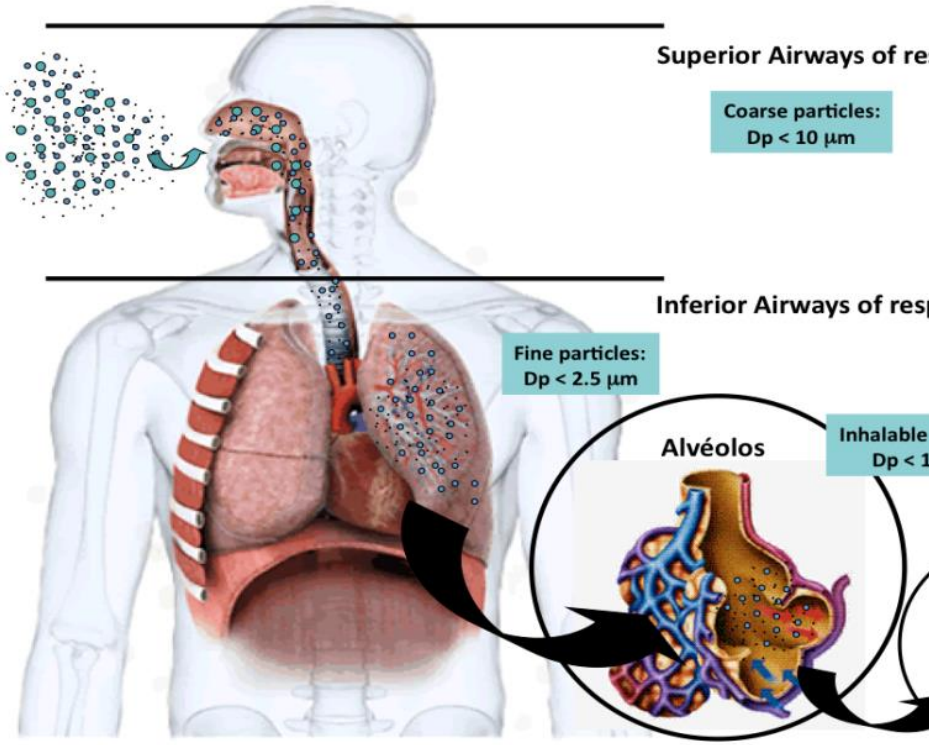

AIR POLLUTION AND HEALTH: TAKING STOCK OF THE PROPOSED REVISION TO THE AMBIENT AIR QUALITY DIRECTIVE
CLEAN AIR IN EUROPE FOR ALL

Reviewing the latest science on air pollution and health – Part 1

Chairs: Hanna Boogaard (HEI and ISEE) and Klea Katsouyanni (Imperial College London)



Life after WHO 2021 AQG – What does science tell us?

ERS

24th May, 2023

Zorana Jovanovic Andersen, Chair of the European Respiratory Society (ERS) Environment and Health Committee; Professor in Environmental Epidemiology, Department of Public Health, University of Copenhagen, Denmark

WHO 2021 AQG – main messages and beyond

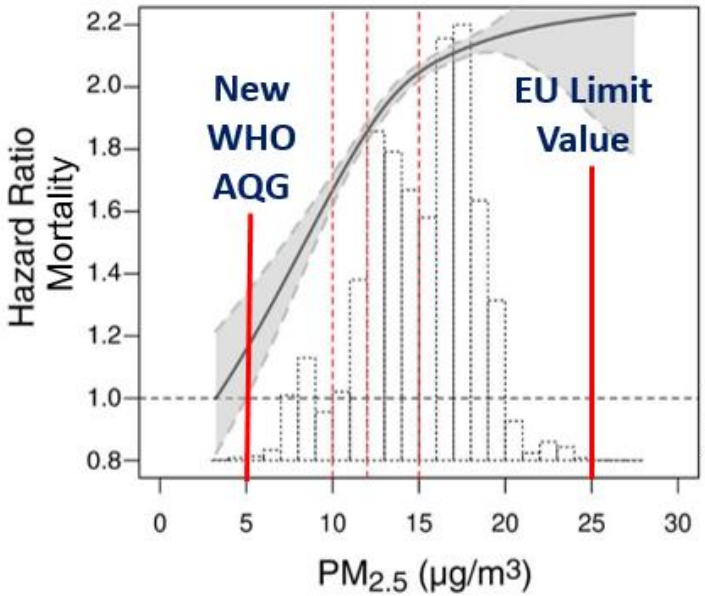
WHO AIR QUALITY GUIDELINES

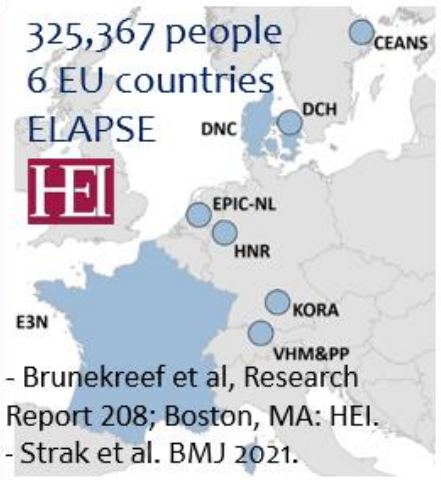
NO2	2005: 40 µg/m³, annual	
	2021: 10 µg/m³, annual	
PM2.5	2005: 10 µg/m³, annual	
	2021: 5 µg/m³, annual	

1. Everyone is exposed – no lower threshold

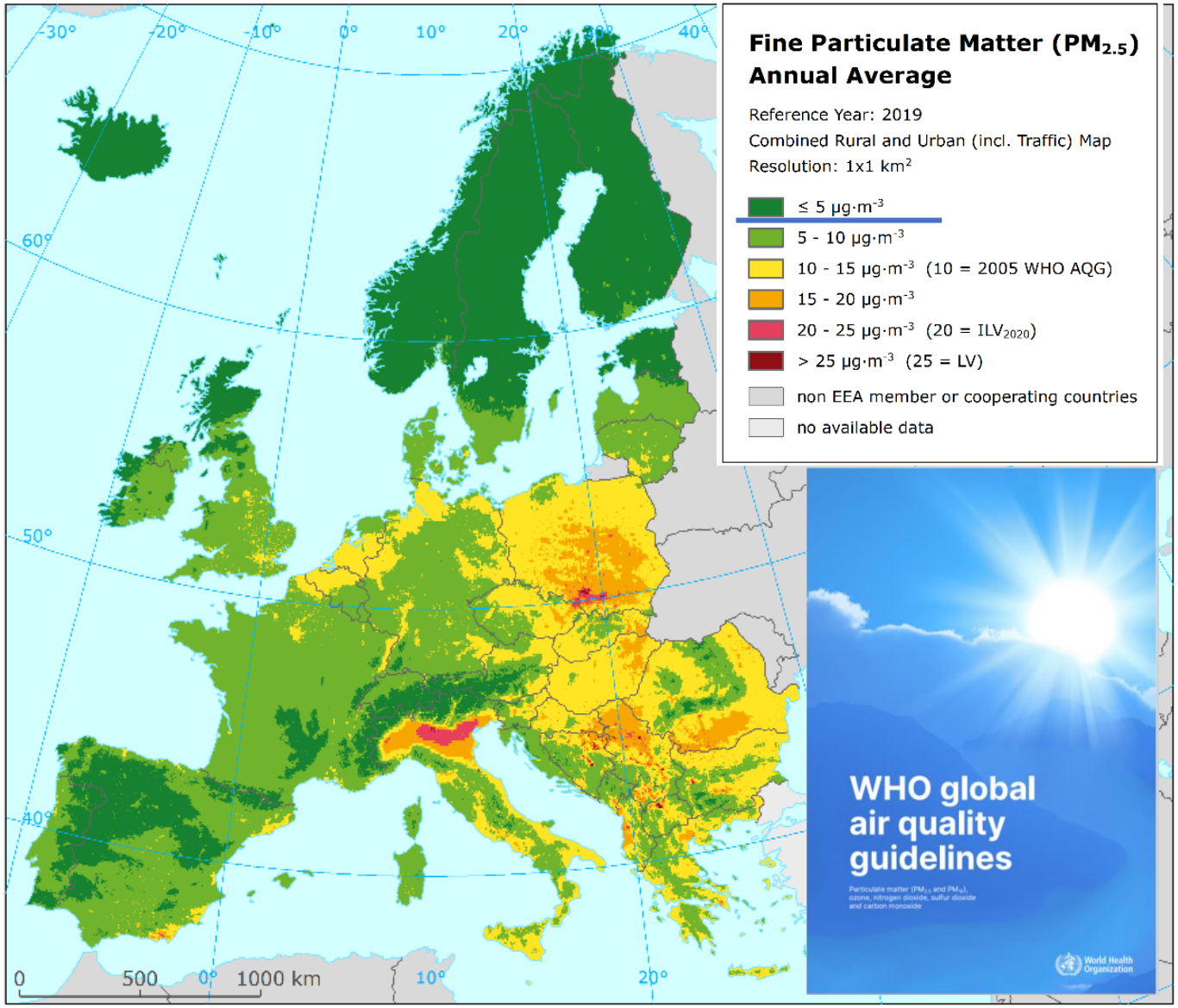
1. Everyone in Europe is exposed to harmful levels of air pollution (97.5% European population)

2. No lower threshold below which air pollution is safe





- Brunekreef et al, Research Report 208; Boston, MA: HEI.
- Strak et al. BMJ 2021.



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2. Air pollution burden is huge, increasing & underestimated

- WHO 2005 AQG (Hoek et al. 2013): **6.2%***
- **WHO 2021 AQG (Chen & Hoek 2020): 8.0%**

Global

EEA

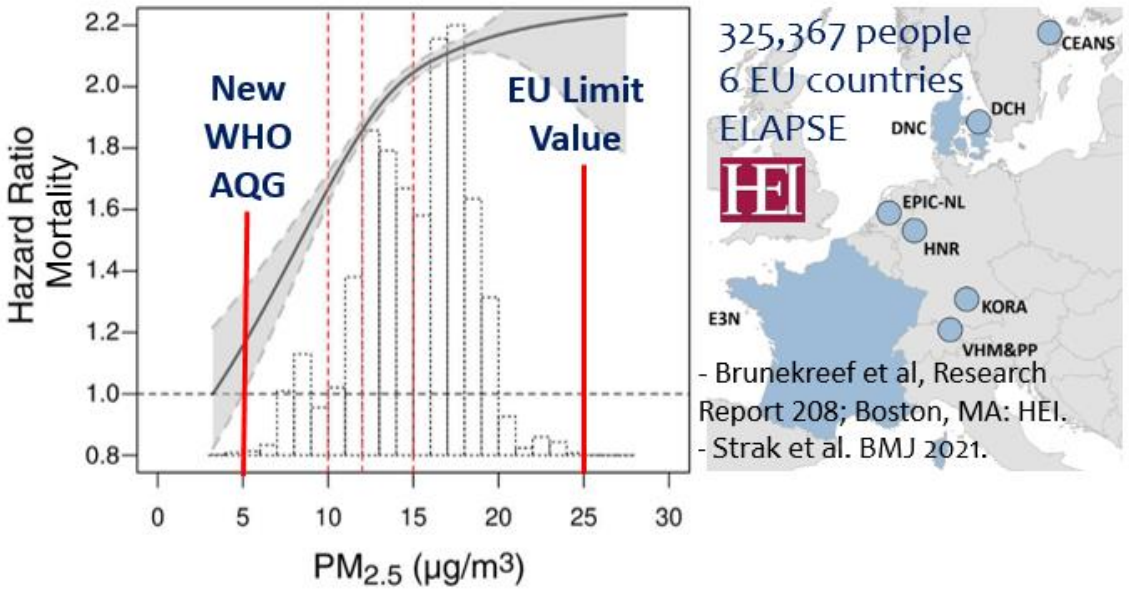
2019: 307,000 deaths attributed to $PM_{2.5}$

2020: 412,000 deaths attributed to $PM_{2.5}$

238,000 deaths > 5 µg/m³ $PM_{2.5}$

1. ELAPSE (after WHO 2021 AQG): 11.8%
2. Stronger effects at low levels?

EU



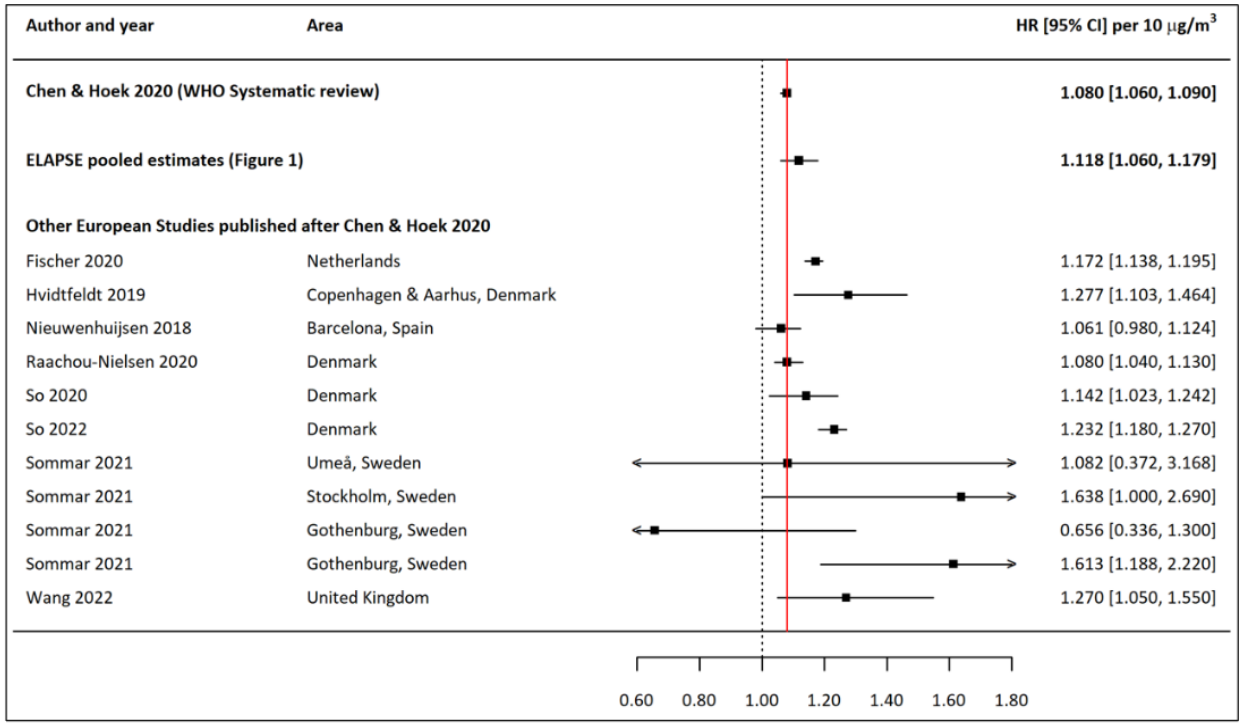


Figure 3. Total mortality and long-term $PM_{2.5}$ from other European studies published since the WHO systematic review by Chen & Hoek (2020).*

*Red line indicates the summary estimate from the systematic review by Chen & Hoek (2020). Range of mean $PM_{2.5}$ exposure in European studies from 5.8 to 20.3 µg/m³.

- https://www.ersnet.org/wp-content/uploads/2022/04/Statement-HIA-by-ERS_ISEE_final-002.pdf
- https://journals.lww.com/environepidem/Fulltext/2022/10000/Benefits_of_future_clean_air_policies_in_Europe_.5.aspx

*interpretation: 6.2 % increase in mortality risk for each 10 µg/m³ increase in $PM_{2.5}$

3. Air pollution and climate change – inseparable issues

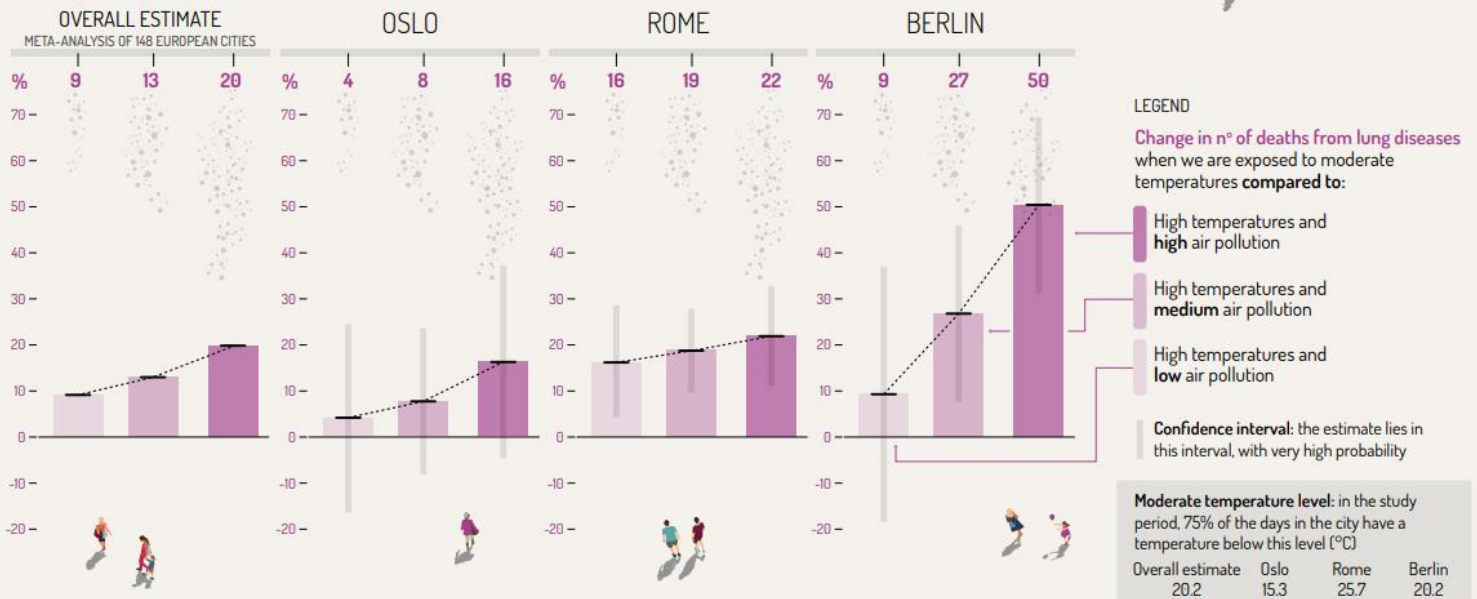
EXHAUSTION
www.exhaustion.eu

WE BREATHE CLIMATE CHANGE

More people will die of **lung** diseases in our cities when high temperatures are combined with high levels of air pollution. This is especially true for those of us who are 65 and older.

The good news
Policies that make us less exposed to heat and air pollution will be beneficial for our health and wellbeing.

Change in number of deaths from lung diseases in European cities (%) in association with high temperatures, by different levels of air pollution (PM2.5)



LEGEND

Change in n° of deaths from lung diseases when we are exposed to moderate temperatures **compared to:**

- High temperatures and **high** air pollution
- High temperatures and **medium** air pollution
- High temperatures and **low** air pollution

Confidence interval: the estimate lies in this interval, with very high probability

Low, medium and high levels of air pollution (fine particles PM2.5, μg/m³)

	Overall estimate			Oslo			Rome			Berlin		
	low	medium	high	low	medium	high	low	medium	high	low	medium	high
	4	10	21	2	6	15	9	15	23	7	12	21

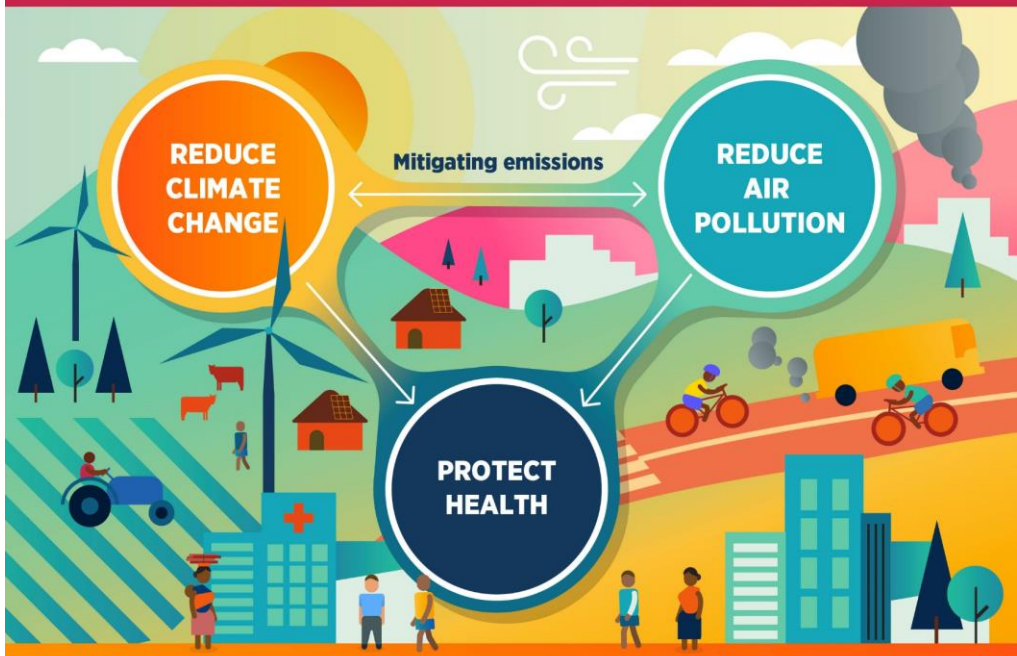
Moderate temperature level: in the study period, 75% of the days in the city have a temperature below this level (°C)

Overall estimate	Oslo	Rome	Berlin
20.2	15.3	25.7	20.2

High temperature level: in the study period, 1% of the days in the city have a temperature above this level (°C)

