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# Air Today, Gone Tomorrow – The changing face of air pollution

John A. O'Brien




04 May 2017

# Air Pollution

- We breathe about 250 million litres of air during our lives

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# Air Pollution







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ISLE OF MAN
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# For first time in 135 years, Britain set to go without coal power for whole day

By **Rachel Millard**
City Correspondent

**BRITAIN yesterday looked set to go a whole day without using electricity made with coal – for the first time since the Victorian era.**

Barring an energy emergency late last night, it marked the first full day without coal-fired energy since the first coal power station opened in 1882.

The nation was instead powered by electricity from gas, nuclear energy, wind, water and biomass.

Campaigners hailed it as a milestone in the UK's efforts to stop using coal-fired power plants altogether by 2025, in a bid to reduce carbon emissions.

Hannah Martin, from Greenpeace UK, said: 'The first day without coal in Britain since the Industrial Revolution marks a watershed in the energy transition. A decade ago, a day without coal would have been unimaginable and in ten years' time our energy system will have radically transformed again.

'It is a clear message to any new government that they should prioritise making the UK a world leader in clean, green technology.'



Bygone era: Miners with lamps on their helmets dig for coal

The West Burton A coal power station was the last to be switched off the National Grid at 10.50pm on Thursday.

As the Mail went to press yesterday, the National Grid said it had no plans to switch any back on – barring a major failure with other plants. Cordi O'Hara, of the National Grid, said: 'The UK benefits from highly diverse and flexible sources of electricity. Our energy mix continues to change.' But she added: 'It's important to remember coal is still an important source of energy as we transition to a low carbon system.'

The world's first coal-fired power station kick-started an economic revolution when it opened in Holborn, London, in 1882.

Coal was used to generate around 95 per cent of the UK's electricity until the early 1950s but has since been partly replaced by gas and renewables. In 2016 it made up about 9 per cent of UK electricity generation and over the last four weeks it has supplied only around 2 per cent.

In the last month around 50 per cent of UK electricity has come from low-carbon sources such as nuclear, solar and wind, while 45 per cent came from gas, and the rest from imports and coal.

Coal use started to be cut completely from April last year.

Dr Simon Evans, of the website Carbon Brief, said: 'Symbolically it is hugely important. The UK was the first country in the world to have a coal-fired public electricity generation system.

'Now we are getting to the stage where the UK is one of the first major industrialised economies to be getting towards stopping using coal.'

Engineer and energy expert Dr Andrew Crossland said: 'I think it's a real demonstration that we can keep the lights on without coal, which is really important. It shows that renewables can make such a big contribution.'

But Dr Crossland said attention must also shift to using less gas.

'If we continue to run the system with this much gas we will miss the carbon targets,' he said.

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# Great Smog of December 1952

- Estimated 12000 deaths
- Prompted the clean air acts of 1956 and 1968

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# Kids Get 'Smog Day' As Pollution Shuts Down Chinese City

Choking pollution measured at 40 times what the WHO says is safe

By Emily Rauhala / Beijing | Oct. 21, 2013

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Winter is coming, that's for sure. The northeastern city of Harbin today ushered in the season with smog so thick that visibility was reportedly limited to 10 meters in places. Classes were canceled, roads closed, and planes grounded.

State media said the PM 2.5 reading (which measures the level of harmful particulate matter in the air) "exceeded" 500. A Reuters report put the figure at 1000, or 40 times higher than what the World Health Organization deems safe. Photographs from the city show air so murky it would be easy to mistake Monday morning for deep, dark night.



Kyodo News / AP

A woman wearing a mask walk through a street covered by dense smog in Harbin, northern China, Oct. 21, 2013.

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CHINA

# China's Youngest Lung-Cancer Patient Is Just 8 Years Old, and Pollution Is to Blame

Smog-related cancer deaths in China are soaring. Now children are being affected

By Emily Rauhala / Beijing | Nov. 05, 2013

Share Tweet G+1 28 Share 24 Read Later

To the list of China's environmental horrors, add one: an 8-year-old with lung cancer. Doctors at a hospital in coastal Jiangsu province blamed the girl's condition on pollution, according to a state media. The child, who has not been identified, reportedly lived near a busy road and was exposed to harmful particles and dust. She is being called China's youngest-ever lung-cancer patient.

The news comes amid growing concern about the health effects of air pollution. Last month the World Health Organization for the first time classified air pollution as a cause of cancer. The agency said air pollution caused 220,000 cancer deaths in 2010 and that more than half of lung-cancer deaths from



ChinaFotoPress / Getty Images

A woman and her son wearing masks walk along a road as heavy smog engulfs the city on Oct. 21, 2013 in Changchun, China

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# Estimates and 25-year trends of the global burden of disease attributable to ambient air pollution: an analysis of data from the Global Burden of Diseases Study 2015

*Aaron J Cohen*, Michael Brauer*, Richard Burnett, H Ross Anderson, Joseph Frostad, Kara Estep, Kalpana Balakrishnan, Bert Brunekreef, Lalit Dandona, Rakhi Dandona, Valery Feigin, Greg Freedman, Bryan Hubbell, Amelia Jobling, Haidong Kan, Luke Knibbs, Yang Liu, Randall Martin, Lidia Morawska, C Arden Pope III, Hwashin Shin, Kurt Straif, Gavin Shaddick, Matthew Thomas, Rita van Dingenen, Aaron van Donkelaar, Theo Vos, Christopher J L Murray, Mohammad H Forouzanfar†*

## Summary

**Background** Exposure to ambient air pollution increases morbidity and mortality, and is a leading contributor to global disease burden. We explored spatial and temporal trends in mortality and burden of disease attributable to ambient air pollution from 1990 to 2015 at global, regional, and country levels.

**Methods** We estimated global population-weighted mean concentrations of particle mass with aerodynamic diameter less than 2·5 μm ($PM_{2\cdot5}$) and ozone at an approximate 11 km×11 km resolution with satellite-based estimates, chemical transport models, and ground-level measurements. Using integrated exposure–response functions for each cause of death, we estimated the relative risk of mortality from ischaemic heart disease, cerebrovascular disease, chronic obstructive pulmonary disease, lung cancer, and lower respiratory infections from epidemiological studies using non-linear exposure–response functions spanning the global range of exposure.

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See Online/Comment
http://dx.doi.org/10.1016/S0140-6736(17)30884-X

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†Senior author

**Health Effects Institute, Boston, MA, USA** (A J Cohen DSc); **University of British Columbia, Vancouver,**

## Estimates and 25-year trends of the global burden of disease attributable to ambient air pollution: an analysis of data from the Global Burden of Diseases Study 2015

- Ambient $PM_{2.5}$ was the fifth-ranking mortality risk factor in 2015
- Caused 4·2 million and 103·1 million disability-adjusted life-years (DALYs) in 2015
- Deaths attributable to ambient $PM_{2.5}$ increased from 3·5 million in 1990 to 4·2 million in 2015.
- Exposure to ozone caused an additional 254 000 deaths and a loss of 4·1 million DALYs from chronic obstructive pulmonary disease in 2015.

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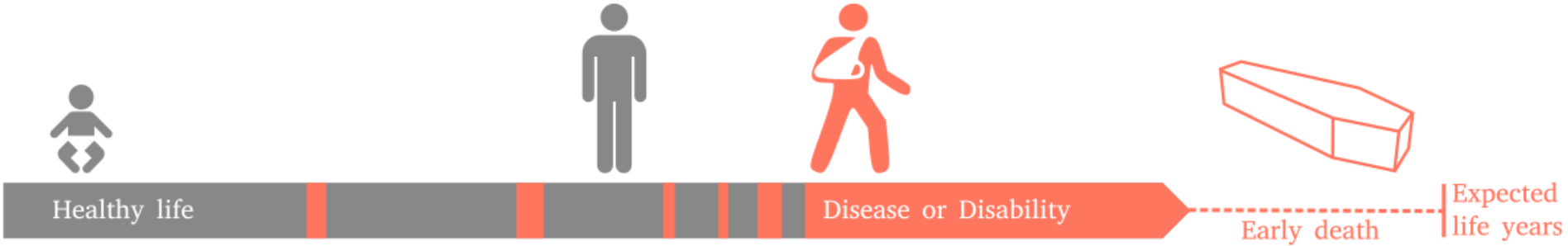
# Disability Adjusted Life Years

## DALY

Disability Adjusted Life Year is a measure of overall disease burden, expressed as the cumulative number of years lost due to ill-health, disability or early death

