Global air pollution and health: revealing the differences in the quality of the air that we breathe

Matthew Thomas

TIES 2018, Guanajuato

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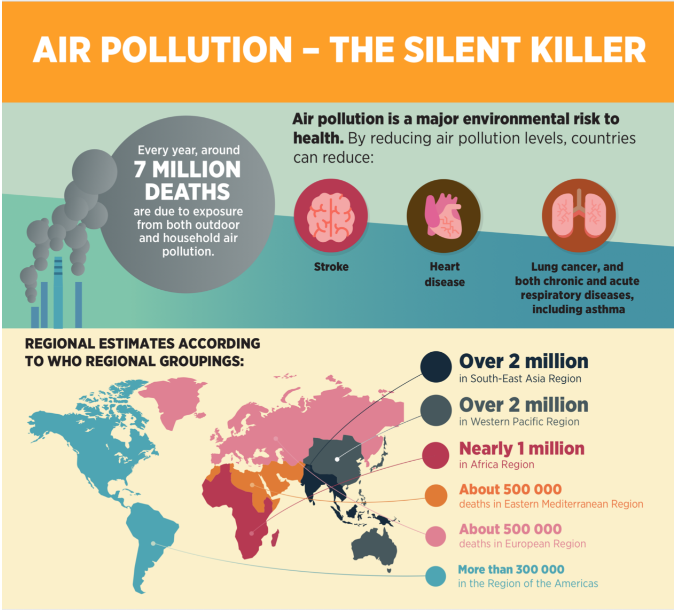

AIR POLLUTION – THE SILENT KILLER
Every year, around
7 MILLION DEATHS
are due to exposure from both outdoor and household air pollution.
Air pollution is a major environmental risk to health. By reducing air pollution levels, countries can reduce:
Stroke
Heart disease
Lung cancer, and both chronic and acute respiratory diseases, including asthma
REGIONAL ESTIMATES ACCORDING TO WHO REGIONAL GROUPINGS:
Over 2 million
in South-East Asia Region
Over 2 million
in Western Pacific Region
Nearly 1 million
in Africa Region
About 500 000
deaths in Eastern Mediterranean Region
About 500 000
deaths in European Region
More than 300 000
in the Region of the Americas

OUTLINE

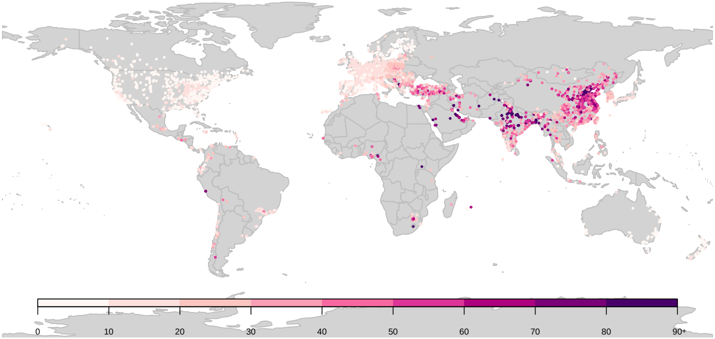
- Introduction
- DIMAQ
- Sustainable Development Goals
- Burden of Disease
- Summary
- Further Information

Introduction

- Ambient air pollution (AAP) has been identified as a global health priority
- In 2016, the World Health Organisation (WHO) estimated that over 4 million deaths can be attributed to ambient air pollution
- The Global Burden of Disease (GBD) project estimate that in 2015 ambient air pollution was in the top ten leading risks to global health
- Burden of disease calculations require accurate estimates of population exposure for each country

INTRODUCTION

- Accurate estimates of exposure to air pollution are required
  - Global, national and local levels
  - Associated measures of uncertainty
- While networks are expanding, ground monitoring is limited in many areas of the world