Overall estimate	Oslo	Rome	Berlin
26.4	21.7	29.6	27.1

REDUCING AIR POLLUTION AND MITIGATING CLIMATE CHANGE, TOGETHER HELP TO PROTECT OUR HEALTH

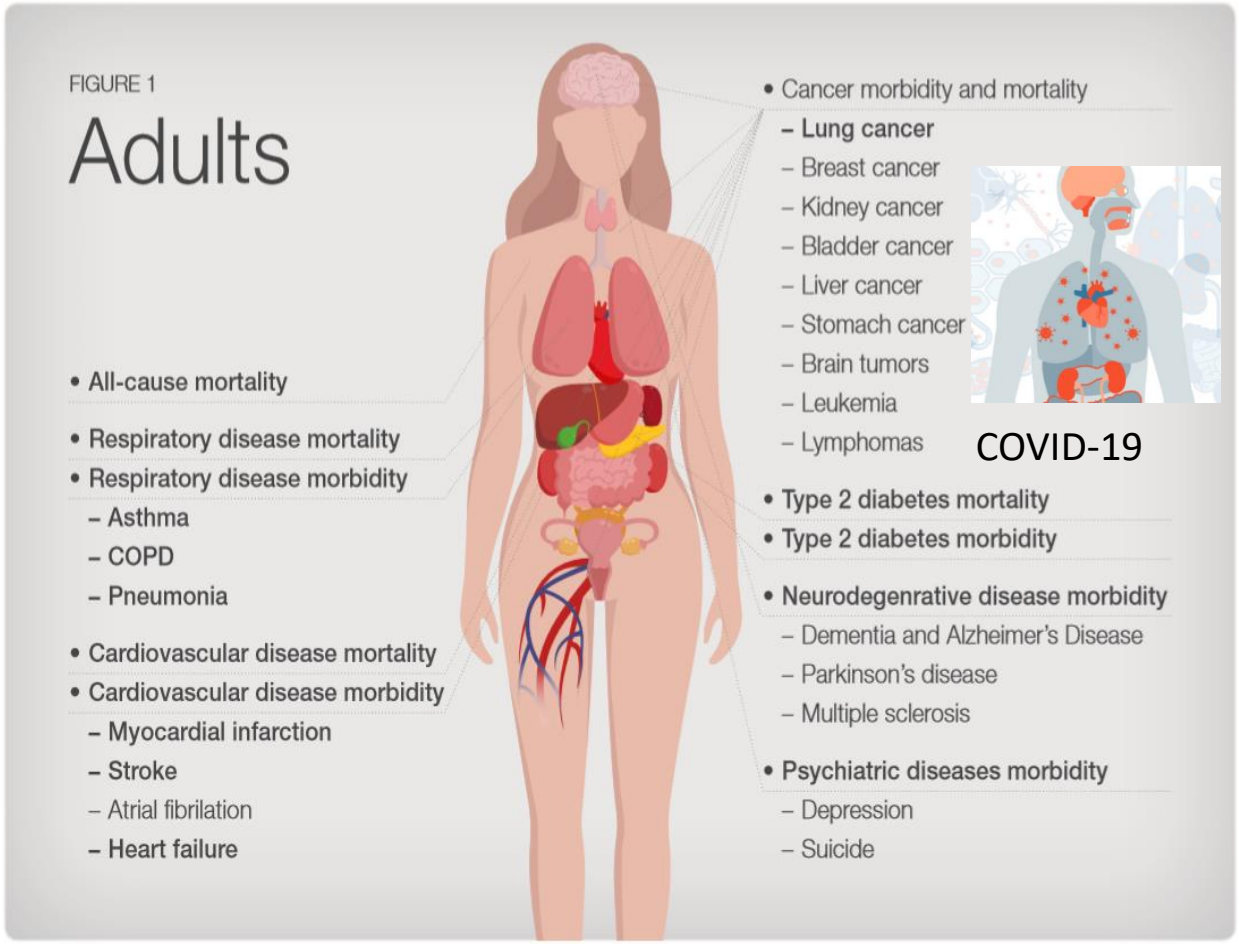


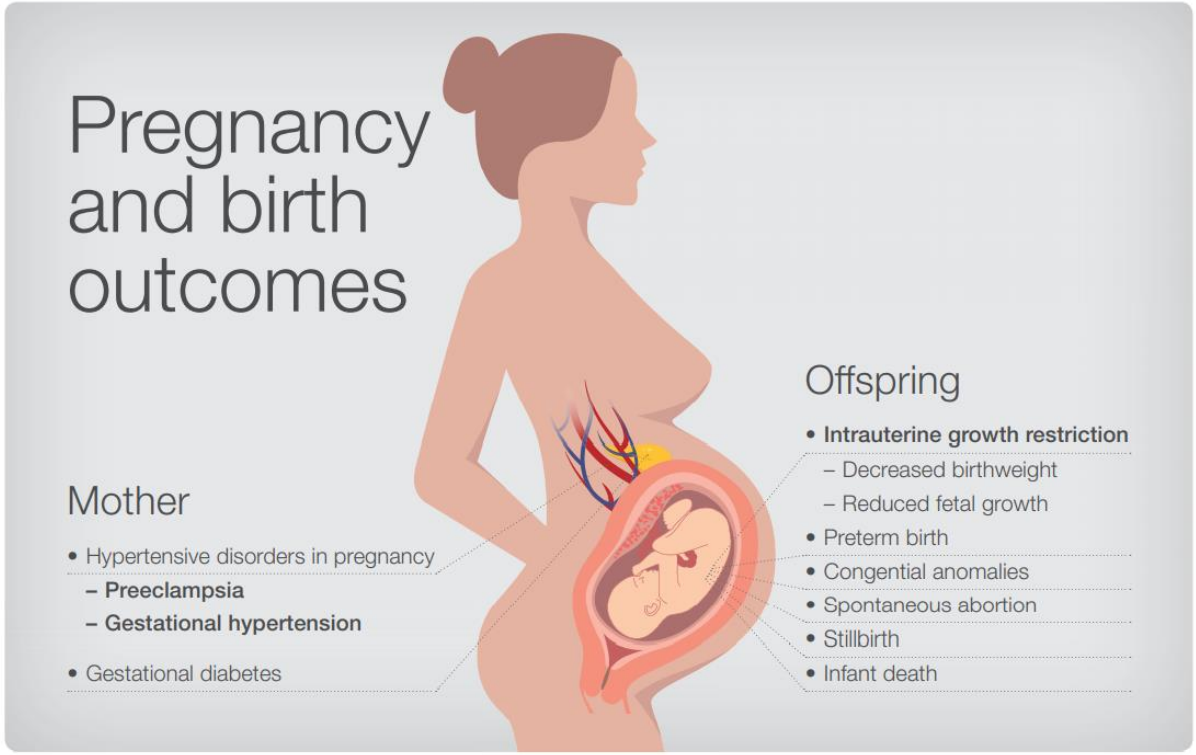
WHO Air Quality Guidelines set goals to protect millions of lives from air pollution.

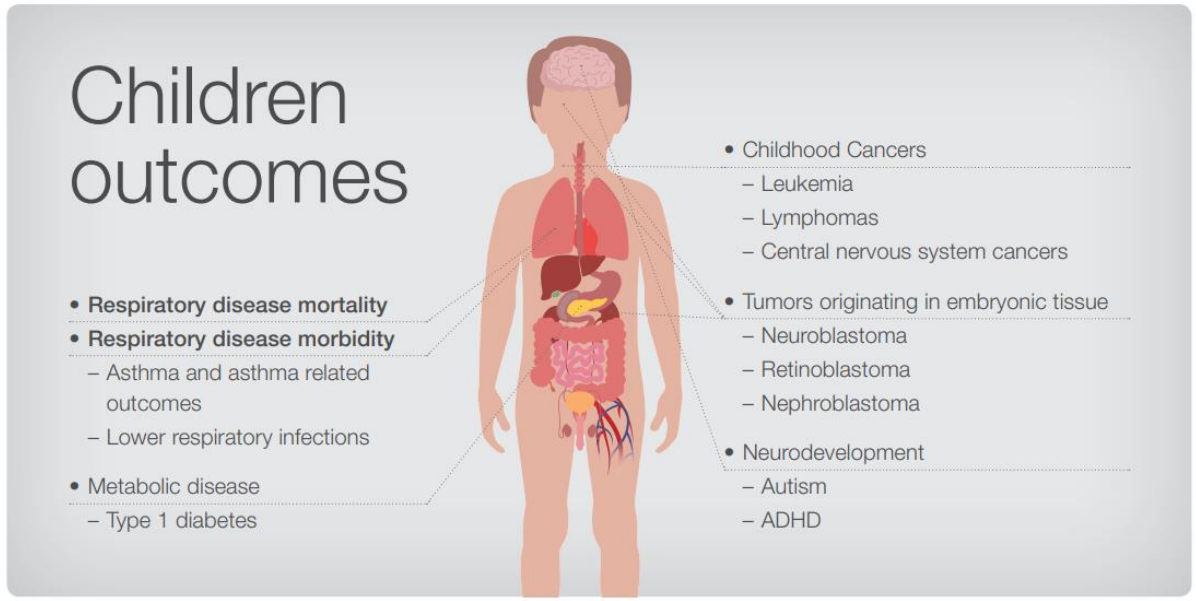
CLEAN AIR FOR HEALTH #AirPollution World Health Organization

Health burden of air pollution

Premature deaths + millions of new cases of disease, symptoms, worsened quality of life, doctor visits, ER visits, hospital admissions, sick days (school & work), medication use….







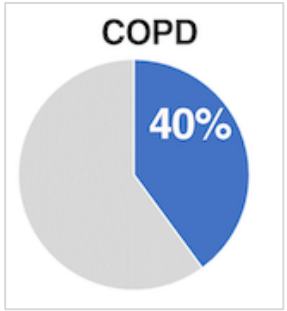
Air Pollution and Lung (Erik)

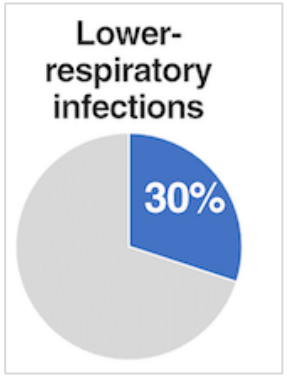
- **Long-term (years, lifetime) exposure to air pollution** can lead to impaired lung function and development of new lung disease in healthy individuals and increased risk of dying from those diseases:

asthma, COPD, pneumonia, COVID-19, lung cancer

- **Short-term (hours, days) exposure to air pollution** can exacerbate existing lung disease in lung patients and trigger:

wheezing, cough, shortness of breath, need for medication, ER visits, hospitalizations, and death





GBD - Mortality specific-causes, 'fraction attributable' to air pollution https://www.stateofglobalair.org/

16% asthma cases in children due to air pollution*

*Khreis H, et al.. Environ. Int. 2017

Ella Adoo-Kissi-Debrah: Air pollution a factor in girl's death, inquest finds

16 December 2020

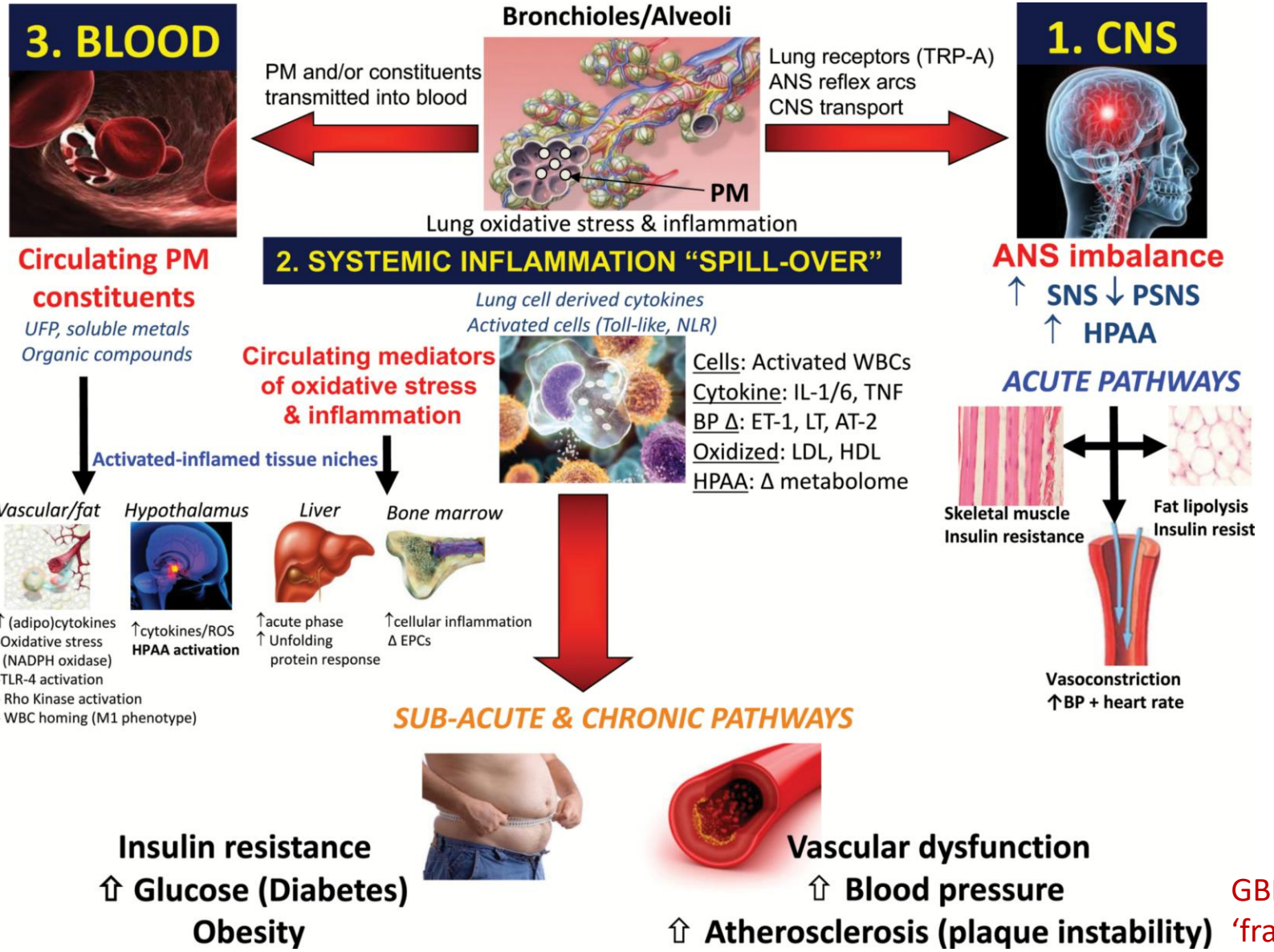
Ella Adoo-Kissi-Debrah lived 25 metres from the South Circular Road in south-east London

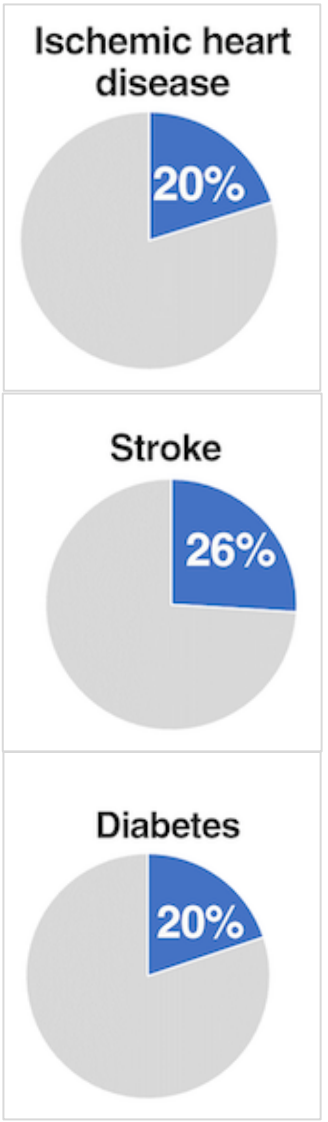
A nine-year-old girl who died following an asthma attack has become the first person in the UK to have air pollution listed as a cause of death.

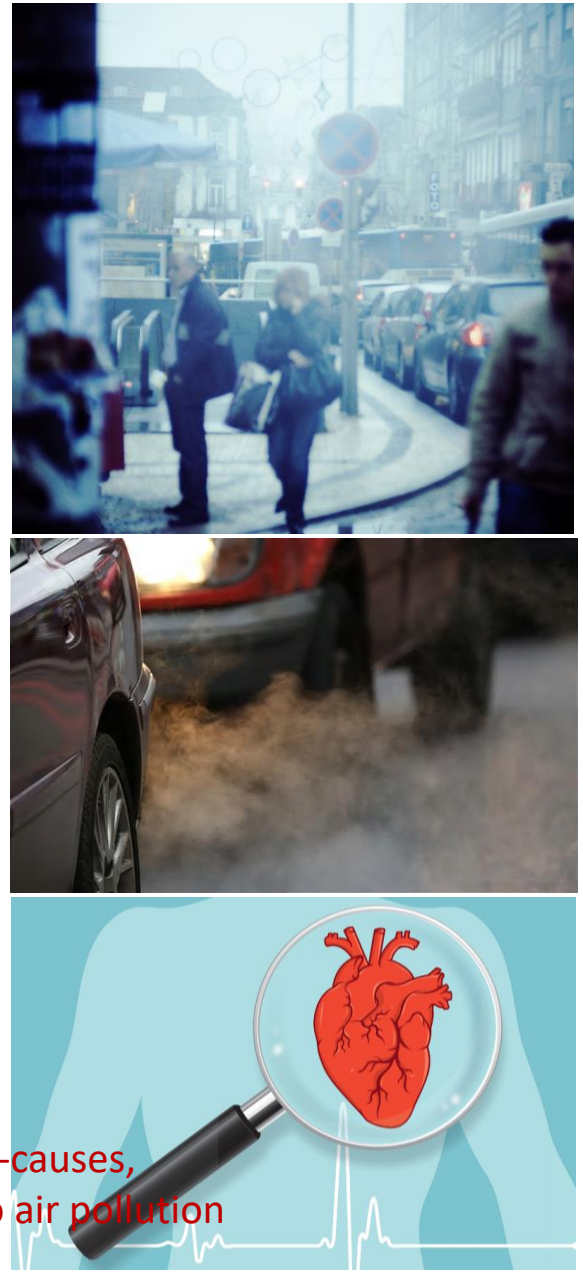
Ella Adoo-Kissi-Debrah, who lived near the South Circular Road in Lewisham, south-east London, died in 2013.

Ella Kissi-Debrah - 9 year old girl suffered fatal asthma attack triggered by air pollution, London, February 2013

Air pollution and cardio-metabolic health (Petter)







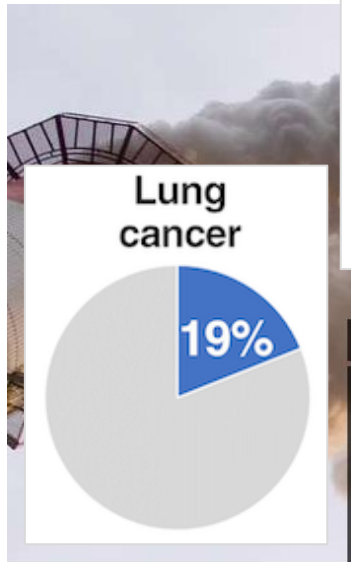
GBD - Mortality specific-causes, 'fraction attributable' to air pollution

https://www.stateofglobalair.org/

Air pollution and cancer (Michelle)

"In 2020, while we were all fighting against the COVID-19 pandemic, many of us were fighting a silent battle. The battle against cancer. In 2020, we lost 1.3 million Europeans to this disease. And sadly, the number of cases is on the rise. This is why we present Europe's Beating Cancer Plan today. The fight of t

- Cancer causes 1 in 4 deaths in the EU (1.3 million cancer deaths in 2020)
- Air pollution is carcinogenic,* causes lung cancer and possibly other (breast, liver, blood, stomach, colon) cancers
- BECA - the EU Green Deal is a key tool to limit people's exposure to (air) pollution and prevent cancer,



> Cutting pollution through the EU's Zero Pollution Action Plan and the Chemical Strategy for Sustainability as well as strong implementation of other existing EU policies would go a long way to reduce cancer cases and deaths. This would be an effective investment in our citizen's well-being.
>
> Hans Bruyninckx, EEA Executive Director

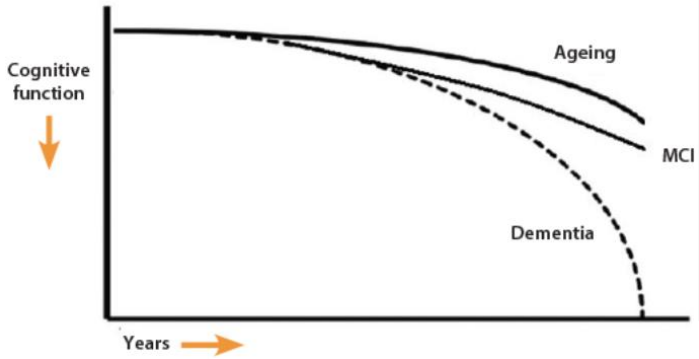
GBD - 'fraction attributable' to air pollution
https://www.stateofglobalair.org/

*International Agency for Research on Cancer (IARC) 'Air Pollution and Cancer' 2013

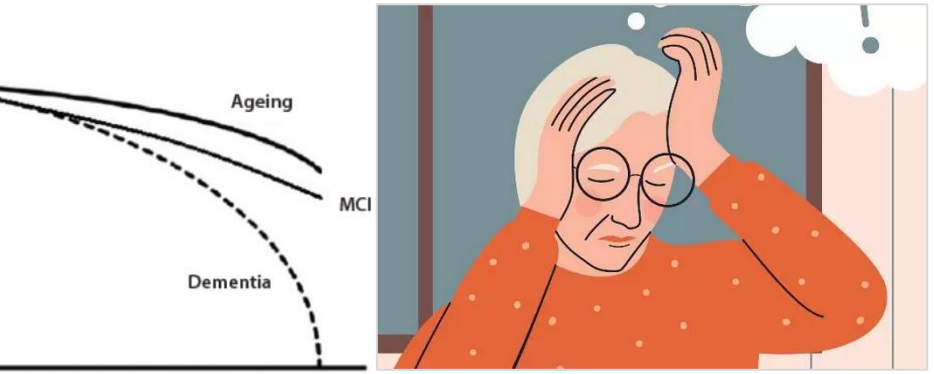
Emerging issues: air pollution and the brain (Barbara)

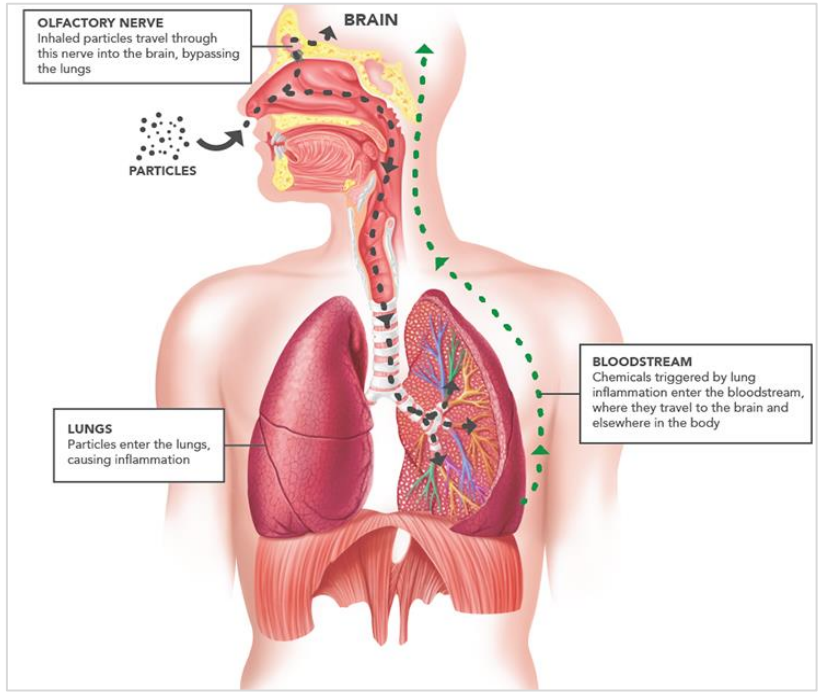
- Impaired neurocognitive development in children (learning difficulties, loss of IQ, ADHD, autism)
- Accelerated cognitive decline (dementia) elderly
- **Mental health (suicide, depression, anxiety)**

Adulthood



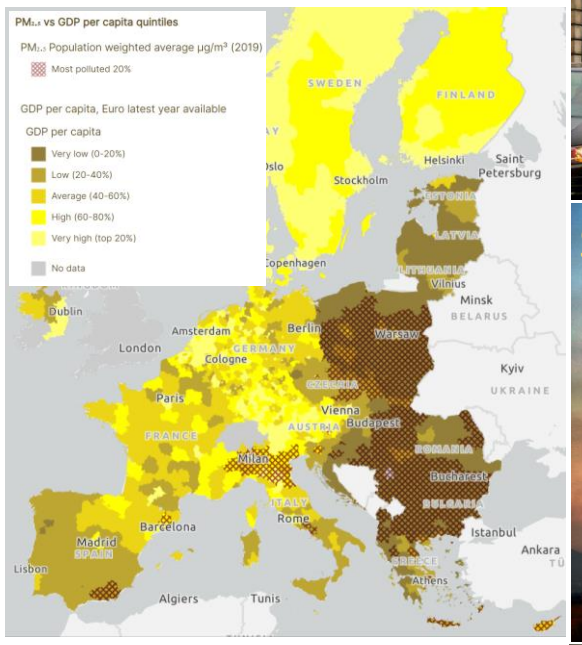
Old age





Everyone is exposed – some are more vulnerable

- Children
- Pregnant women
- Elderly
- Chronic diseases patients
- Poor (environmental inequality)

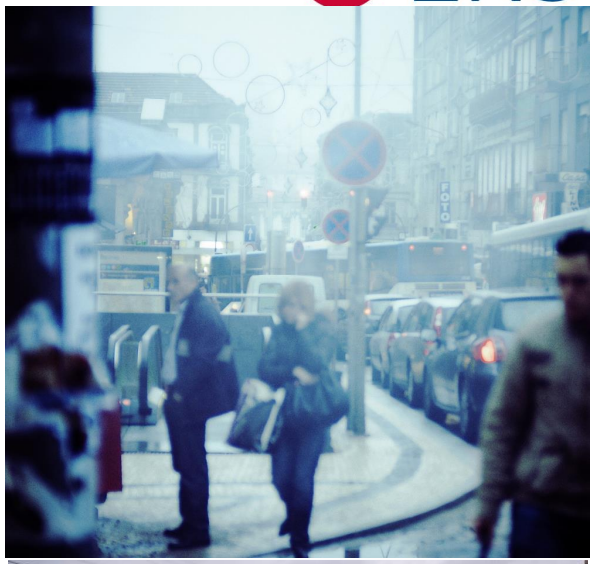


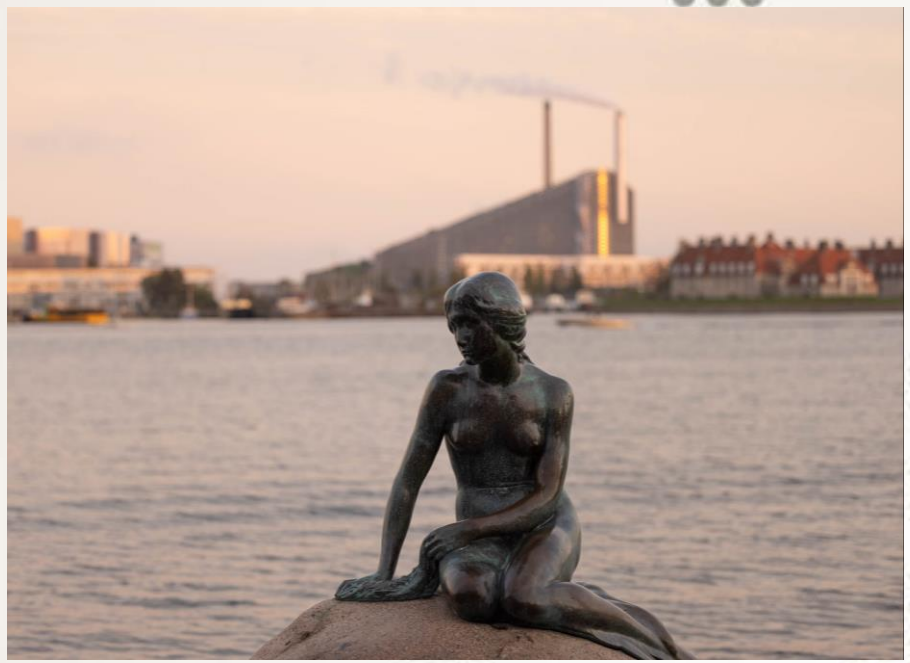
Conclusion

New AAQD, fully aligned with WHO 2021 AQG, is a major public and planetary health opportunity, that would:

