ICIMOD CAPHER-India HEI

Early-Career Training on Air Pollution and Health, August 12-14, 2024 | ICIMOD, Kathmandu, Nepal

Air Pollution and Health

Why are we here?

Michal Krzyzanowski
Visiting Professor, Imperial College London

IMPERIAL

This presentation

- Why air pollution and health matters?
- Current state of the science on air quality & health
- Role of the scientific evidence on health effects of air pollution in policy making

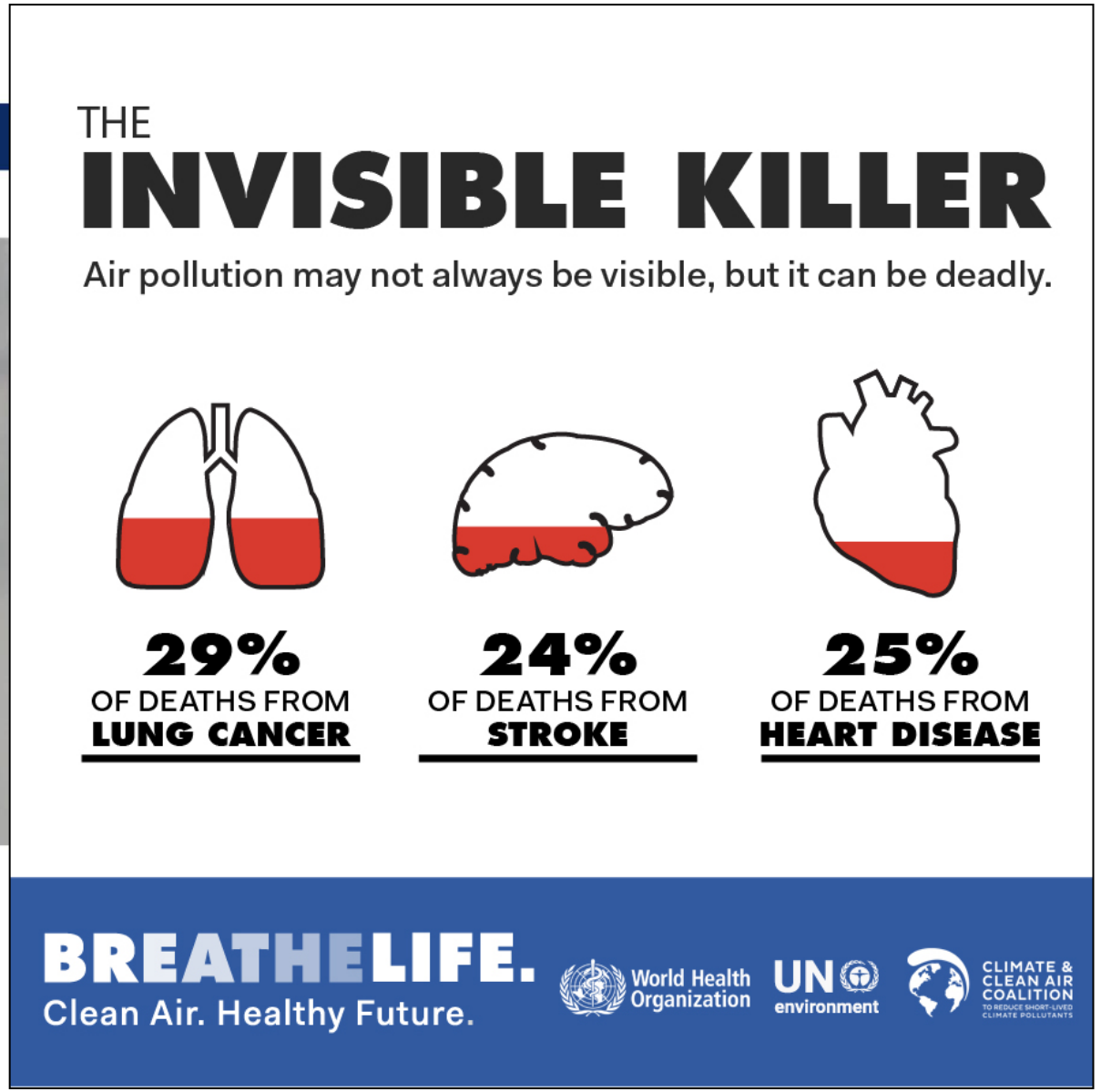
- *What I wish you knew as an early career researcher?*

World Health Organization

Health Topics | Countries | Newsroom | Emergencies

Home / News / Billions of people still breathe unhealthy air: new WHO data

Billions of people still breathe unhealthy air: new WHO data

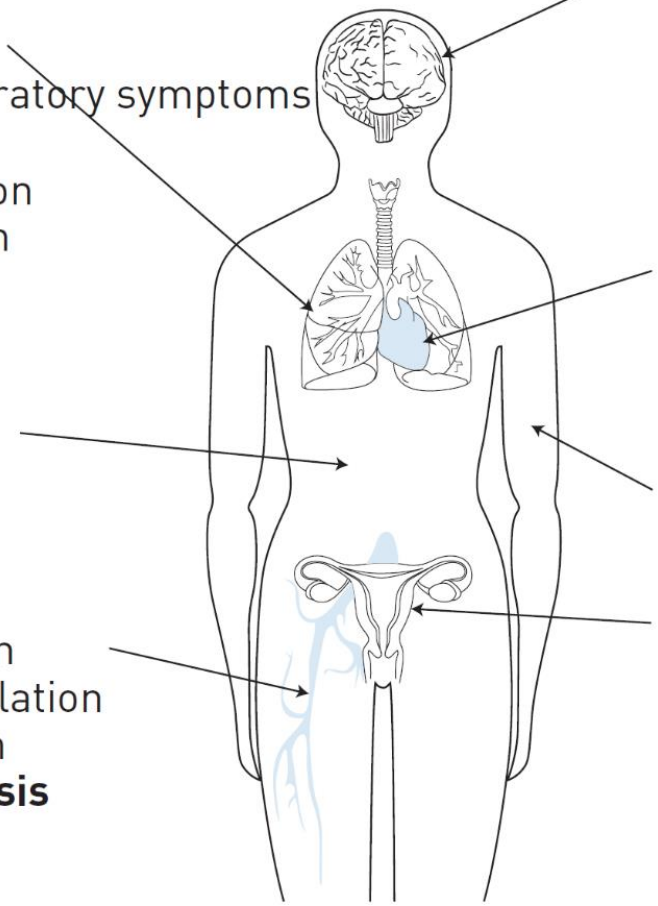


Diseases, conditions and biomarkers affected by outdoor air pollution

Respiratory disease mortality
Respiratory disease morbidity
Lung cancer
Pneumonia
Upper and lower respiratory symptoms
Airway inflammation
Decreased lung function
Decreased lung growth

Insulin resistance
Type 2 diabetes
Type 1 diabetes
Bone metabolism

High blood pressure
Endothelial dysfunction
Increased blood coagulation
Systemic inflammation
Deep venous thrombosis



Stroke
Neurological development
Mental health
Neurodegenerative diseases

Cardiovascular disease mortality
Cardiovascular disease morbidity
Myocardial infarction
Arrhythmia
Congestive heart failure
Changes in heart rate variability
ST-segment depression

Skin ageing

Premature birth
Decreased birthweight
Decreased fetal growth
Intrauterine growth retardation
Decreased sperm quality
Pre-eclampsia

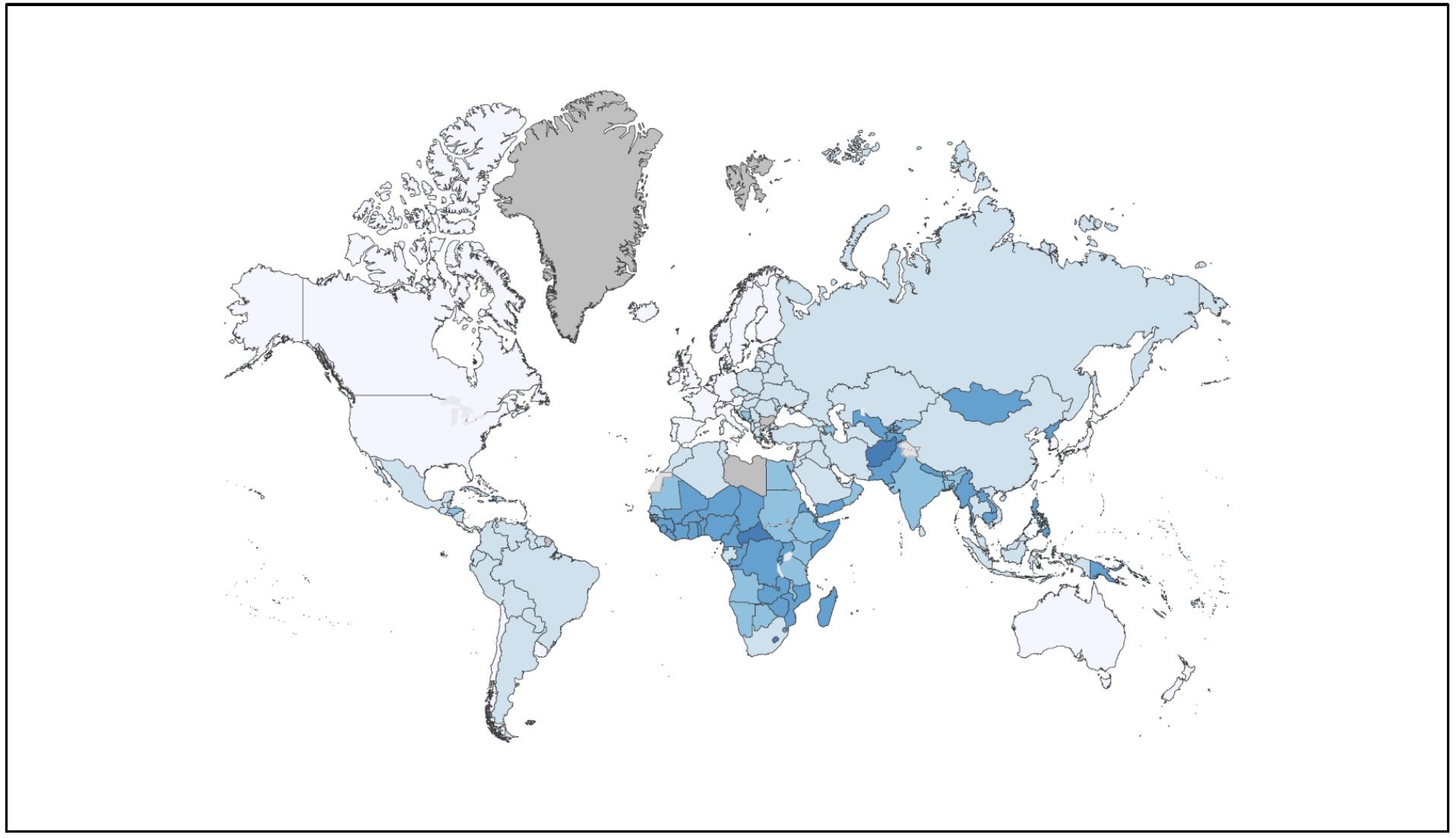
Thurston et al. ERS/ATS Statement. Eur Resp J 2017

