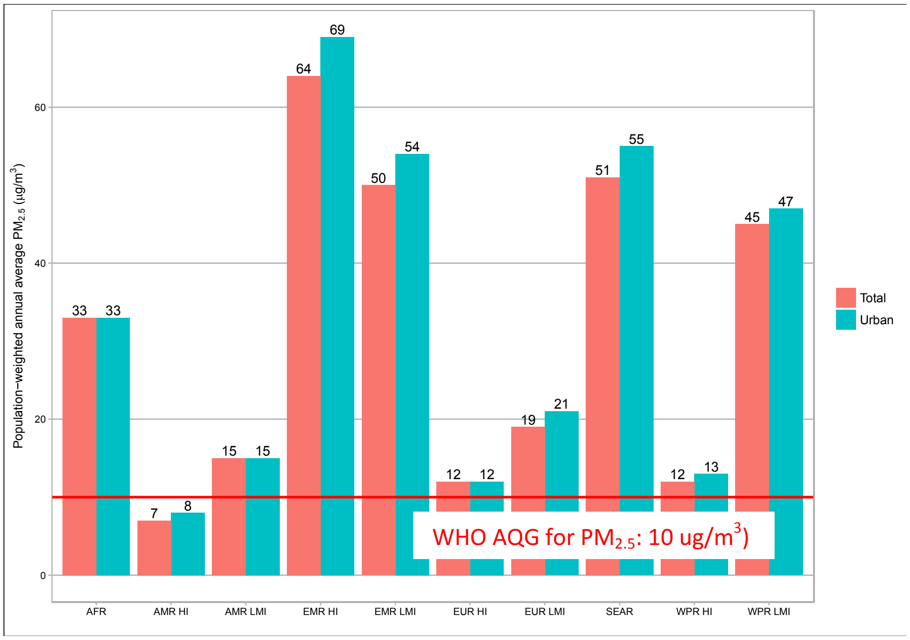


AFR: Africa; AMR: America; EMR: Eastern Mediterranean; EUR: Europe; SEAR: South-East Asia; WPR: Western Pacific; LMIC: Low- and middle-income countries; HIC: High-income countries.

In all regions apart from the high income region of the Americas, populations are exposed to levels of fine particulate matter air pollution ($PM_{2.5}$) that exceed the annual mean value of 10 $\mu g/m^3$ recommended in the WHO air quality guideline (AQG) (Figure 3). In urban areas in the Eastern Mediterranean region (both low- and middle- income and high income), the African and South-East Asian regions and the low-income areas within the Western Pacific region (population-weighted) exposures are over three times the WHO AQG value.

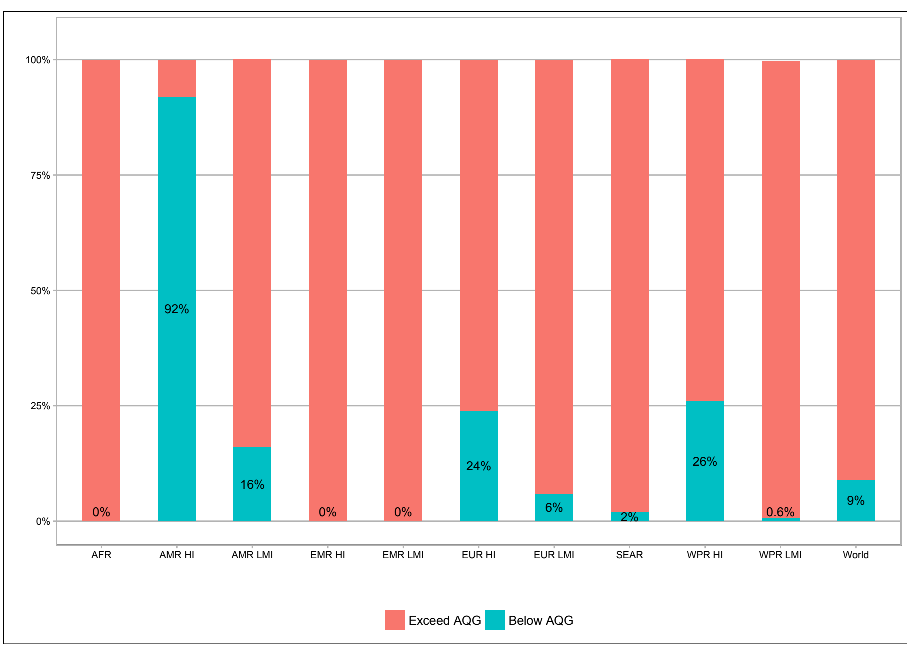
Based the modelled data, 91% of the world population are exposed to $PM_{2.5}$ air pollution concentrations that are above the annual mean WHO air quality guideline levels of 10 $\mu g/m^3$ (Figure 4). Apart from the high income region of the Americas, all regions – both high-income and low-and middle income – have less than 26% of the population living in places in compliance with the WHO AQG.