1. prevent a substantial number of new cases of major NCDs
2. make EU citizens more resilient to seasonal influenza epidemics and COVID-19-like new pandemics
3. improve life of lung, heart, and other chronic disease patients
4. Indirect benefit for health - help mitigate unprecedented climate change impact on our health and our planet

Clean air as a basic civil right - no one should get sick or die from breathing





Thank You

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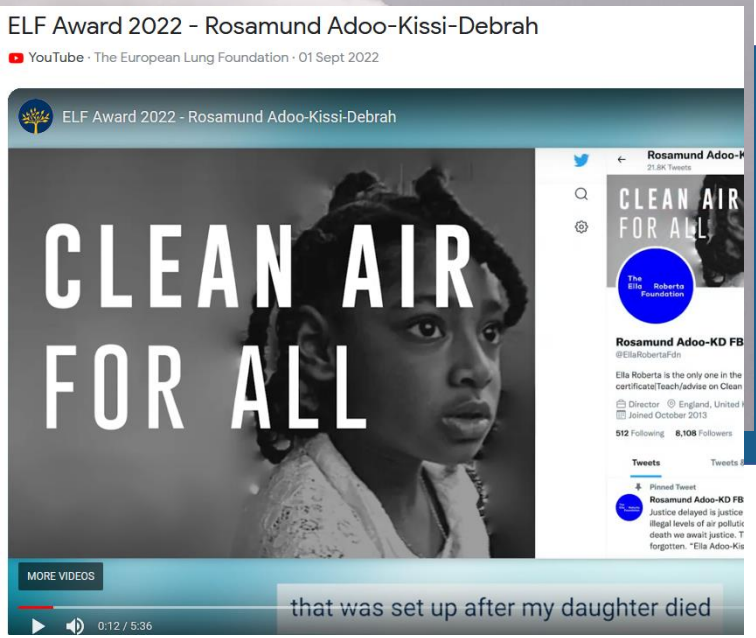
@zoranajova

Rosamund Adoo Kissi Debrah:*'We need to ensure parents know the impact air pollution has on their children'*



https://www.youtube.com/watch?v=V673obDHCVc

Effects of low-level air pollution: A study in Europe, and a harmonized analysis with large studies in Canada and the United States

Bert Brunekreef, PhD

Emeritus Professor of Environmental Epidemiology

Utrecht University, The Netherlands

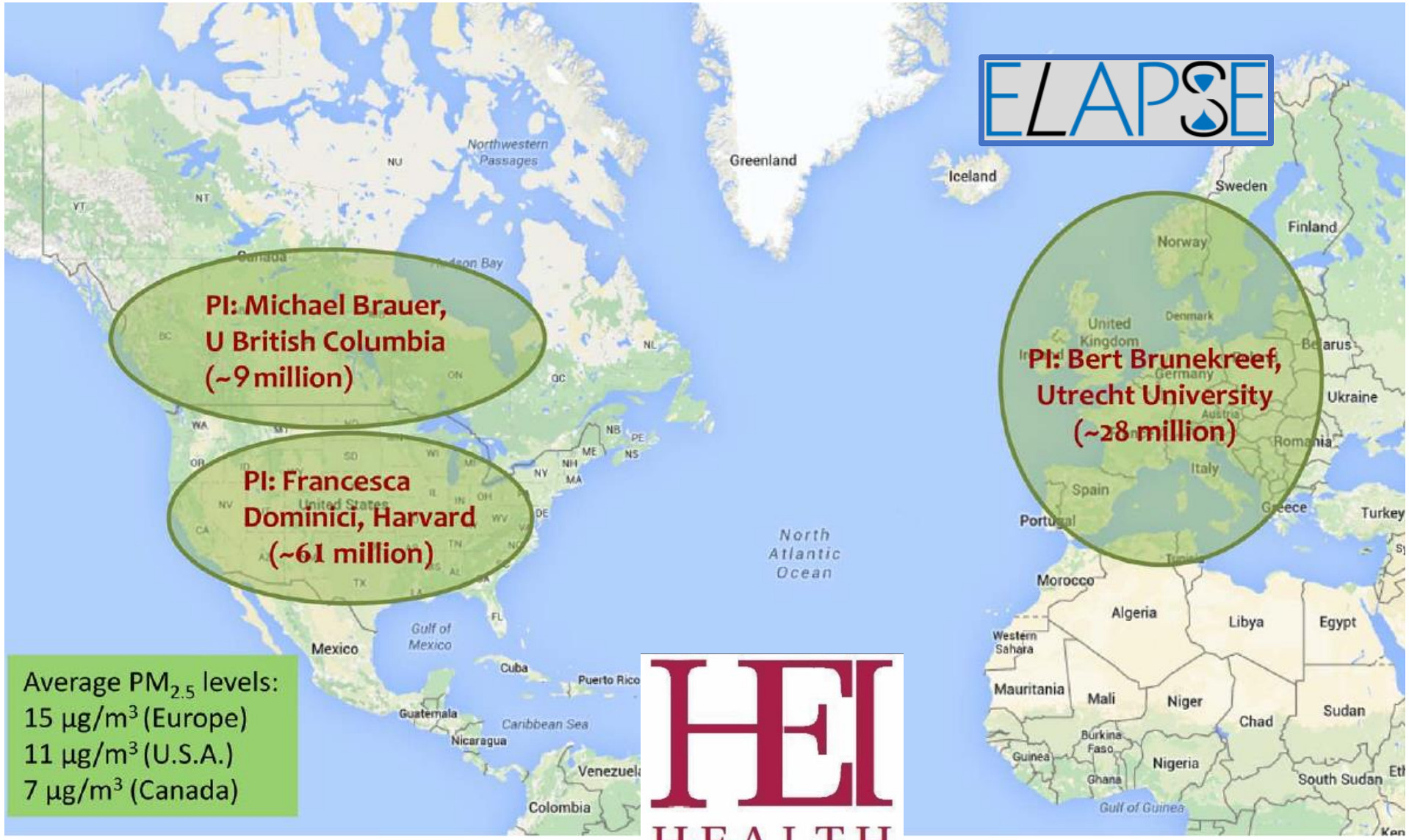
The WHO AQGs and low-level studies

- The AQGs are defined as the lowest level at which adverse effects on health have been **demonstrated beyond reasonable doubt**
- Technically: the AQGs have been set at the mean of the 5th percentiles of the exposure distributions in a reasonable number of high-quality studies showing these adverse effects
- The 2021 AQG report does **not identify thresholds**
- Non-zero thresholds **may not exist** – we simply don't know, and we probably never will

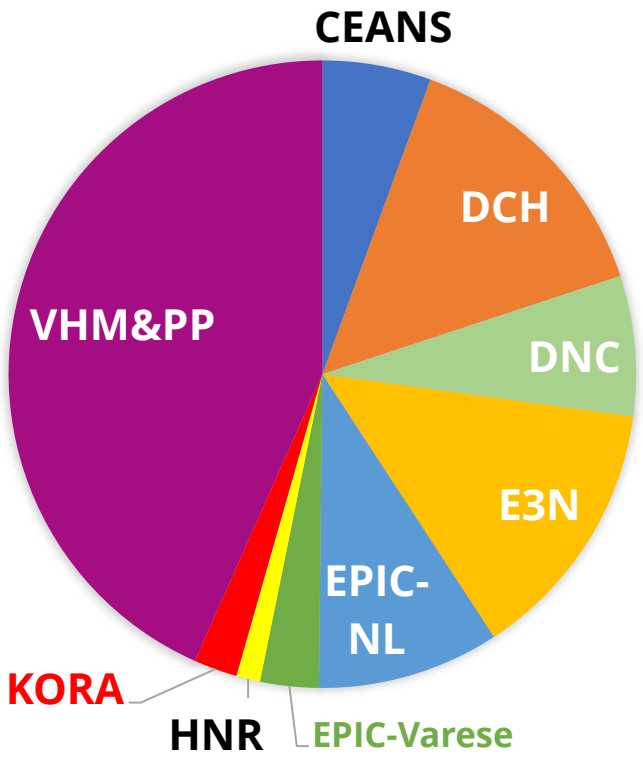
2021 WHO Air Quality Guidelines

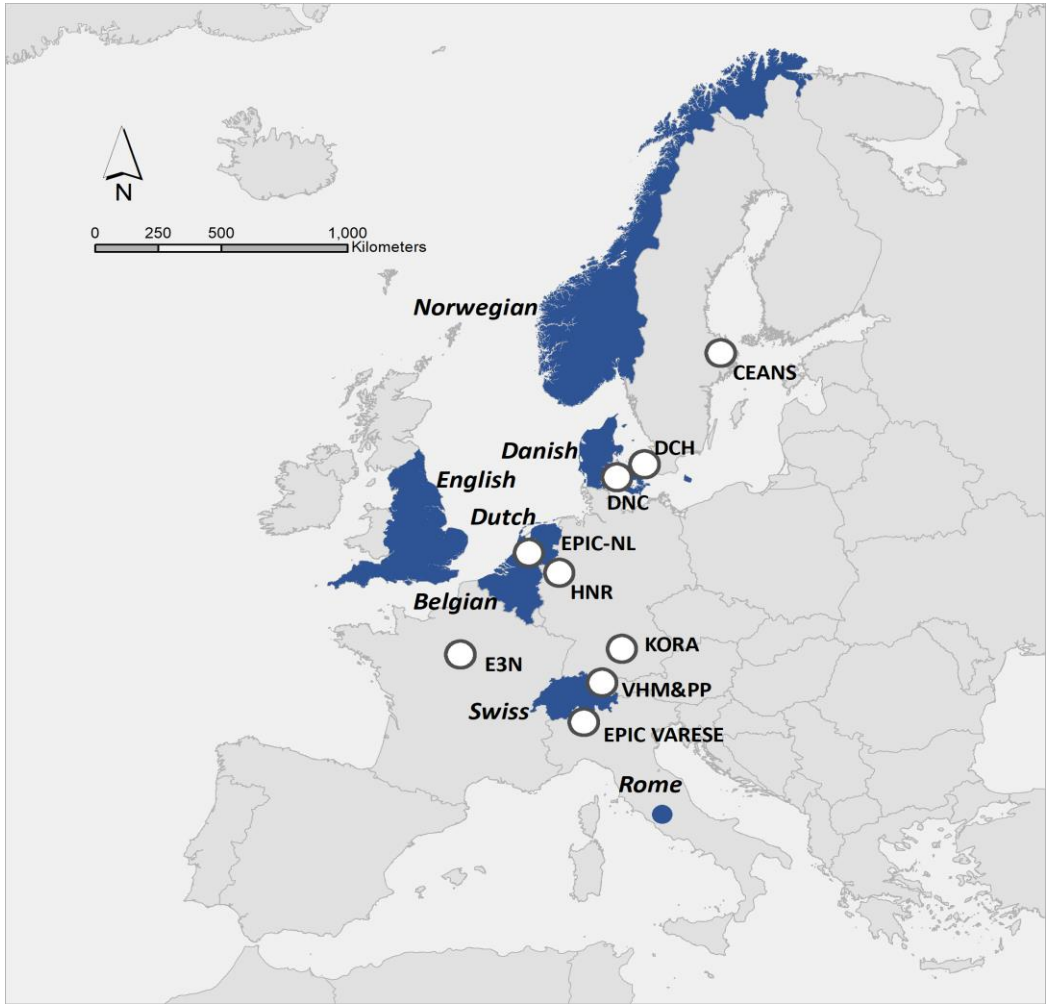
Pollutant	AQG 2005	AQG 2021
$PM_{2.5}$ year	10 µg/m³	5 µg/m³
$PM_{2.5}$ 24 hrs	25 µg/m³	15 µg/m³
PM_{10} year	20 µg/m³	15 µg/m³
PM_{10} 24 hrs	50 µg/m³	45 µg/m³
O_3 warm	--	60 µg/m³
O_3 8 hrs	100 µg/m³	100 µg/m³
NO_2 year	40 µg/m³	10 µg/m³
NO_2 24 hrs	--	25 µg/m³
SO_2 24 hrs	20 µg/m³	40 µg/m³
CO 24 hrs	--	4 mg/m³

New studies into effects of low air pollution concentrations



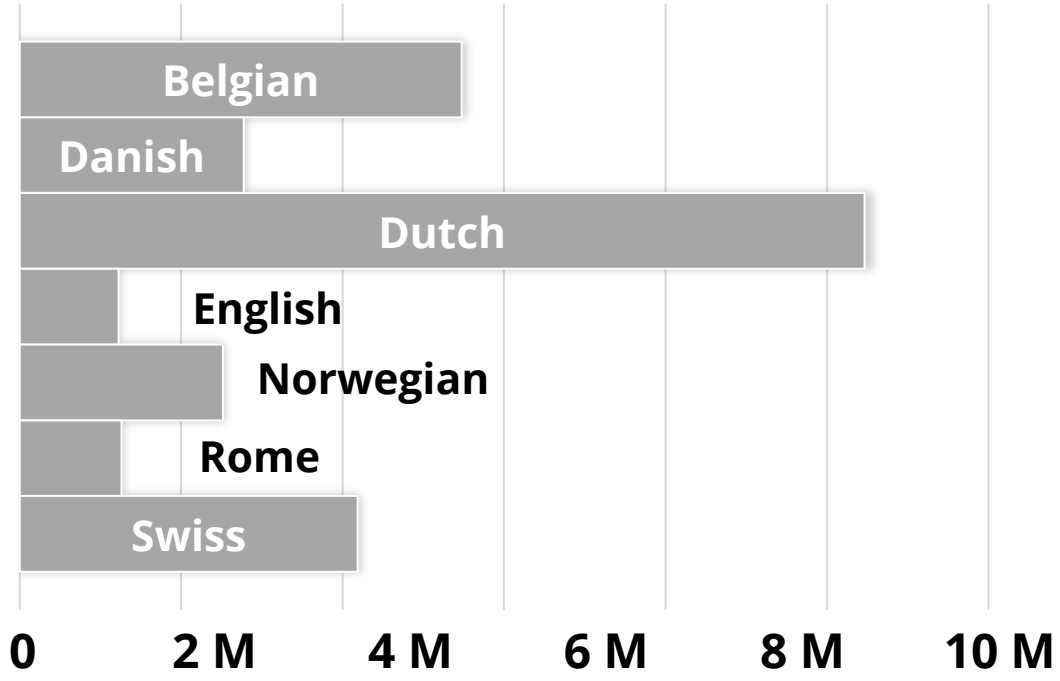
Pooled cohort

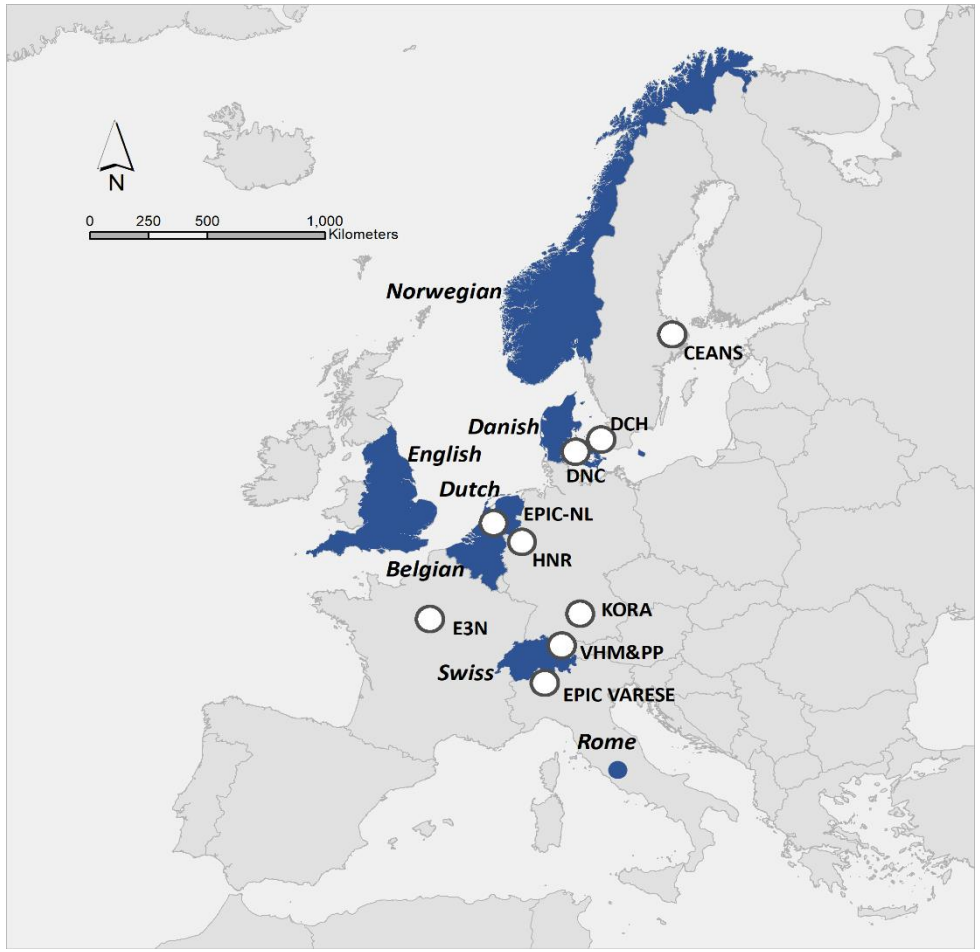




- **N = 392,826**
- Extensive covariate information

Administrative cohorts

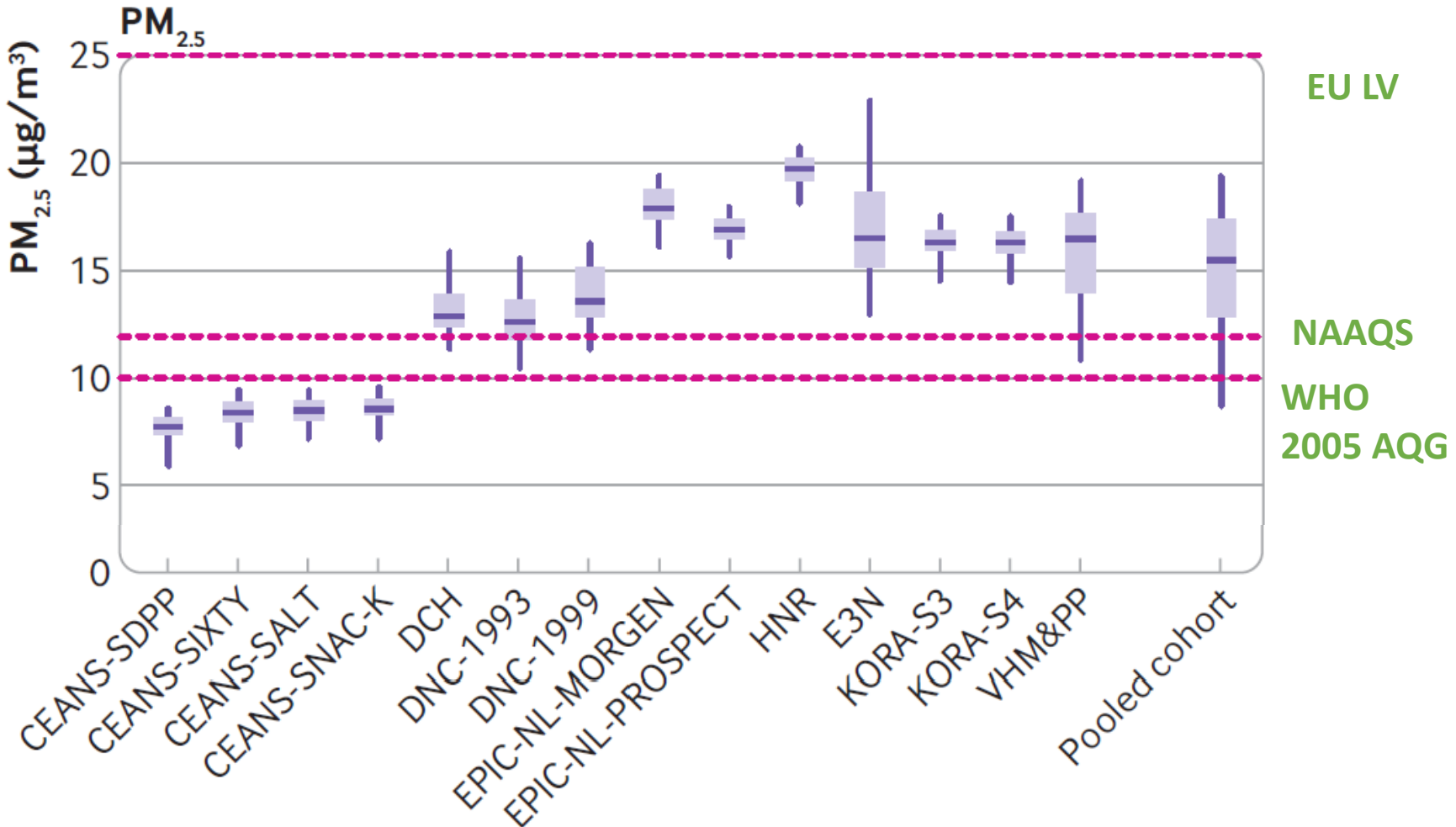




- **N = 27,910,693**
- Limited covariate info (except English)
- Analyzed individually -> Meta-analysis

Long term exposure to low level air pollution and mortality in eight European cohorts within the ELAPSE project: pooled analysis