Causality determinations on the long- and short-term effects of air pollutants for different disease categories

Category	$PM_{2.5}$ (EPA 2019)		NO_2 (EPA 2016)		Ozone (EPA 2020)	
	Long-term	Short-term	Long-term	Short-term	Long-term	Short-ter
Reproductive and Developmental effects	*Suggestive*	*Suggestive*	*Suggestive*	*Suggestive*	*Suggestive*	
Respiratory effects	***Likely***	***Likely***	***Likely***	***Causal***	***Likely***	***Causal***
Cardiovascular diseases	***Causal***	***Causal***	*Suggestive*	*Suggestive*	*Suggestive*	*Suggestive*
Metabolic effects	*Suggestive*	*Suggestive*	*Suggestive*	*Suggestive*	*Suggestive*	***Likely***
Neurological effects	***Likely***	*Suggestive*			*Suggestive*	*Suggestive*
Cancer (lung cancer)	***Likely (a)***		*Suggestive*		*Inadequate*	
Mortality	***Causal***	***Causal***	*Suggestive*	*Suggestive*	*Suggestive*	*Inadequate*

(a) IARC 2013: $PM_{2.5}$ and PM_{10} exposure is carcinogenic to humans (Group 1)

Age-standardized mortality rates (ASMR) attributed to household and ambient air pollution jointly, 2019



18/4/2024

ASMR (per 100,000 people)

7.44 - 20

> 20 - 100

> 100 - 150

> 150 - 250

> 250 - 309.51

Data not available

1:207,012,870

0 487.5 975 1,950 mi

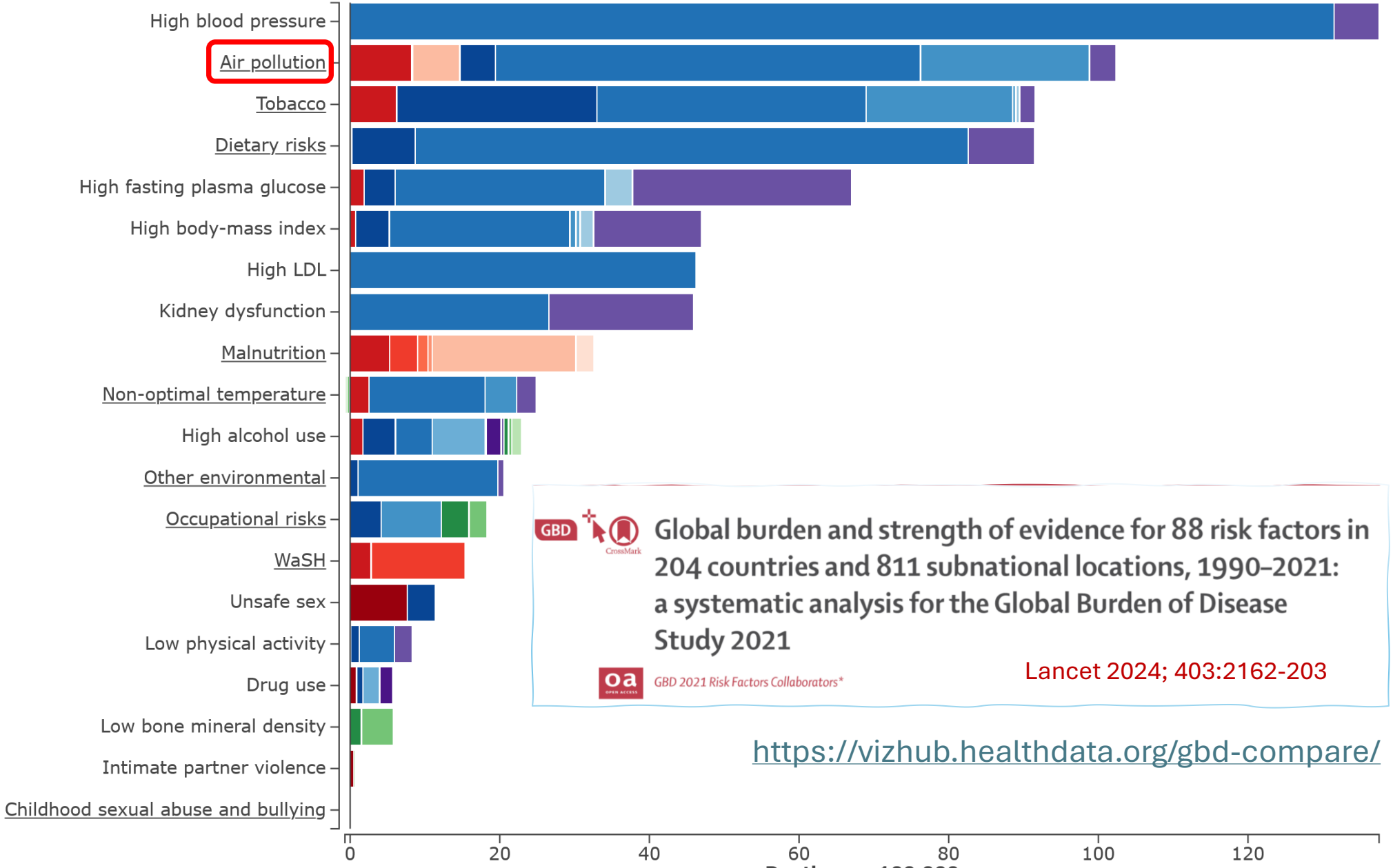
0 500 1,000 2,000 km

6.7 million deaths attributed to household and ambient air pollution jointly, in 2019

Equivalent to an age-standardized mortality rate of 104 deaths per 100 000 people

Back

Global, Both sexes, All ages, 2021



GBD

Global burden and strength of evidence for 88 risk factors in 204 countries and 811 subnational locations, 1990–2021: a systematic analysis for the Global Burden of Disease Study 2021

oa

GBD 2021 Risk Factors Collaborators*

Lancet 2024; 403:2162-203

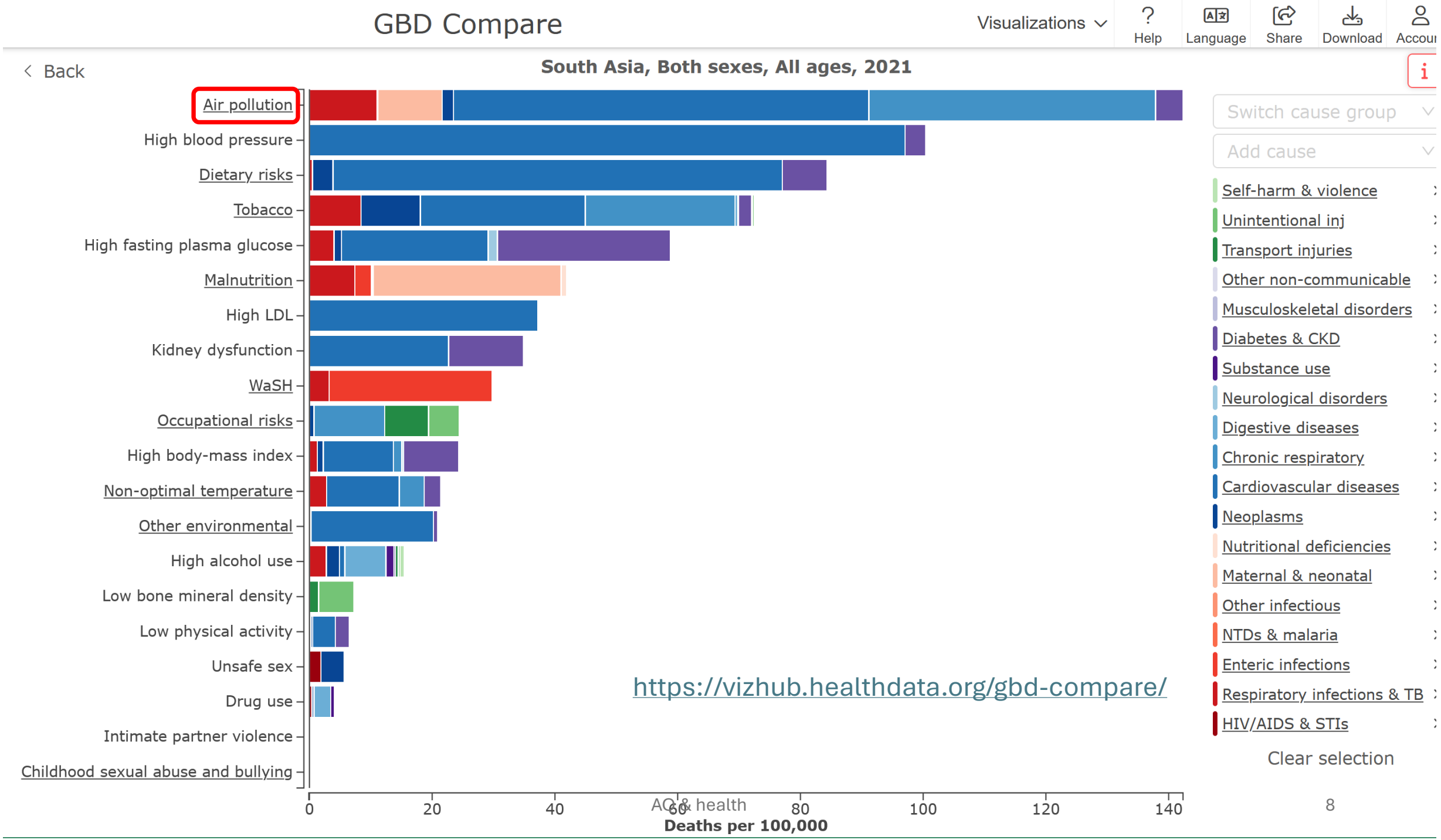
https://vizhub.healthdata.org/gbd-compare/