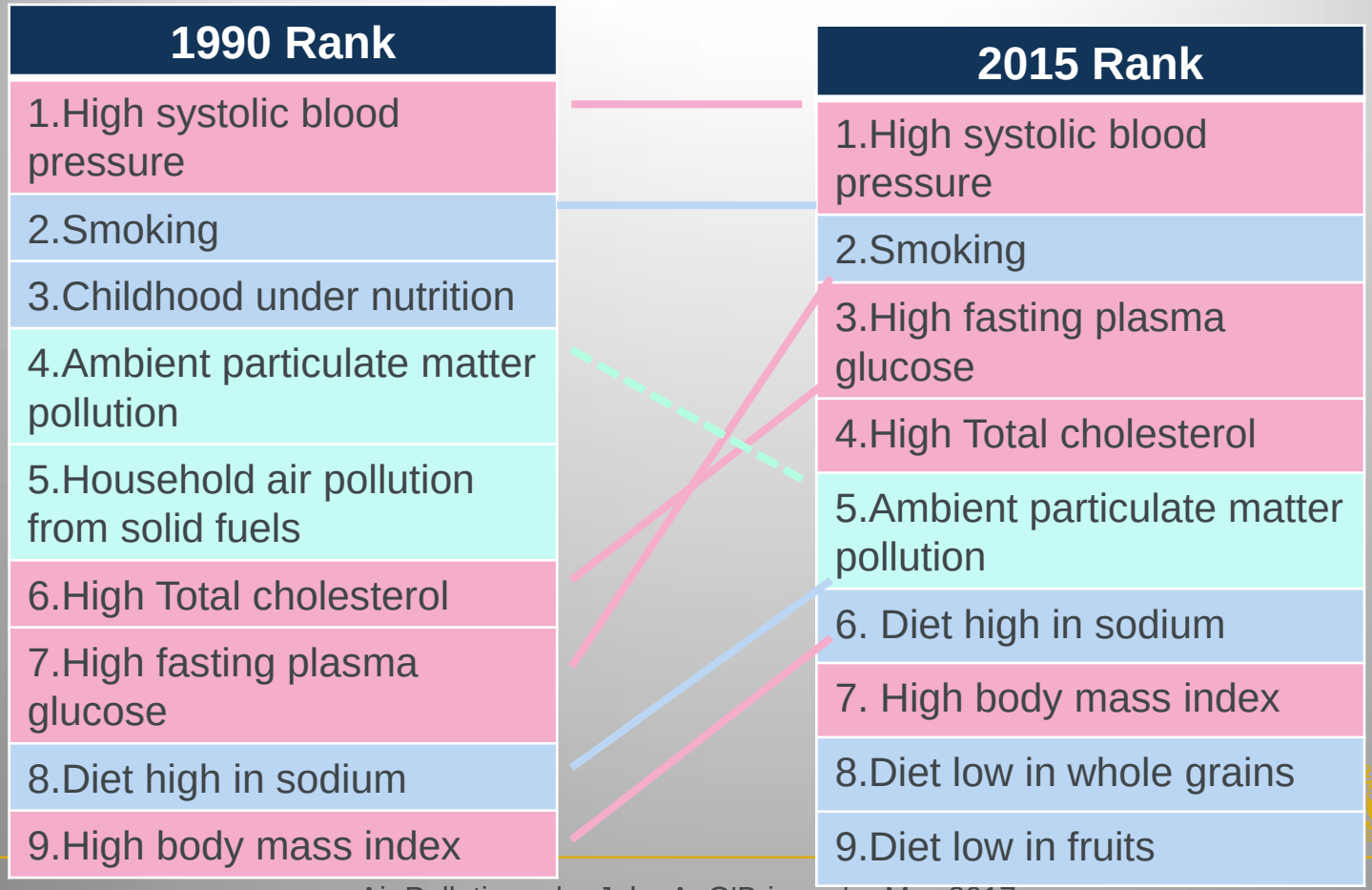
= YLD
Years Lived with Disability

\+ YLL
Years of Life Lost



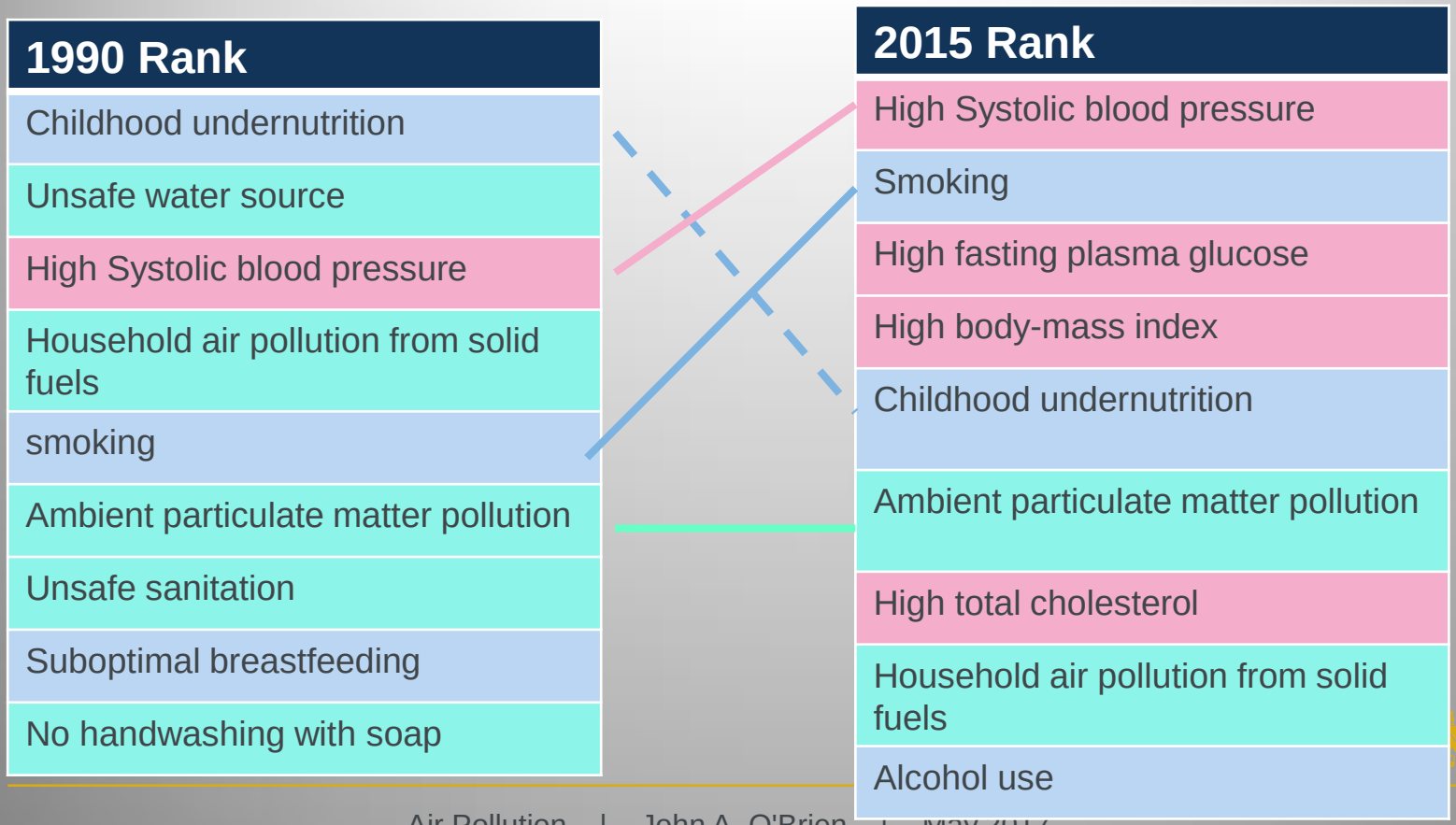

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# Global risk factors for death