Strak, BMJ 2021



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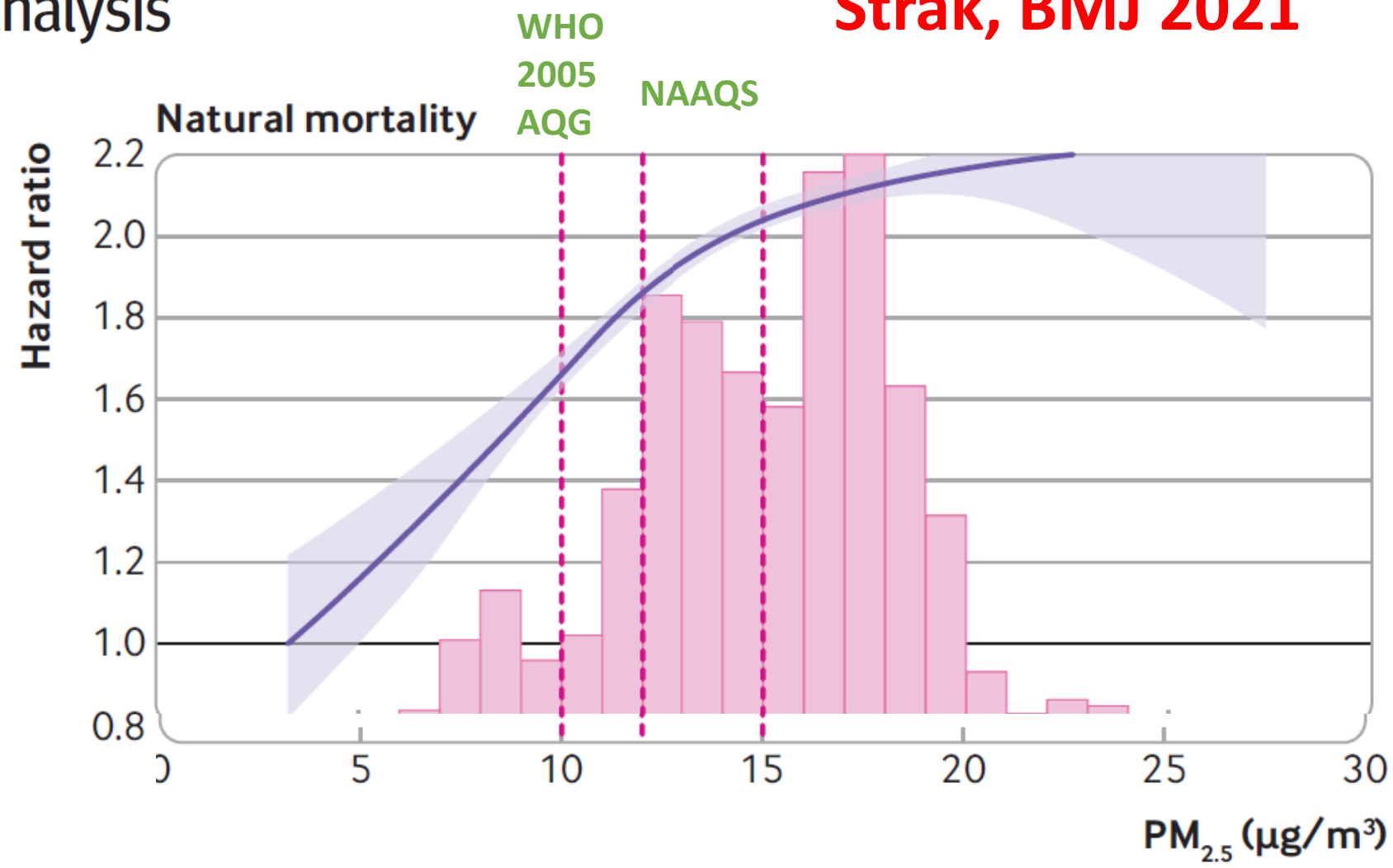
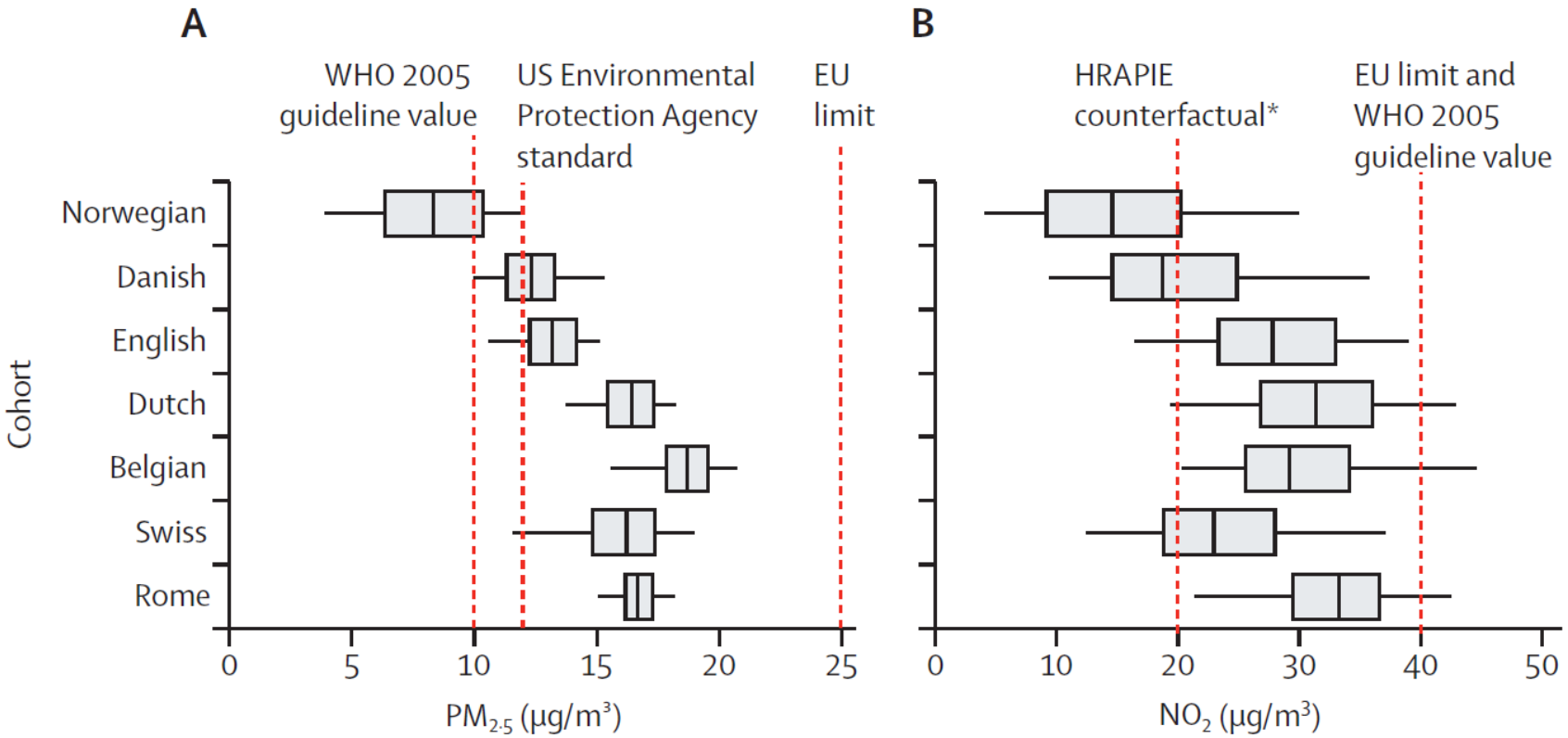


Long-term exposure to low ambient air pollution concentrations and mortality among 28 million people: results from seven large European cohorts within the ELAPSE project

Stafoggia, Lancet Plan Health 2022



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Stafoggia, Lancet Plan Health 2022

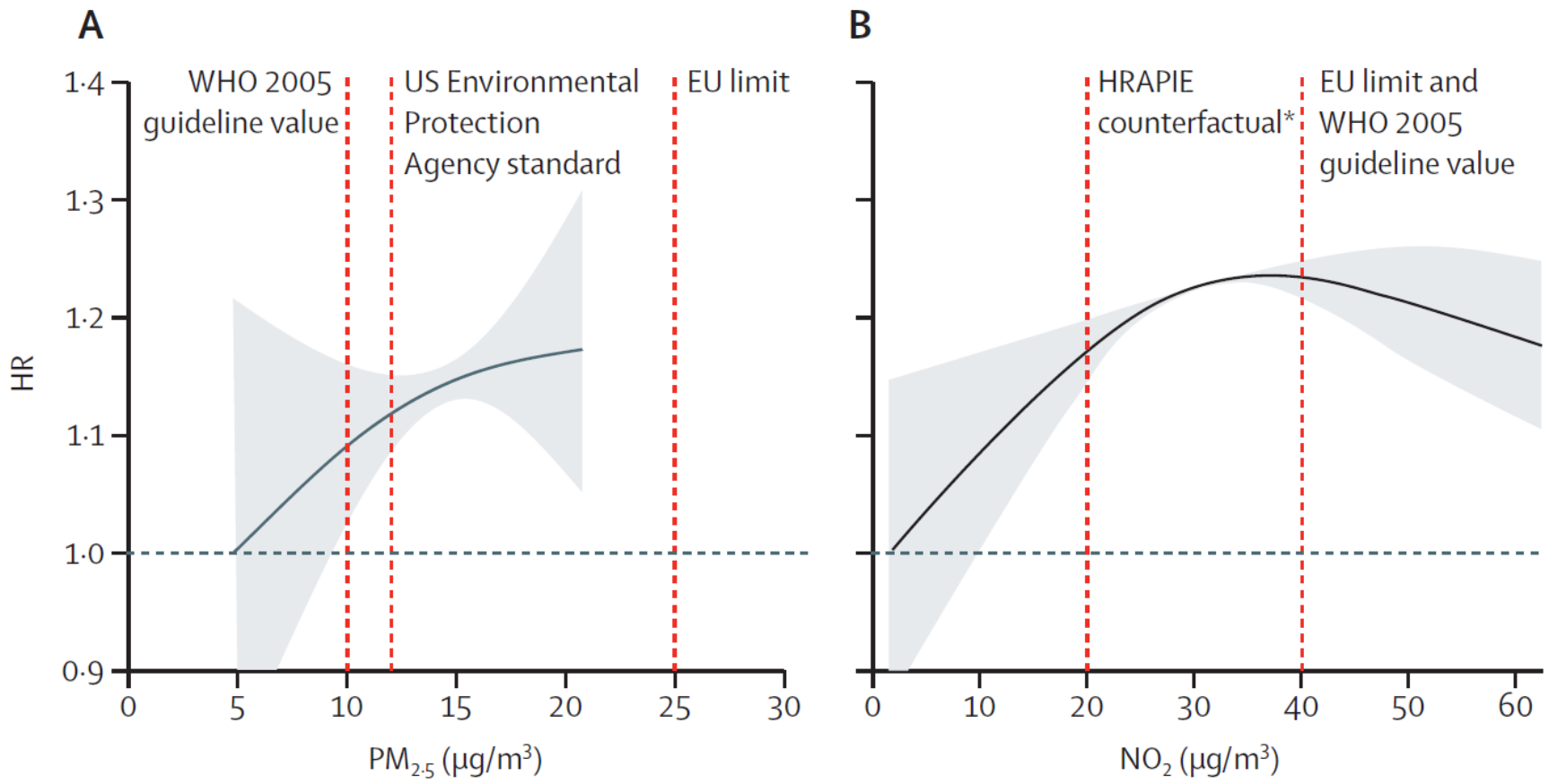


Table 7. Hazard Ratios for Associations Between Air Pollution and Natural-Cause Mortality in Subset Analysis[a]

Pollutant	Subset	N	HR (95% CI)
$PM_{2.5}$			
	Full dataset	325,367	1.130 (1.106, 1.155)
	<25 μg/m^3	325,339	1.131 (1.107, 1.156)
	< 20 μg/m^3	316,540	1.138 (1.113, 1.164)
	<15 μg/m^3	151,250	1.257 (1.193, 1.324)
	<12 μg/m^3	52,528	1.296 (1.140, 1.474)
	<10 μg/m^3	25,422	1.146 (0.931, 1.410)
NO_2			
	Full dataset	325,367	1.086 (1.070, 1.102)
	<40 μg/m^3	310,643	1.101 (1.083, 1.119)
	<30 μg/m^3	247,039	1.114 (1.088, 1.140)
	<20 μg/m^3	88,510	1.099 (1.033, 1.170)

HEI RR 208

https://www.healtheffects.org/publication/mortality-and-morbidity-effects-long-term-exposure-low-level-pm25-bc-no2-and-o3-analysis

The data cloud…

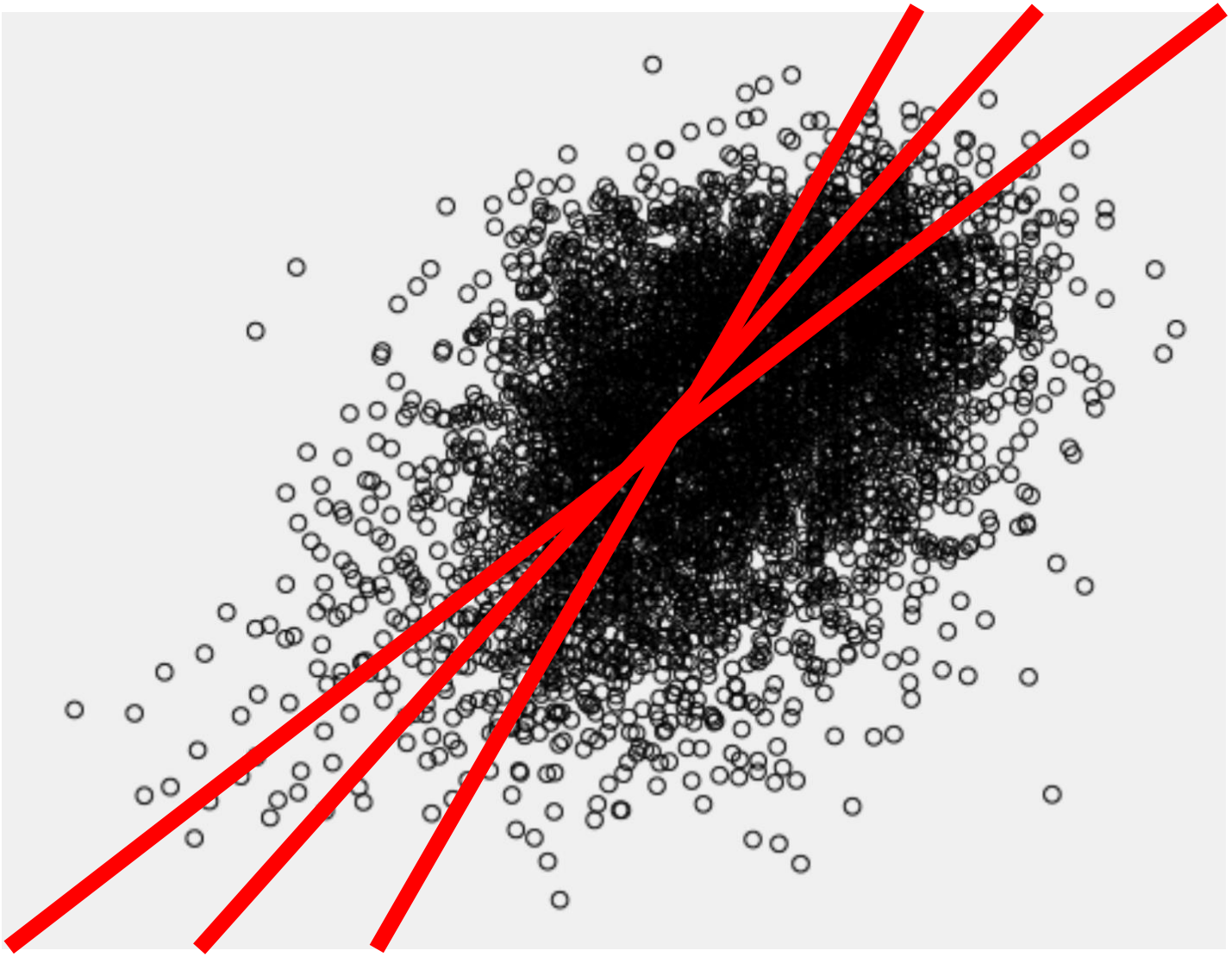
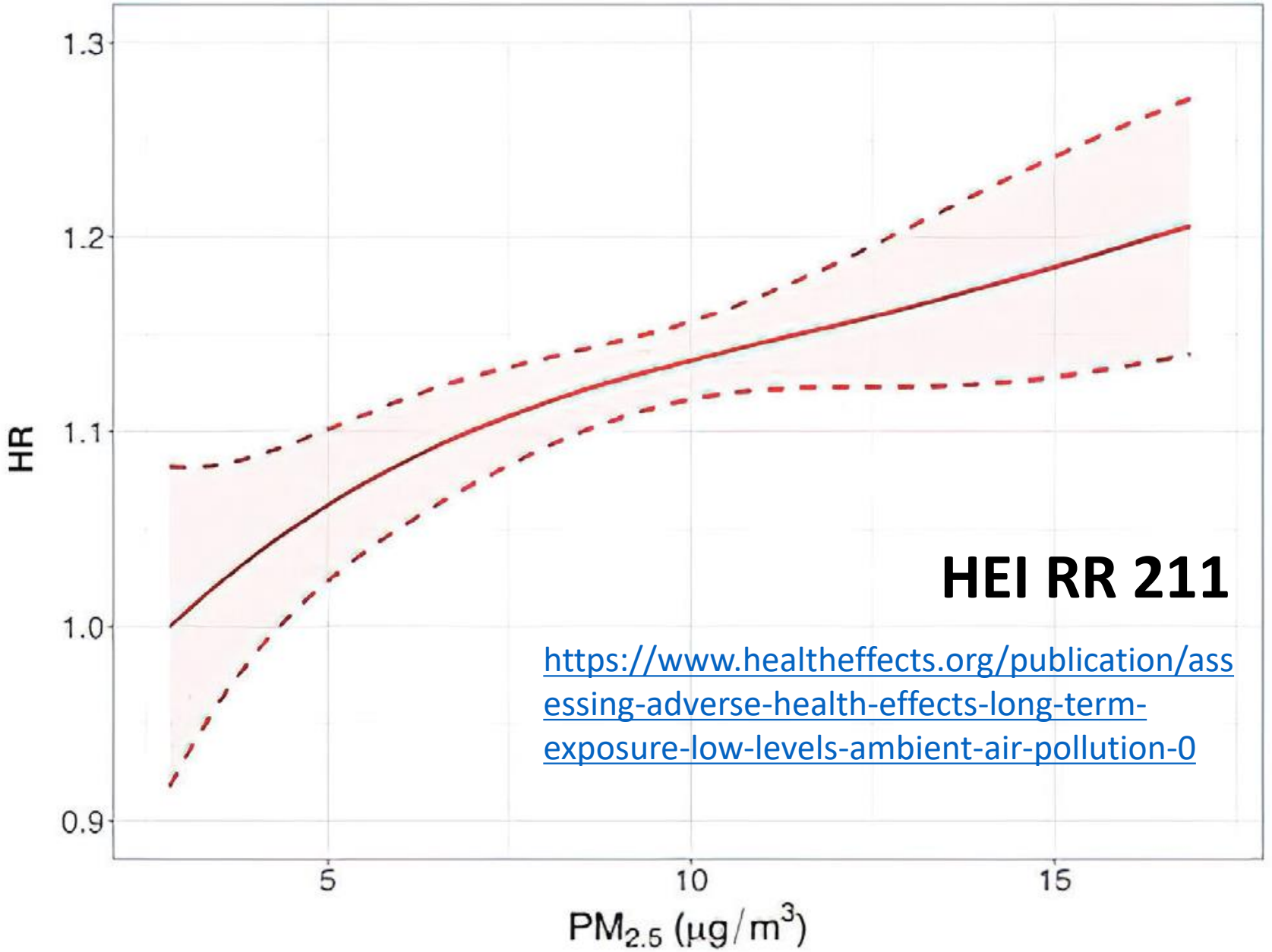


Table P7 Comparison of performance of models with and without a threshold: **natural-cause mortality**

Pollutant	Threshold	AIC	BIC
$PM_{2.5}$	None	831671.6	831803.0
	5 µg/m³	831671.6	831803.0
	7.5 µg/m³	831672.7	831804.1
	10 µg/m³	831677.4	831808.8
NO_2	None	831678.6	831810.0
	10 µg/m³	831680.1	831811.6
	15 µg/m³	831685.4	831816.9
	20 µg/m³	831709.6	

HEI RR 208

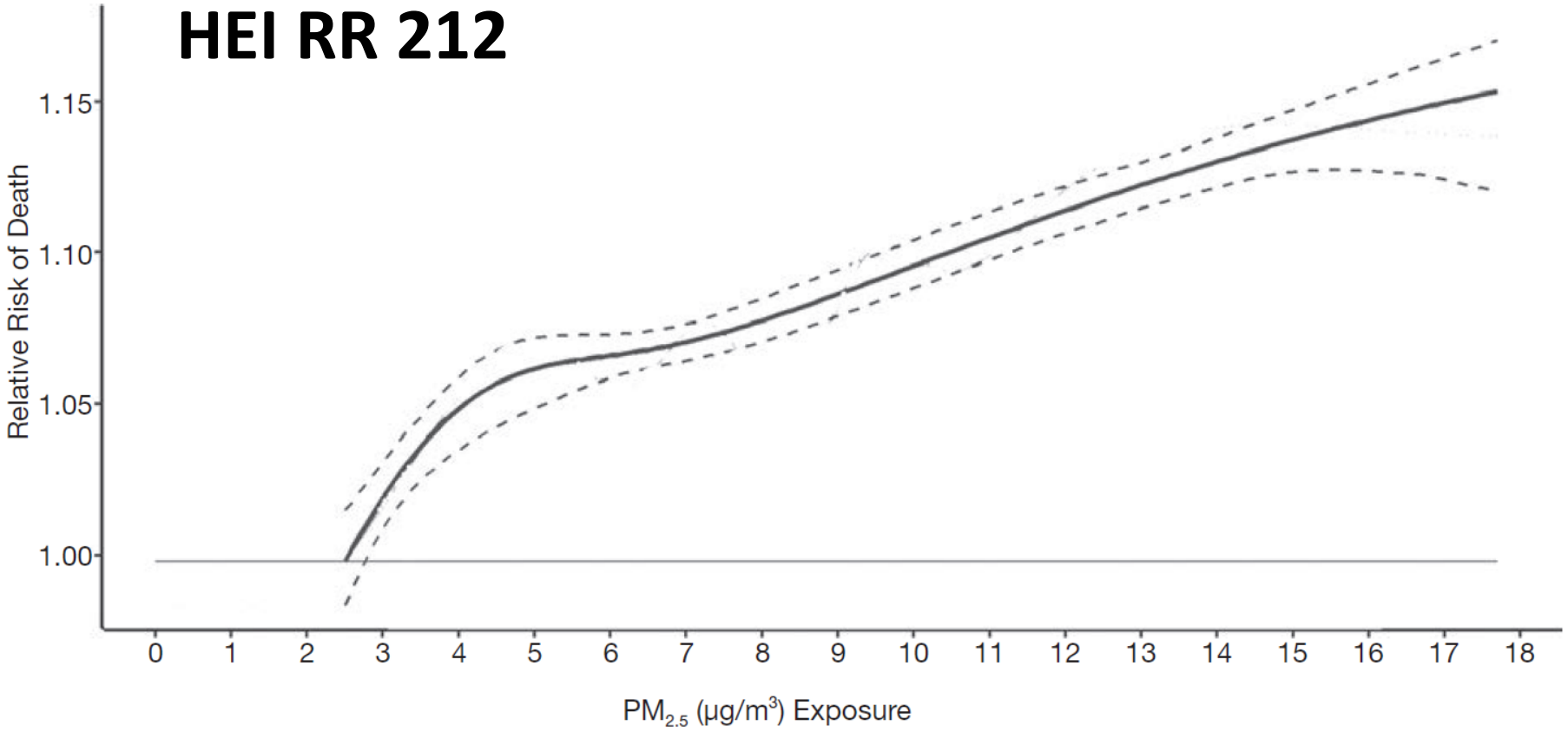
Medicare, USA, all-cause mortality



HEI RR 211

https://www.healtheffects.org/publication/assessing-adverse-health-effects-long-term-exposure-low-levels-ambient-air-pollution-0

CanCHEC, non-accidental mortality



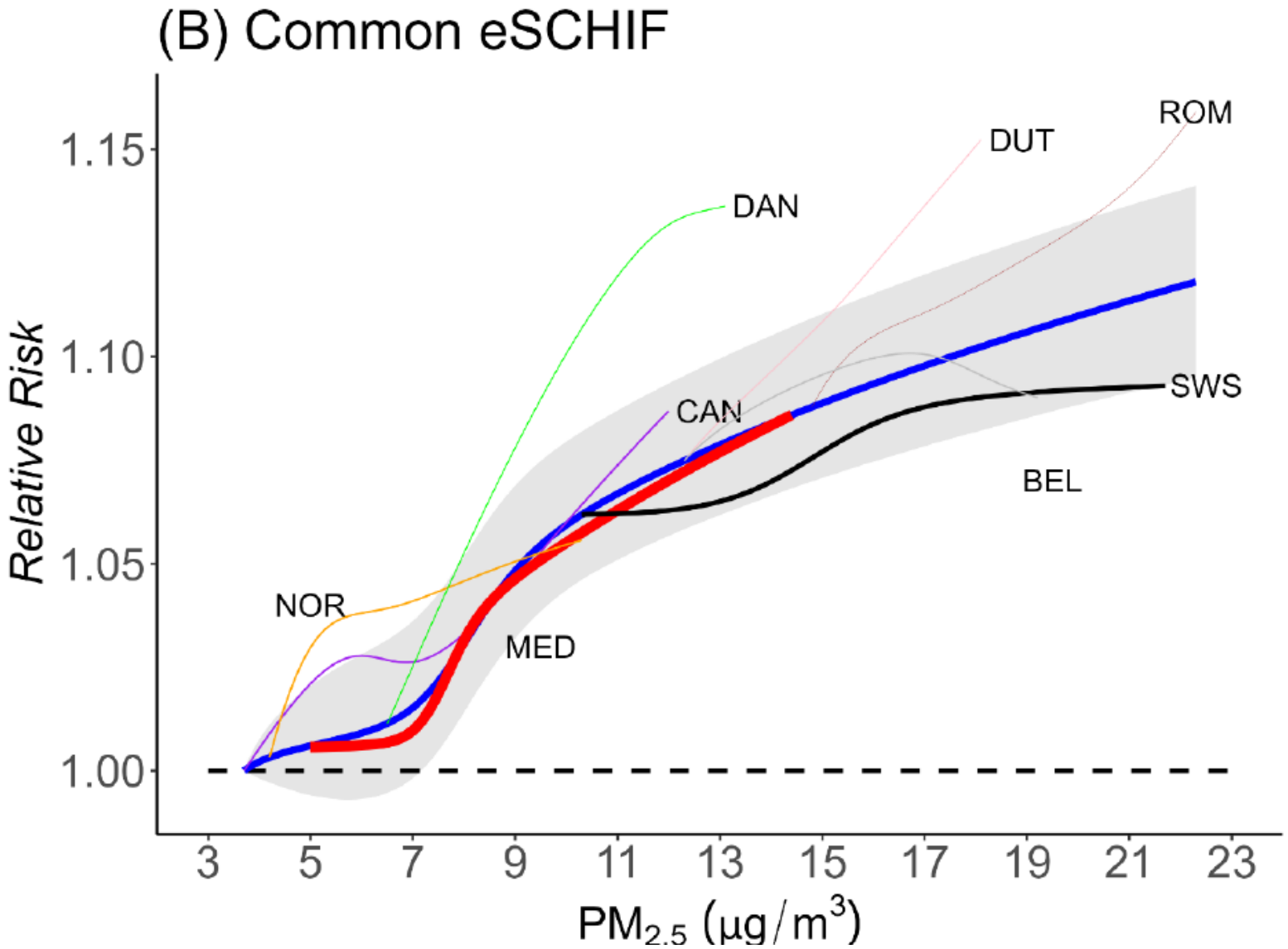
Statement Figure. Shape of the association between outdoor $PM_{2.5}$ exposure and nonaccidental death. This plot shows how the risk of death changes over different $PM_{2.5}$ exposure concentrations. The relative risk of death compares the lowest observed $PM_{2.5}$ concentration (2.5 µg/m³) to all higher concentrations. (Adapted from Investigators' Report Figure 29.)

https://www.healtheffects.org/announcements/new-canadian-study-reports-health-effects-very-low-air-pollution-levels.

