Quantifying the Air Pollution Burden of Disease

Bert Brunekreef, PhD

THE TIMES

March 13 2019

Air pollution kills more people than smoking, German scientists say

World Health Organization

4.2 million

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

THE DAILY NEWSLETTER
Sign up to our daily email newsletter

NewScientist

News Technology Space Physics Health Mind Environment More Shop Tours

Does air pollution really kill nearly 9 million people each year?

HEALTH | ANALYSIS 12 March 2019

A look under the hood….

Quantifying the Burden is a Burden

- **Numbers of deaths attributed to air pollution**
- Years of Life Lost due to air pollution
- Loss of Life Expectancy due to air pollution
- Disability before death, due to air pollution

A few definitions

- Disability Adjusted Life Years (DALY) = Years of Life Lost (YLL) + Years of Life with Disability (YLD)
- YLL = N x LE (**N of deaths** x ***Life Expectancy at age of death***)
- YLD = I x DW x L (Incidence x ***Disability Weight*** x Length of period until death or remission)
- Effects on life expectancy are **NOT** the same as effects on YLL…..

Quantifying the number of attributable deaths

- **Attributable Risk, AR = (RR – 1) / RR**

(RR = Relative Risk)

- **Exposure Fraction (EF) = Fraction Exposed (=1, everybody in case of air pollution)**
- **Air Pollution *Population Attributable Fraction:***
  PAF = (EF (RR – 1)) / (1 + EF (RR – 1))
- **So, when, RR = 1.1 and EF = 1, then:**

PAF = 0.1 / 1.1 = .09

Key Questions….

- **Which Relative Risk (RR) to use?**
- **Which Exposure Distribution to use?**
- **What's the shape of the Exposure-Response function?**
- **RR for specific causes of death only or for all natural-cause mortality?**
- **Threshold?**
- **Age dependency?**
- **Recoding of causes of death?**
- **How to interpret the attributed numbers of deaths?**

Differences between GBD, EEA and WHO for PM2.5

	GBD	EEA	WHO
Exposure	Sat., CTM, Meas., geog. 10x10 km	Airbase 1x1 km	As in GBD
Threshold	2.4-5.9 µg/m³	0 or 2.5 µg/m³	As in GBD
Basis	AAP, HAP, SHS, AS	AAP	As in GBD
Causes	IHD, Stroke, LRI, COPD, Lung CA, diabetes	Natural-cause	As in GBD
Shape	Curvilinear	Linear	As in GBD
Age dep. RR	YES (IHD only)	NO	As in GBD?
COD recoding	YES	NO	??

ESTIMATED NUMBER OF ANNUAL PREMATURE DEATHS ATTRIBUTED TO PM ~ 2017

	GBD	EEA	WHO
NETHERLANDS	6,800	11,200	5,320
FINLAND	1,600	2,150	1,028
FRANCE	20,000	34,880	16,294
EU 28	258,000	399,000	

Air quality in Europe — 2017 report

European Environment Agency

Refers to:
ETC/ACM, 2016c, Quantifying the health impacts of ambient air pollution — Methodology and input data, de Leeuw, F. and Horálek, J., Technical Paper 2016/5, European Topic Centre on Air Pollution and Climate Change Mitigation.