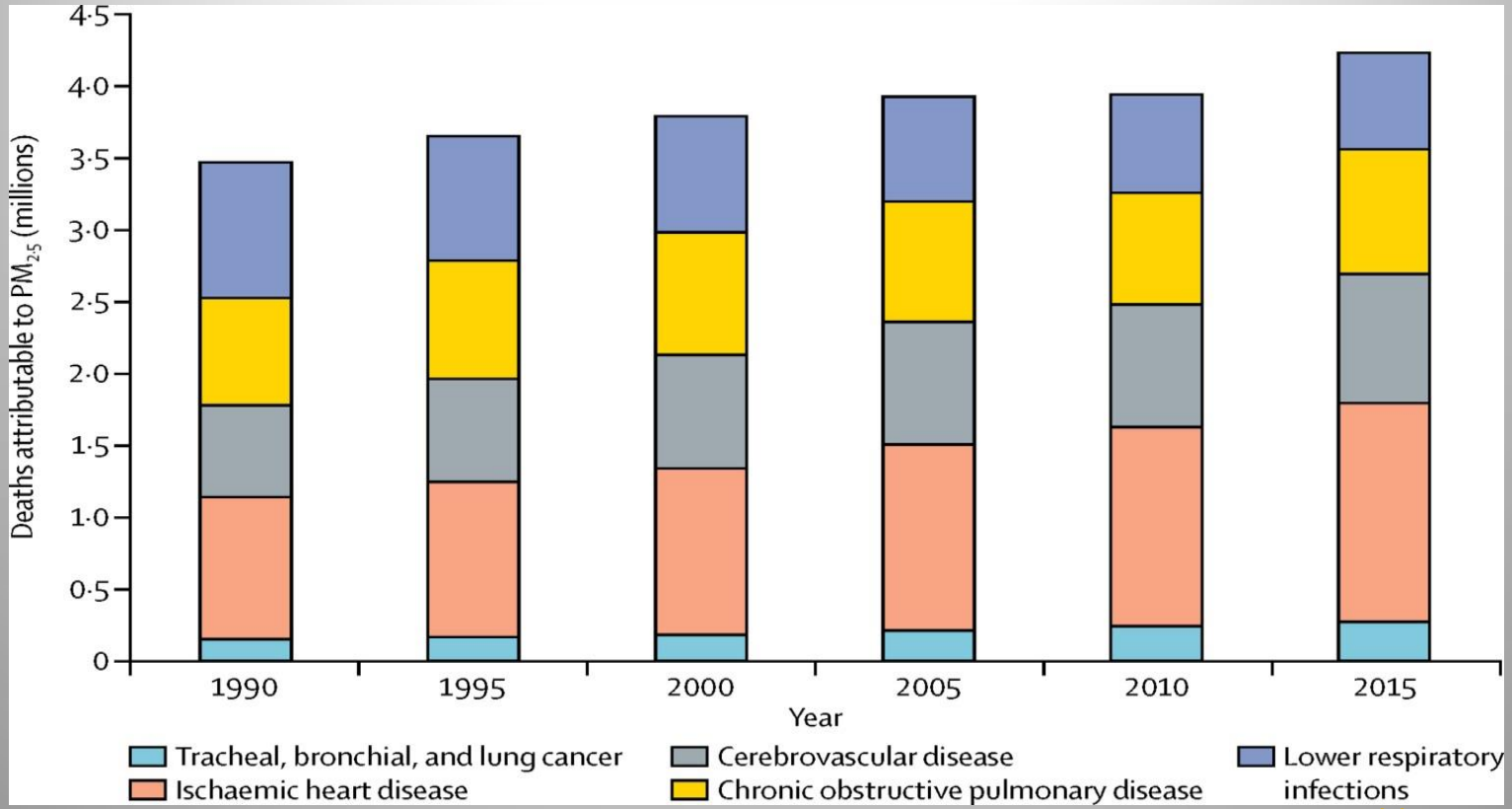



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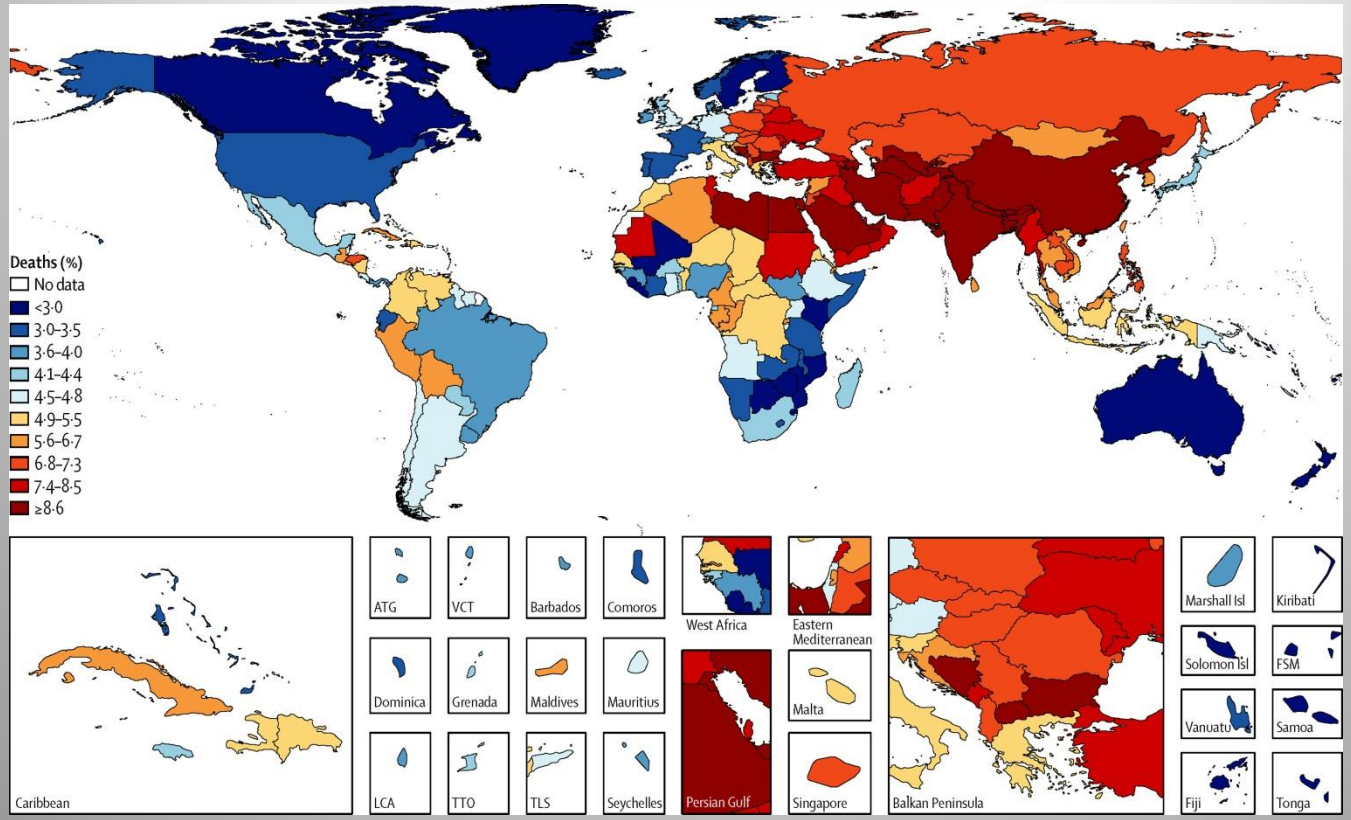
# Global Risk for DALYS




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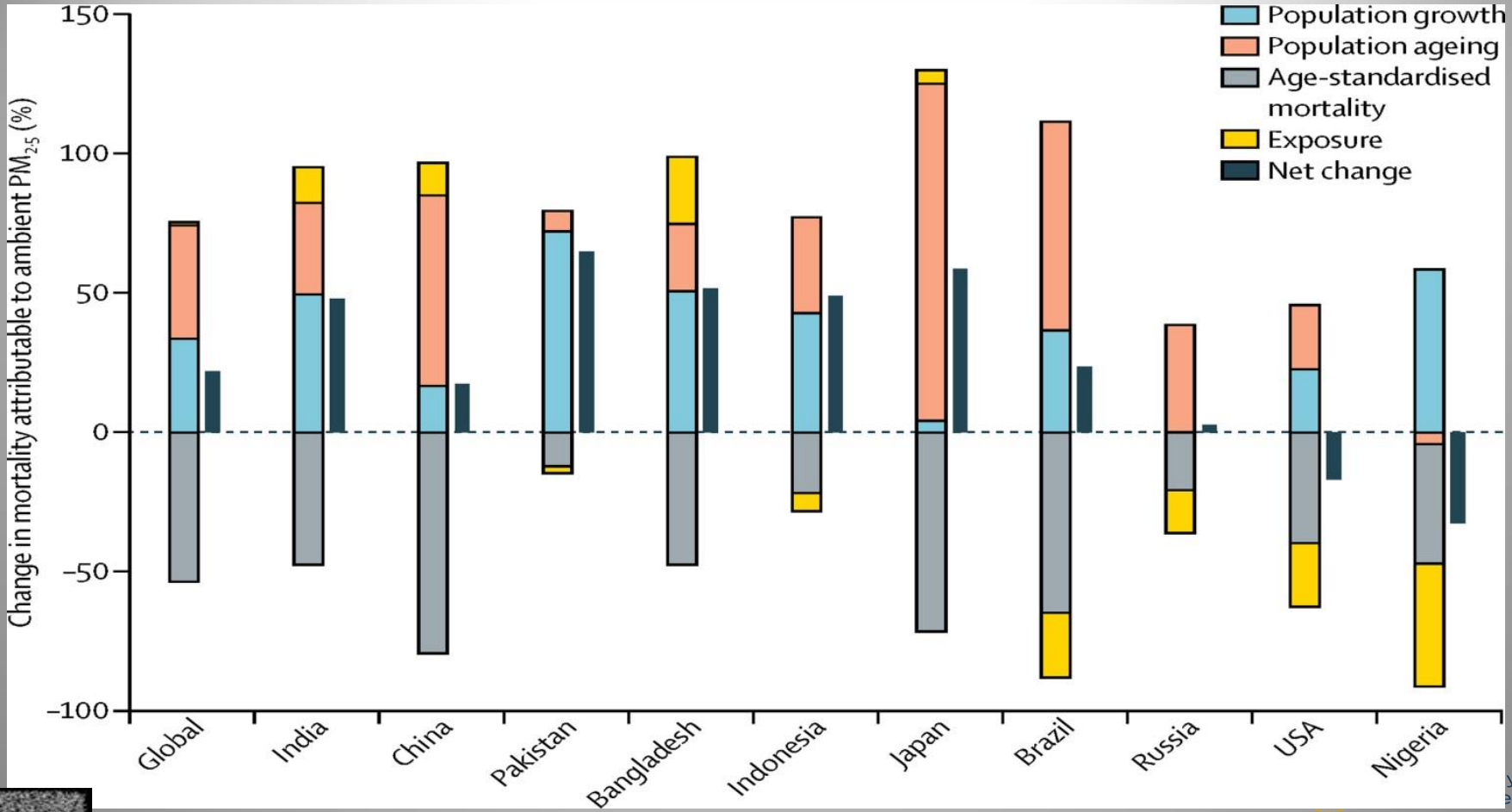