Harmonized analysis of Canadian, US and European studies

- We harmonized the study populations to individuals age 65+, applied the same satellite-derived PM2.5 exposure estimates, selected the same sets of potential confounders and the same outcome.
- Hazard ratios for all-cause mortality associated with a 5 $\mu g/m^3$ increase in PM2.5 were:
- 1.039 (1.032, 1.046) in CanCHEC - Canada,
- 1.025 (1.021, 1.029) in Medicare- USA, and
- 1.041 (1.014, 1.069) in ELAPSE - Europe.

Chen, EHP 2023 (under review)



Commentary

ENVIRONMENTAL EPIDEMIOLOGY

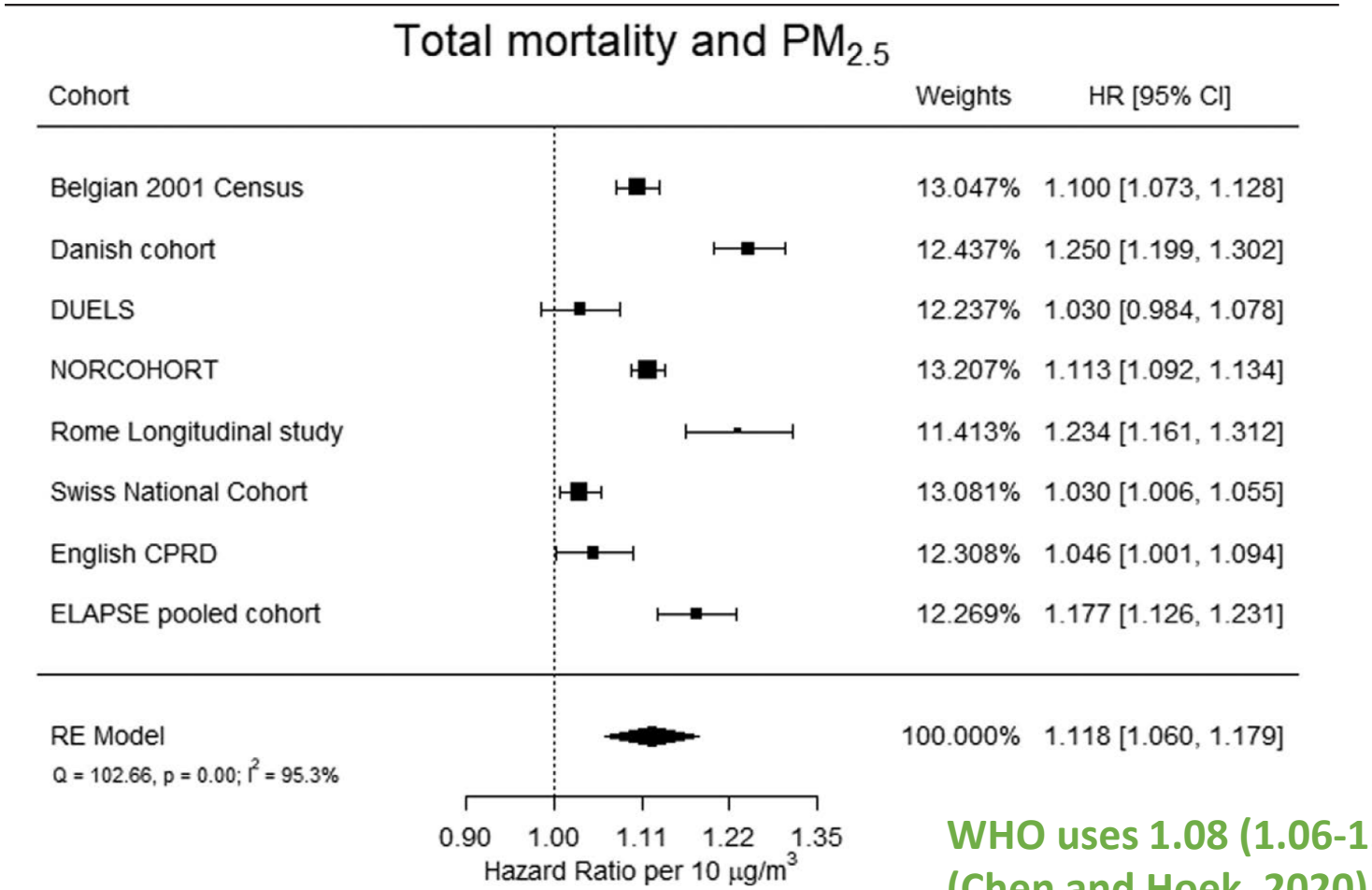
OPEN

Benefits of future clean air policies in Europe

2022

Proposed analyses of the mortality impacts of $PM_{2.5}$ and NO_2

Barbara Hoffmann[a], Bert Brunekreef[b], Zorana J. Andersen[c], Francesco Forastiere[d], Hanna Boogaard[e*]



WHO uses 1.08 (1.06-1.09)
(Chen and Hoek, 2020)

What about ozone?

- No association between long-term O3 and mortality in ELAPSE
- Associations with PM2.5, NO2 in ELAPSE robust against adjustment for O3
- Positive association in Medicare and CanCHEC even after adjustment for PM2.5 and NO2
- O3 ***positively*** correlated with PM2.5 and NO2 in Medicare and CanCHEC
- O3 ***negatively*** correlated with PM2.5 and NO2 in ELAPSE
- O3 modeled on different spatial scales, and concentration ranges small in ELAPSE cohorts

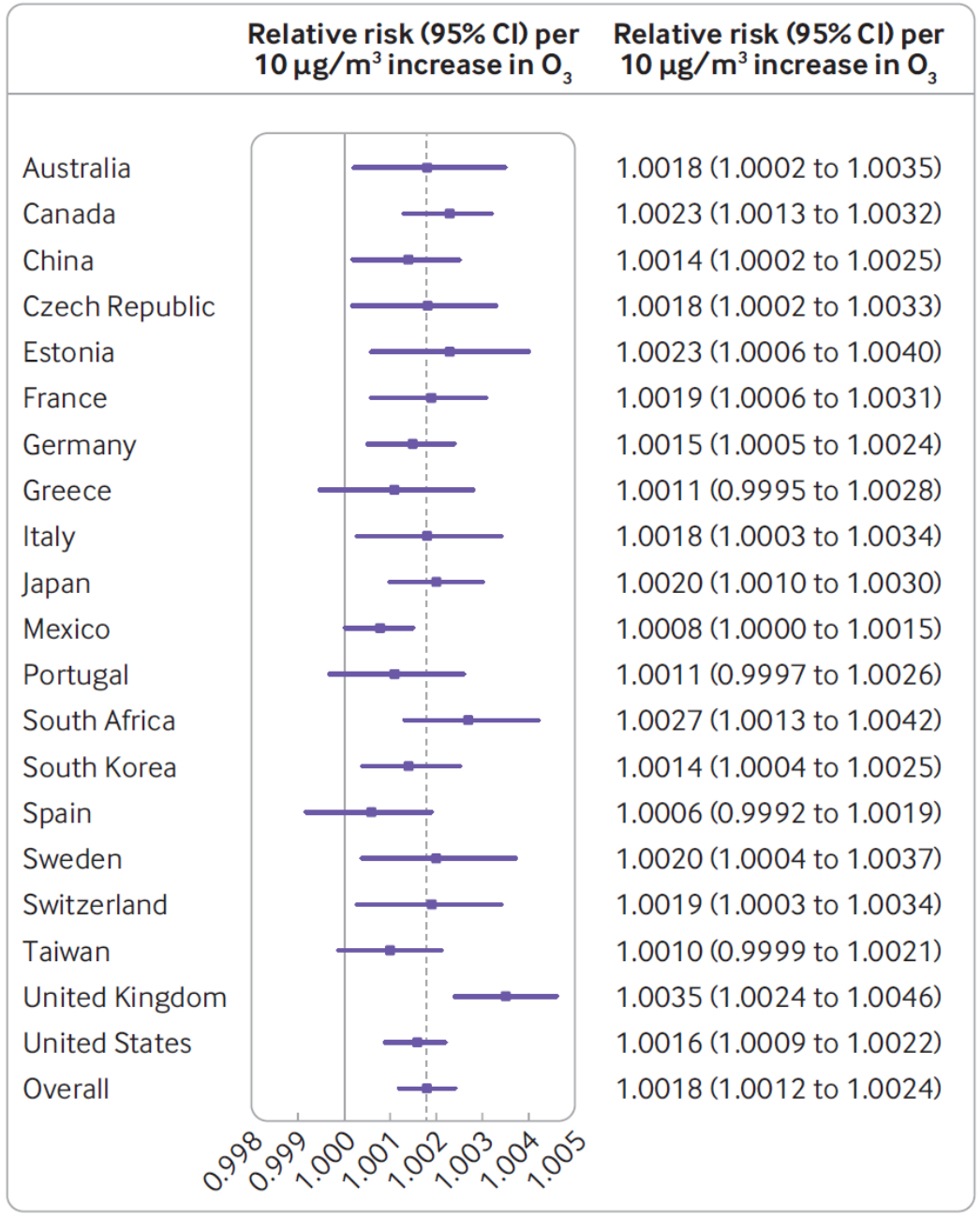


Fig 2 | Overall and country specific short term ozone-mortality association, expressed as relative risk per 10 µg/m³ increase in ozone (O_3, maximum eight hour average) (lag 01)

Short-term O3 is associated with mortality in all parts of the world Vicedo-Cabrera, BMJ 2020

Concluding remarks

- WHO 2021 Air Quality Guidelines much lower than in 2005 for long-term PM2.5 and NO2
- Mostly because we know better what happens at low concentrations >> role of science has been crucial in documenting effects at low levels in great detail
- AAQD needs to specify how and when Limit Values will be aligned with new WHO AQGs

THANK YOU FOR LISTENING!

Reviewing the latest science on air pollution and health – Part 1

Beyond mortality: summarising important health effects of air pollution across the life course

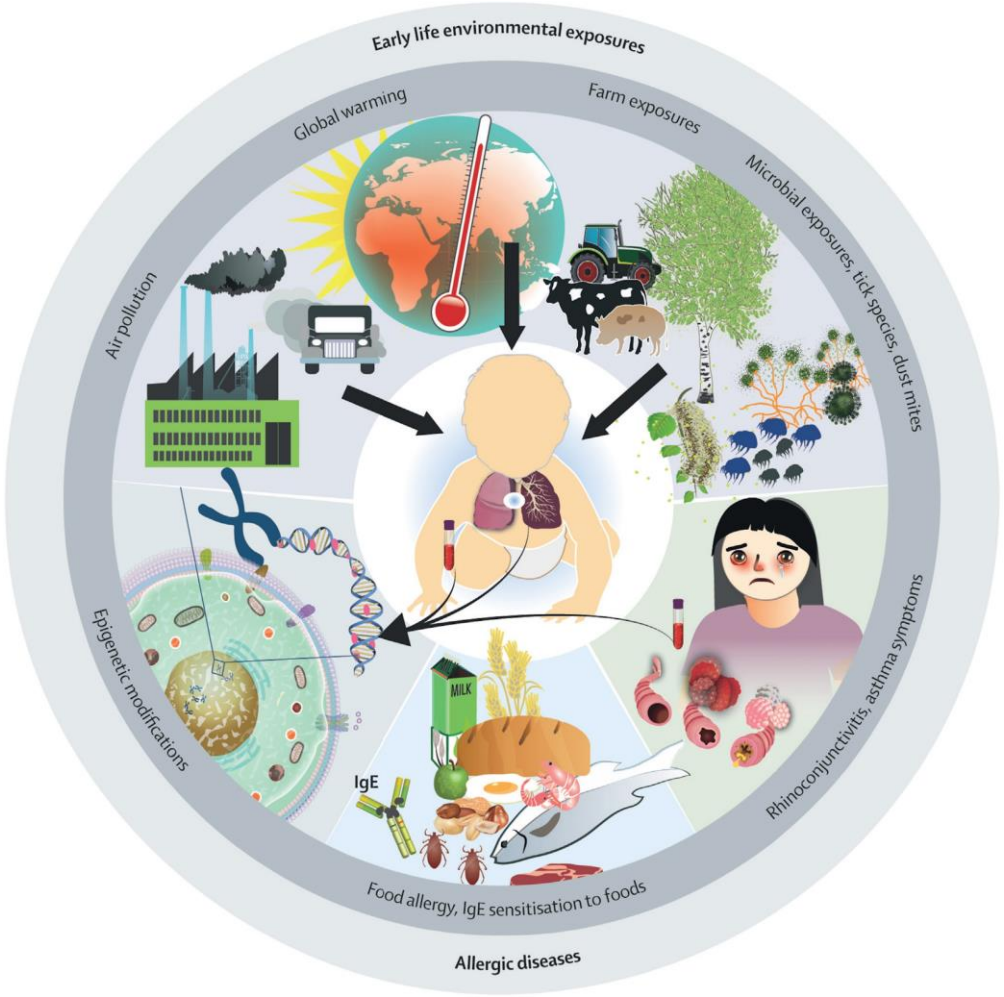
Chairs: Hanna Boogaard (HEI and ISEE) and Klea Katsouyanni (Imperial College London)

Pregnancy and childhood

ERS-ISEE-HEI workshop, May 24th 2023

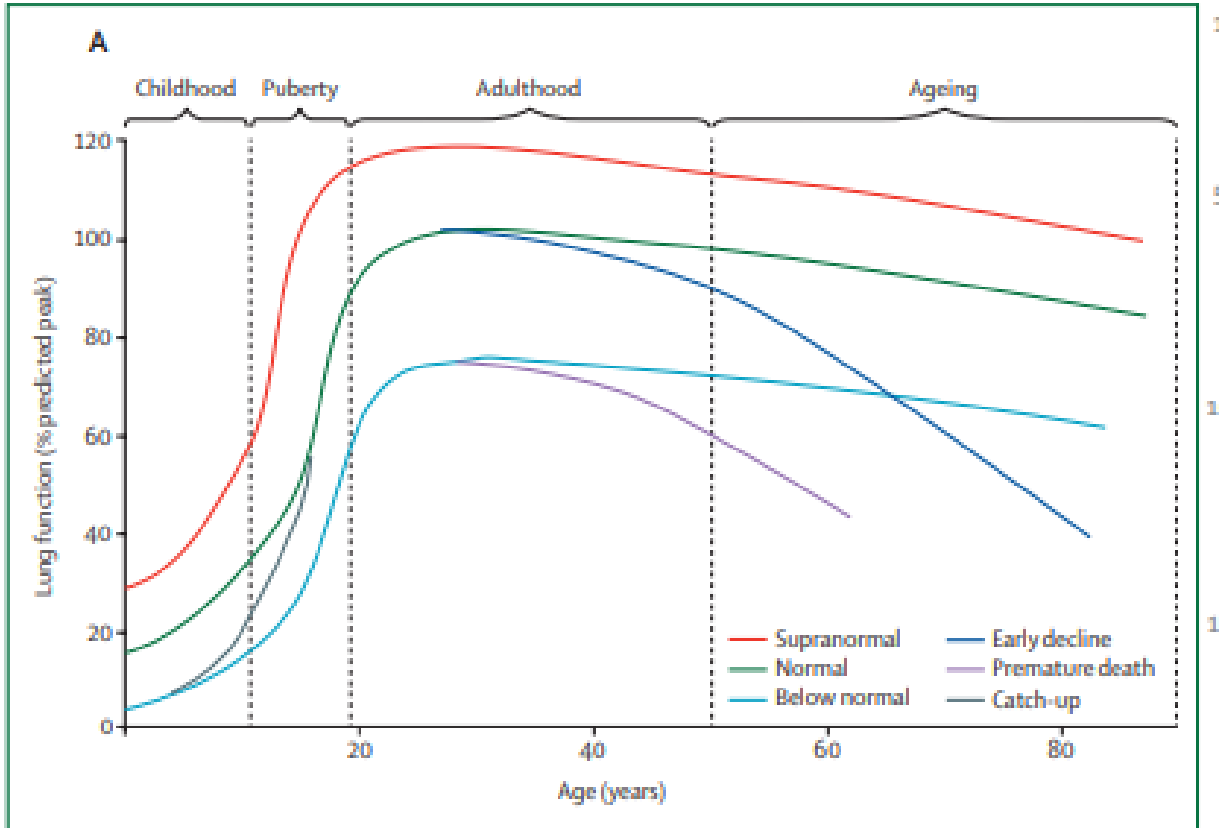
Erik Melén, MD, PhD
Professor, senior consultant pediatric allergy
ERS Environmental Health Committee

A life-course perspective



Melén, Koppelman et al. *Lancet Child & Adolescent Health* 2022

The example of lung function trajectories



Agusti, Melén et al. *Lancet Resp Med* 2022

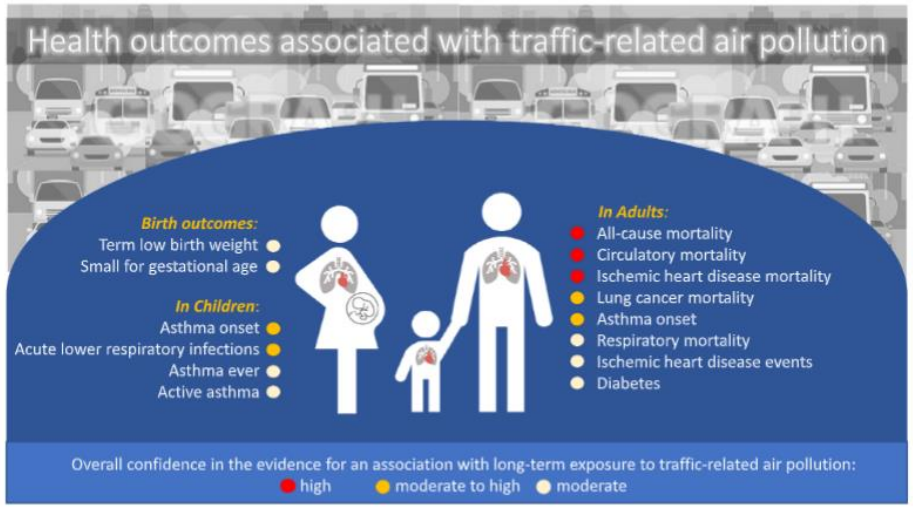
Children are particularly vulnerable to environmental hazards:

- More time outside, physically active
- Higher rates of breathing and ventilation rates relative to body size
- Narrower airways
- Ineffective airway particle filtering
- Underdeveloped detoxification systems
- Typically don’t choose lifestyle and environment

https://www.svt.se/nyheter/inrikes/avgaser-ger-barn-samre-lungor

Exposure affects children in many ways:

- *In utero exposure; growth impairment, preterm birth*
- *Lower respiratory infections*
- *Asthma, lung growth limitation → COPD risk*
- *Impede cognitive development*
- *Mortality (600,000 / y globally)*



Boogaard et al. *Environ Int* 2022

ACTA PÆDIATRICA
NURTURING THE CHILD

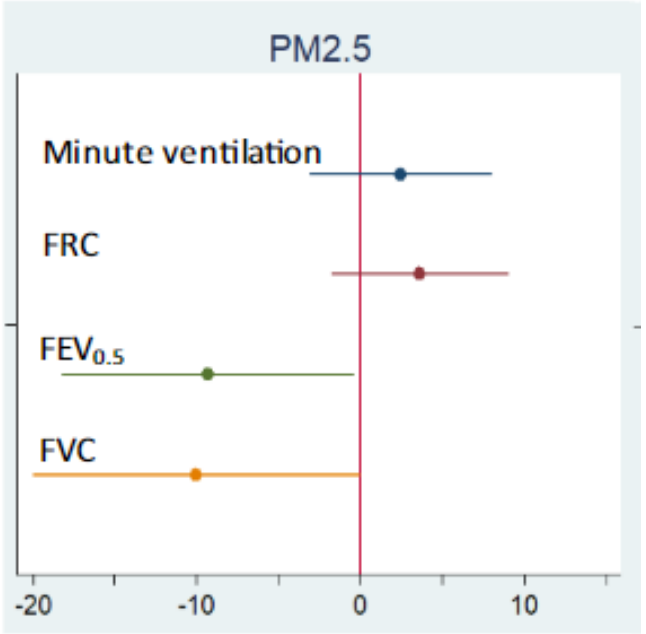
ORIGINAL ARTICLE | Open Access

Air pollution exposure impairs lung function in infants

Björn Lundberg, Olena Gruzieva, Kristina Eneroth, Erik Melén, Åsa Persson, Jenny Hallberg, Göran Pershagen

First published: 17 May 2022 | https://doi.org/10.1111/apa.16412

BAMSE-PROJEKTET
BARN • ALLERGI • MILJÖ • EPIDEMIOLOGI
SEDAN 1994 • STOCKHOLM •



Early life exposure and health in young adults

- **Chronic bronchitis** 5,5%
- **Irreversible airflow limitation** according to COPD-criteria 2%
- Cough, phlegm, recurrent airway infections and respiratory symptoms
- **Air pollution exposure 0-1 y strongly associated (OR 2-3)**

Wang et al, *Eur Resp J* 2021; *Thorax* 2021
Yu et al, *JAMA Open Network* 2022;
Lancet Regional Health Europe 2023


The Washington Post
Democracy Dies in Darkness

Growing evidence links air pollution exposure and covid-19 risks

By Allyson Chiu
May 13, 2022 at 8:00 a.m. EDT

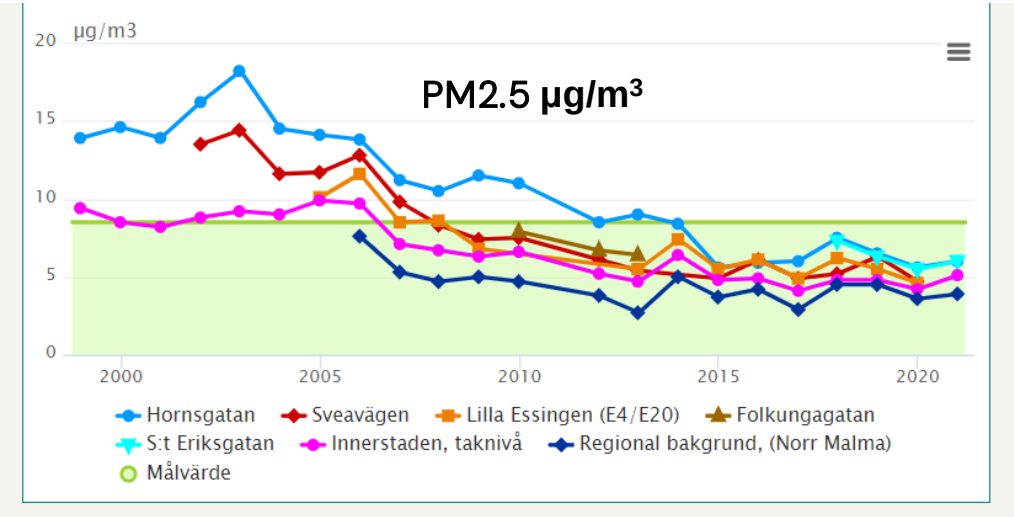
How can we mitigate air pollution health effects?