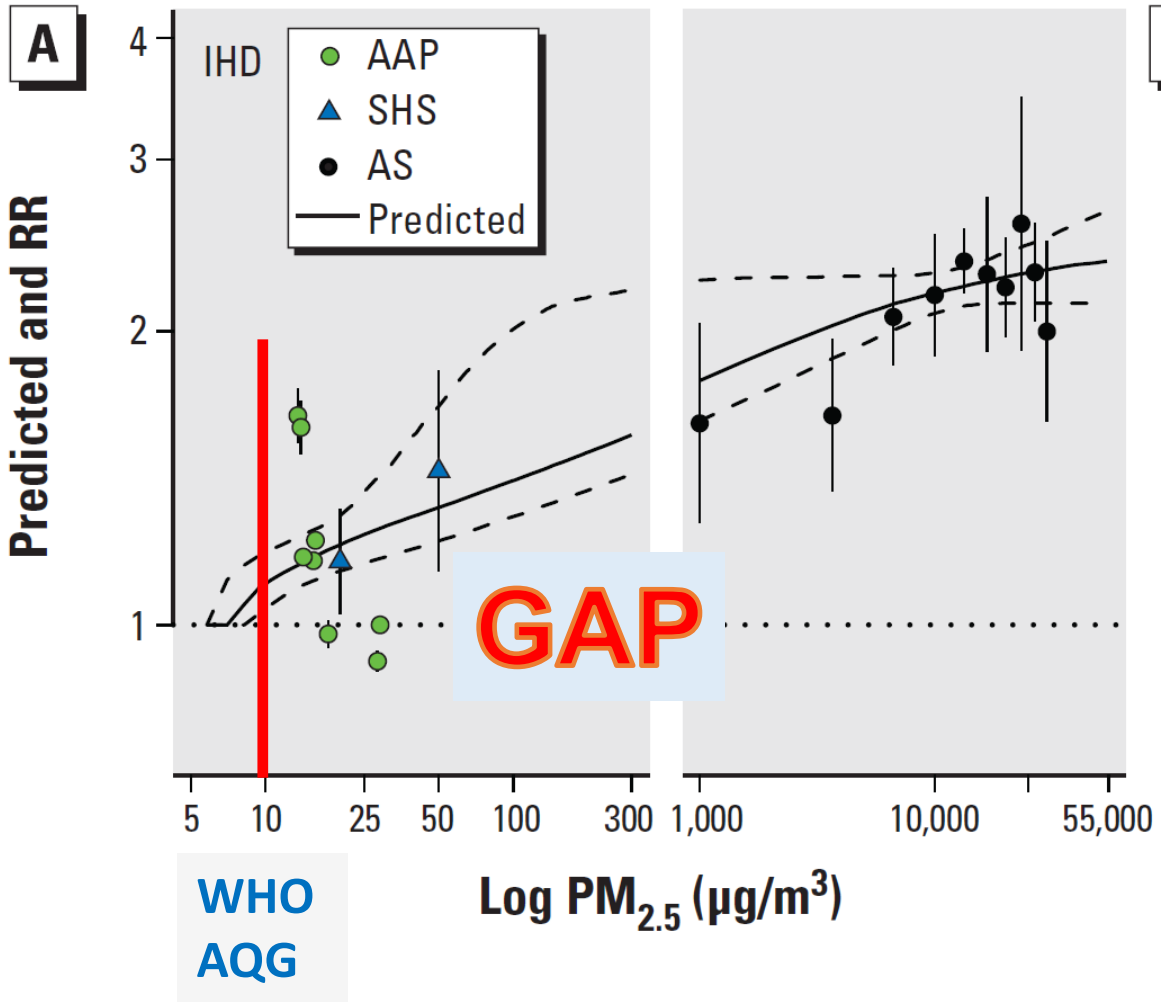
Refers to:
WHO (2013a) Health risks of air pollution in Europe – HRAPIE project Recommendations for concentration–response functions for cost–benefit analysis of particulate matter, ozone and nitrogen dioxide Recommendations for concentration–response functions for cost–benefit analysis of particulate matter, ozone and nitrogen dioxide.

Refers to:
Hoek G et al. (2013). Long-term air pollution exposure and cardio-respiratory mortality: a review. Environmental Health, 12:43.

An Integrated Risk Function for Estimating the Global Burden of Disease Attributable to Ambient Fine Particulate Matter Exposure

*Richard T. Burnett,[1] C. Arden Pope III,[2] Majid Ezzati,[3] Casey Olives,[4] Stephen S. Lim,[5] Sumi Mehta,[6] Hwashin H. Shin,[1] Gitanjali Singh,[7] Bryan Hubbell,[8] Michael Brauer,[9] H. Ross Anderson,[10] Kirk R. Smith,[11] John R. Balmes,[12,13] Nigel G. Bruce,[14] Haidong Kan,[15] Francine Laden,[16] Annette Prüss-Ustün,[17] Michelle C. Turner,[18] Susan M. Gapstur,[19] W. Ryan Diver,[19] and Aaron Cohen[20]**