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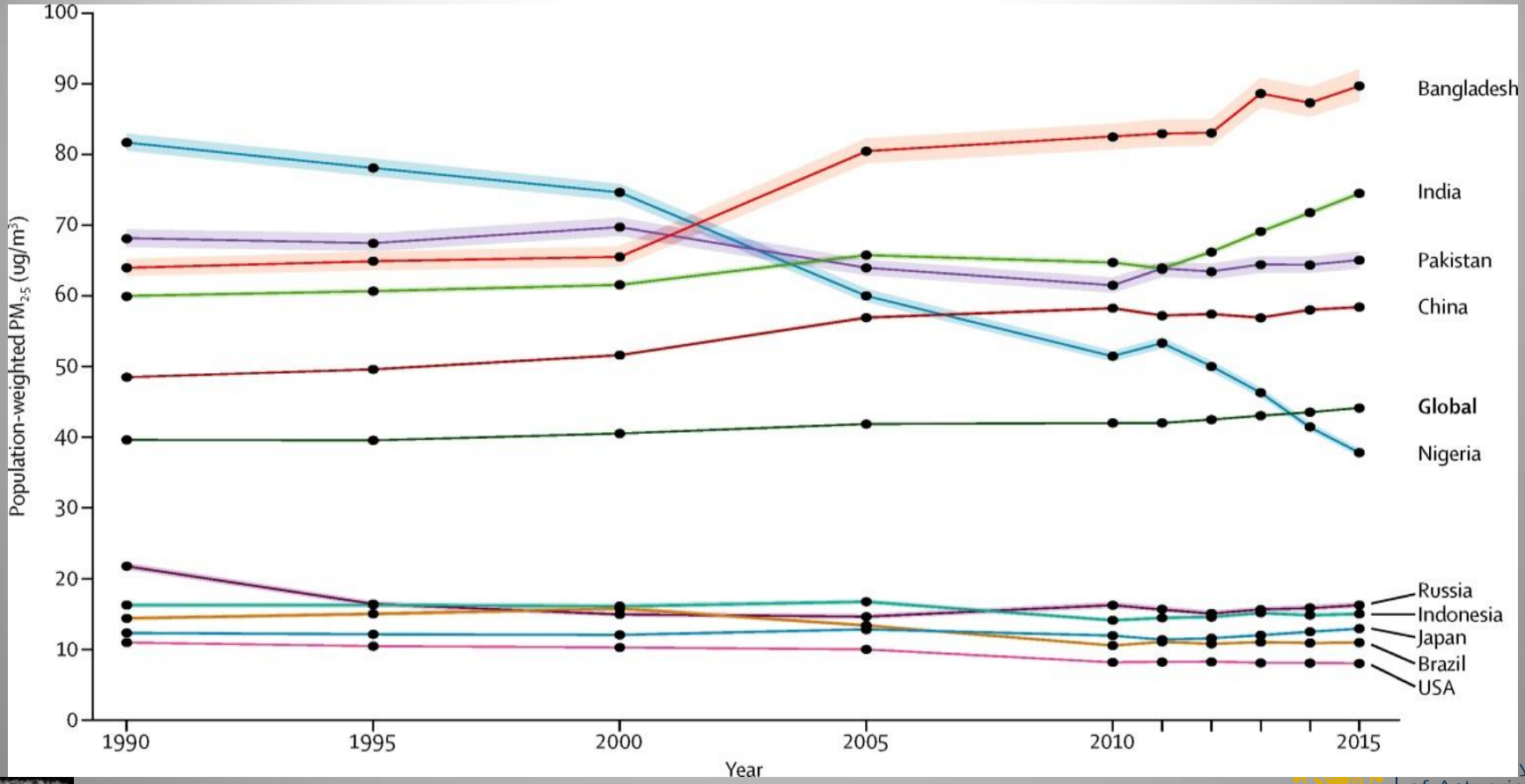





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# Air Pollution

- We do not see this picture in developed countries
- So why are we worried?
- Current pollution is more insidious and invisible
- But still has significant health effects

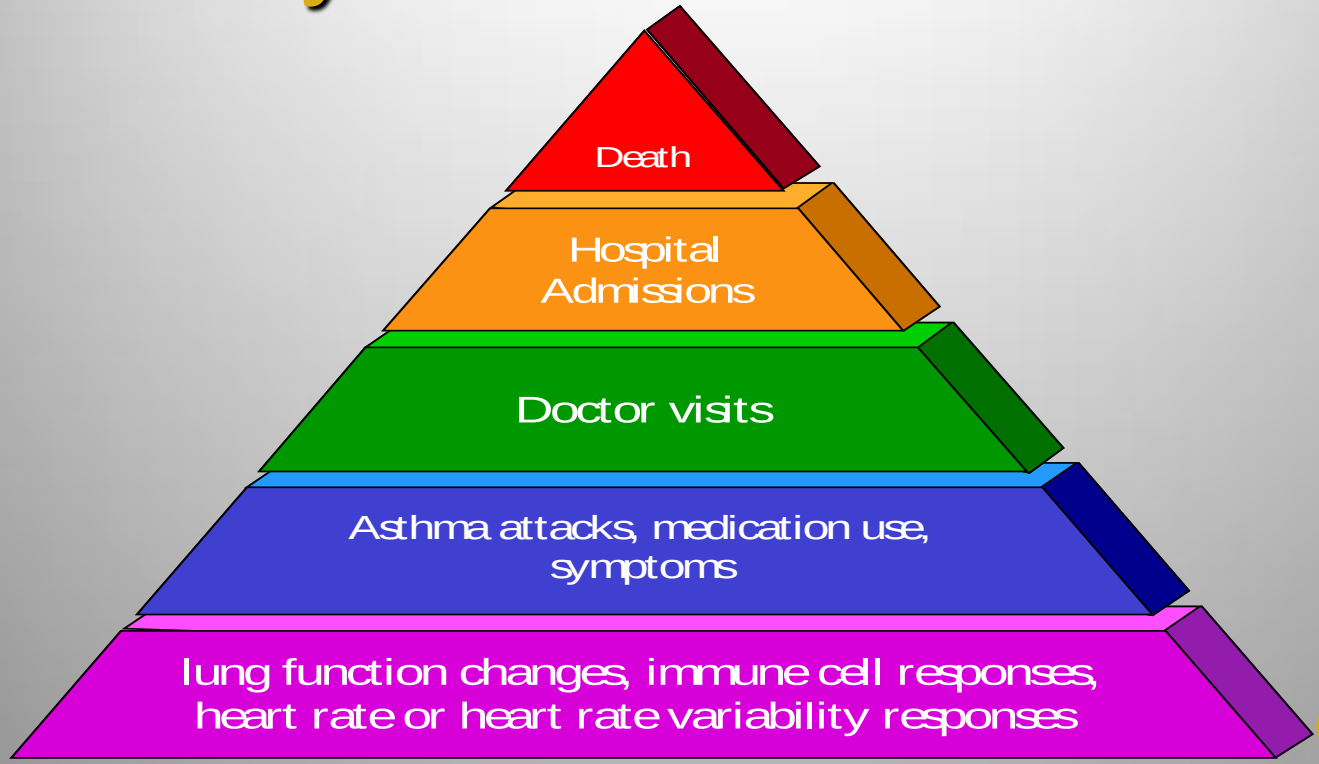
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# How big is the health problem in the UK?

- Outdoor pollution estimated to be responsible for 40 000 deaths annually in the UK

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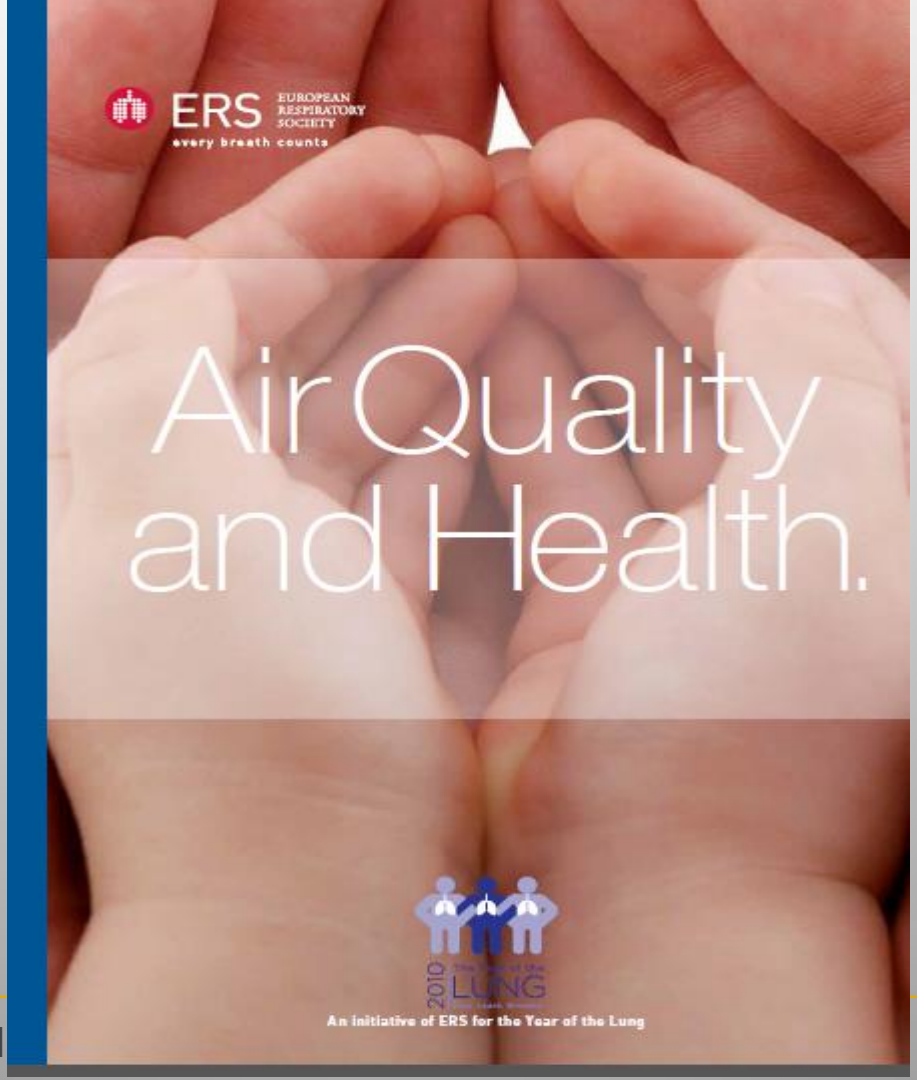
# “Pyramid of Effects”