Switch cause group

Add cause

- Self-harm & violence
- Unintentional inj
- Transport injuries
- Other non-communicable
- Musculoskeletal disorders
- Diabetes & CKD
- Substance use
- Neurological disorders
- Digestive diseases
- Chronic respiratory
- Cardiovascular diseases
- Neoplasms
- Nutritional deficiencies
- Maternal & neonatal
- Other infectious
- NTDs & malaria
- Enteric infections
- Respiratory infections & TB
- HIV/AIDS & STIs

Clear selection


GBD Compare
Visualizations
Help
Language
Share
Download
Accou
Back
South Asia, Both sexes, All ages, 2021
Air pollution
High blood pressure
Dietary risks
Tobacco
High fasting plasma glucose
Malnutrition
High LDL
Kidney dysfunction
WaSH
Occupational risks
High body-mass index
Non-optimal temperature
Other environmental
High alcohol use
Low bone mineral density
Low physical activity
Unsafe sex
Drug use
Intimate partner violence
Childhood sexual abuse and bullying
0
20
40
60
80
100
120
140
Deaths per 100,000
https://vizhub.healthdata.org/gbd-compare/
Switch cause group
Add cause
Self-harm & violence
Unintentional inj
Transport injuries
Other non-communicable
Musculoskeletal disorders
Diabetes & CKD
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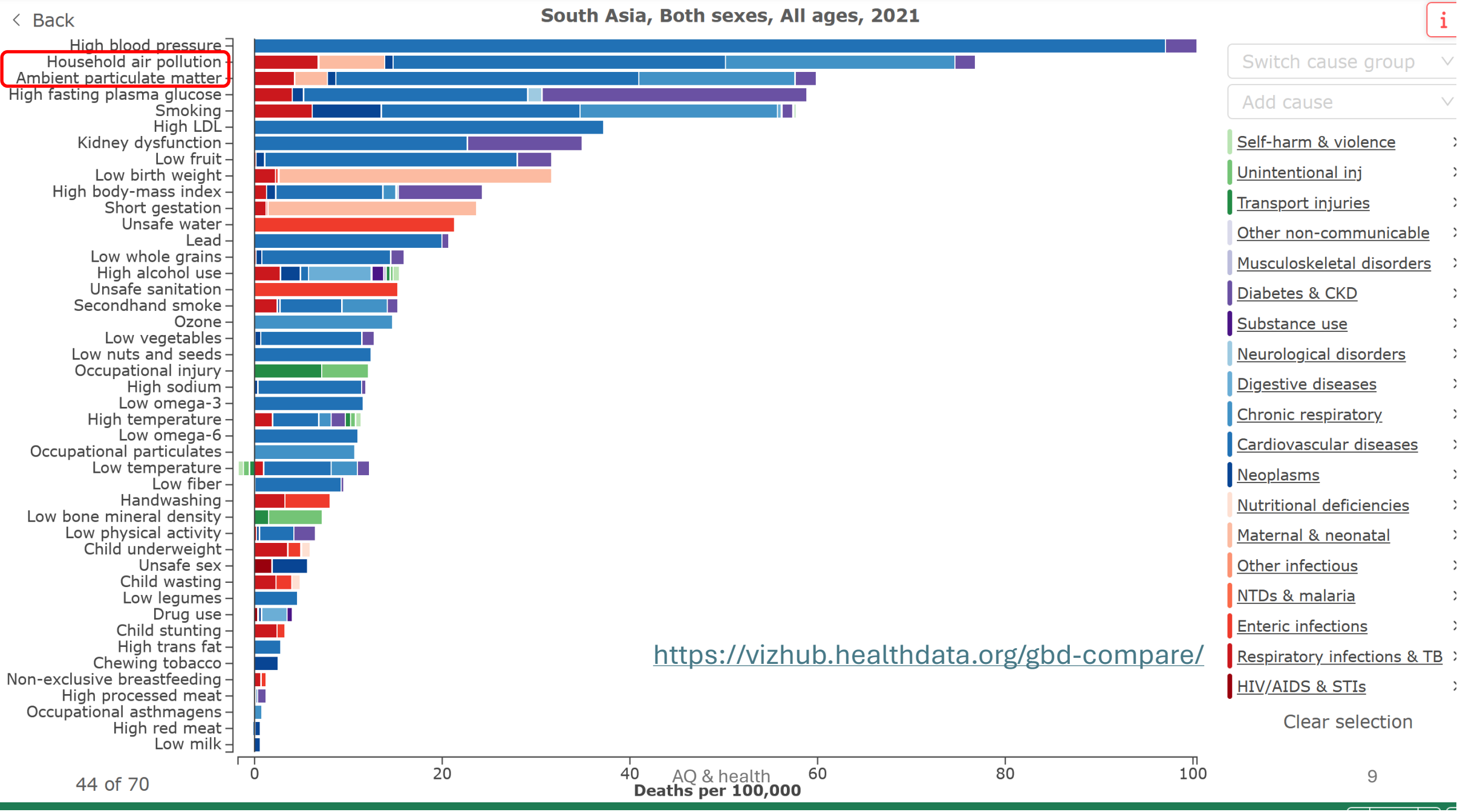
South Asia, Both sexes, All ages, 2021
High blood pressure
Household air pollution
Ambient particulate matter
High fasting plasma glucose
Smoking
High LDL
Kidney dysfunction
Low fruit
Low birth weight
High body-mass index
Short gestation
Unsafe water
Lead
Low whole grains
High alcohol use
Unsafe sanitation
Secondhand smoke
Ozone
Low vegetables
Low nuts and seeds
Occupational injury
High sodium
Low omega-3
High temperature
Low omega-6
Occupational particulates
Low temperature
Low fiber
Handwashing
Low bone mineral density
Low physical activity
Child underweight
Unsafe sex
Child wasting
Low legumes
Drug use
Child stunting
High trans fat
Chewing tobacco
Non-exclusive breastfeeding
High processed meat
Occupational asthmagens
High red meat
Low milk
0
20
40
60
80
100
Deaths per 100,000
https://vizhub.healthdata.org/gbd-compare/
Switch cause group
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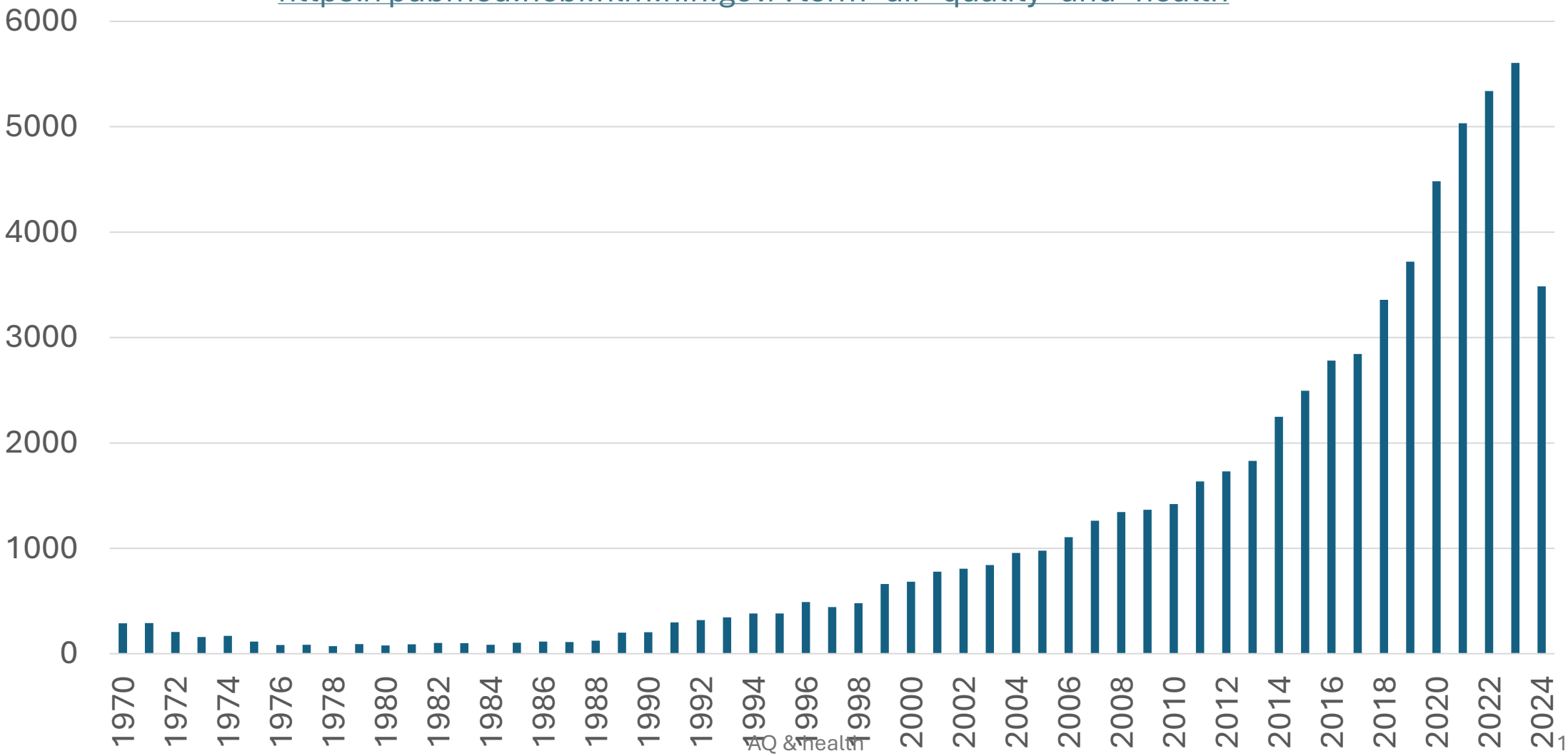
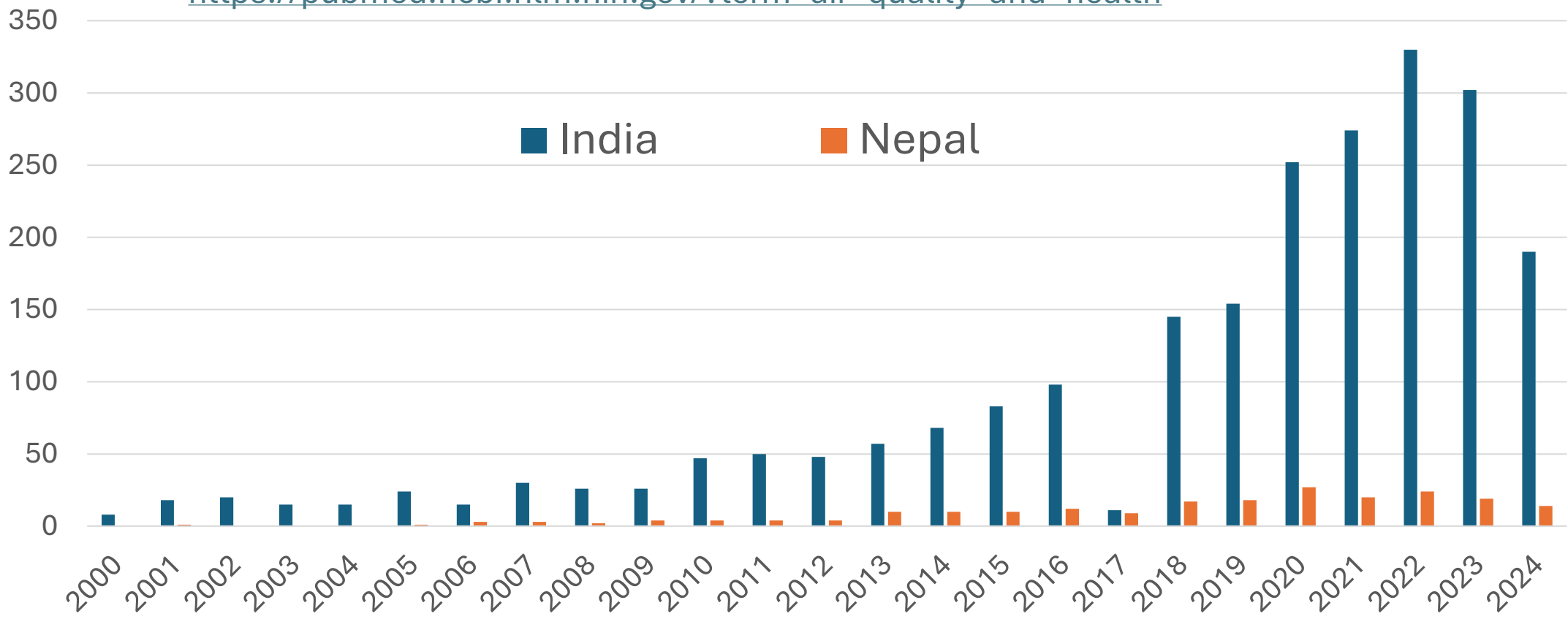
Number of publications / year with keywords “Air quality and Health” in PubMed (as of 30.07.2024)