EHP
2014



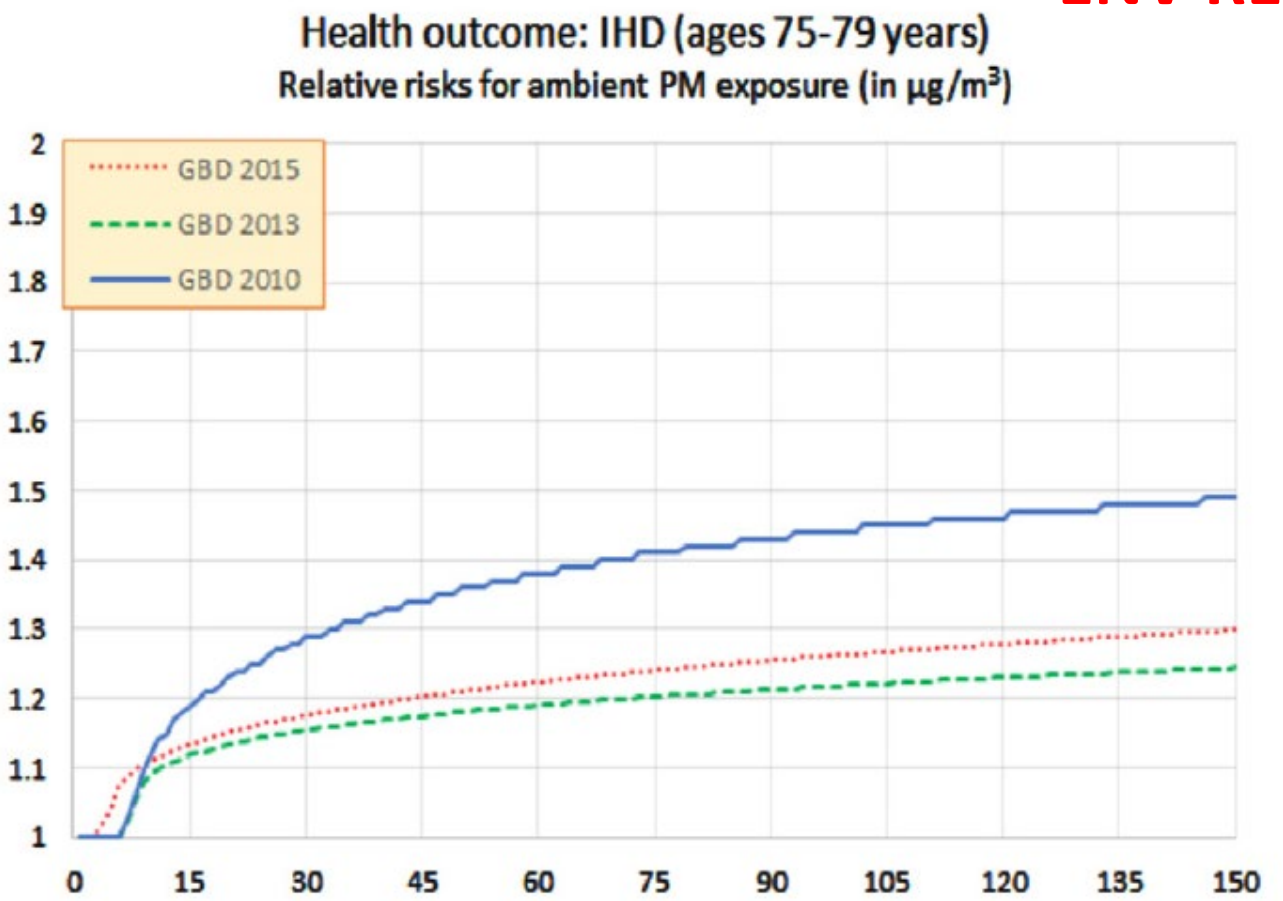
GBD thousands of deaths attributed to ambient pm, household air pollution and ozone, 2012-2018

pollutant	2012		2015		2016		2017		2018	
	1990	*2010*	*1990*	*2013*	*2005*	*2015*	*2006*	*2016*	*2007*	*2017*
PM	2910	3224	2238	2926	3934	4241	3687	4093	4380	4580
HAP	4580	3546	2857	2893	3280	2854	3267	2576	1960	1640
OZONE	143	152	133	257	207	254	188	254	392	472
TOTAL			4808	5527	6466	6485	6219	6116	4630	4900

Assessing the recent estimates of the global burden of disease for ambient air pollution: Methodological changes and implications for low- and middle-income countries

Bart Ostro[a,*], Joseph V. Spadaro[b], Sophie Gumy[c], Pierpaolo Mudu[c], Yewande Awe[d], Francesco Forastiere[e], Annette Peters[f]

ENV RES 2018



Global estimates of mortality associated with long-term exposure to outdoor fine particulate matter