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# Risks of air pollution

- Cancer
- Asthma
- COPD
- Stroke
- Diabetes
- Obesity
- Dementia

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# Risks of air pollution

- Prenatal
- Life long
- Particular risk for young
- Vulnerable during growth and development
- Long term impact

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# Risks of air pollution

- Worse for vulnerable populations
- Economically disadvantaged
- Areas of higher pollution
- Pre-existing medical conditions or vulnerability

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# Major pollutants in developed countries

- Sulphur Dioxide $SO_2$)
- Nitrogen Oxides (NOx) including Nitrogen dioxide ($NO_2$)
- Volatile organic compounds (VOCs)
- Particulate matter
- Ammonia ($NH_3$)
- Ozone ($O_3$)

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# Major pollutants in developed countries

- SOx gases are formed when fuel containing sulphur is burned, when gasoline is extracted from oil and when metals are extracted from ore.
- Respiratory and cardiac effects – acute and chronic effects - concentration dependent
- Acid rain effects on vegetation and materials and paints

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# Major pollutants in developed countries

- Nitrogen Oxides (Nox)
- Main source is high-temperature combustion
- Road traffic is dominant source
- They react with hemoglobin producing inert compounds including methemoglobin hampering  the oxygenation of tissues causing tachycardia, high blood pressure, and arrhythmia

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# Major pollutants in developed countries

- Volatile Organic compounds VOCs)
- Organic chemical compounds that have sufficiently high vapour pressures under normal conditions to vaporise significantly and enter the atmosphere
- A wide range of carbon-based molecules, such as aldehydes, ketones and other light hydrocarbons

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# Major pollutants in developed countries

- Ammonia ($NH_3$)
- Common by product of animal waste
- High protein with surplus nitrogen which is excreted - released into the air during manure decomposition

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# Pollutant definitions

- **Particulate matter (PM)**
- Historically black smoke – Air passed through a filter
- Now replaced by metrics – Aerodynamic

Thus $PM_{10}$ is the amount of particulate matter that is generally less than 10 µm in diameter.

$PM_{2.5}$ is the smaller fraction of PM10 and consists of particles <2.5 µm across (often re

Coarse PM is the difference between $PM_{10}$ and $PM_{2.5}$ referred to as ‘fine’ particles).

Ultra-fine particles are the smallest fractions of $PM_{2.5}$ and are <0.1 µm (100 nm) in diameter.

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# Particulate Matter

- Composition varies –
- near to roads - vehicle emissions
- rural areas – chemical reactions in the air
- Primary particles
- Directly emitted to the air
- Secondary particles
- formed by atmospheric processes

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# Major pollutants in developed countries

- Ozone ($O_3$)
- Not emitted directly
- Formed by reactions between NOx and VOCs in the presence of heat and sunlight

NOx + VOCs + sun radiation → $O_3$ + Photochemical pollution

Photochemical smog occurs in sunny periods with high temperatures, low moisture and relatively high levels of nitrogen oxides and hydrocarbons.

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# Ozone's physiology

Caustic gas--clear , colorless, odorless

Oxidizes proteins and lipids in the mucosal fluid layer

Highly irritating to lung linings

Increases lung secretions, decreases oxygenation

Sets off airway bronchospasm

Recruits inflammatory cells

Increases responses to allergens

Damages infection fighting responses

Chronic lung damage/remodeling

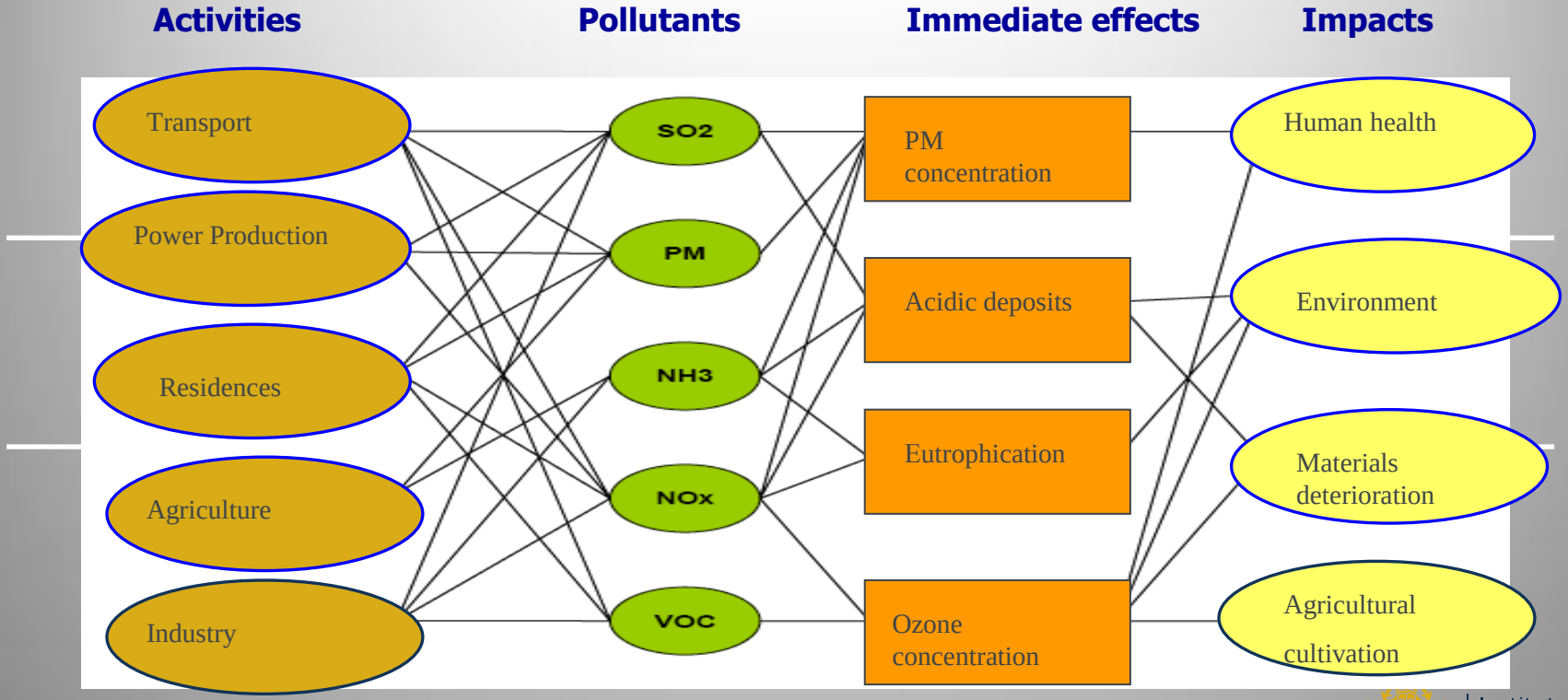
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# Pollutant definitions

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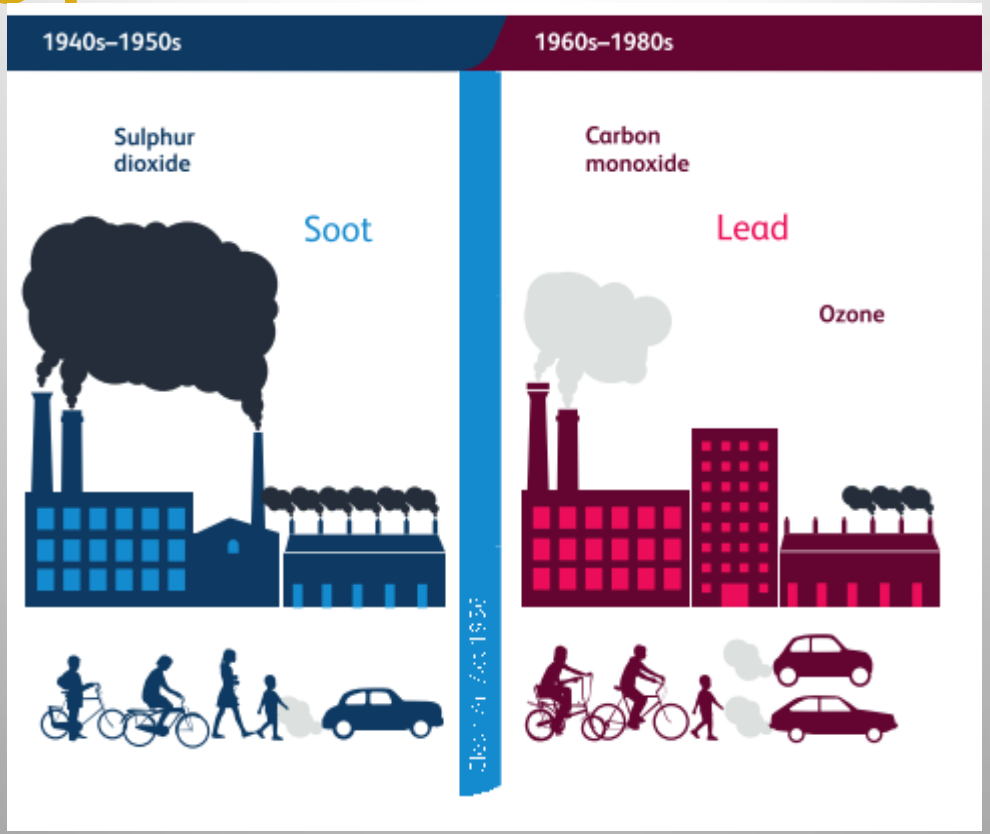
- Black carbon - This is the part of particulate matter that most strongly absorbs light It is created by the incomplete combustion of fuels and is a major part of soot.
- Carbon monoxide (CO) - This gas is produced when carbon-containing fuel burns without an adequate supply of oxygen.
- Diesel exhaust - Diesel exhaust is composed of gases and particles.