Figure 3: *Annual average (population-weighted) exposure to ambient (outdoor) fine particulate matter air pollution ($PM_{2.5}$) in $\mu g/m^3$, by region – total and urban populations, 2016. Red line indicates the WHO Air Quality Guideline (AQG) for $PM_{2.5}$: 10 $\mu g/m^3$.*



AFR: Africa; AMR: America; EMR: Eastern Mediterranean; EUR: Europe; SEAR: South-East Asia; WPR: Western Pacific; LMCI: Low- and middle-income countries; HIC: High-income countries.

Figure 4: *Percentage of regional populations residing in areas in which the WHO Air Quality Guideline (AQG: annual average $PM_{2.5}$ exceeds 10 $\mu g/m^3$) is exceeded.*



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Linkages to the tracking of the Sustainable Development Goals

The population-weighted annual urban mean concentration of $PM_{2.5}$ serves as one of the two main indicators (together with solid waste collection) for monitoring progress towards the SDG 11 target on making cities and human settlements inclusive, safe, resilient and sustainable. These estimates are also used in the calculation of the mortality rate attributed to the joint effects of ambient and household air pollution, SDG 3 indicator 3.9.1.

Methods

Assessment of the global burden of air pollution from particulate matter requires a comprehensive set of estimated exposures for all populations. The primary source of information for estimating exposures has been measurements from ground monitoring networks but, although coverage by monitoring stations is increasing, there are several large areas of the planet in which monitoring is limited. Ground monitoring data therefore needs to be supplemented with information from other sources, such as satellite retrievals of aerosol optical depth, chemical transport models, and ad hoc measurements available for a limited period of time (e.g. in relation to a scientific study). In addition to these estimates of air quality, other information is used in estimating air pollution exposure, including population estimates and topography (e.g. elevation). The Data Integration Model for Air Quality (DIMAQ)[1] was developed by the WHO Data Integration Task Force to integrate data from multiple sources in order to provide estimates of exposures to $PM_{2.5}$ at high spatial resolution ($0.1^{o}\times0.1^{o}$, that corresponds approximately to 10x10 km^2) globally.

Data sources: The multiple sources of data include ground measurements from 9,690 monitoring locations around the world, covering more than 4’300 cities and towns, from the WHO ambient air quality database together with satellite remote sensing, population estimates, topography, and information on local monitoring networks and measures of specific contributors of air pollution from chemical transport models[2].

Modelling technique: The DIMAQ model calibrates data from these sources with ground measurements. The relationships between the different sources of data may be complex and will vary between regions due to differences in the composition of $PM_{2.5}$ and other factors. Within DIMAQ, these relationships are expressed in terms of a series of calibration equations which change over space. DIMAQ has a hierarchical structure that uses individual country’s data, where available, to construct these equations. The WHO has been working with the University of Exeter on recent developments to DIMAQ which, where there is sufficient data, now allows the calibration equations to vary both within and between countries. Where there is insufficient data within a country, to produce accurate equations, it is supplemented with information from the wider region.