https://pubmed.ncbi.nlm.nih.gov/?term=air+quality+and+health



Number of publications / year with keywords “Air quality and Health” and India or Nepal in PubMed (as of 30.07.2024)

https://pubmed.ncbi.nlm.nih.gov/?term=air+quality+and+health

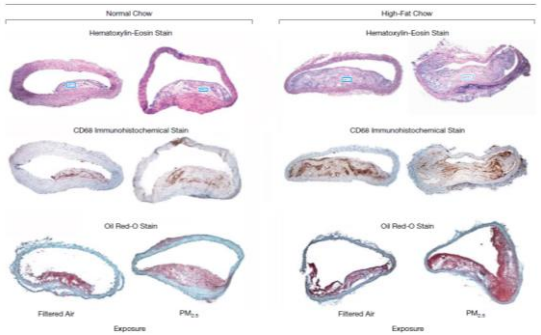


Sources of scientific evidence on air pollution health effects

- Epidemiological studies

- Clinical (controlled exposure) studies

- Animal / mechanistic studies



WHO air quality guidelines: 1987 - 2021

1987

2000

2005

2009

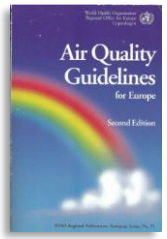
2010

2014

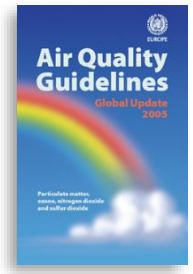
2016

2021

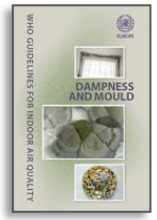
AQG for Europe

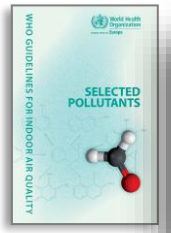


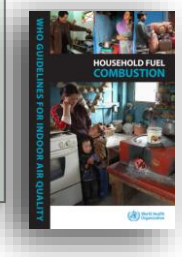
AQG for Europe, 2nd ed.



AQG – Global update 2005



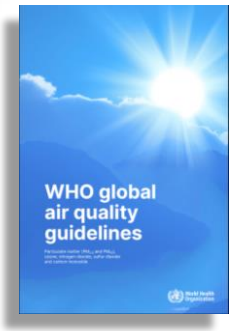




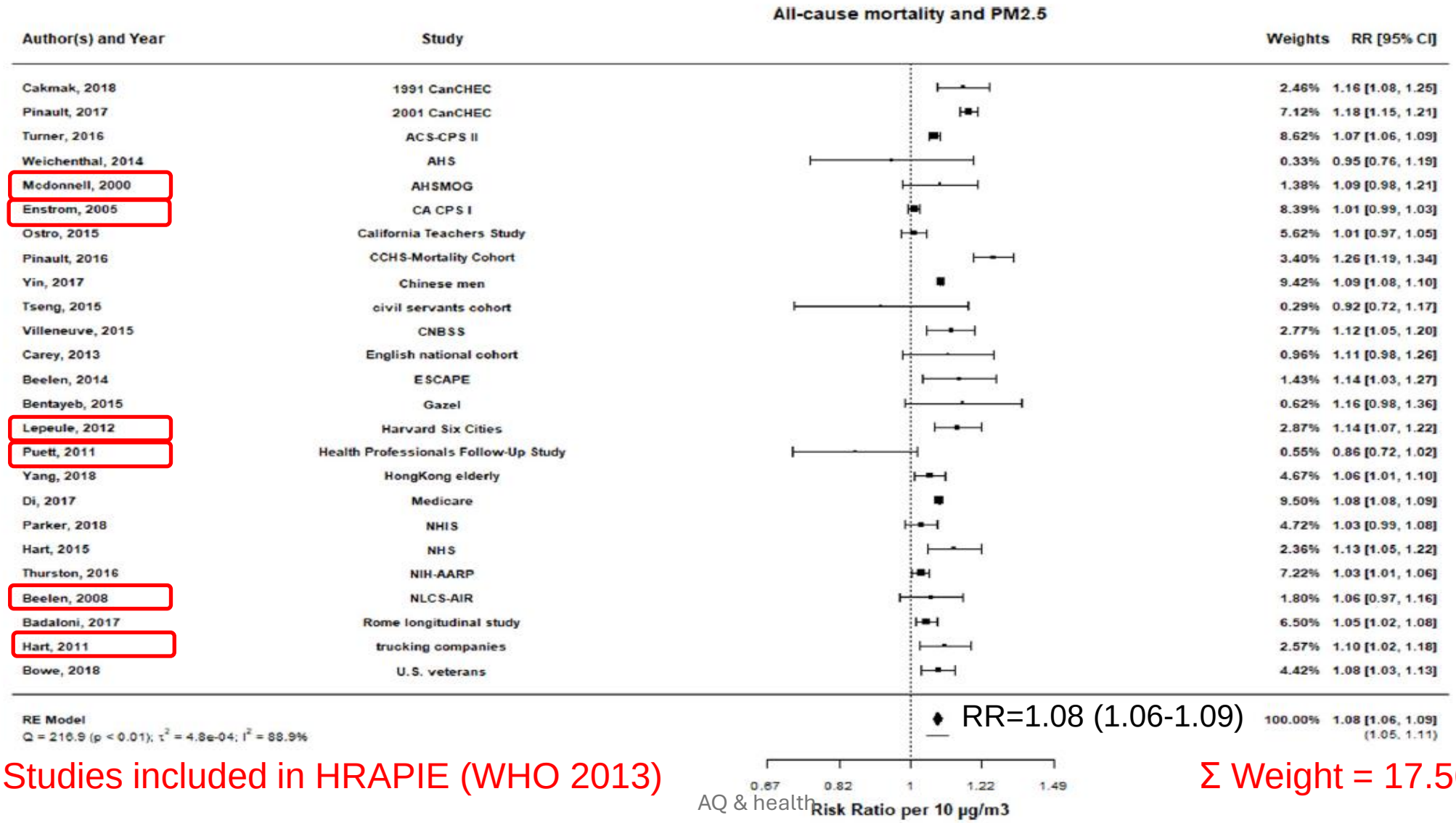
Guidelines for indoor AQ:
- Dampness and mould
- Selected pollutants
- Household fuels combustion

AQG update process

WHO global AQGs 2021



Long-term exposure to PM2.5 and natural-cause mortality – systematic review and meta-analysis supporting WHO 2021 update



Chen & Hoek, Env Internat 2020

Studies included in HRAPIE (WHO 2013)