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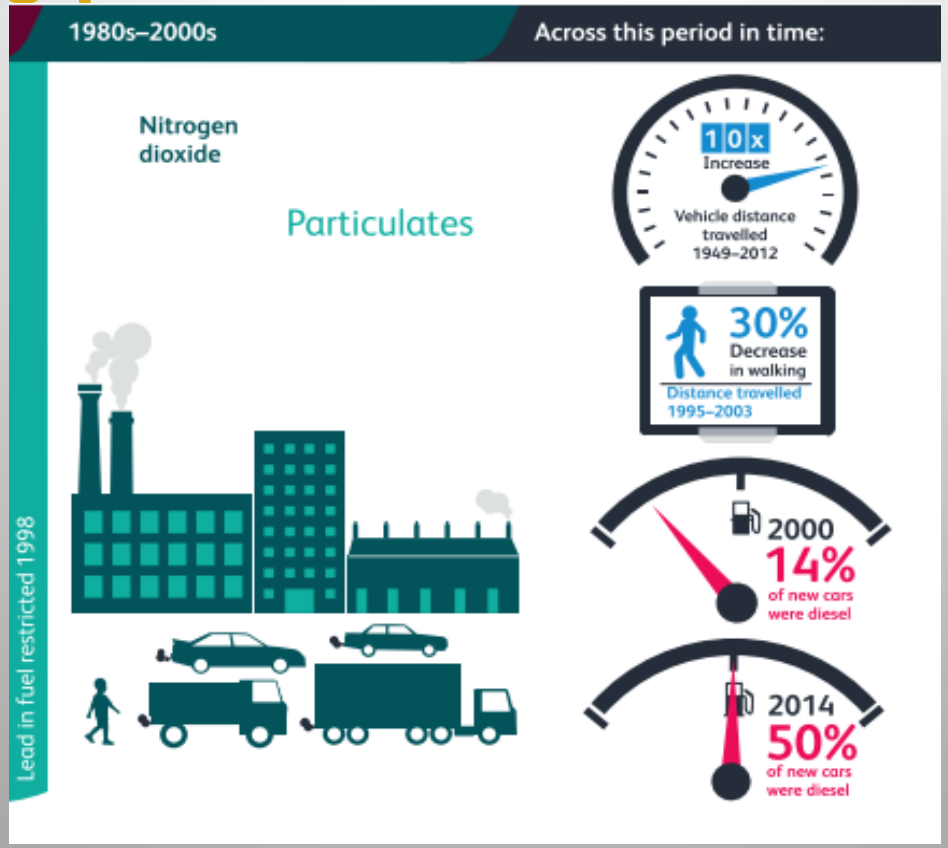

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# Changing pollutants




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# Changing pollutants




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# How do we know about the effects of Pollution?

- Acute events e.g Smog of 1952
- Mortality trends and regional pollution
- Biological evidence of disease mechanisms

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The New England
Journal of Medicine

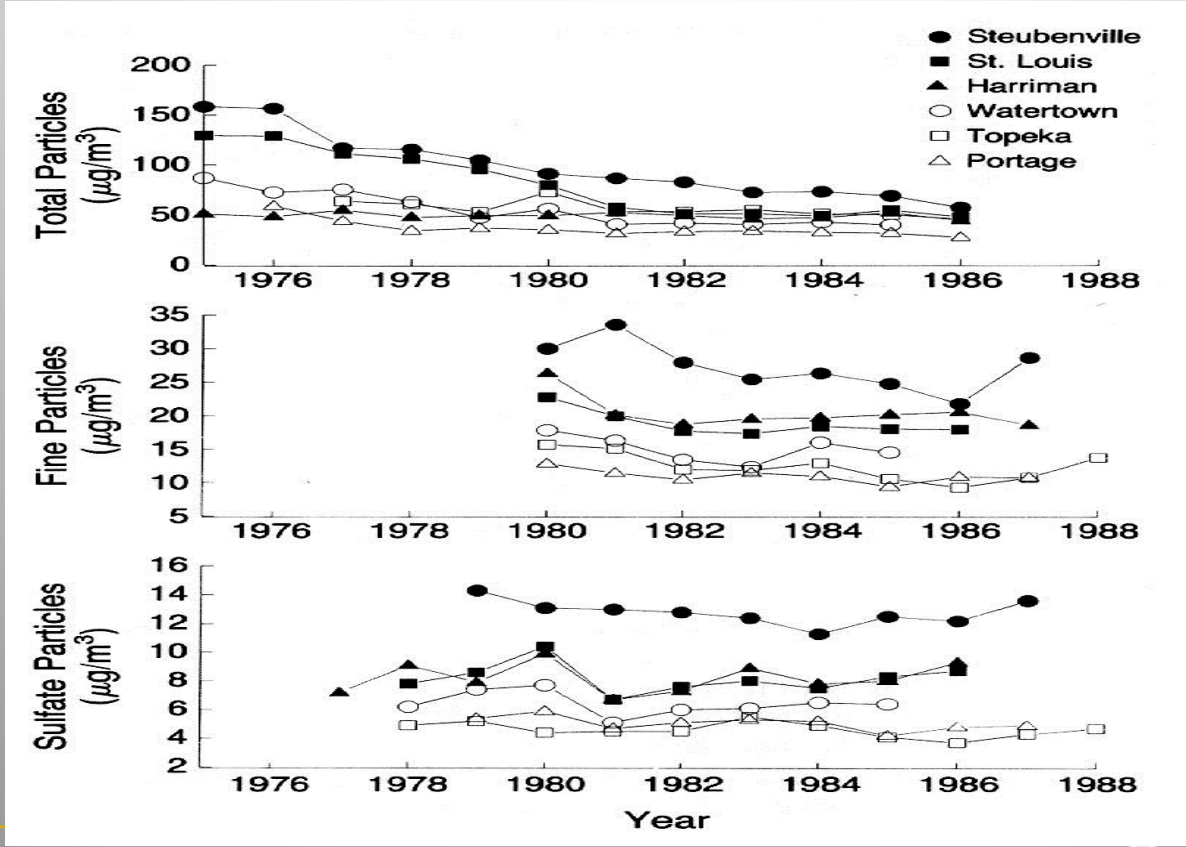
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Volume 329 DECEMBER 9, 1993 Number 24

# AN ASSOCIATION BETWEEN AIR POLLUTION AND MORTALITY IN SIX U.S. CITIES

Douglas W. Dockery, Sc.D., C. Arden Pope III, Ph.D., Xiping Xu, M.D., Ph.D.,
John D. Spengler, Ph.D., James H. Ware, Ph.D., Martha E. Fay, M.P.H.,
Benjamin G. Ferris, Jr., M.D., and Frank E. Speizer, M.D.