When calibration equations have been established and tested, the model is used to estimate exposures, together with associated measures of the uncertainty, across the globe. These high-resolution estimates of $PM_{2.5}$ can be used to produce air quality profiles for individual countries, regions and globally. Further to this, by defining areas as either urban or rural (based on land-use,

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[1] Shaddick, G. *et al.*, 2018. Data integration model for air quality: a hierarchical approach to the global estimation of exposures to ambient air pollution. *Journal of the Royal Statistical Society: Series C (Applied Statistics)*, *67*(1), pp.231-253

[2] For more information on the input data, please consult www.who.int/airpollution/data

derived from satellite images, and population estimates[3]) at a 0.1°×0.1° resolution to match the estimates of air pollution from DIMAQ, the profiles can presented separately for urban and rural areas.

A full description of the model development and evaluation is available elsewhere[4]. For further details of its implementation for 2016 can be found at www.exeter.ac.uk/globalairquality.

Discussion

Global population exposure to $PM_{2.5}$ has been modelled for the year 2016 to provide a comprehensive global coverage of estimates of air quality. Annual mean concentration of $PM_{2.5}$ is highly relevant for estimating health impacts and used as exposure indicator for calculating the burden of disease attributable to ambient air pollution.

The model, however, currently has the following limitations. Population data: The data quality for estimates of population and population density used to calculate the average estimates of $PM_{2.5}$ for urban and rural areas is generally good for high-income countries, but it is relatively poor for some low- and middle-income areas. Furthermore, the definition of urban/rural may greatly vary by country. Lack of ground monitoring data in countries: The model produces a calibration equation within each country using country level data as a priority, with regional data being used to supplement local information for countries with sparse, or no, ground monitoring data. It is acknowledged that the estimates for data-poor countries may be relatively imprecise. In order to achieve enhanced accuracy reduced uncertainty in modelled data it is important that countries continue and/or improve ground measurement programmes. Conversion from PM_{10}: Where measurements of $PM_{2.5}$ are not available, PM_{10} measurements are used after conversion to $PM_{2.5}$ using country or regional conversion factors. Conversion factors range between 0.3-0.8 depending on location. Localised conversion factors are likely to be more accurate but the ability to calculate them relies on localised data being available. The potential for inaccuracies in conversion factors means that model outputs for areas using large numbers of converted values may be less accurate than those based directly on measurements of $PM_{2.5}$ and extra care should be taken in their interpretation.

For more information :

Ambient air pollution:	www.who.int/airpollution/ambient
Maps and databases :	www.who.int/airpollution/data
Global Health Observatory:	www.who.int/gho/phe/outdoor_air_pollution
SDG 11.6.2:	apps.who.int/gho/data/node.sdg.11-6

[3] European Human Settlement Grid; http://ghsl.jrc.ec.europa.eu/ghs_smod.php
4 https://rss.onlinelibrary.wiley.com/doi/full/10.1111/rssc.12227

World Health Organization

Acknowledgments

Gavin Shaddick (University of Exeter), Matthew Thomas (University of Bath), Michael Brauer (University of British Columbia) and members of the WHO Data Integration Task Force led the recent developments of the model (DIMAQ) used to produce the modelled estimates of global exposures to particulate matter $PM_{2.5}$. Aaron van Donkelaar and Randall Martin (Dalhousie University) provided the satellite estimates and measures of specific contributors of air pollution from chemical transport models used in DIMAQ. Amelia Green (University of Bath) provided statistical support in the post-processing of results from DIMAQ to produce country, and regional, population-weighted exposures. The interactive map of exposure to air pollution were prepared by Ranjith Chinnasamy and Ravi Santhana Gopala Krishnan (WHO).

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