Σ Weight = 17.56%

Number of studies included in the SR / MA in 2020 and 2024

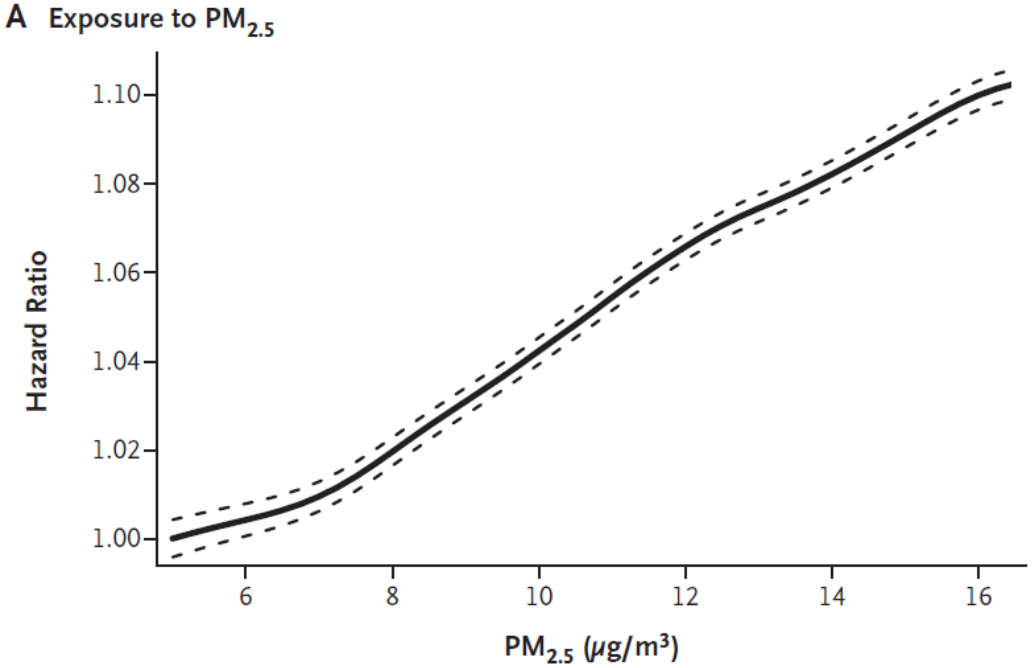
(examples for selected mortality causes)

Pollutant	Mortality	SR2020	Updated SR 2024*
PM2.5	All-cause	25	53
	Circulatory	21	42
PM10	All-cause	17	29
NO2	All-cause	11	34
	Circulatory	0	28
	ALRI	0	9
O3 (annual mean)	All-cause	9	9
	Respiratory	4	6
O3 (peak season)	All-cause	7	12
	Respiratory	4	9

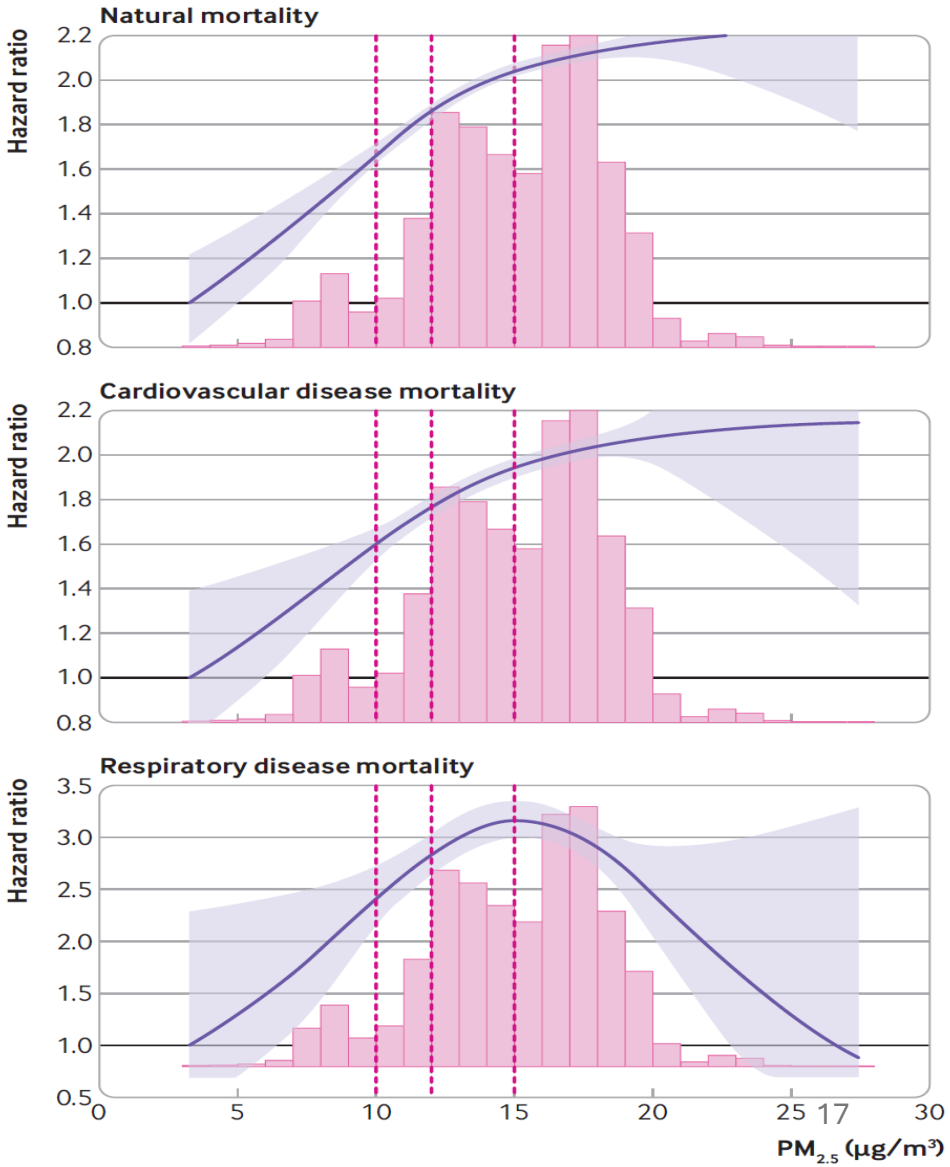
** Based on WHO HRAPIE-2 project; Orellano et al, 2024 (submitted) and Samoli et al, 2024 (submitted);*
Studies from AMR, EUR, WPR but no from SER or AFR

Risk increases with exposure level

Cohort of 60 925 433 US adults, age 65+, followed 2000-2012 *(Di et al, NEJM 2017)*

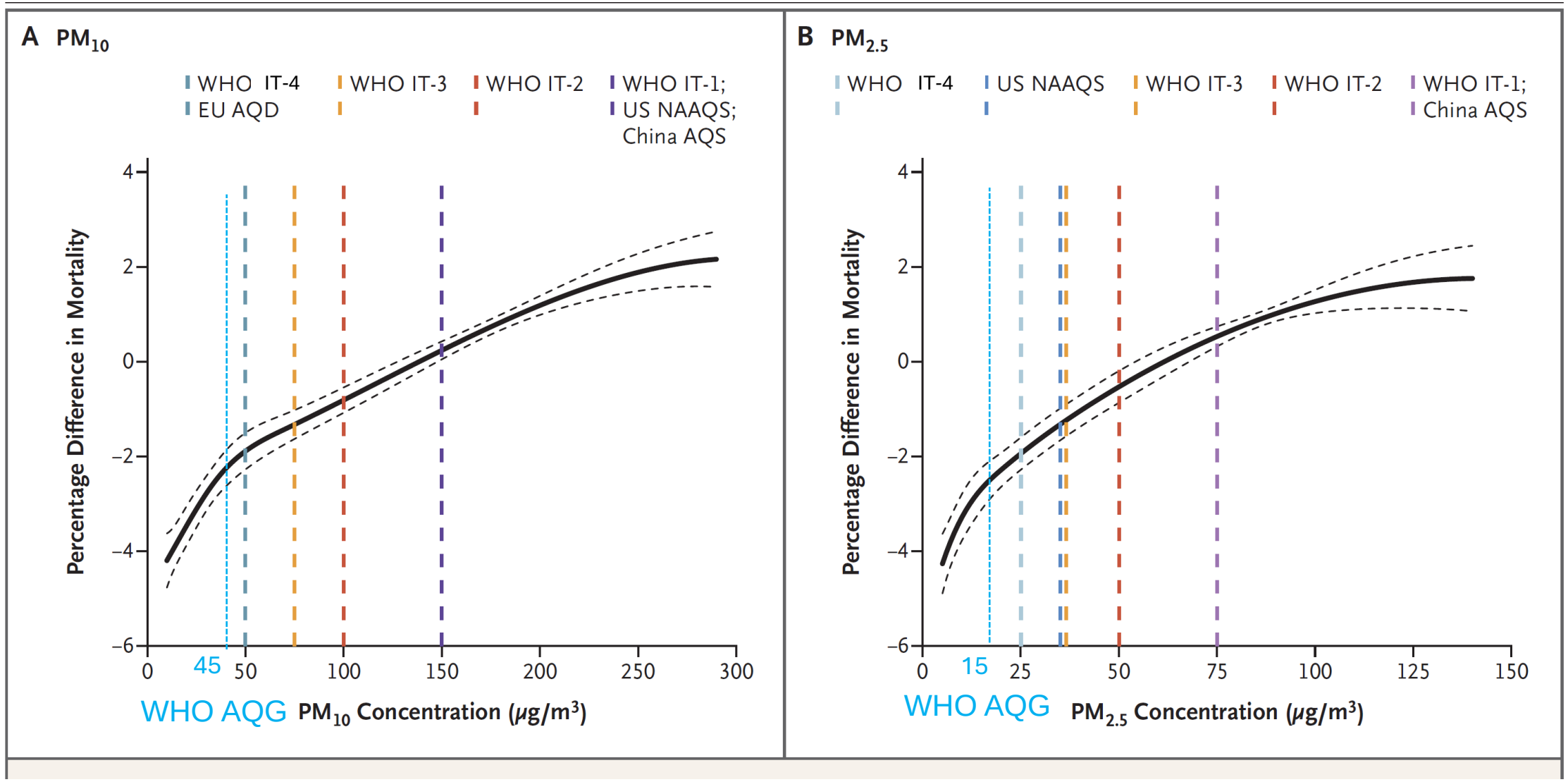


Pooled analysis of eight European cohorts in ELAPSE study. 325 367 adults followed for av. 19.5 years. *(Strak et al, BMJ 2021)*