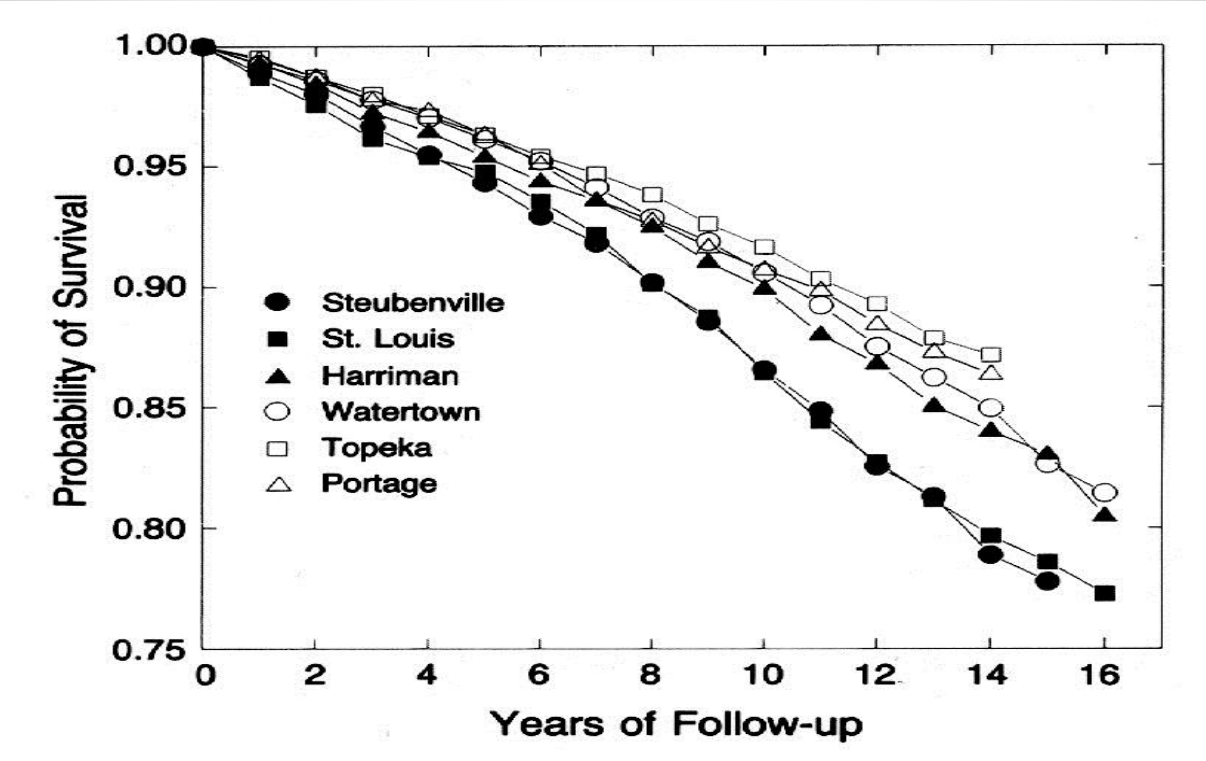
# Annual Average Concentrations of Total Particles, Fine Particles, and Sulfate Particles in the Six Cities.




Dockery DW et al. N Engl J Med 1993;329:1753-1759.

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The NEW ENGLAND JOURNAL of MEDICINE

# Crude Probability of Survival in the Six Cities, According to Years of Follow-up.




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Dockery DW et al. N Engl J Med 1993;329:1753-1759.

The NEW ENGLAND JOURNAL of MEDICINE

# Crude Probability of Survival in the Six Cities, According to Years of Follow-up.

- Controlled for smoking rates, education level, diabetes and work place pollution
- Worst affected city had a death rate around 30% higher than the least polluted city

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Special Article

# Fine-Particulate Air Pollution and Life Expectancy in the United States

C. Arden Pope, III, Ph.D., Majid Ezzati, Ph.D., and Douglas W. Dockery, Sc.D.

N Engl J Med
Volume 360(4):376-386
January 22, 2009

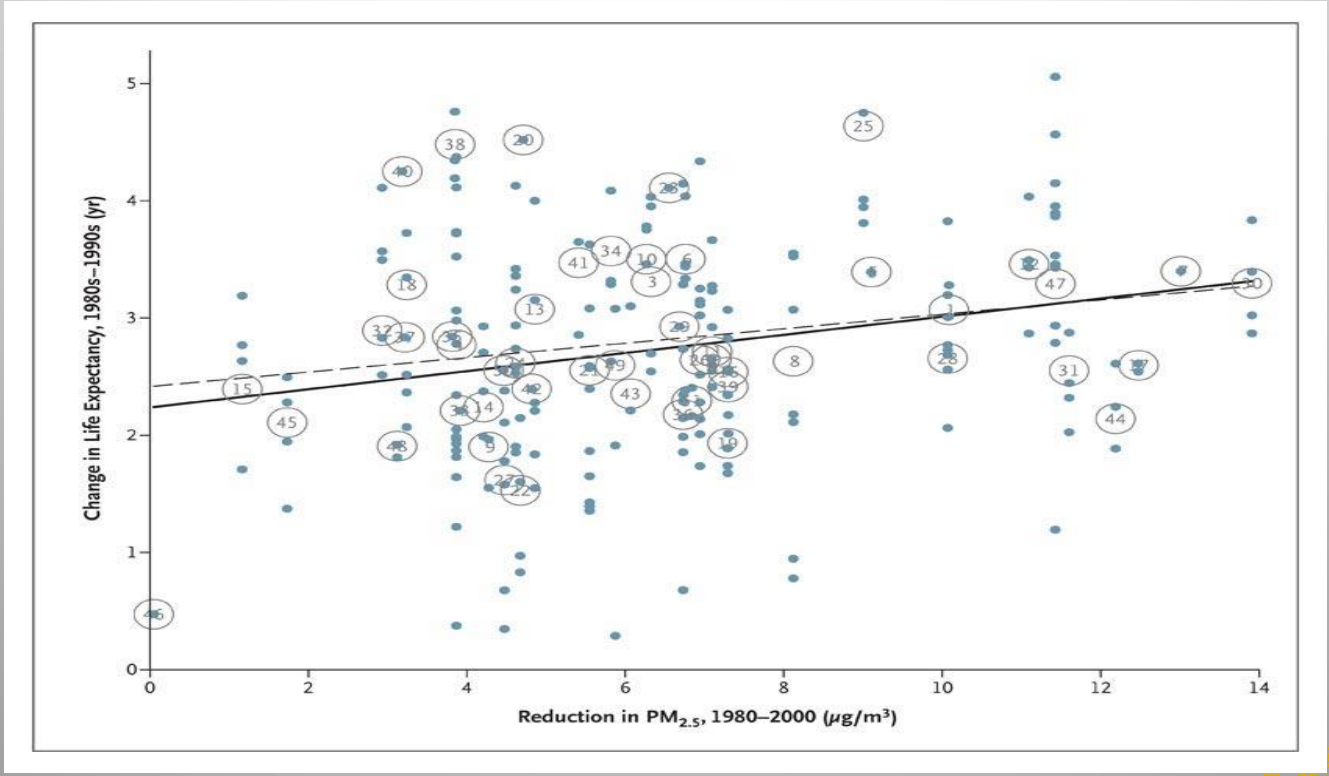
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The NEW ENGLAND JOURNAL of MEDICINE

- Reductions in air pollution accounted for
- as much as 15% of the overall increase in life expectancy in the study areas.
- A decrease of 10 μg per cubic meter in the concentration of fine particulate matter was associated with an estimated increase in mean life expectancy of 0.61 year (P=0.004)

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# Changes in Life Expectancy for the 1980s-1990s, Plotted against Reductions in $PM_{2.5}$ Concentrations for 1980-2000

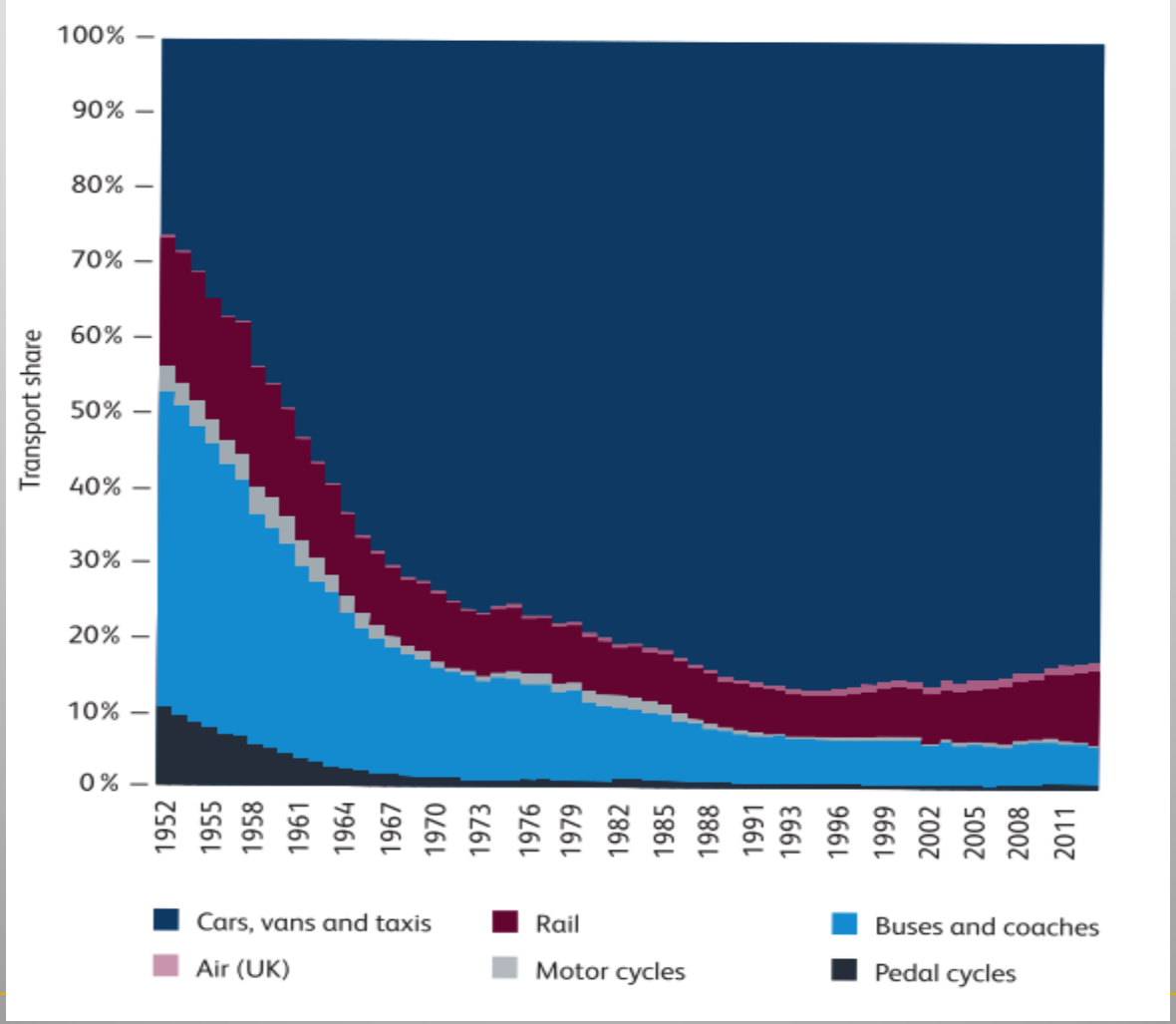



Pope CA 3rd et al. N Engl J Med 2009;360:376-386

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# Contributors to air pollution