Richard Burnett[a], Hong Chen[a,b], Mieczysław Szyszkowicz[a,1], Neal Fann[c], Bryan Hubbell[d], C. Arden Pope III[e], Joshua S. Apte[f], Michael Brauer[g], Aaron Cohen[h], Scott Weichenthal[i,j], Jay Coggins[k], Qian Di[l], Bert Brunekreef[m], Joseph Frostad[n], Stephen S. Lim[n], Haidong Kan[o], Katherine D. Walker[h], George D. Thurston[p], Richard B. Hayes[q], Chris C. Lim[r], Michelle C. Turner[s], Michael Jerrett[t], Daniel Krewski[u], Susan M. Gapstur[v], W. Ryan Diver[v], Bart Ostro[w], Debbie Goldberg[x], Daniel L. Crouse[y], Randall V. Martin[z], Paul Peters[aa,bb,cc], Lauren Pinault[dd], Michael Tjepkema[dd], Aaron van Donkelaar[z], Paul J. Villeneuve[aa], Anthony B. Miller[ee], Peng Yin[ff], Maigeng Zhou[ff], Lijun Wang[ff], Nicole A. H. Janssen[gg], Marten Marra[gg], Richard W. Atkinson[hh,ii], Hilda Tsang[jj], Thuan Quoc Thach[jj], John B. Cannon[e], Ryan T. Allen[e], Jaime E. Hart[kk], Francine Laden[kk], Giulia Cesaroni[ll], Francesco Forastiere[ll], Gudrun Weinmayr[mm], Andrea Jaensch[mm], Gabriele Nagel[mm], Hans Concin[nn], and Joseph V. Spadaro[oo]

- ***ANALYSIS OF OUTDOOR PM COHORT STUDIES ONLY***
- ***41 COHORTS FROM 16 COUNTRIES WITH 20,000,000 SUBJECTS AND 2,500,000 DEATHS***
  - ***INCLUDING STUDIES FROM CHINA AT HIGH LEVELS OF EXPOSURE***
  - ***INCLUDING STUDIES FROM CANADA AND USA AT LOW LEVELS OF EXPOSURE***
- ***FOCUS ON NCD (non communicable diseases) + LRI (lower respiratory illness) (= 99% OF ALL-CAUSE), NON-ACCIDENTAL MORTALITY***