EUROPEAN RESPIRATORY JOURNAL
ORIGINAL RESEARCH ARTICLE
Z. YU ET AL.

Eur Resp J 2023

Associations of improved air quality with lung function growth from childhood to adulthood: the BAMSE study

Zhebin Yu[1], Simon Kebede Merid[2], Tom Bellander[1,3], Anna Bergström[1,3], Kristina Eneroth[4], Antonios Georgelis[1,3], Jenny Hallberg[2,5], Inger Kull[2,5], Petter Ljungman[1,6], Susanna Klevebro[2,5], Massimo Stafoggia[1,7], Gang Wang[1,2], Göran Pershagen[1,3], Olena Gruzieva[1,3] and Erik Melén[2,5]



Association between improvement of air quality and differences in lung function growth from age 8 to 24 years

	Unit of improvement in exposure	Raw value	
		Difference in FEV_1 growth, mL per year (95% CI)#	Difference in FVC growth, mL per year (95% CI)#
$PM_{2.5}$	2.19 µg·m^{-3}	4.63 (1.64–7.61)	9.38 (4.76–14.00)
PM_{10}	1.00 µg·m^{-3}	0.72 (−0.91–2.35)	2.77 (0.19–5.35)
BC	0.28 µg·m^{-3}	2.80 (0.66–4.93)	5.59 (2.30–8.87)
NO_x	6.17 µg·m^{-3}	1.70 (−0.16–3.57)	3.29 (0.35–6.23)

Exposure improvement associated with 22% lower risk of having low lung function at age 24 years

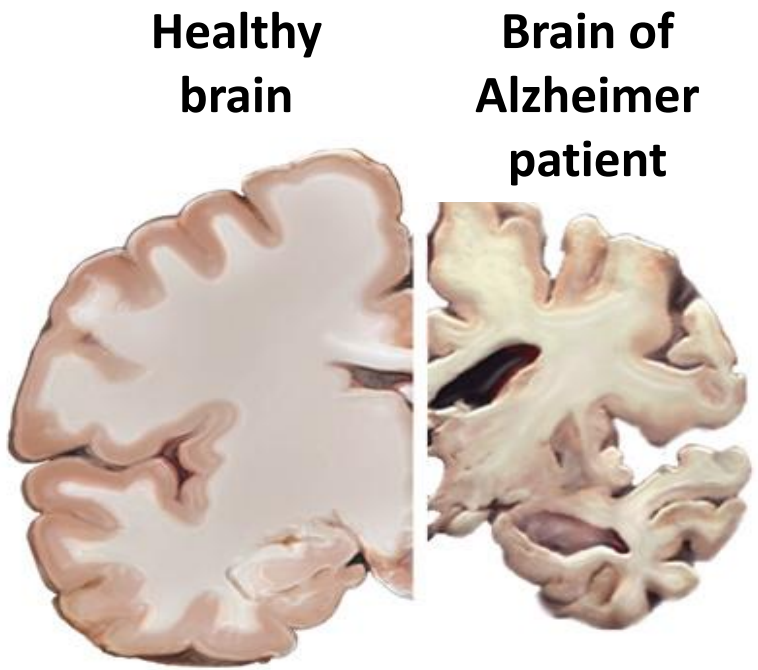
Conclusions

- Better air quality – better health, bigger lungs!
- Prevention of chronic adult disease? Start early.

Cognitive development and neurologic disorders

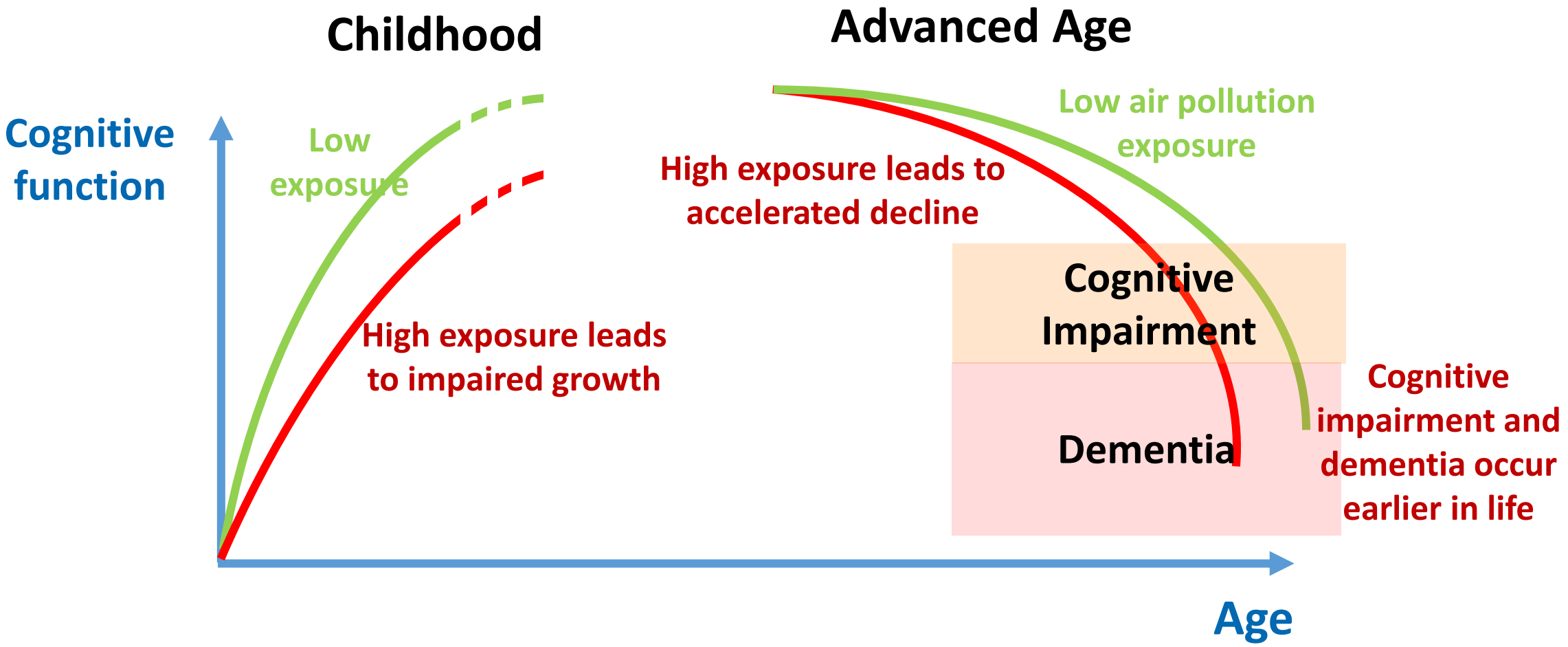
Barbara Hoffmann, Heinrich-Heine-University of Düsseldorf,
ERS Advocacy Chair Elect

Clean Air in Europe for All
Brussels, May 24, 2023



Air pollution and brain function

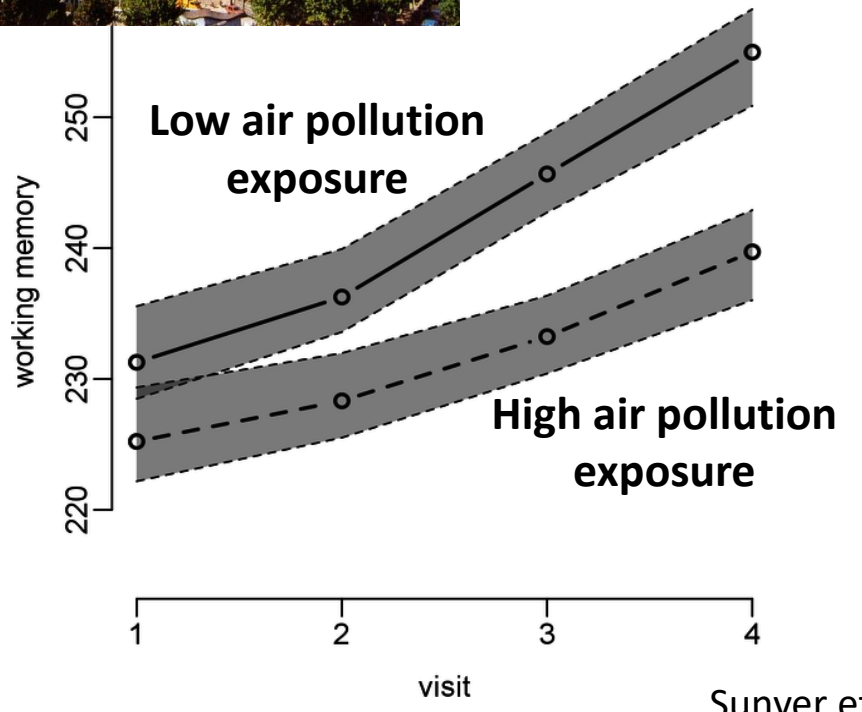
Hypotheses



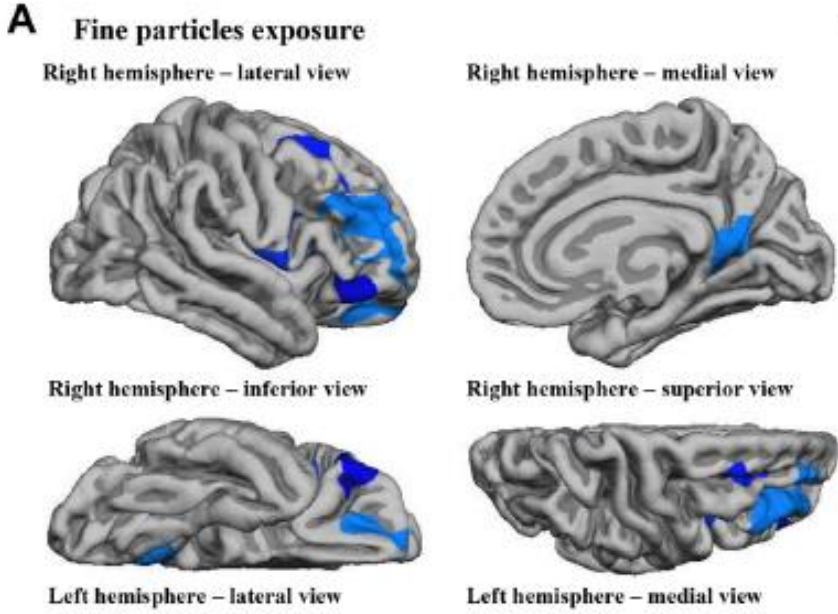
Cognitive development and brain structure in children

Barcelona and Rotterdam

Lower cognitive growth among highly exposed



- **Decrease in gray matter / cortical thickness**
- **Changes in white matter structure (wiring)**



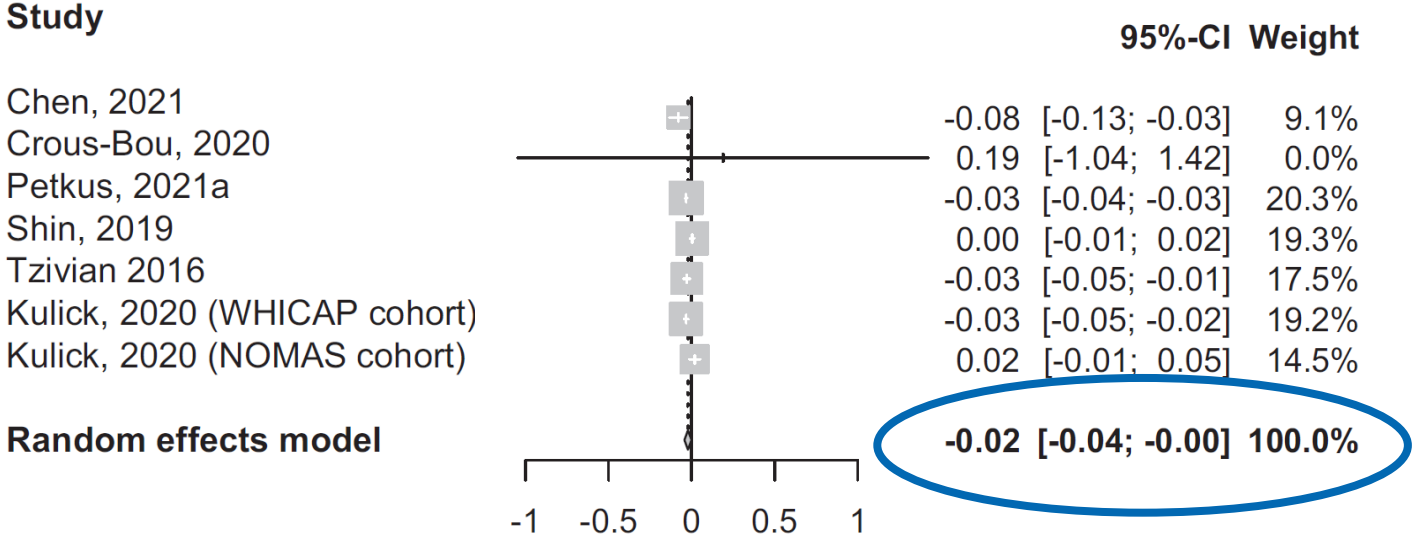
Sunyer et al. Plos Med 2015

Guxens et al. BPS 2018

Impact on the aging brain

Meta-analyses

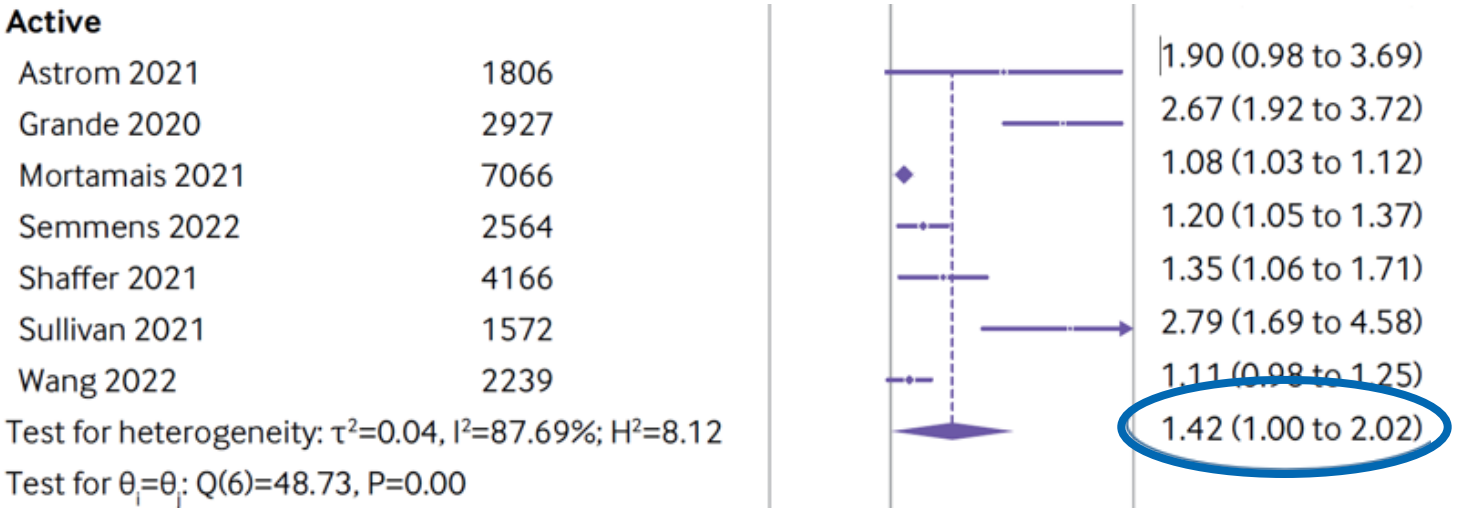
Thompson et al, 2023



Air pollution is related to accelerated cognitive decline

Wilker et al, BMJ, 2023

Air pollution is related to incidence of dementia



Conclusions

- Air pollution impairs cognitive growth in babies and children
- Air pollution accelerates cognitive decline and development of dementia in the aging brain

ERS EUROPEAN RESPIRATORY SOCIETY every breath counts

HEI

ISEE

Heart disease from the air we breathe

Petter Ljungman, MD PhD

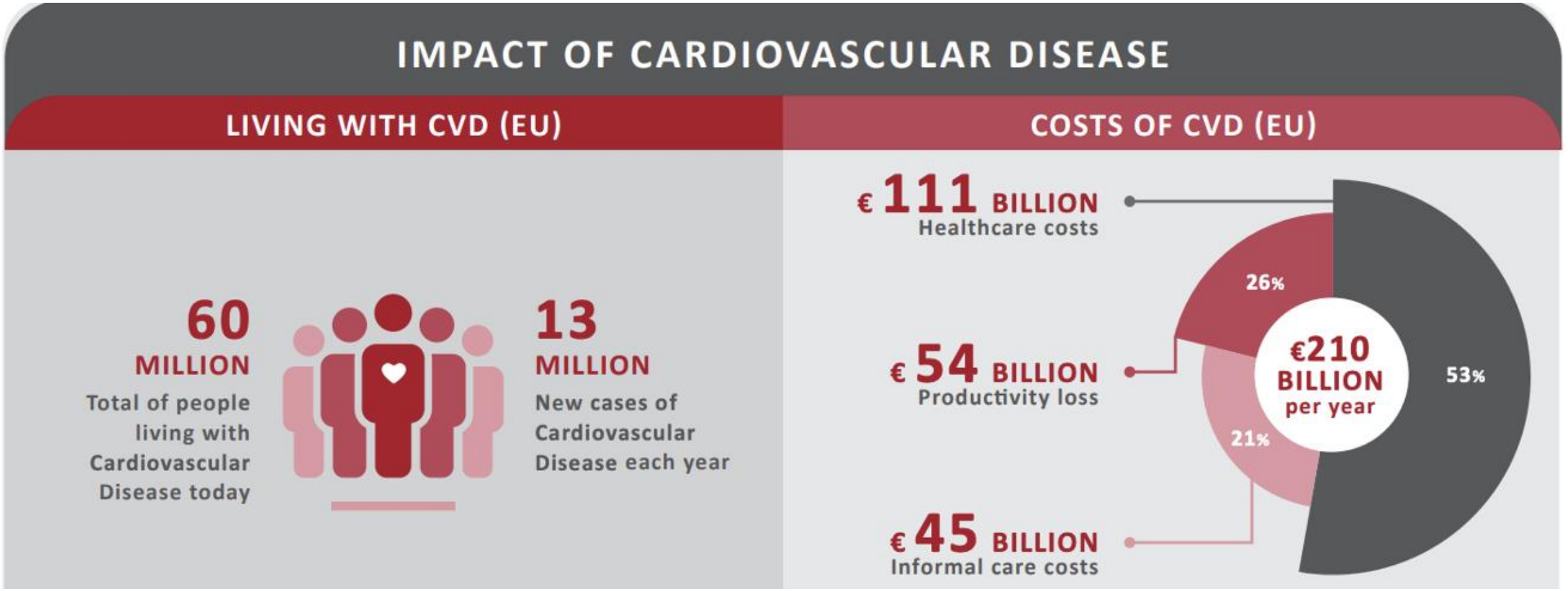
Associate professor, Karolinska Institutet

Senior consultant of cardiology, Danderyd Hospital, Sweden

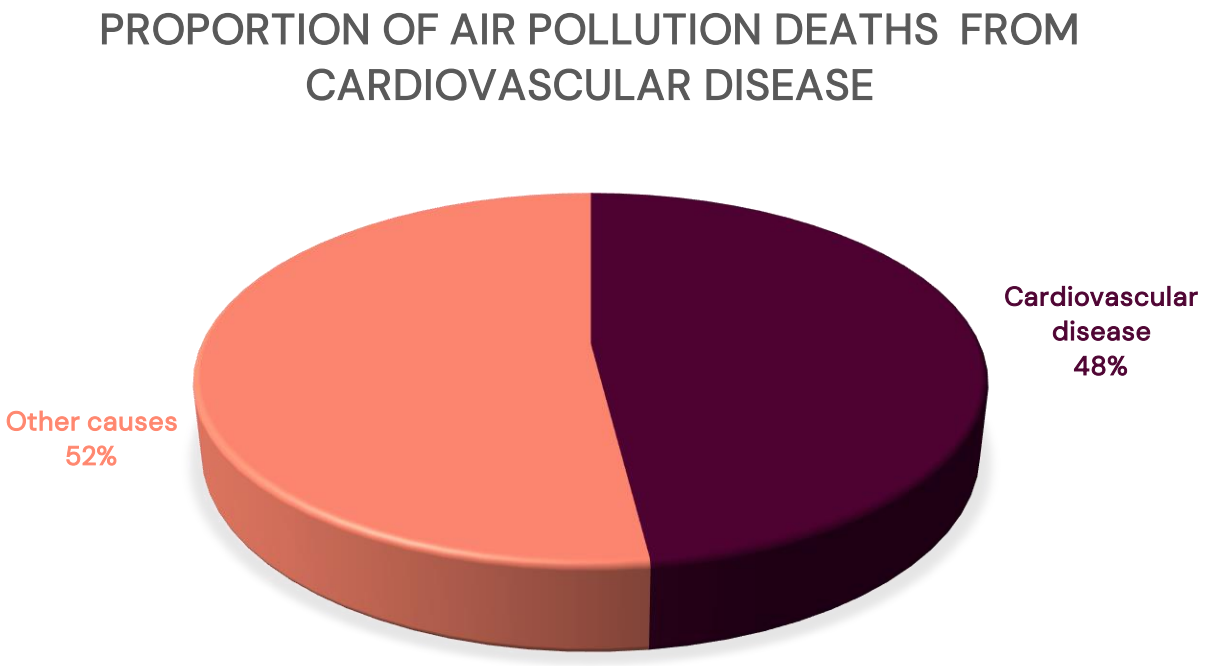
Co-chair ISEE Europe, Scientific Secretary of the Swedish Society of Cardiology

Cardiovascular disease

Very common and the leading cause of death in the EU



Cardiovascular deaths from air pollution across Europe



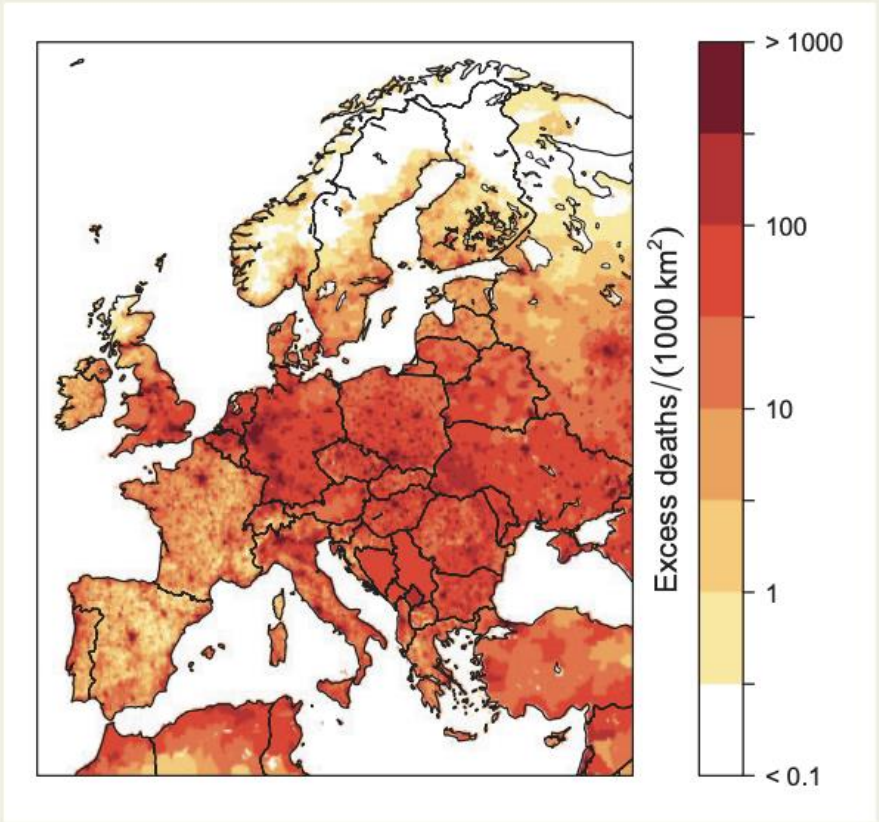


Figure 2 Regional distribution of estimated annual excess mortality rates from cardiovascular diseases (CVD = IHD + CEV) attributed to air pollution. These rates are lower limits as other non-communicable diseases are not included.