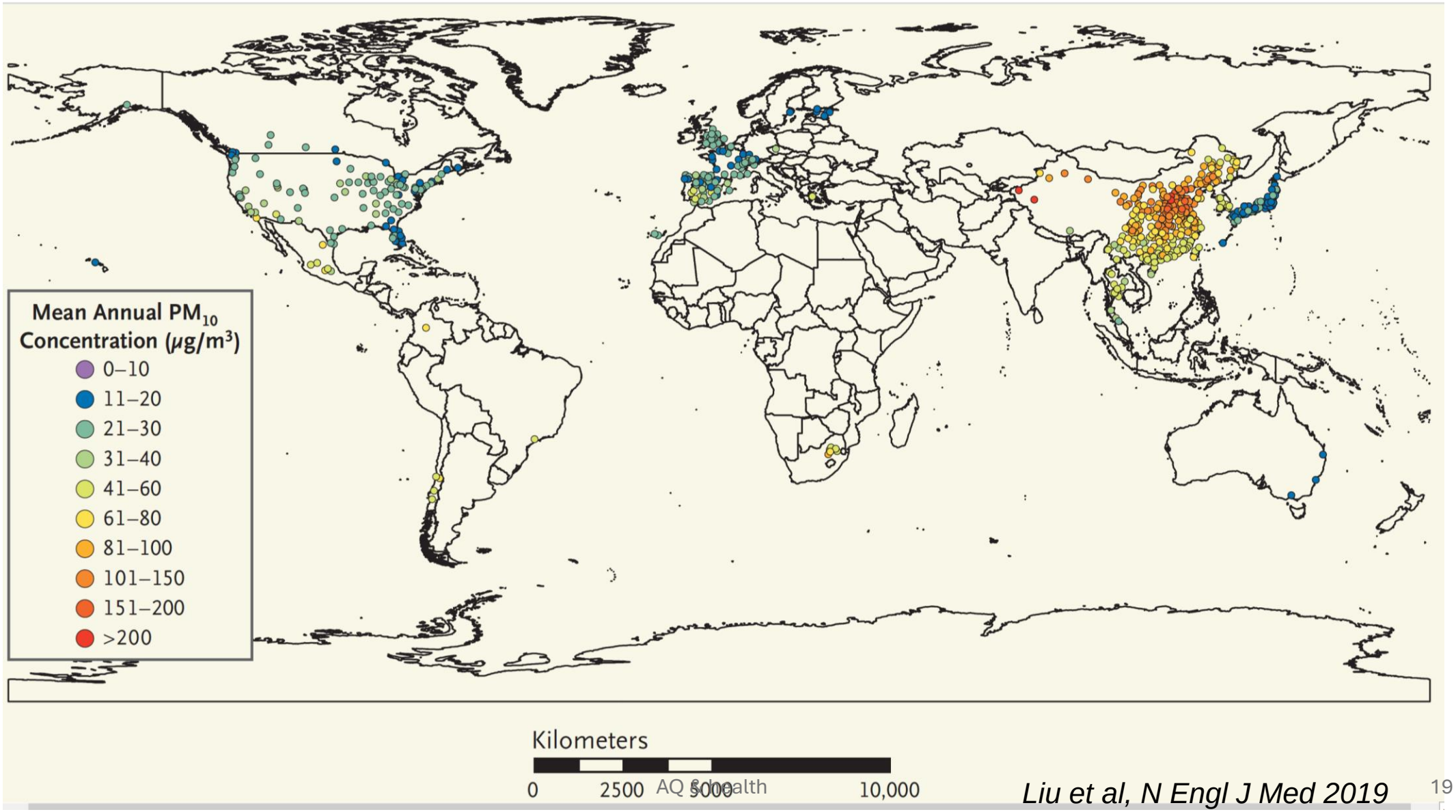
Daily mean PM concentration and daily mortality

Results of joint analysis of data from 652 cities in 24 countries or regions



Liu et al, N Engl J Med 2019

Cities with daily data on PM10 included in Liu et al. analysis



Liu et al, N Engl J Med 2019

Relative risk estimates for incidence of diseases from selected systematic reviews recommended for health risk assessment of $PM_{2.5}$

Outcome (incidence)	ICD10 codes	Age (years)	List	RR (95%CI) per 10 µg/m³	Mean exposure range (µg/m³)	SR reference
Asthma in children	J45	0 - 18	A	1.34 (1.10; 1.63)	5 - 38	Khreis et al. (2017)
COPD	J41 – J44	30+	A	1.18 (1.13; 1.23)	5 - 26	Park et al. (2021)
IHD events	I21-I22	30+	A	1.13 (1.05; 1.22)†	5 - 65	Zhu et al. (2021)
Stroke	I60 – I64	30+	A	1.16 (1.12; 1.20)†	5 - 36	Yuan et al. (2019)
Hypertension	I10 - I11	30+	A	1.17 (1.05; 1.30)†	5 - 77	Qin et al. (2021)
Diabetes	E11 – E14	30+	B+	1.10 (1.03; 1.18)†	5 - 79	Yang BY et al. (2020)
Dementia	F00-F03, G30	60+	A	1.46 (1.12; 1.77)†	5 – 25§	Cheng et al. (2022)
Autism SD	F84.0, F84.1, F84.5, F84.8, F84.9	2 - 12	B+	1.66 (1.23; 2.25)†	5 – 30§	Lin LZ et al. (2022)
Lung cancer	C34	30+	A	1.16 (1.10; 1.23)	5 - 44	Yu et al. (2021)

† Relative risk estimates from revised meta-analysis

§ Restrict applicability of the CRFs of these conditions to exposure differences not larger than 10 µg/m³ within the indicated concentration ranges

Relative risk estimates for incidence of diseases from selected systematic reviews recommended for health risk assessment of NO_2

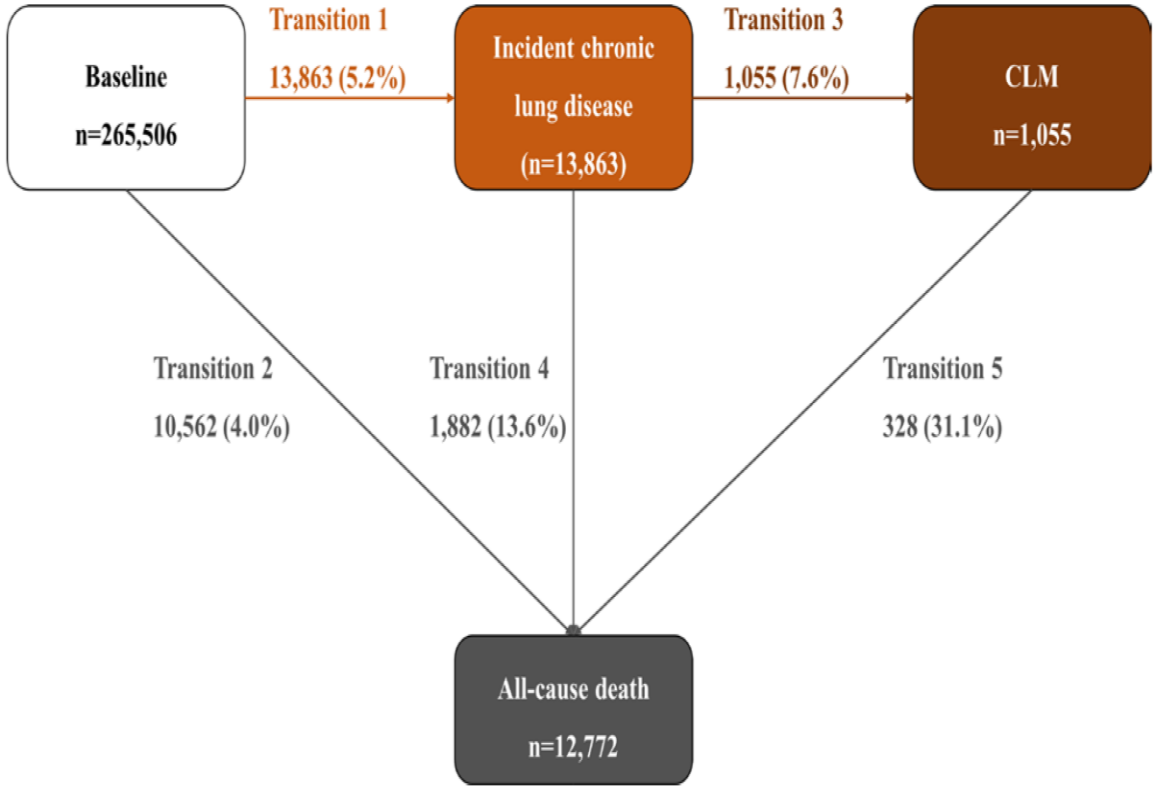
Outcome (incidence)	ICD10 codes	Age (years)	List	RR (95%CI) per 10 µg/m³	Mean exposure range (µg/m³)	SR reference
Asthma in children	J45	0 - 18	A	1.10 (1.05; 1.18)	10 - 39	Khreis et al. (2017)
Asthma in adults	J45	19+	A	1.10 (1.01; 1.21)	10 - 40	HEI (2022)
ALRI in children	J12 – J18, J20 – J22	0 - 12	A	1.09 (1.03; 1.16)	10 - 56	HEI (2022)

Relative risk estimates for short-term morbidity effects recommended for HRA

Outcome	ICD10 codes	Age (years)	List	RR (95%CI) per 10 µg/m^3	SR reference
Short-term exposure to $PM_{2.5}$					
All cardiovascular admissions	I00-I99	All ages	A	1.0090 (1.0026; 1.0153)	(Atkinson et al., 2014)
Short-term exposure to NO_2					
All respiratory hospital admissions	J00-J99	All ages	A	1.0057 (1.0033, 1.0082)	(Mills et al., 2015)
Short-term exposure to O_3					
All respiratory hospital admissions	J00-J99	All ages	B+	1.0075 (1.003, 1.0119)	(Walton et al., 2014), (COMEAP, 2015)

Risk of transition between stages of chronic lung disease associated with long term PM2.5 exposure

Analysis of data from (median) 11.9 years follow up of adults in the UK Biobank cohort free of respiratory disease at the start of the study



	HR (95% CI), per 5 µg/m^3
	$PM_{2.5}$
Baseline → incident chronic lung disease	1.31 (1.22 to 1.42)
Incident chronic lung disease → chronic lung multimorbidity	1.27 (1.01 to 1.57)
Baseline → death	1.32 (1.21 to 1.45)
Incident chronic lung disease → death	1.24 (1.01 to 1.53)
Chronic lung multimorbidity → death	1.91 (1.14 to 3.20)