PNAS2018

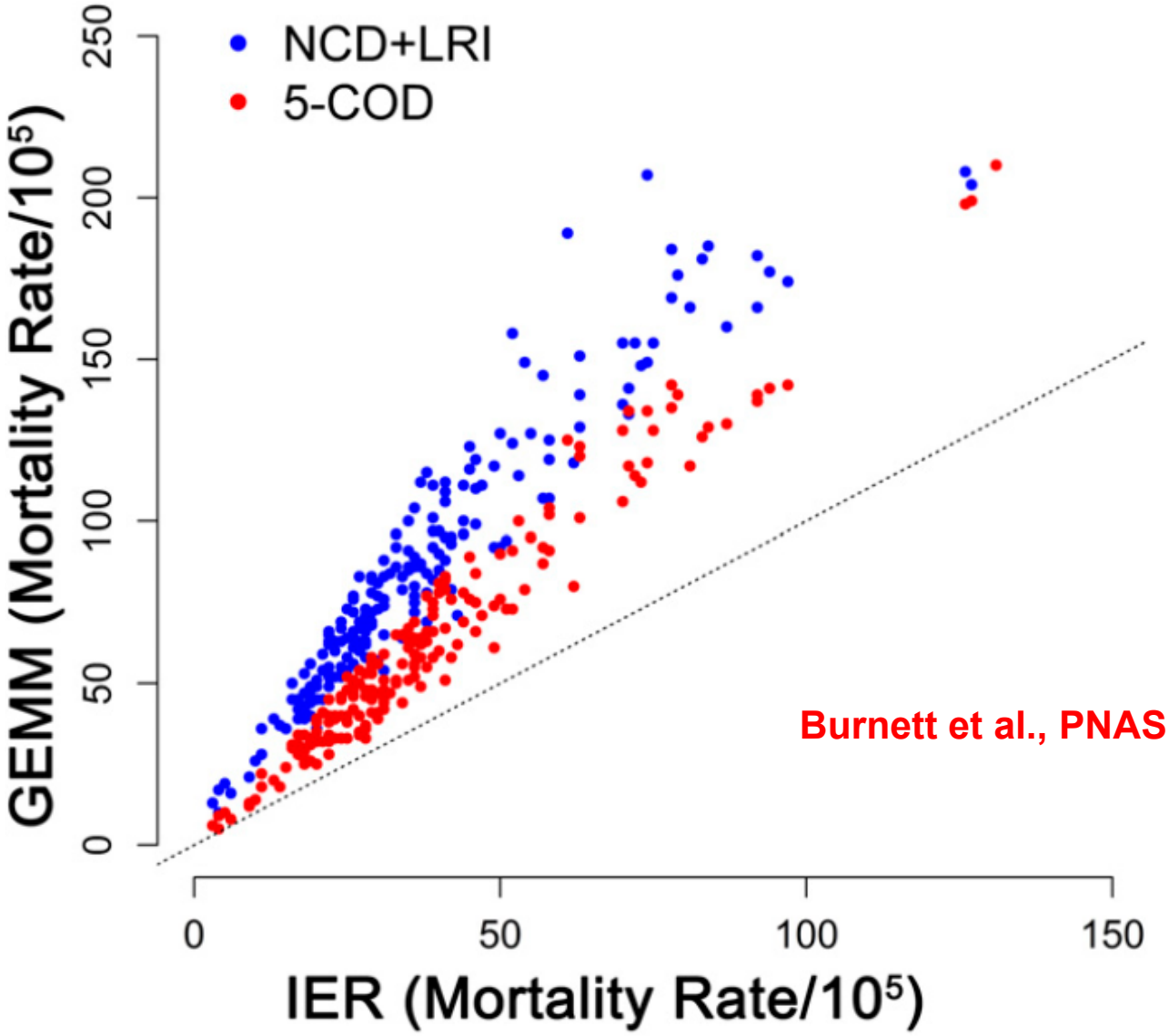
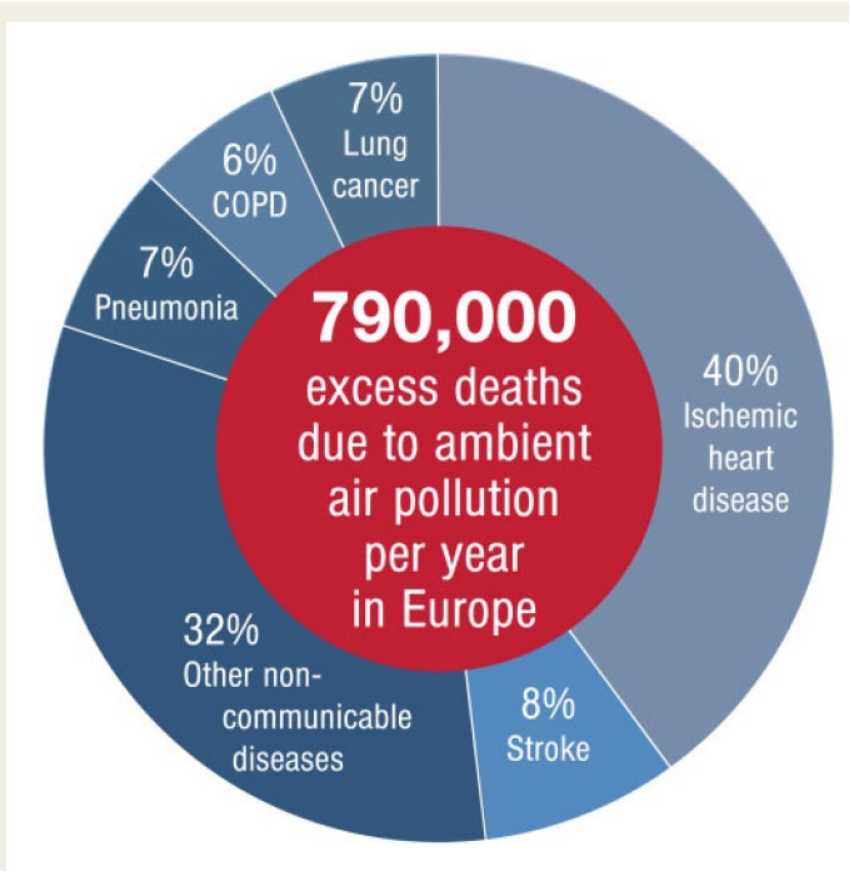