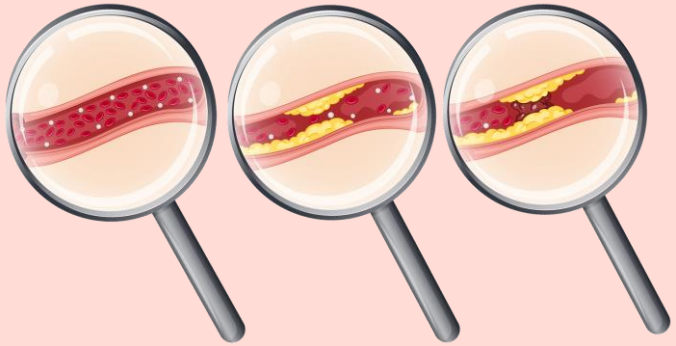
Eur Heart J, Volume 40, Issue 20, 21 May 2019, Pages 1590–1596, https://doi.org/10.1093/eurheartj/ehz135

How does air pollution affect your heart?

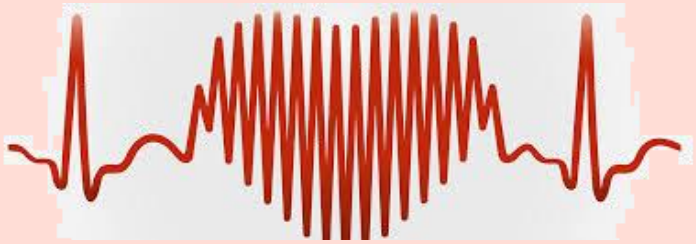
Exposure

Disease processes

Blood vessel narrowing and clots



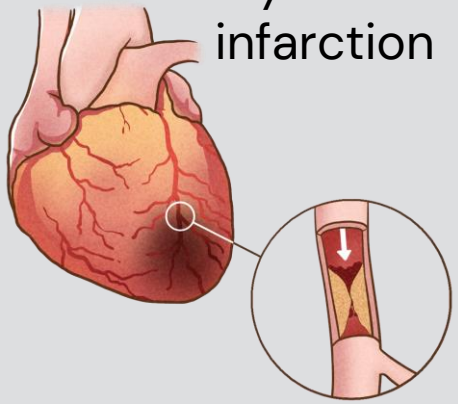
Electrical disturbances



Clinical outcomes

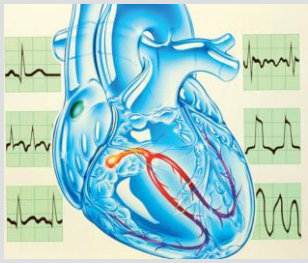
Heart failure

Myocardial infarction

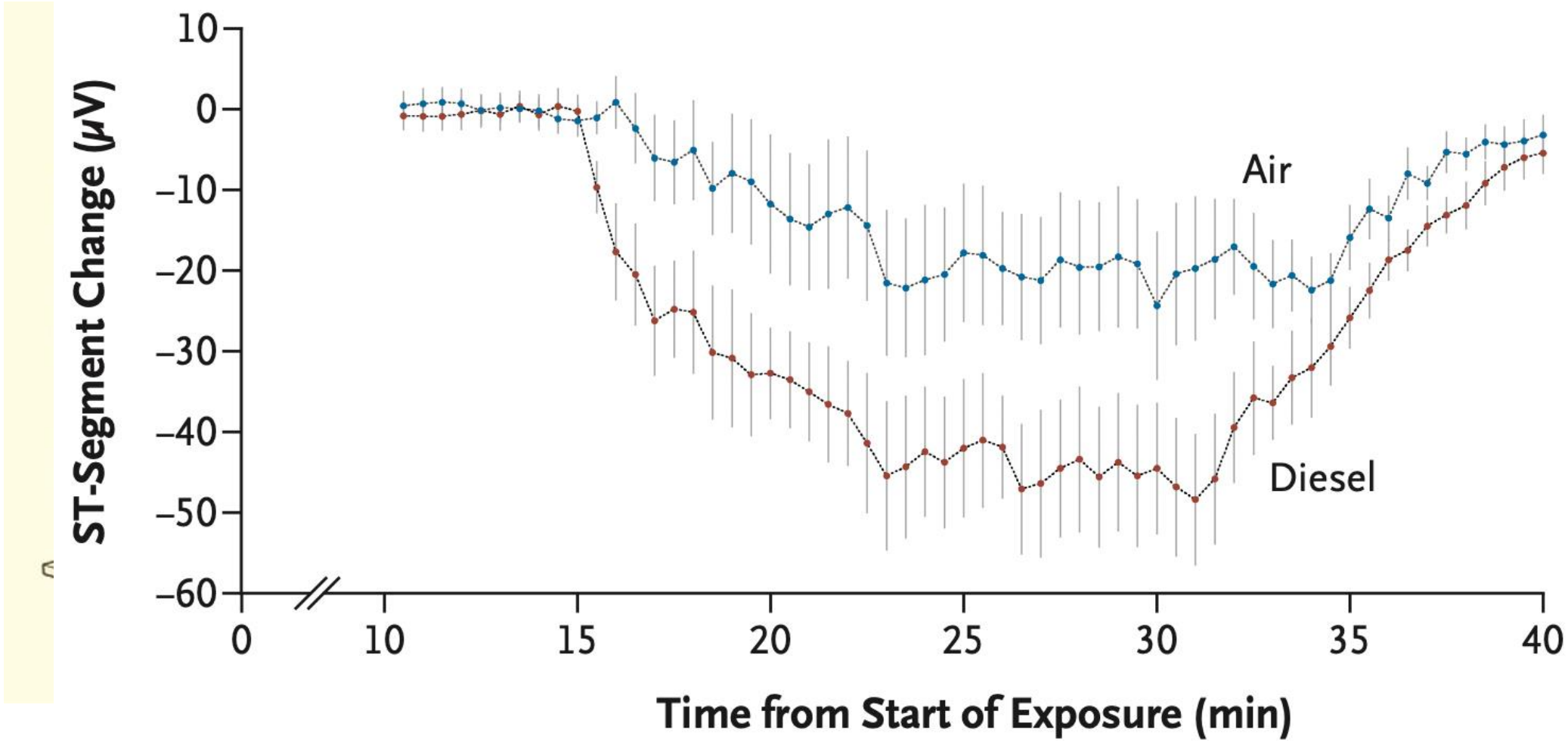


Stroke

Arrhythmias

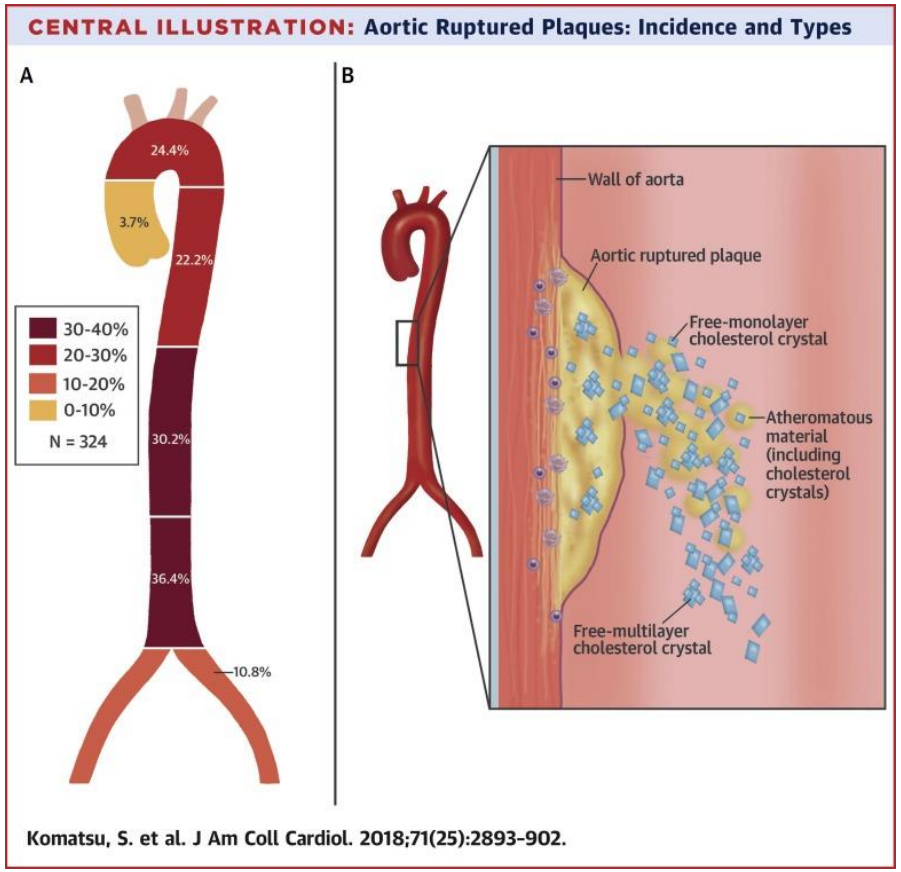


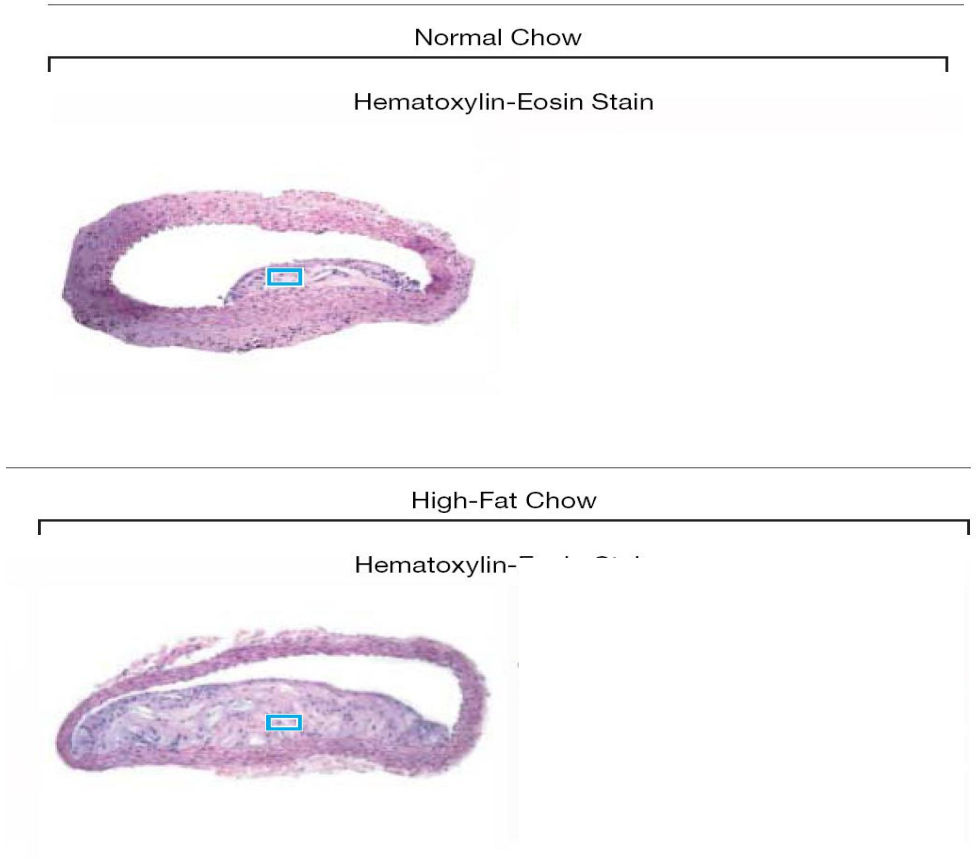
Immediate coronary effects of diesel



Mills NEJM 2007

Air pollution increases atherosclerosis





(n=28 apoE$^{-/-}$ mice; 6 months, 6hr/day*5 day/week)

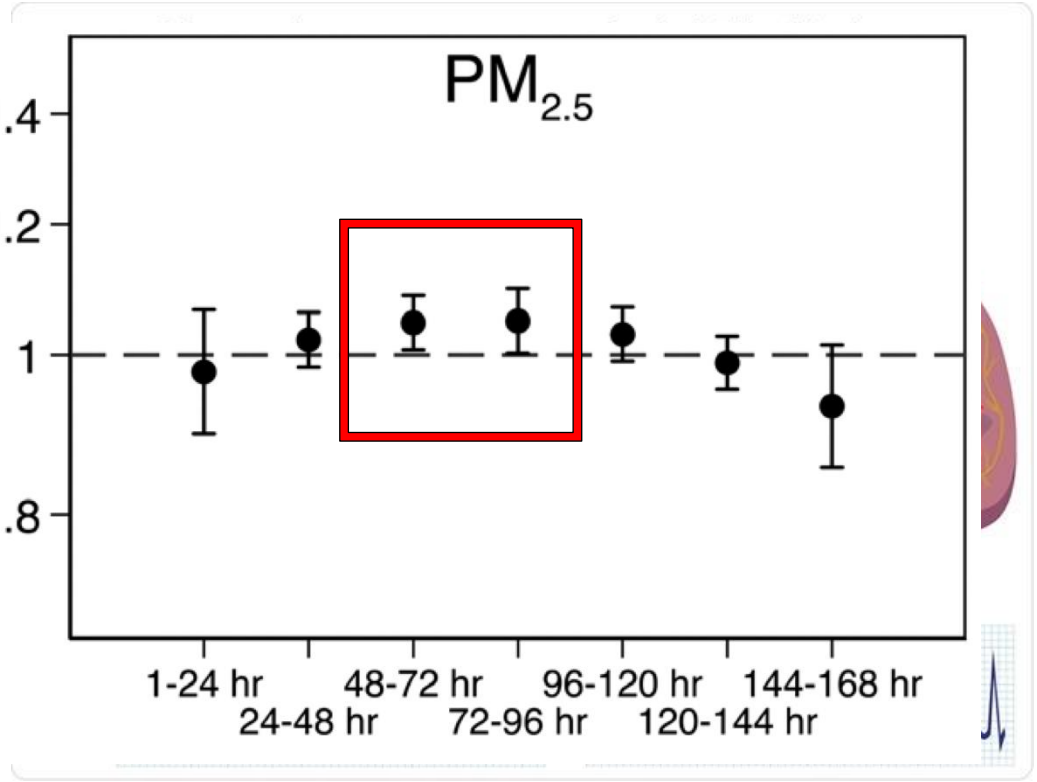
Filtered air

$PM_{2.5}$

Sun JAMA 2005

Air pollution and arrhythmias at very low levels

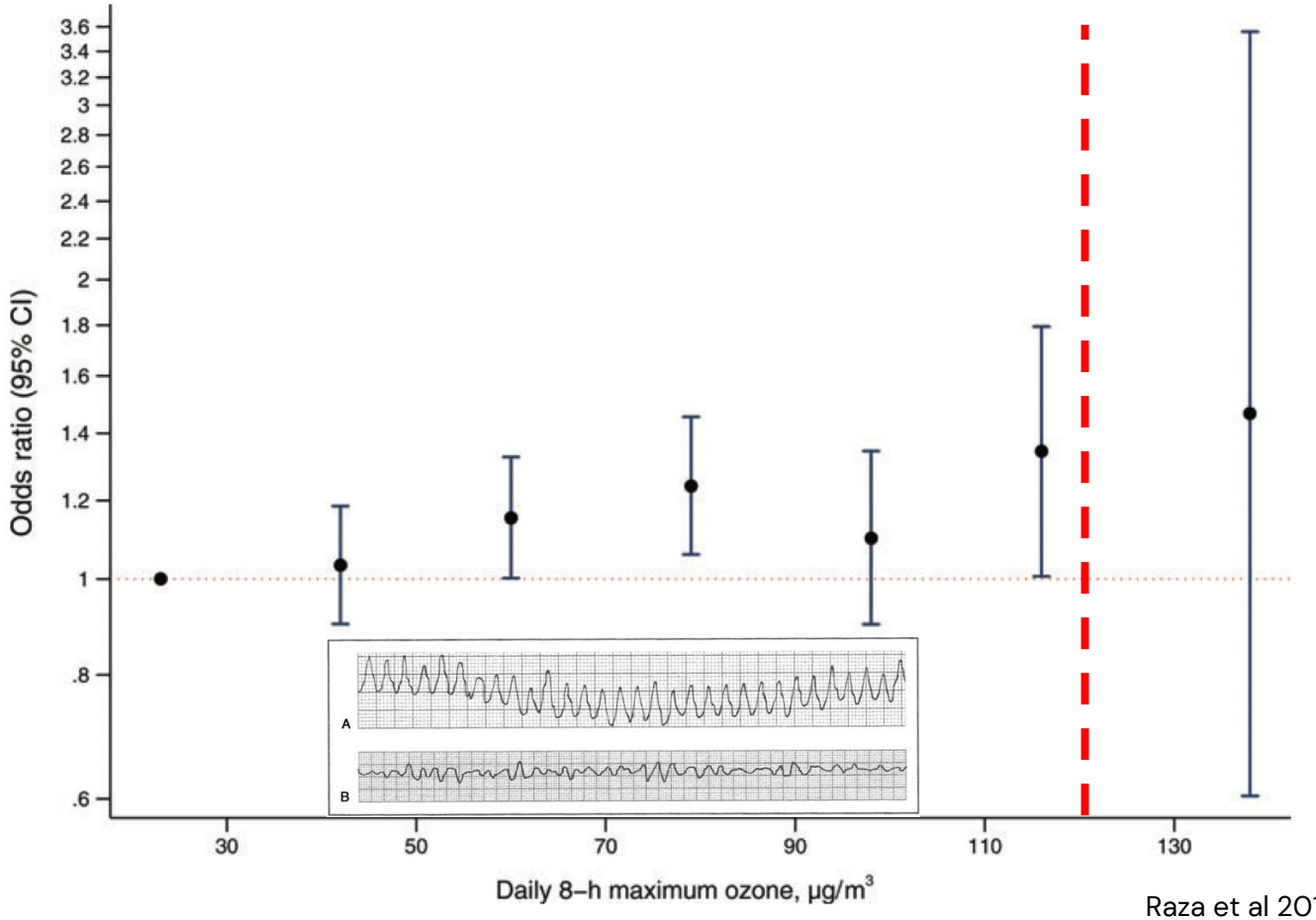
Atrial Fibrillation



Mean 4.7µg/m3

Dahlquist et al 2022. Env Epi

Cardiac Arrest



Raza et al 2014. EHJ

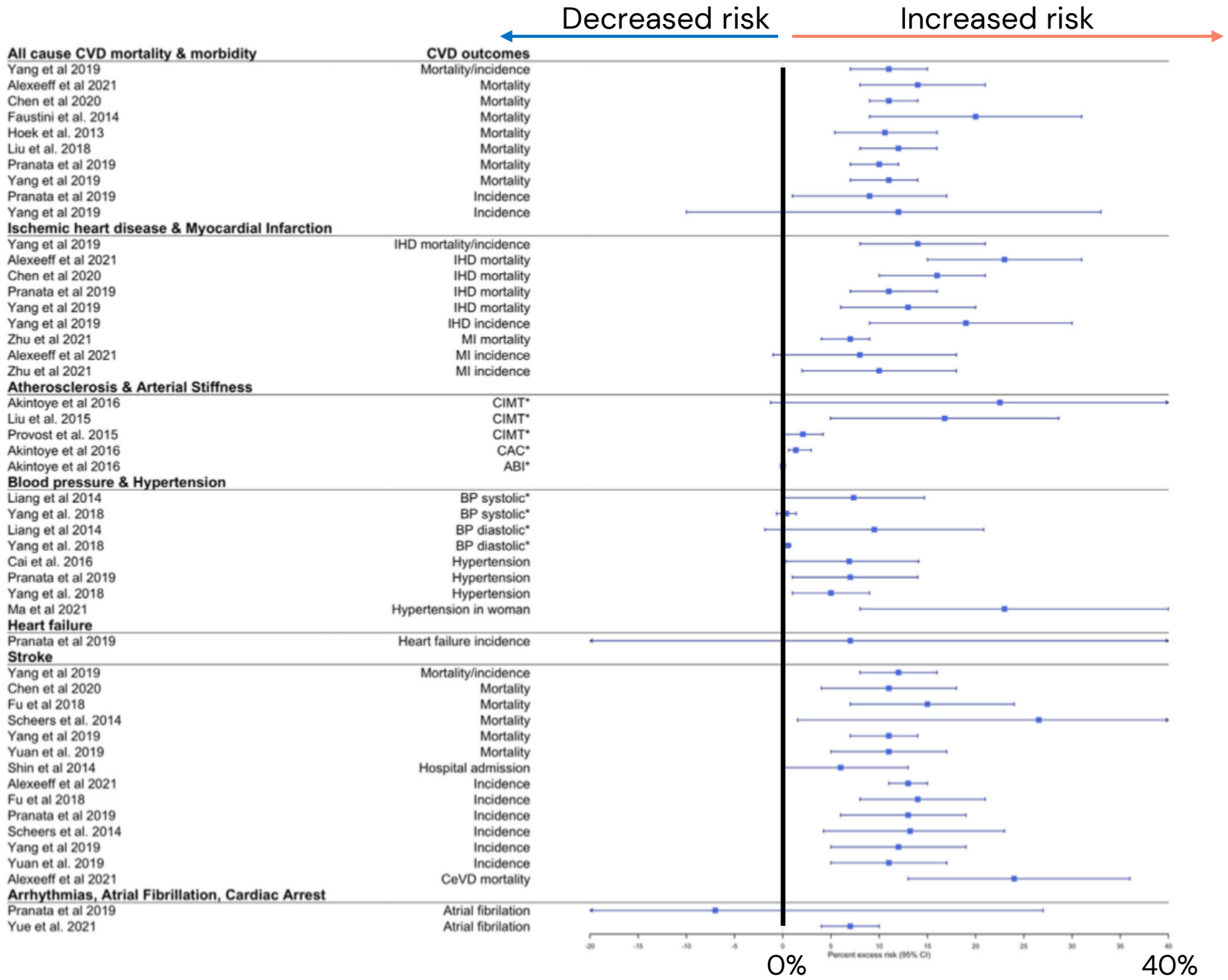


Fig. 5 *Effect estimates of the association between long-term exposure to $PM_{2.5}$ and CVDs. Note: we selected the main effect estimate from the meta-analyses if multiple effect estimates were available for each CVD outcome in the same meta-analysis. Effect estimates are estimated per 10 $\mu g/m^3$ range increase in $PM_{2.5}$. Abbreviations: ABI, ankle-brachial index, BP, blood pressure; CAC, coronary artery calcification; CeVD, cerebrovascular diseases; CIMT, carotid intima-media thickness test; CVD, cardiovascular diseases; IHD, ischemic heart diseases; MI, myocardial infarction; PM, particulate matter. *Beta coefficient (linear regression) for change in systolic, diastolic, CIMT, CAC, or ABI values per increase of $PM_{2.5}$.*

Air pollution affects a multitude of cardiovascular outcomes

de Bont 2022. Journal of Internal Medicine

Conclusions

1. Cardiovascular diseases are the most common causes of death and disease in the EU with considerable impacts on health and related costs

2. Air pollution contributes to a range of cardiovascular diseases as well as to a large proportion of all cardiovascular diseases

3. Stricter control of air pollution offers an effective strategy that will prevent new disease, reduce suffering and save many lives from the consequences of cardiovascular disease in the EU.