Introduction

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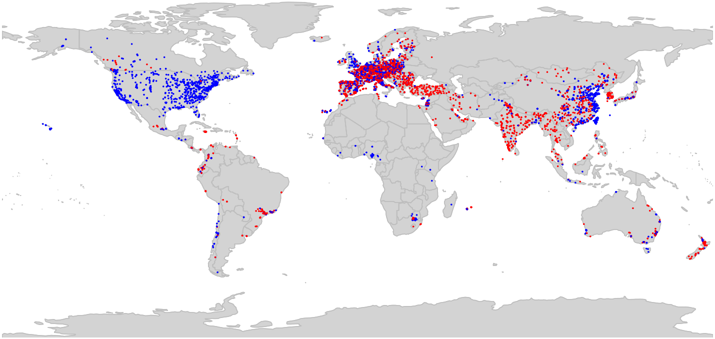
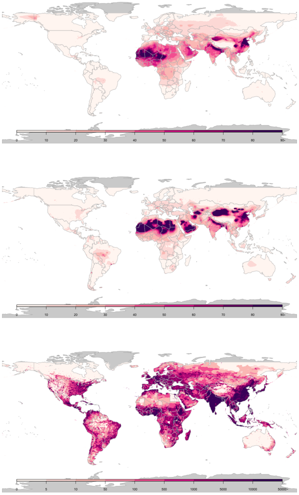


ESTIMATING $PM_{2.5}$

- Can utilise information from other sources
  - Satellite remote sensing
  - Chemical transport models
  - Population estimates
  - Land use
  - Local network characteristics
- Result of modelling and will be subject to uncertainties and biases



Statistical Calibration

- Developed to the Data Integration Model for Air Quality (DIMAQ)
- The aim is to calibrate estimates from chemical transport models, satellite remote sensing, land use regression and topography, X_{pl_s}, against measurements from ground monitors, Y_s,

$$Y_s = \beta_0 + \sum_{i=1}^{N} \beta_i X_{il_s} + \epsilon_s$$

- This will allow us to predict surface $PM_{2.5}$ where there is no ground monitoring information
- However, the relationship between ground monitors and other variables may vary over space

DIMAQ1

- Coefficients can vary spatially

$$Y_s = \tilde{\beta}_{0s} + \sum_{i=1}^{P} \tilde{\beta}_{is} X_{il_s} + \sum_{i=P}^{N} \beta_i X_{il_s} + \epsilon_s$$

- The coefficients in the calibration model are estimated by country
- Model allows borrowing from higher aggregations and if information is not available on a country level
- Exploits a geographical nested hierarchy
- Achieved using a series of hierarchical random effects
- Inference based on Integrated Nested Laplace Approximations (INLA)

REGIONS

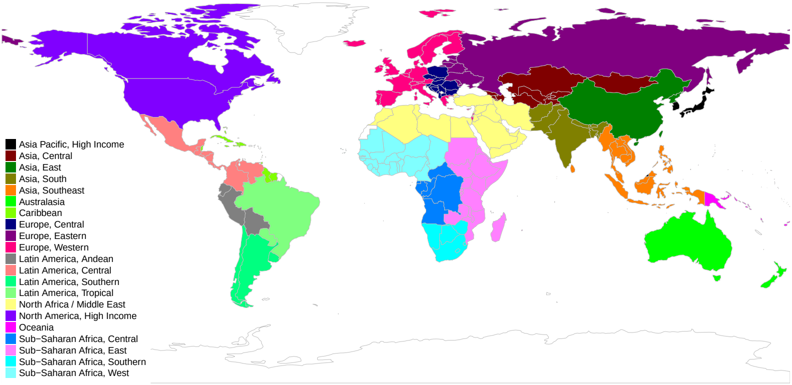


Figure: Map of regions

SUPER-REGIONS

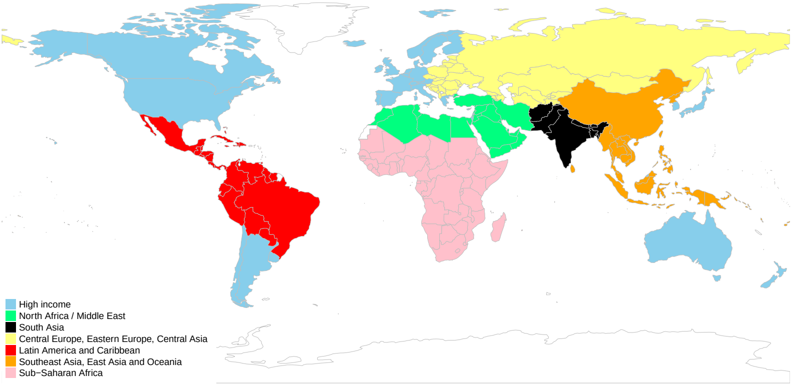


Figure: Map of super-regions

DIMAQ1

- Developed a model to integrate data from multiple sources with the aim of producing high-resolution estimates of population exposures to ambient particulate matter
- DIMAQ1 based on a country-level spatial structure
- Need to account for within country variability
- Inclusion of time