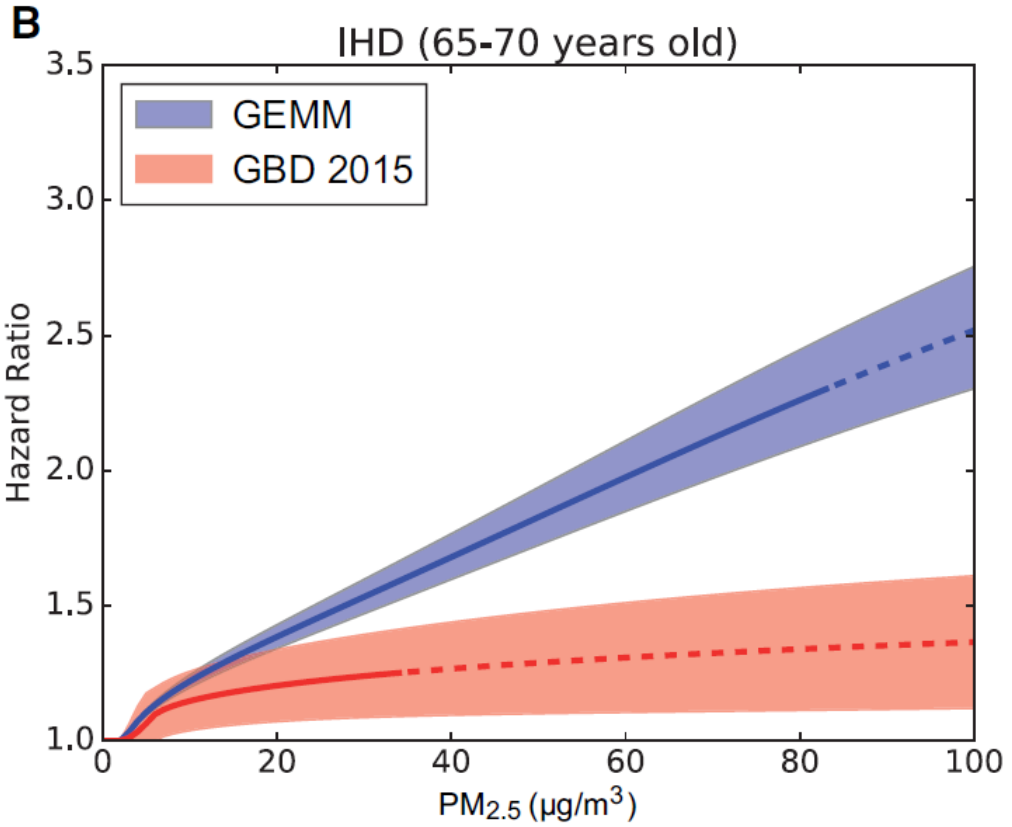
Fig. 2. Country-specific estimates of excess mortality rates associated with 100% reduction to the counterfactual concentration in population-weighted country average fine particulate matter concentrations by age-adjusted GEMM NCD+LRI vs. IER (blue dots) and GEMM 5 Causes of Death (COD) vs. IER (red dots). Dotted line represents 1:1 association.

Cardiovascular disease burden from ambient air pollution in Europe reassessed using novel hazard ratio functions

EHJ 2019

Jos Lelieveld[1,2]*, Klaus Klingmüller[1], Andrea Pozzer[1], Ulrich Pöschl[1], Mohammed Fnais[3], Andreas Daiber[4,5], and Thomas Münzel[4,5]*





How to interpret the number of attributable deaths?

Imagine…

European Community (1957)