Karolinska Institutet

ISEE

Danderyds Sjukhus

ESC
European Society of Cardiology

Summarising important health effects of air pollution across the life-course: Cancer

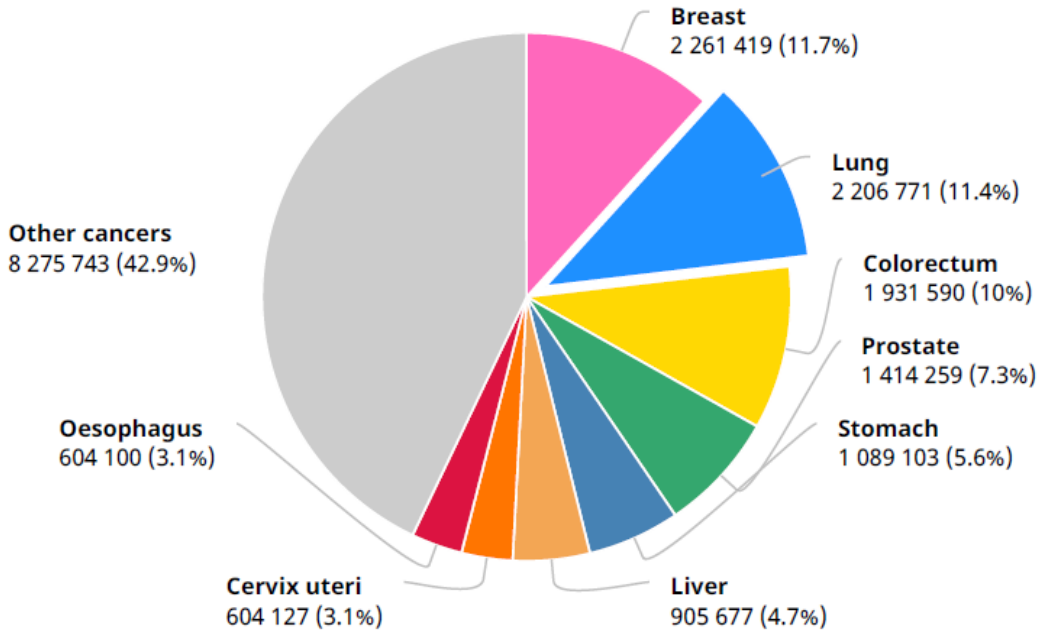
MICHELLE C TURNER, PHD
ASSOCIATE RESEARCH PROFESSOR
BARCELONA INSTITUTE FOR GLOBAL HEALTH (ISGLOBAL), SPAIN

International Agency for Research on Cancer
World Health Organization

Lung

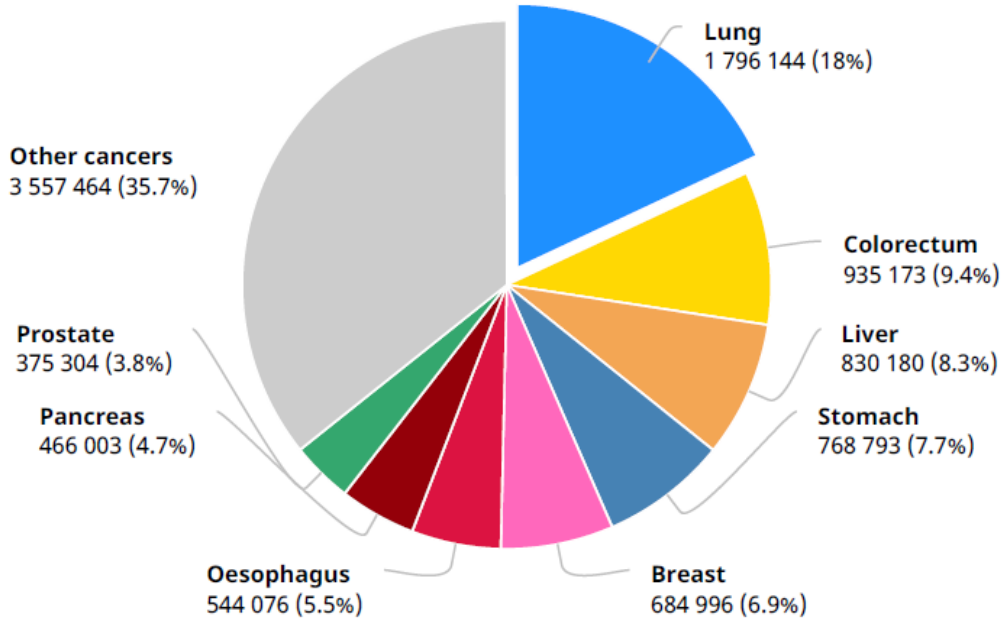
Source: Globocan 2020

Number of new cases in 2020, both sexes, all ages



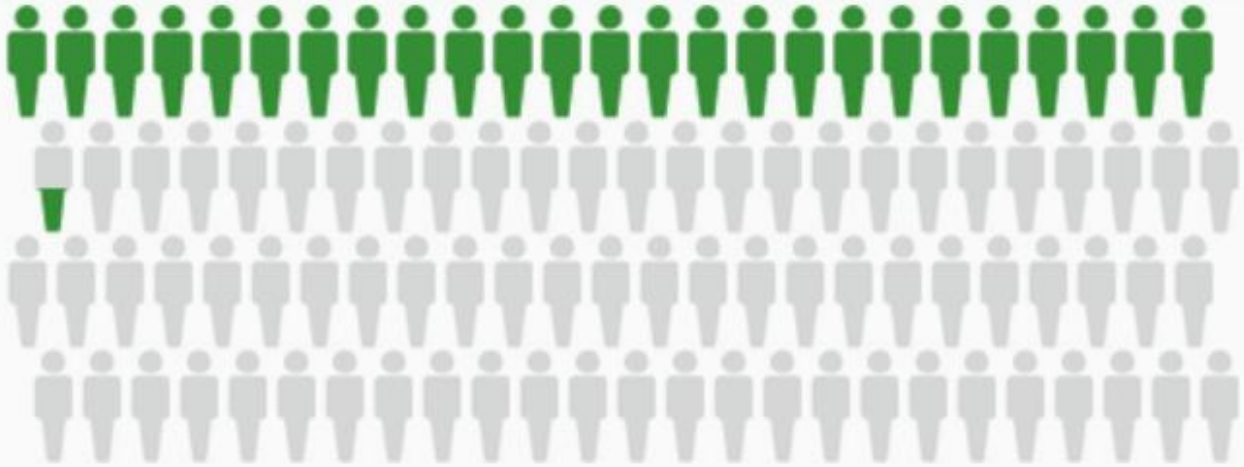
Total: 19 292 789 cases

Number of deaths in 2020, both sexes, all ages



Total: 9 958 133 deaths

https://gco.iarc.fr/today/data/factsheets/cancers/15-Lung-fact-sheet.pdf



5-Year Relative Survival

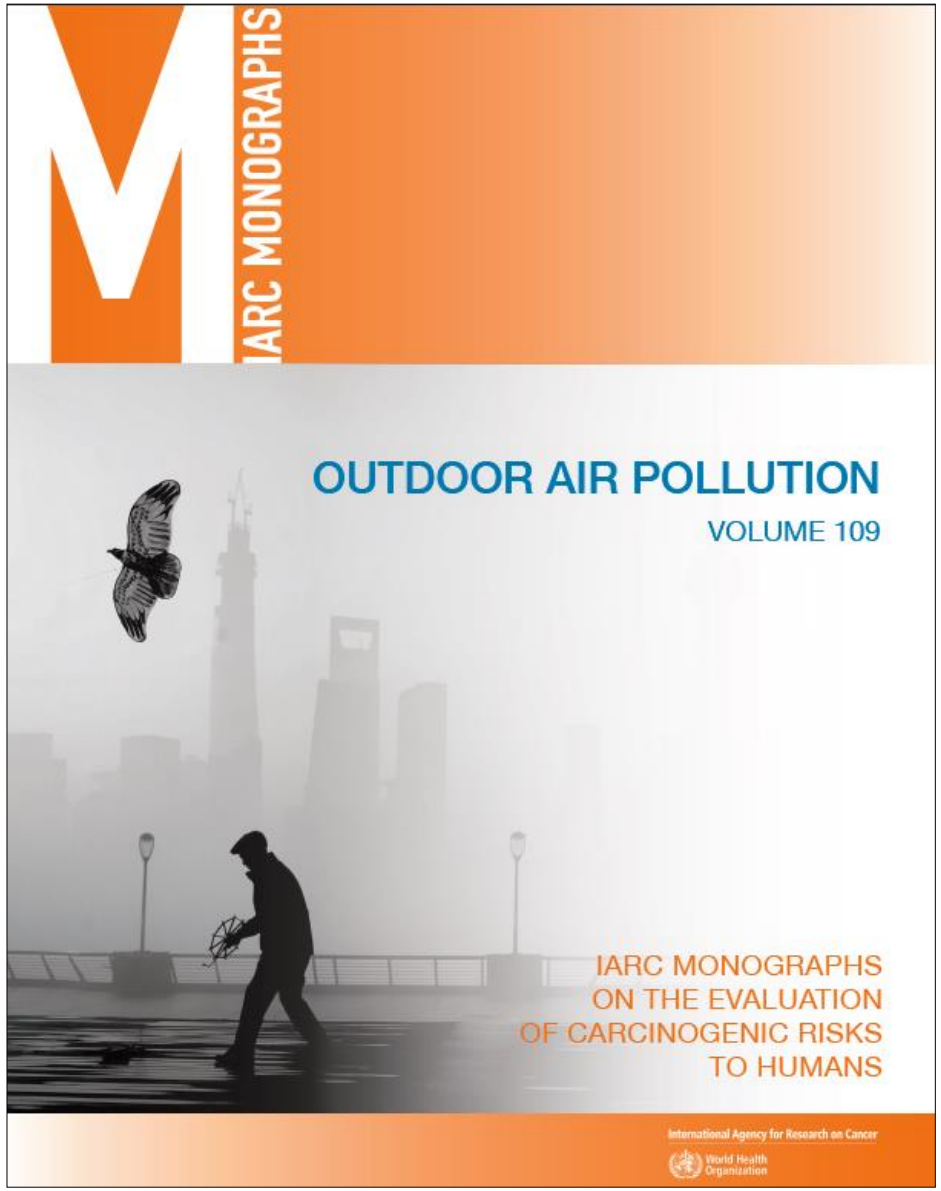
25.4%

Based on data from SEER 22 (Excluding IL/MA) 2013–2019. Gray figures represent those who have died from lung and bronchus cancer. Green figures represent those who have survived 5 years or more.

https://seer.cancer.gov/statfacts/html/lungb.html

Both sexes	Global	Low SDI	Low-middle SDI	Middle SDI	High-middle SDI	High SDI	Central Asia	Central Europe	Eastern Europe	Australasia	High-income Asia Pacific	High-income North America	Southern Latin America	Western Europe	Andean Latin America	Caribbean	Central Latin America	Tropical Latin America	North Africa and Middle East	South Asia	East Asia	Oceania	Southeast Asia	Central sub-Saharan Africa	Eastern sub-Saharan Africa	Southern sub-Saharan Africa	Western sub-Saharan Africa
Occupational exposure to beryllium	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
Occupational exposure to cadmium	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
Occupational exposure to chromium	14	14	14	14	14	14	14	14	14	13	13	13	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
Occupational exposure to polycyclic aromatic hydrocarbons	13	13	13	13	13	12	13	13	13	12	12	12	13	12	13	13	13	13	13	13	13	13	13	13	13	13	13
Occupational exposure to nickel	12	11	11	11	12	11	11	11	11	10	10	11	11	10	12	12	11	11	11	11	11	11	11	11	11	11	11
Occupational exposure to arsenic	11	12	12	12	11	9	12	10	9	9	9	9	12	9	11	11	12	12	12	12	12	12	12	12	12	12	12
Occupational exposure to diesel engine exhaust	10	10	10	10	10	10	10	12	12	11	11	10	9	11	9	10	10	10	9	10	10	10	10	10	10	10	10
Occupational exposure to silica	9	9	9	9	8	8	8	8	8	7	7	8	6	8	8	8	8	7	7	9	9	9	8	8	8	9	9
Diet low in fruits	8	5	7	7	7	6	7	7	6	4	5	6	8	7	7	7	7	8	8	5	7	6	6	5	6	5	5
Household air pollution from solid fuels	7	2	3	5	9	13	9	9	10	14	14	14	10	13	5	6	6	9	10	3	5	2	3	2	2	6	2
Residential radon	6	6	8	8	6	5	4	6	3	8	8	4	7	5	6	9	5	6	6	8	6	8	9	7	7	7	6
Secondhand smoke	5	8	5	4	5	7	5	5	7	5	6	7	5	6	10	4	9	5	5	7	3	5	5	9	9	8	7
High fasting plasma glucose	4	4	4	3	3	3	3	3	5	3	4	3	4	3	3	2	3	2	3	4	4	3	4	3	3	4	4
Occupational exposure to asbestos	3	7	6	6	4	2	6	4	4	2	2	2	3	2	4	5	4	3	4	6	8	4	7	6	5	2	8
Ambient particulate matter pollution	2	3	2	2	2	4	2	2	2	6	3	5	2	4	2	3	2	4	2	2	2	7	2	4	4	3	3
Smoking	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

GBD 2019 Respiratory Tract Cancers Collaborators, 2021



Outdoor air pollution is carcinogenic to humans (Group 1)

- Causes lung cancer
- Positive associations with bladder cancer

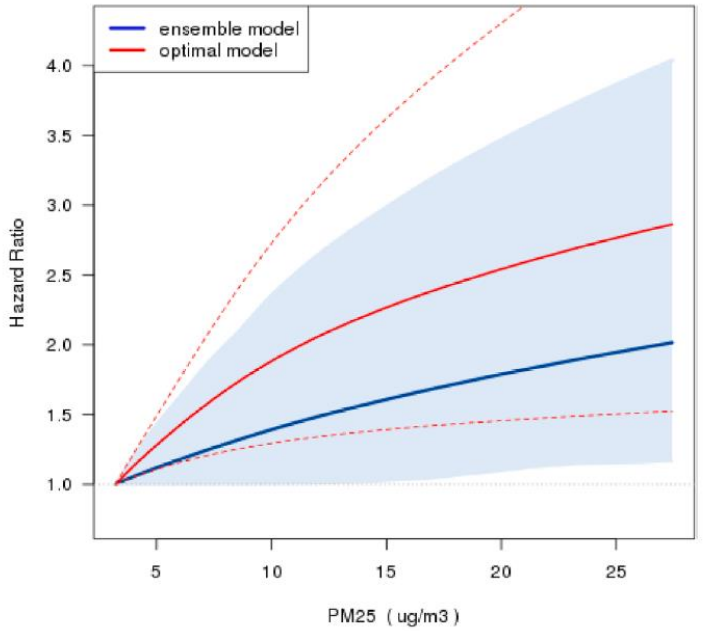
Particulate matter in outdoor air pollution is carcinogenic to humans (Group 1)

- Causes lung cancer

Strongly supported by documented genetic and related effects in humans and experimental animals (increases in genetic damage, promotes cancer progression)

Long-term low-level ambient air pollution exposure and risk of lung cancer – A pooled analysis of 7 European cohorts

Ulla Arthur Hvidtfeldt [a,*], Gianluca Severi [b,c], Zorana Jovanovic Andersen [d], Richard Atkinson [e], Mariska Bauwelinck [f], Tom Bellander [g,h], Marie-Christine Boutron-Ruault [b], Jørgen Brandt [i,j], Bert Brunekreef [k], Giulia Cesaroni [l], Jie Chen [k], Hans Concin [m], Francesco Forastiere [n,o], Carla H. van Gils [p], John Gulliver [q], Ole Hertel [i], Gerard Hoek [k], Barbara Hoffmann [r], Kees de Hoogh [s,t], Nicole Janssen [u], Karl-Heinz Jöckel [v], Jeanette Therming Jørgensen [d], Klea Katsouyanni [w,x], Matthias Ketzel [i,y], Jochem O. Klompmaker [k,u], Norun Hjertager Krog [z], Alois Lang [aa], Karin Leander [g], Shuo Liu [d], Petter L.S. Ljungman [g,ab], Patrik K.E. Magnusson [ac], Amar Jayant Mehta [ad,ae], Gabriele Nagel [af,m], Bente Oftedal [z], Göran Pershagen [g,h], Raphael Simon Peter [af], Annette Peters [ah,ai], Matteo Renzi [l], Debora Rizzuto [aj,ak], Sophia Rodopoulou [w], Evangelia Samoli [w], Per Everhard Schwarze [al], Torben Sigsgaard [am], Mette Kildevæld Simonsen [an], Massimo Stafoggia [l,g], Maciek Strak [k,u], Danielle Vienneau [s,t], Gudrun Weinmayr [af], Kathrin Wolf [ah], Ole Raaschou-Nielsen [a,i,1], Daniela Fecht [ao,1]



Conclusions: Long-term ambient $PM_{2.5}$ exposure is associated with lung cancer incidence even at concentrations below current EU limit values and possibly WHO Air Quality Guidelines.

Review article

Long-term exposure to PM and all-cause and cause-specific mortality: A systematic review and meta-analysis

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Table 2
Pooled effect estimates for all pollutant-outcome combinations.

	$PM_{2.5}$			
	N	pooled RR per 10 μg/m^3	I^2 (%)	Prediction interval
Natural-cause	25	1.08 (1.06, 1.09)	88.9	(1.05, 1.11)
Circulatory	21	1.11 (1.09, 1.14)	72.1	(1.06, 1.17)
IHD	22	1.16 (1.10, 1.21)	77.5	(1.04, 1.29)
Stroke	16	1.11 (1.04, 1.18)	84.7	(0.98, 1.25)
Respiratory	17	1.10 (1.03, 1.18)	83.6	(0.95, 1.29)
COPD	11	1.11 (1.05, 1.17)	49.6	(1.02, 1.21)
ALRI	4	1.16 (1.01, 1.34)	83.0	(0.88, 1.54)
Lung cancer	15	1.12 (1.07, 1.16)	39.4	(1.05, 1.18)

N = number of studies

Lung adenocarcinoma promotion by air pollutants

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William Hill[1,126], Emilia L. Lim[1,2,126,127], Clare E. Weeden[1,126], Claudia Lee[1,2,3], Marcellus Augustine[1,2,3,4], Kezhong Chen[2,5], Feng-Che Kuan[6,7], Fabio Marongiu[8,9], Edward J. Evans Jr[8], David A. Moore[1,2,10], Felipe S. Rodrigues[11], Oriol Pich[1], Bjorn Bakker[1], Hongui Cha[2,12], Renelle Myers[13], Febe van Maldegem[14,15], Jesse Boumelha[14], Selvaraju Veeriah[2], Andrew Rowan[1], Cristina Naceur-Lombardelli[2], Takahiro Karasaki[1,2,16], Monica Sivakumar[2], Swapnanil De[2], Deborah R. Caswell[1], Ai Nagano[1,2], James R. M. Black[2,17], Carlos Martínez-Ruiz[2,17], Min Hyung Ryu[18], Ryan D. Huff[18], Shijia Li[18], Marie-Julie Favé[19], Alastair Magness[1,2], Alejandro Suárez-Bonnet[20,21], Simon L. Priestnall[20,21], Margreet Lüchtenborg[22,23], Katrina Lavelle[22], Joanna Pethick[22], Steven Hardy[22], Fiona E. McRonald[22], Meng-Hung Lin[24], Clara I. Troccoli[8,25], Moumita Ghosh[26], York E. Miller[26,27], Daniel T. Merrick[28], Robert L. Keith[26,27], Maise Al Bakir[1,2], Chris Bailey[1], Mark S. Hill[1], Lao H. Saal[29,30], Yilun Chen[29,30], Anthony M. George[29,30], Christopher Abbosh[2], Nnennaya Kanu[2], Se-Hoon Lee[12], Nicholas McGranahan[2,17], Christine D. Berg[31], Peter Sasieni[32], Richard Houlston[33], Clare Turnbull[33], Stephen Lam[13], Philip Awadalla[19], Eva Grönroos[1], Julian Downward[14], Tyler Jacks[34,35], Christopher Carlsten[18], Ilaria Malanchi[11], Allan Hackshaw[36], Kevin Litchfield[2,4], TRACERx Consortium*, James DeGregori[8,127], Mariam Jamal-Hanjani[2,16,37,127] & Charles Swanton[1,2,37]

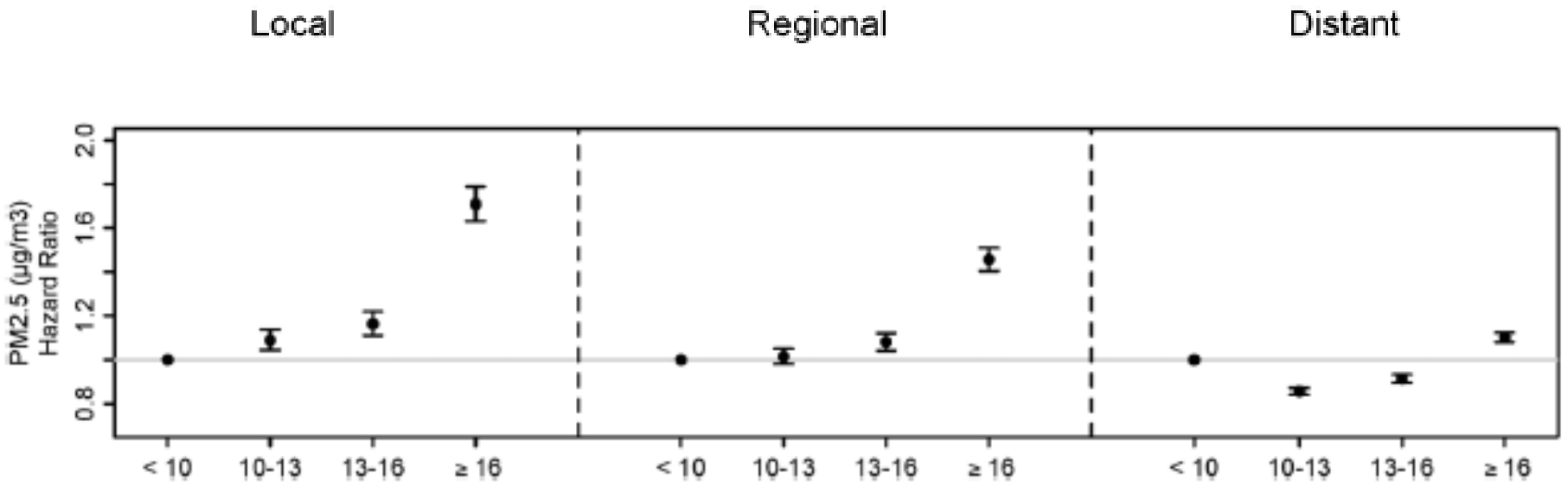
Collectively, these data, combined with published evidence[6], indicate that there is an association between the estimated incidence of *EGFR*-driven lung cancer and of $PM_{2.5}$ exposure levels and that 3 years of air pollution exposure may be sufficient for this association to manifest.

In conclusion, our data suggest a mechanistic and causative link between air pollutants and lung cancer, as previously proposed[45], and substantiate earlier findings on tumour promotion[1], providing a public health mandate to restrict particulate emissions in urban areas.

ORIGINAL ARTICLE

Air pollution affects lung cancer survival

Sandrah P Eckel,[1] Myles Cockburn,[1] Yu-Hsiang Shu,[1,2] Huiyu Deng,[1]
Frederick W Lurmann,[3] Lihua Liu,[1] Frank D Gilliland[1]



Outdoor Air Pollution and Cancer: An Overview of the Current Evidence and Public Health Recommendations

Michelle C. Turner, PhD [1,2,3,4]; Zorana J. Andersen, PhD [5]; Andrea Baccarelli, MD, MPH, PhD [6]; W. Ryan Diver, MSPH [7]; Susan M. Gapstur, PhD [7]; C. Arden Pope, III, PhD [8]; Diddier Prada, MD, PhD [6,9]; Jonathan Samet, MD, MS [10]; George Thurston, ScD [11]; Aaron Cohen, DSc [12,13]

- There is clear and substantial evidence of a link between outdoor ambient air pollution, and particularly PM in outdoor air, with lung cancer
- This is an urgent worldwide public health challenge requiring multiple multilevel public health and policy interventions for cancer prevention
- Expanding literature on air pollution and other cancers

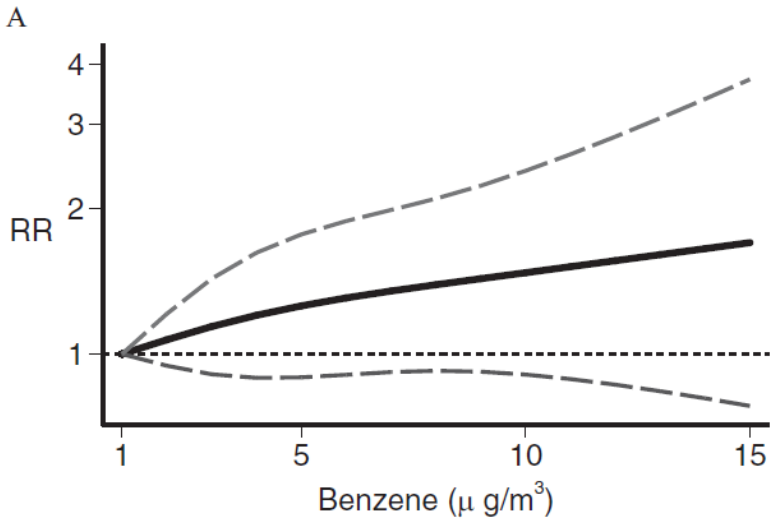
Ambient Air Pollution and Cancer Mortality in the Cancer Prevention Study II

Breast Cancer Incidence in Relation to Long-Term Low-Level Exposure to Air Pollution in the ELAPSE Pooled Cohort

Long-term exposure to ambient air pollution and bladder cancer incidence in a pooled European cohort: the ELAPSE project

Long-term exposure to air pollution and liver cancer incidence in six European cohorts

Association between Outdoor Air Pollution and Childhood Leukemia: A Systematic Review and Dose-Response Meta-Analysis



Thank you

Thank you and keep in touch!

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