DIMAQ2

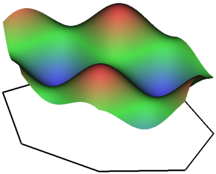
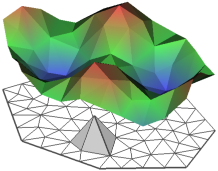
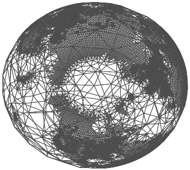
- Coefficients can vary spatio-temporally

$$Y_{st} = \tilde{\beta}_{0st} + \sum_{i=1}^{P} \tilde{\beta}_{ist} X_{il_st} + \sum_{i=P}^{N} \beta_i X_{il_st} + \epsilon_s$$

- Inclusion of a continuous spatial process
  - Within country variability
  - Within grid-cell variability (Downscaling)
- Temporal variation in the calibration coefficients
  - Regional
  - Random walk

APPROXIMATION TO THE SPATIO-TEMPORAL FIELDS

- Computationally challenging to fit multiple spatio-temporal processes
- The approximation to the spatial field is the solution to Stochastic Partial Differential Equation (SPDE)
- Inference based on Integrated Nested Laplace Approximations (INLA)
- Penalised complexity priors for model hyperparameters

PREDICTION

- High resolution estimates of air pollution concentrations are required over space and time
- Computationally expensive
- Monte Carlo Simulation
  - Draw M samples from the joint posterior of the model parameters
  - Produce M joint samples using the linear predictor
  - Aggregation is fairly straightforward
  - Summaries of the marginal posterior distributions can then be made

CONCENTRATIONS OF $PM_{2.5}$

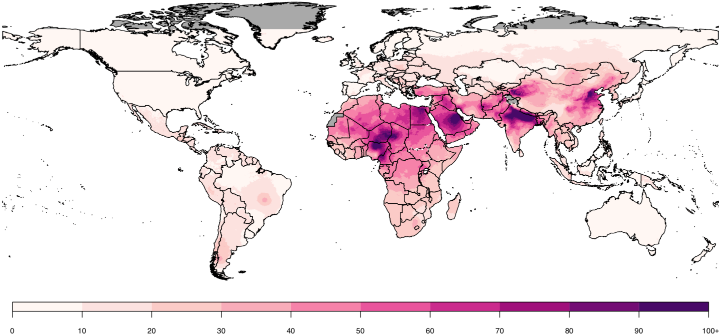


Figure: Median estimates of annual averages of $PM_{2.5}$ (μgm^{-3}) for 2016 for each grid cell ($0.1^o \times 0.1^o$ resolution) using DIMAQ2

Coefficient of Variation

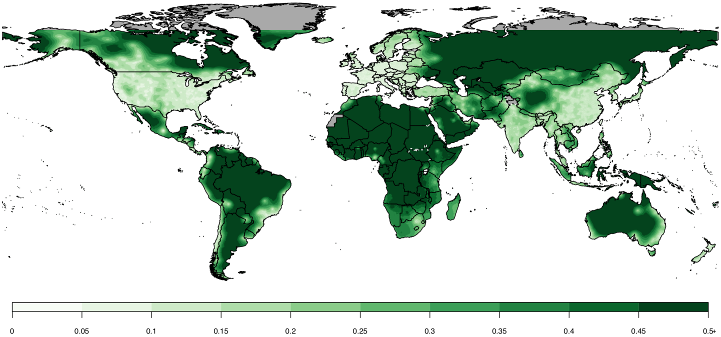


Figure: Coefficient of variation of annual averages of $PM_{2.5}$ (μgm^{-3}) for 2016 for each grid cell ($0.1^o \times 0.1^o$ resolution) using DIMAQ2