Imagine…

A study

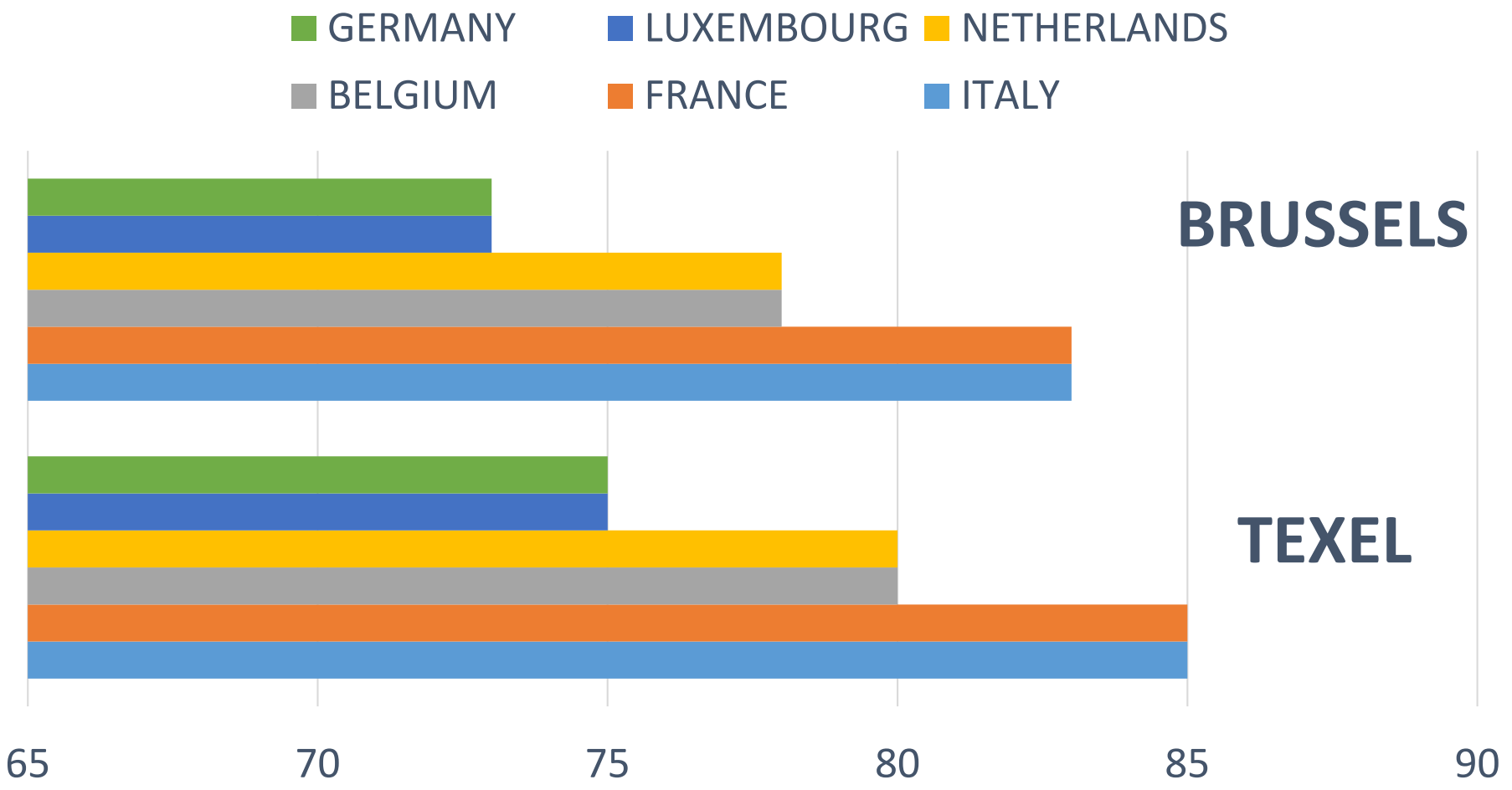
- 6 identical twins, born 1930, in IT, FR, GE, NL, BE, LU
- In 1960, one of each moves to polluted Brussels, the other to clean Texel Island (Marine Research Lab ;-))
- Exact same habits within twins, EXCEPT air pollution
- Studied from 2000 (all alive) - 2015 (all dead)