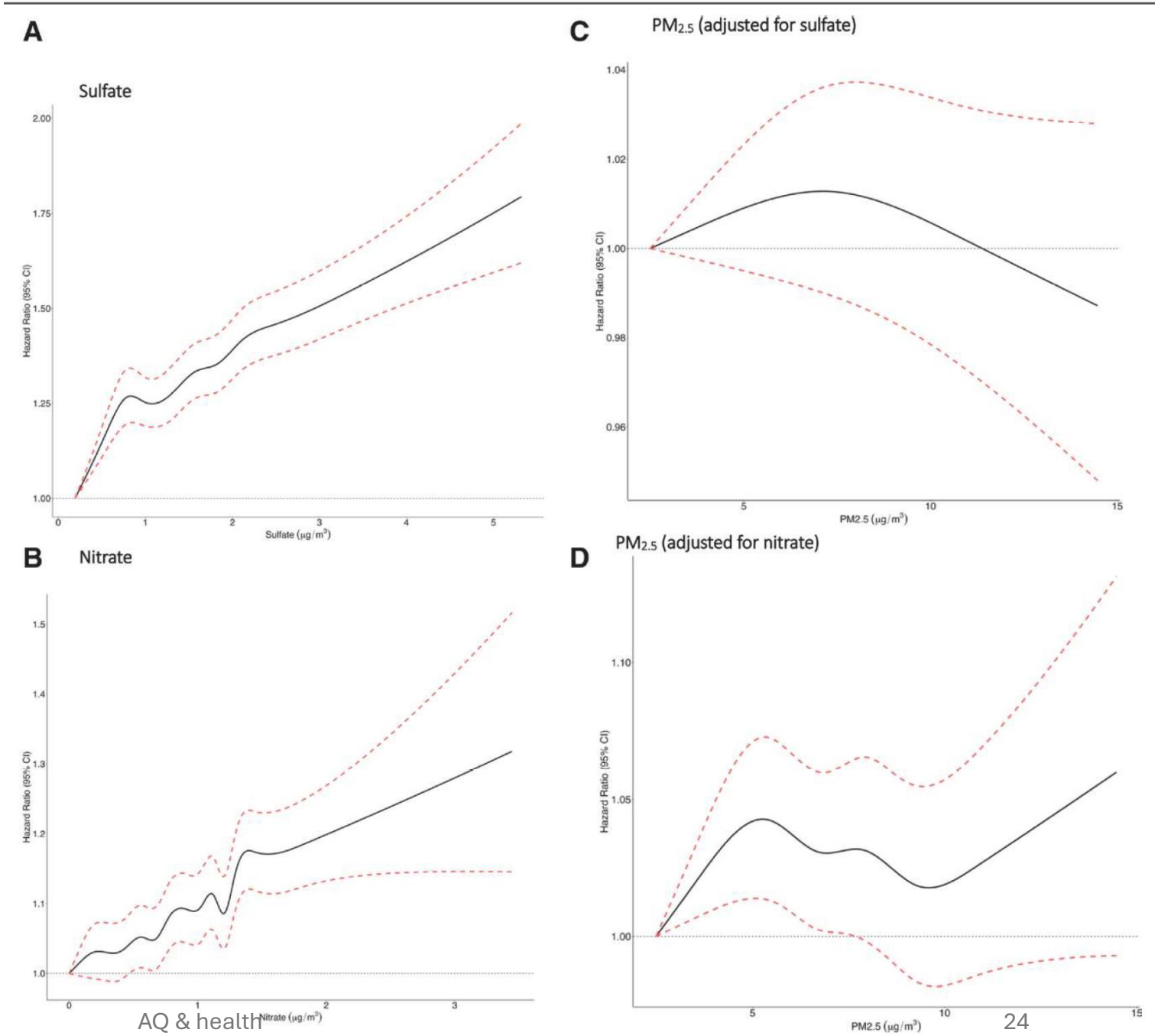
Wang X, et al. Thorax 2023

Relationships of non-accidental mortality with sulfate, nitrate and PM2.5 adjusted for individual components

CanCHEC 2006 study including a cohort of ca. 3 million adult Canada residents followed from 2006 to 2019.

Long term (10 years moving mean) exposure estimated with ca 1 km^2 resolution combining data from several satellite retrievals, atmospheric models and ground monitoring

Weichenthal et al, Env Epi 2024



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- Current state of the science on air quality & health
  - Reach and growing evidence on a broad range of health effects (mortality and morbidity) associated with PM2.5
  - Growing evidence on health effects of NO2, less progress on ozone
  - Domination of studies from AMR, EUR and WPR
- Role of the scientific evidence on health effects of air pollution in policy making
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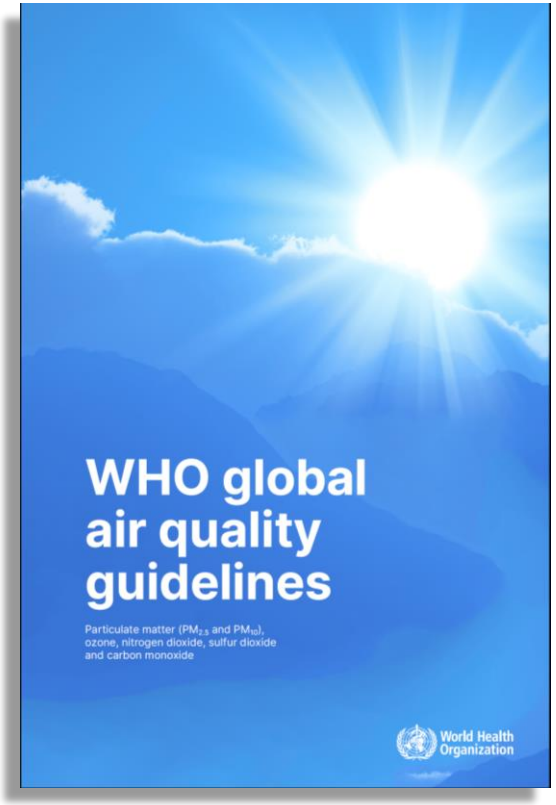
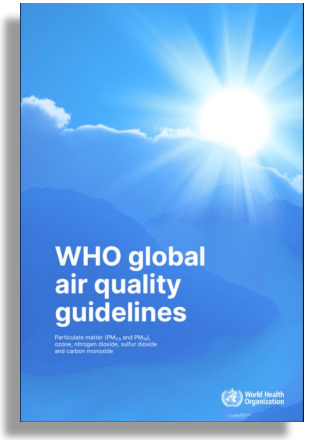
AQG objectives

- Provide health evidence-informed recommendations for air quality management, expressed as long- or short-term concentrations for key air pollutants.
- Exceedance of the air quality guideline (AQG) levels is associated with important risks to public health.
- These guidelines are not legally binding standards; however, they do provide WHO Member States with an evidence-informed tool that they can use to inform legislation and policy.
- Ultimately, the goal is to provide guidance to help reduce levels of air pollutants to decrease the health burden resulting from exposure to air pollution worldwide.



https://www.who.int/publications/i/item/9789240034228

Summary of recommended long- and short-term AQG levels and interim targets



Pollutant	Averaging time	Interim target				AQG level
		1	2	3	4	
$PM_{2.5}$, µg/m³	Annual	35	25	15	**10**	**5**
	24-hour[a]	75	50	37.5	**25**	**15**
PM_{10}, µg/m³	Annual	70	50	30	**20**	**15**
	24-hour[a]	150	100	75	**50**	**45**
O_3, µg/m³	Peak season[b]	100	70	–	–	**60**
	8-hour[a]	160	120	–	–	**100**
NO_2, µg/m³	Annual	**40**	30	20	–	**10**
	24-hour[a]	120	50	–	–	**25**
SO_2, µg/m³	24-hour[a]	125	50	–	–	**40**
CO, mg/m³	24-hour[a]	7	–	–	–	**4**

[a] 99th percentile (i.e., 3–4 exceedance days per year).

[b] Average of daily maximum 8-hour mean O_3 concentration in the six consecutive months with the highest six-month running-average O_3 concentration.

WHO AQG support EU in formulation of its AQ Directives

DIRECTIVE 2008/50/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

of 21 May 2008

on ambient air quality and cleaner air for Europe

CIL OF THE EURO-

uropean Commu-

nission,

(2) In order to protect human health and the environment as a whole, it is particularly important to combat emissions of pollutants at source and to identify and implement the most effective emission reduction measures at local, national and Community level. Therefore, emissions of harmful air pollutants should be avoided, prevented or reduced and appropriate objectives set for ambient air quality taking into account relevant World Health Organisation standards, guidelines and programmes.

EUROPEAN COMMISSION

Brussels, 26.10.2022
COM(2022) 542 final

2022/0347 (COD)

Proposal for a

DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

on ambient air quality and cleaner air for Europe

(recast)

{SEC(2022) 542 final} - {SWD(2022) 345 final} - {SWD(2022) 542 final} - {SWD(2022) 545 final}

In December 2019, in the European Green Deal[8], the European Commission committed to further improving air quality and to aligning EU air quality standards more closely with the recommendations of the World Health Organization (WHO). The WHO recommendations were most recently revised in September 2021[9] and are subject to periodic scientific review,

1. On air quality standards:
   a. setting clear EU air quality standards, defined as limit values for 2030, based on a political choice between policy options 'full alignment' (I-1), 'closer alignment' (I-2) and 'partial alignment' (I-3), with a limited number of temporary exceptions where these are clearly warranted;
   b. pointing to a post-2030 perspective for a full alignment with the 2021 WHO Air Quality Guidelines, whilst getting on track towards alignment also with future WHO Guidelines to achieve the zero pollution vision by the year 2050;

IJPH | SSPH+ SWISS SCHOOL OF PUBLIC HEALTH

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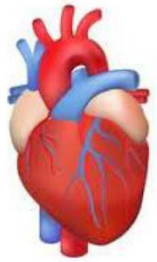
ERS EUROPEAN RESPIRATORY SOCIETY every breath counts

ISEE



WHO Air Quality Guidelines 2021 – Aiming for healthier air for all

A joint statement by medical, public health, scientific societies and patient representative organisations

- 140 endorsements!
- 10 laguagges

ELF EUROPEAN LUNG FOUNDATION

American Heart Association.