Probability of Exceedance

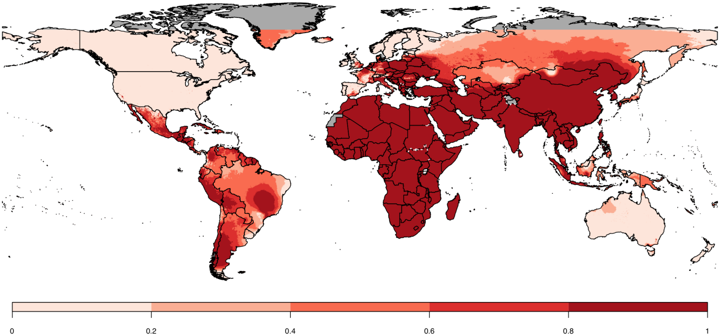


Figure: Probability that annual average $PM_{2.5}$ (μgm^{-3}) exceeds the WHO AQGs for 2016 for each grid cell ($0.1^o \times 0.1^o$ resolution) using DIMAQ2

Sustainable Development Goals

Sustainable Development Goals

- Goal 11: Sustainable Cities and Communities
  - "Make cities and human settlements inclusive, safe, resilient and sustainable."
- Progress of Goal 11 in 2017
  - "Air pollution is a major environmental health risk. In 2014, 9 of 10 people who live in cities were breathing air that did not comply with the safety standard set by WHO."

Sustainable Development Goals

- **Target:** By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management
- **Indicator:** 11.6.2
  - Annual mean levels of fine particulate matter (e.g. PM2.5 and PM10) in cities (population weighted)

COUNTRIES

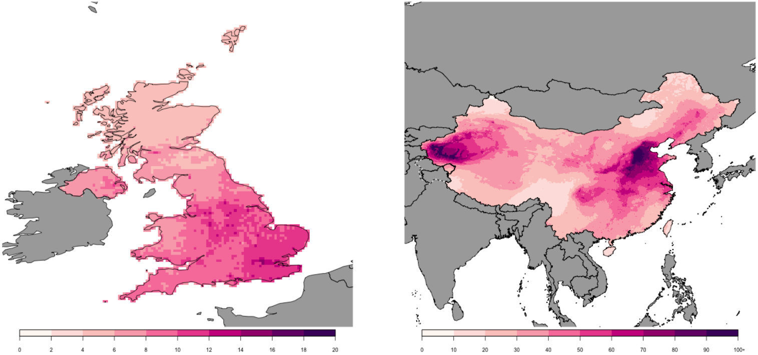


Figure: Medians of posterior distributions for estimates of annual mean $PM_{2.5}$ concentrations (μgm^{-3}) for 2016, in (Left) United Kingdom and (Right) China

Population Exposures

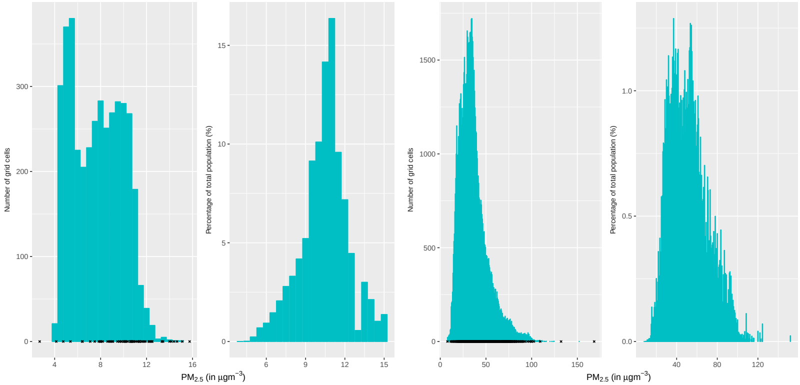


Figure: Estimated annual average concentrations and population level exposures of $PM_{2.5}$ by grid cell ($0.1^o \times 0.1^o$ resolution) in (Left) United Kingdom and (Right) China. Black crosses denote the annual averages recorded at ground monitors