Findings

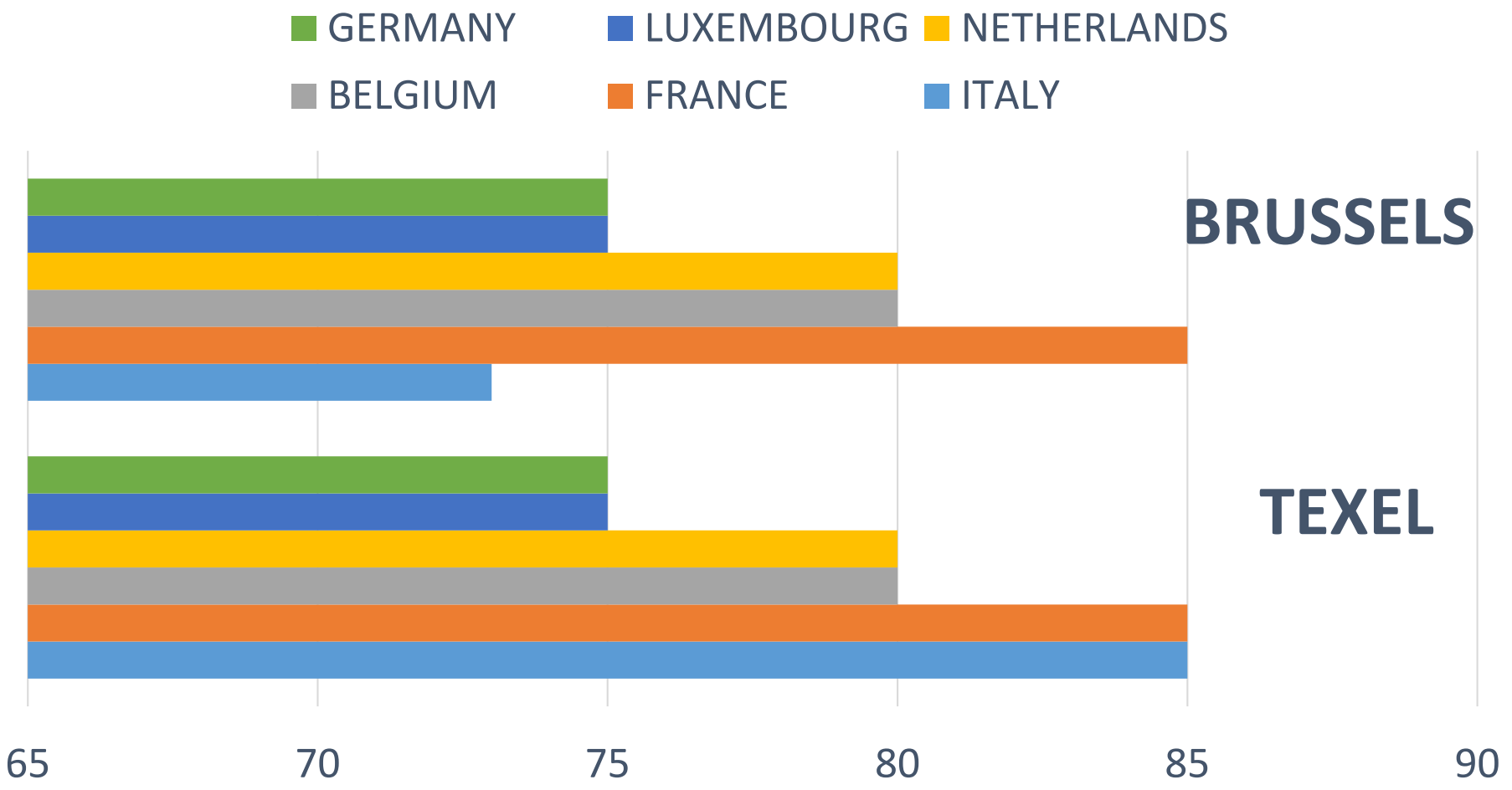
- **Brussels:** average age at death, 78
- **Texel:** average age at death 80
- RR=1.25; AF=20%


TEXEL
BRUSSELS
Leeuwarden
Groningen
Alkmaar
Amsterdam
The Hague
Netherlands
Arnhem
Rotterdam
Eindhoven
Essen
Düsseldorf
Antwerp
Bruges
Ghent
Dunkirk
Cologne
Bonn
Aachen
Liège
Lille
Belgium
A7
A28
A32
A6
A1
A15
A27
A2
A25
A76
E19
E34
E40
E403
E313
E42
31
43
3
57
46
44
61
26

SURVIVAL IN BRUSSELS AND TEXEL, IDENTICAL TWINS FROM 6 EEC COUNTRIES



SURVIVAL IN BRUSSELS AND TEXEL, IDENTICAL TWINS FROM 6 EEC COUNTRIES



ABSOLUTE N OF DEATHS DUE TO AIR POLLUTION CANNOT BE EXACTLY ESTIMATED

- Attributable premature deaths vary from 1/6 (17%) to 6/6 (100%).
- Attributable Fraction calculation says 20%

Concepts and pitfalls in measuring and interpreting attributable fractions, prevented fractions, and causation probabilities

Sander Greenland MA, MS, DrPH [a, b, *]

Annals of Epidemiology

2015

Still, the numbers of premature deaths attributed to air pollution are *comparatively* useful

- **Attributable premature deaths are simply a function of the Relative Risk, the Exposure Fraction and the total N of deaths in a population**

- **Hence, N of attributable premature deaths are comparable across different risk factors – as long as they are being calculated the same way**

Take home messages

- Burden of Disease due to air pollution most often expressed in “attributable numbers of premature deaths”
- These numbers cannot be exactly estimated but are useful to compare burdens of different risk factors to each other
- Some assumptions for BoD calculations are different between GBD, WHO, EEA and GEMM. All estimates have in common that the burden is large, within a factor of ~2
- Methods are still evolving, so prepare for changes in BoD estimates because of this
- New studies keep being published that add to our knowledge of concentration-response functions, so prepare for changes in BoD estimates because of this too