ESC European Society of Cardiology

european cancer ORGANISATION

WORLD HEART FEDERATION

ATS American Thoracic Society

American Cancer Society®

WHO Air Quality Guidelines 2021–Aiming for Healthier Air for all: A Joint Statement by Medical, Public Health, Scientific Societies and Patient Representative Organisations

Barbara Hoffmann[1], Hanna Boogaard[2], Audrey de Nazelle[3], Zorana J. Andersen[4], Michael Abramson[5], Michael Brauer[6], Bert Brunekreef[7], Francesco Forastiere[3], Wei Huang[8], Haidong Kan[9], Joel D. Kaufman[10], Klea Katsouyanni[3,11], Michal Krzyzanowski[3], Nino Kuenzli[12], Francine Laden[13], Mark Nieuwenhuijsen[14], Adetoun Mustapha[3,15], Pippa Powell[16], Mary Rice[13], Aina Roca-Barceló[3], Charlotte J. Roscoe[13], Agnes Soares[17], Kurt Straif[18] and George Thurston[19]*

climate change simultaneously. The updated WHO AQG are bold and stress the importance of lowering air pollution concentrations at every level. The benefits are clear: lowering air pollution levels will lead to enormous improvements in public health for people of all ages breathing cleaner air. We support the recommendations of the new WHO AQG, and urge nations to use the WHO AQG as a guide for ambitious air quality and emission reduction policies around the world.

OPEN ACCESS

Edited and reviewed by:
Olaf von dem Knesebeck, University Medical Center Hamburg-Eppendorf, Germany

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ERS Website: https://www.ersnet.org/news-and-features/news/urge-implement-air-pollution-policies-who-aqgs/
ISEE Website: https://www.iseepi.org/docs/Joint_Letter_to_WHO_DG_Final_4_8_21.pdf

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Final Rule to Strengthen the US National Air Quality Health Standard for Particulate Matter (7 Feb. 2024)

- Scientific evidence shows that long- and short-term exposures to PM2.5 can harm people's health, leading to heart attacks, asthma attacks, and premature death. Large segments of the U.S. population, including children and older adults, people with heart or lung conditions, communities of color, and low socioeconomic status populations, are at elevated risk of adverse health effects from PM2.5.
- **EPA is revising the level of the primary (health-based) annual PM2.5 standard from 12.0 µg/m^3 to 9.0 µg/m^3,** based on scientific evidence that shows the current standard does not protect public health with an adequate margin of safety, as required by the Clean Air Act (CAA).

https://www.epa.gov/pm-pollution/final-reconsideration-national-ambient-air-quality-standards-particulate-matter-pm

National AQ standards in EMR versus WHO AQG levels and Interim Targets

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REVIEW
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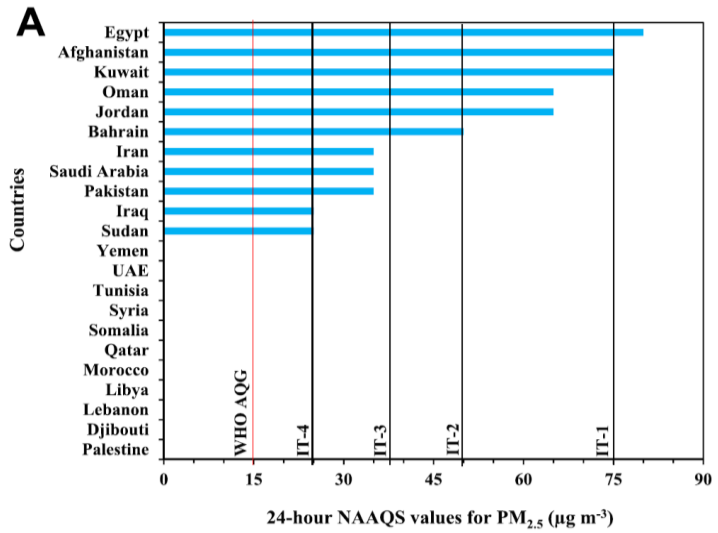
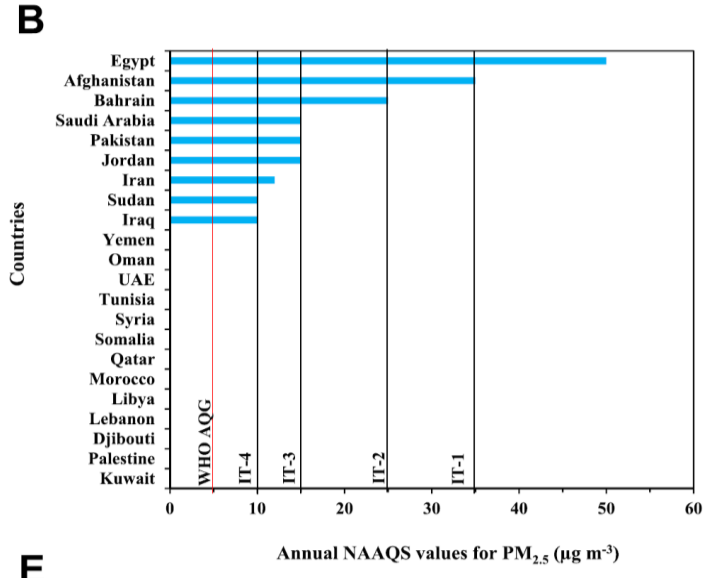
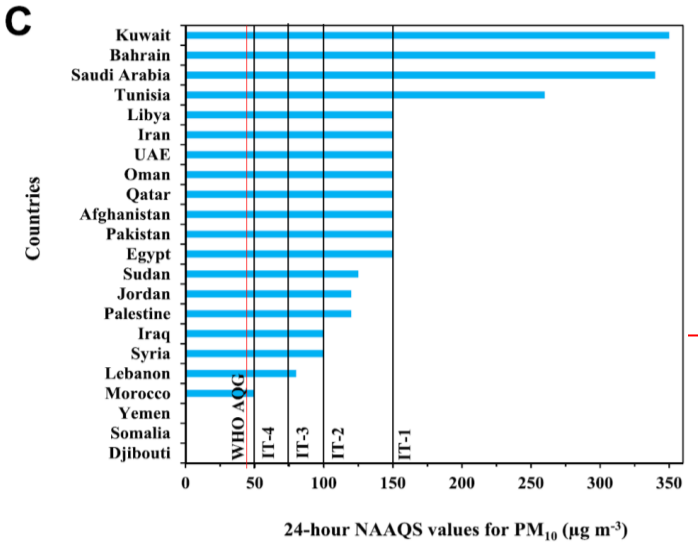
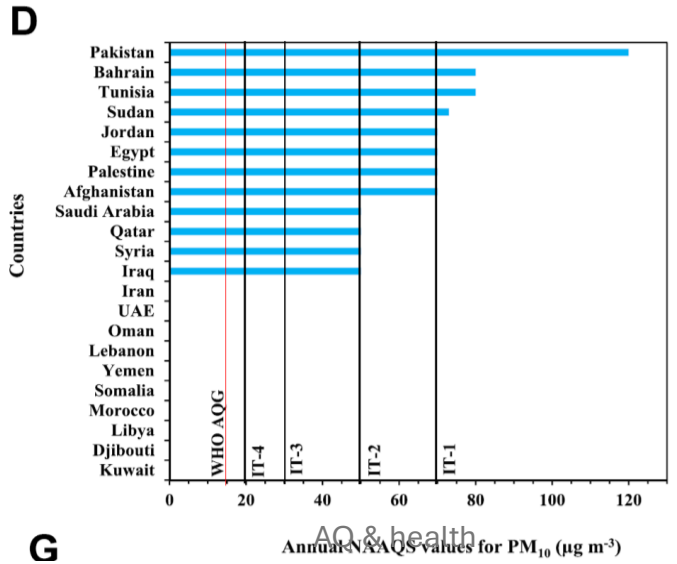
Ambient Air Quality Standards and Policies in Eastern Mediterranean Countries: A Review

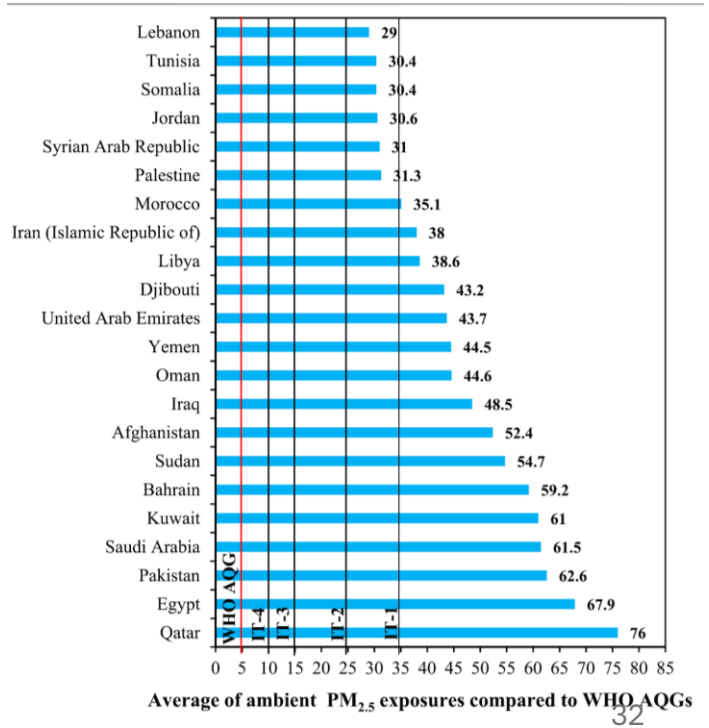
*Sasan Faridi[1,2], Michal Krzyzanowski[3], Aaron J. Cohen[4,5,6], Mazen Malkawi[7], Heba Adel Moh'd Safi[7], Fatemeh Yousefian[8], Faramarz Azimi[9], Kazem Naddafi[1,2], Fatemeh Momeniha[10], Sadegh Niazi[11], Heresh Amini[12], Nino Künzli[13,14], Mansour Shamsipour[15], Adel Mokammel[2], Vahid Roostaei[2] and Mohammad Sadegh Hassanvand[1,2]**











F G

What I wish you knew as an early career researcher?

- **There is reach evidence on health effects of air pollution.** Researchers need to know and use it:
  - ➢ in local health impact assessments;
  - ➢ to communicate it to the public, politicians and authorities to promote actions reducing exposure and its health effects.

- **Relatively few studies originate in South Asia**. You need to know how to:
  - ➢ make local health and air pollution data available for (region-specific and global) analysis;
  - ➢ conduct well designed studies focussed on local environmental, exposure and health conditions.