Population Exposures

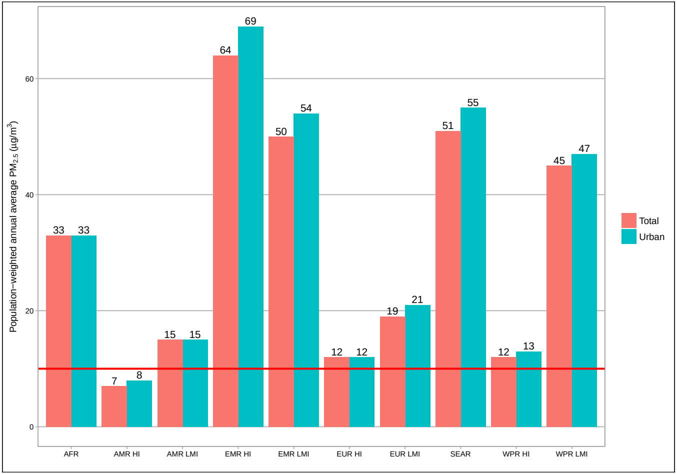


Figure: Estimated population level exposures of $PM_{2.5}$ by grid cell ($0.1^o \times 0.1^o$ resolution) for all and urban areas by WHO Income Region. AFR: Africa; AMR: America; EMR: Eastern Mediterranean; EUR: Europe; SEAR: South-East Asia; WPR: Western Pacific; LMI: Low- and middle-income; HI: High-income

Exceedances

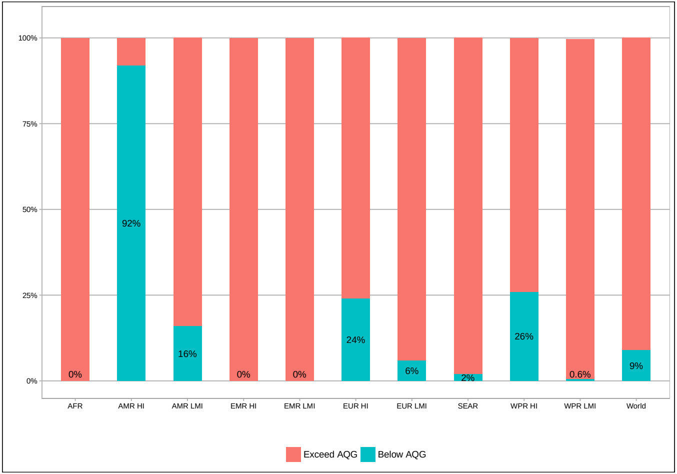


Figure: Percentage of regional populatiosn residing in areas in which the WHO Air Quality Guideline (AQG: annual average $PM_{2.5}$ exceeds 10 $\mu g/m^{-3}$) is exceeded. AFR: Africa; AMR: America; EMR: Eastern Mediterranean; EUR: Europe; SEAR: South-East Asia; WPR: Western Pacific; LMI: Low- and middle-income; HI: High-income

Burden of Disease

- Population attributable fraction (PAF), for each country

$$\text{PAF} = \frac{\sum_{i=1}^{n} P_i(RR_i - 1)}{\sum_{i=1}^{n} P_i(RR_i - 1) + 1}$$

- Attributable burden (AB)

$$\text{AB} = \text{PAF} \times \text{Health Outcome}$$

- Requires the percentage of the population, P_i, exposed to $PM_{2.5}$, by country
  - Increments of $1\mu gm^{-3}$

Burden of Disease

```
> subset(PopTable_2016, CountryName=="China")[,6:8]
    PM25          POP         PROP
802    8 1.428625e+01 1.012236e-08
803    9 3.193078e+03 2.262420e-06
804   10 2.499702e+04 1.771136e-05
805   11 1.313413e+05 9.306039e-05
806   12 1.783991e+05 1.264027e-04
807   13 3.258364e+05 2.308677e-04
808   14 3.774752e+05 2.674558e-04
809   15 2.308018e+06 1.635320e-03
810   16 2.938478e+06 2.082025e-03
811   17 2.416260e+06 1.712014e-03
812   18 3.426306e+06 2.427670e-03
813   19 4.062976e+06 2.878776e-03
814   20 5.434134e+06 3.850295e-03
815   21 4.259990e+06 3.018368e-03
816   22 9.449073e+06 6.695034e-03
817   23 7.711642e+06 5.463997e-03
818   24 9.566212e+06 6.778032e-03
819   25 1.327963e+07 9.409131e-03
820   26 1.786790e+07 1.266010e-02
821   27 1.998274e+07 1.415855e-02
822   28 2.323881e+07 1.646559e-02
823   29 2.355601e+07 1.669035e-02
824   30 2.808526e+07 1.989949e-02
825   31 2.787763e+07 1.975238e-02
826   32 2.907601e+07 2.060148e-02
827   33 2.625109e+07 1.859991e-02
828   34 2.531312e+07 1.793533e-02
829   35 3.028161e+07 2.145569e-02
830   36 2.897744e+07 2.053164e-02
831   37 3.401177e+07 2.409866e-02
832   38 2.829276e+07 2.004651e-02
833   39 3.271357e+07 2.317883e-02
834   40 2.753847e+07 1.951207e-02
835   41 2.884069e+07 2.043475e-02
836   42 2.916204e+07 2.066243e-02
837   43 2.428347e+07 1.720578e-02
838   44 2.632661e+07 1.865342e-02
839   45 2.473716e+07 1.752724e-02
840   46 2.572816e+07 1.822940e-02
841   47 2.456641e+07 1.740625e-02
842   48 2.823383e+07 2.000477e-02
843   49 2.707141e+07 1.918114e-02
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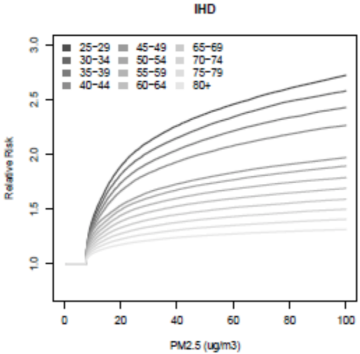


The Global Burden

- Globally, 4.2 million deaths were attributable to ambient air pollution in 2016
- Five diseases included in the assessment
  - Acute lower respiratory infection
  - Lung cancer
  - Chronic obstructive pulmonary disease (COPD)
  - Ischaemic heart disease
  - Stroke
- 91% of these deaths occur in low– and middle–income (LMI) countries
- South-east Asian and Western Pacific regions bear most of the burden with each about 1.3 million deaths
- Non–communicable diseases account for 82% of deaths

Summary

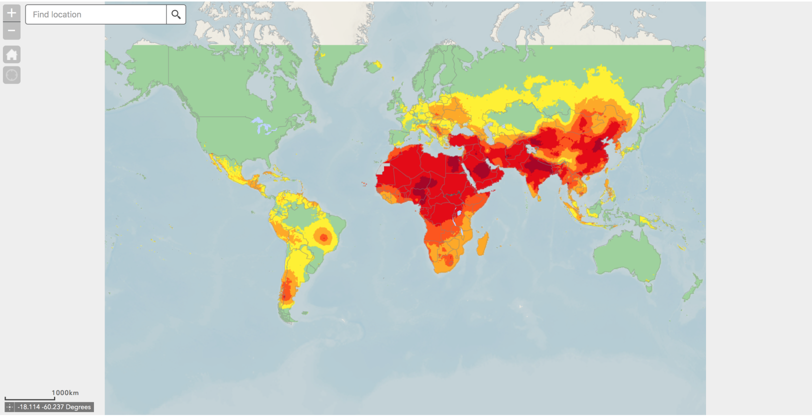
- WHO estimates that around 90% of people worldwide breathe polluted air
- AAP levels have remained high and approximatively stable
- Declining concentrations in parts of Europe and in the Americas
- The highest ambient air pollution levels are in the Eastern Mediterranean Region and in South-East Asia
  - Annual mean levels often exceeding more than 5 times WHO limits
- Followed by low and middle-income cities in Africa and the Western Pacific

Summary

- Increase in burden compared with the previous estimate of 3.0 million deaths from AAP for the year 2014
  - Additional age groups for acute lower respiratory infections are included in the analysis due to new evidence that has become available
  - Revised exposure–response functions
  - Increase in mortality rates from non–communicable diseases
- Future work
  - Higher resolution in space and time

Interactive Map

http://maps.who.int/airpollution/



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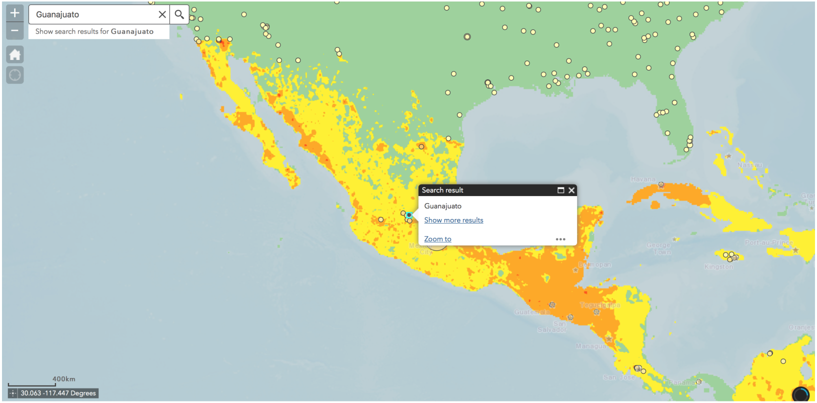

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Further Information

http://www.who.int/airpollution


GLOBAL AIR QUALITY

UNIVERSITY OF EXETER

HOME | AMBIENT/ DIMAQ | HOUSEHOLD / GHHEM | WHO TASKFORCE | LINKS

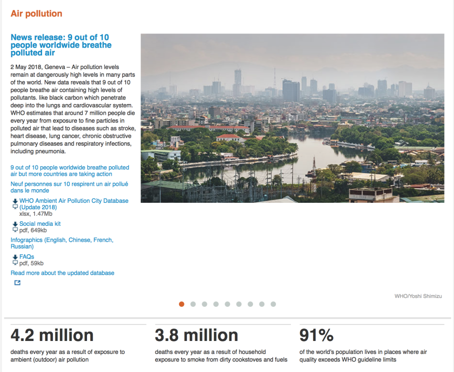
ESTIMATES OF GLOBAL FINE PARTICULATE MATTER AIR POLLUTION (PM2.5) FOR 2016

Air pollution is a major risk factor for global health, with both ambient and household air pollution contributing substantial components of the overall global disease burden. One of the key drivers of adverse health effects is fine particulate matter ambient (outdoor) pollution (PM2.5) to which an estimated 4.2 million deaths can be attributed annually. Together with household air pollution, it is estimated that globally 7 million deaths can be attributable to air pollution annually.

Button

Click here for interactive map

Assessment of the global effects of air pollution 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 is increasing, there remain regions in which monitoring is limited.


Air pollution

News release: 9 out of 10 people worldwide breathe polluted air

2 May 2018, Geneva – Air pollution levels remain at dangerously high levels in many parts of the world. New data reveals that 9 out of 10 people breathe air containing high levels of pollutants. like black carbon which penetrate deep into the lungs and cardiovascular system. WHO estimates that around 7 million people die every year from exposure to fine particles in polluted air that lead to diseases such as stroke, heart disease, lung cancer, chronic obstructive pulmonary diseases and respiratory infections, including pneumonia.

9 out of 10 people worldwide breathe polluted air but more countries are taking action

Neuf personnes sur 10 respirent un air pollué dans le monde

WHO Ambient Air Pollution City Database (Update 2018)
xlsx, 1.47Mb

Social media kit
pdf, 649kb

Infographics (English, Chinese, French, Russian)

FAQs
pdf, 59kb

Read more about the updated database

WHO/Yoshi Shimizu

4.2 million deaths every year as a result of exposure to ambient (outdoor) air pollution

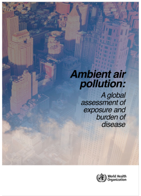
3.8 million deaths every year as a result of household exposure to smoke from dirty cookstoves and fuels

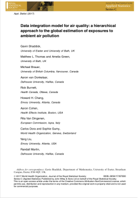
91% of the world's population lives in places where air quality exceeds WHO guideline limits

http://www.exeter.ac.uk/globalairquality

Further Information

- WHO ‘Ambient air pollution: A global assessment of exposure and burden of disease’
- GBD2016 ‘Global, regional, and national comparative risk assessment of 84 behavioural, environmental and occupational, and metabolic risks or clusters of risks, 1990–2016: a systematic analysis for the Global Burden of Disease Study 2016’
- Data Integration Model for Air Quality: A Hierarchical Approach to the Global Estimation of Exposures to Ambient Air Pollution. JRSSC 2018





Any Questions?