- Increased use of motor vehicles




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# Vehicle contributions to pollution

- Fuel combustion
- New petrol car emits 1/20 level of Nitrogen oxides compared to 20 years ago. Lead free fuels. Regulated sulphur.
- Increasing use of diesel for small vehicles and less efficient emission control. Ultra low sulphur diesel
- Reduction in marine fuel sulphur
- Tyres, brakes and the road

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# Indoor air pollution

- Outdoor air
- Biological pollutants – humans, pets, insects, HDM
- Ground house is built on – radon
- Second-hand smoke
- Cookers, boilers, fires
- Construction materials – glues, fabrics, cleaning and DIY

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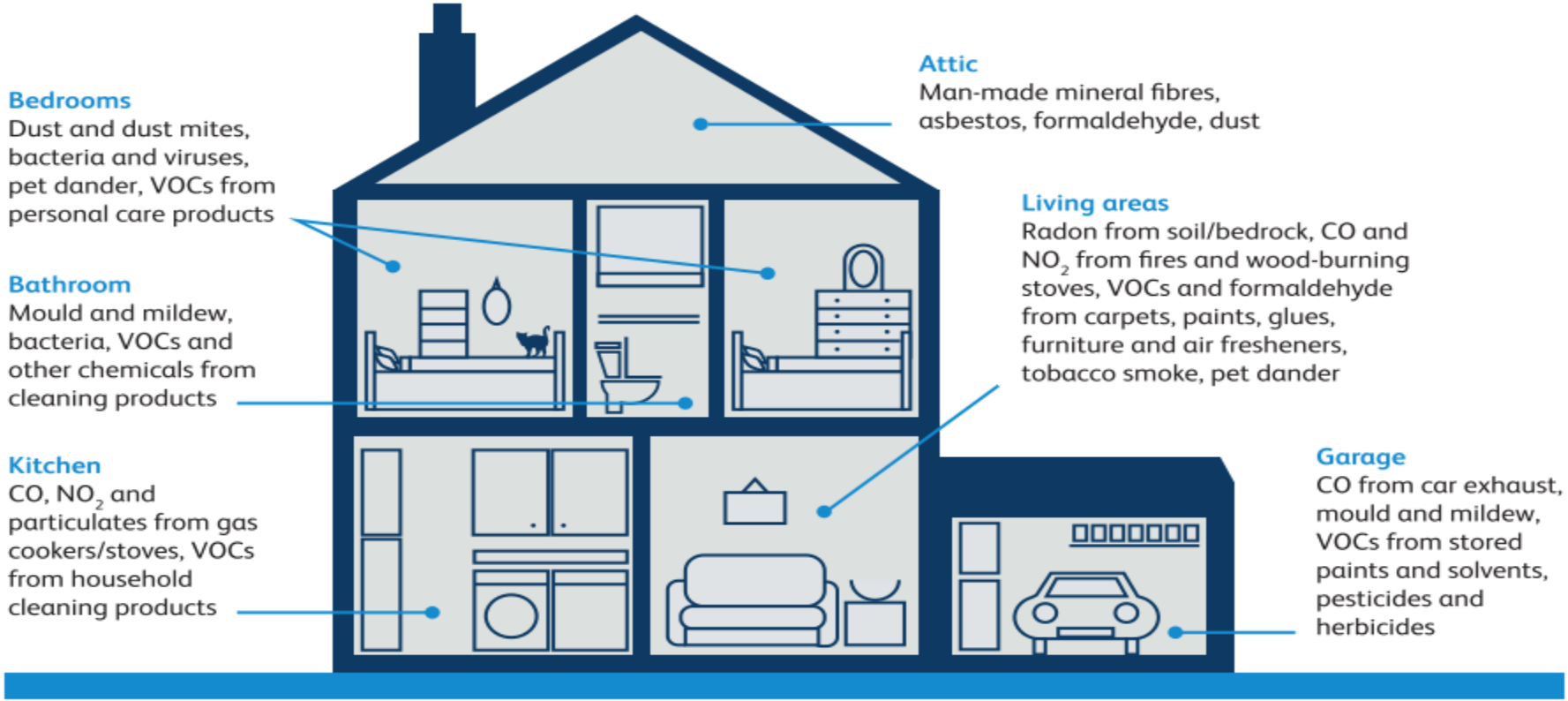



**Fig 3. Sources and types of indoor pollution encountered in homes. VOCs = volatile organic compounds. Please note that these lists are not exhaustive and that the actual pollutants present, and their amounts, will vary from household to household.**

# Indoor air pollution

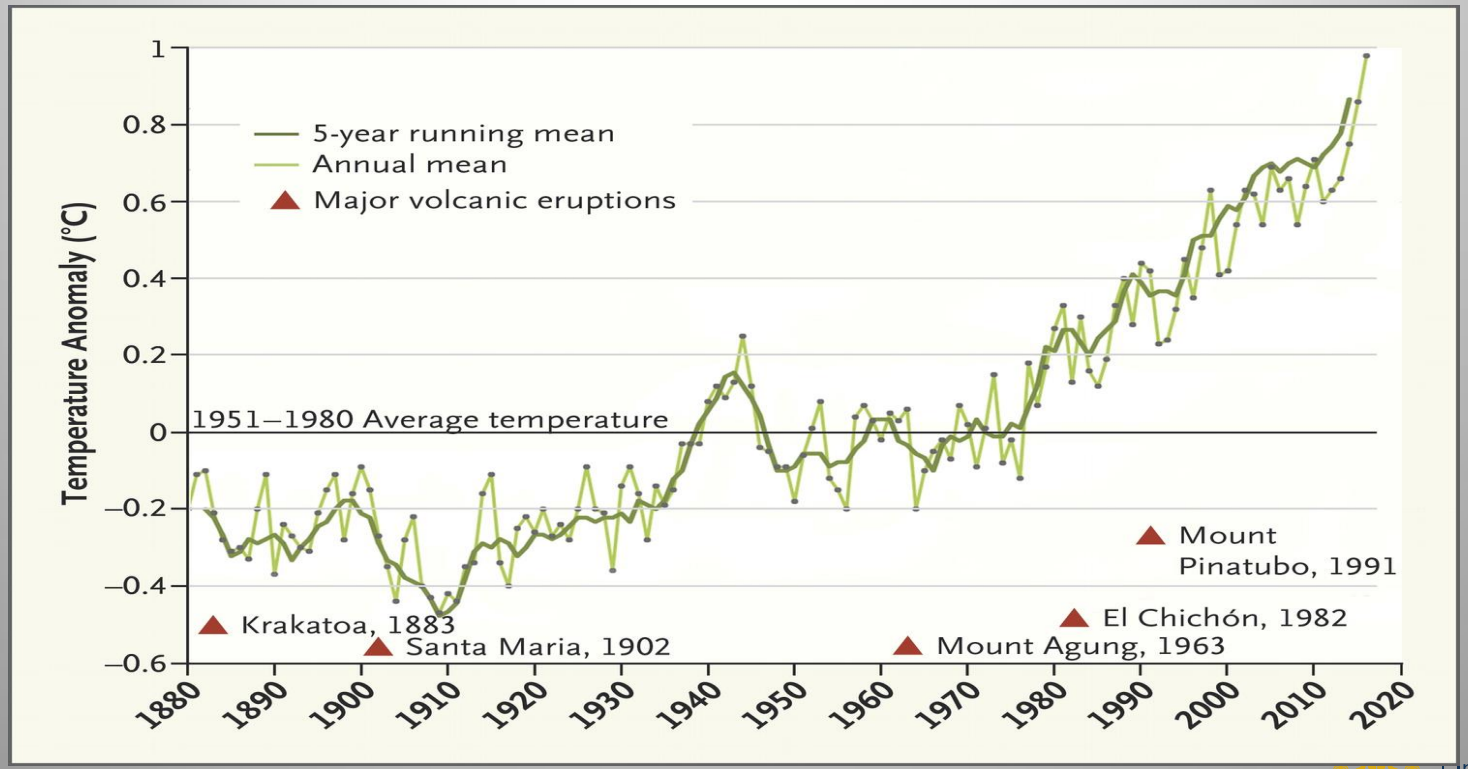
- The most significant of these pollutants (excluding tobacco smoke – see below) in terms of health impact are formaldehyde, NO2, CO, benzene and naphthalene.

# Air Pollution and climate change

- Linked
- Pollution contributes to climate change
- Climate change has significant health risks

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# Annual Changes in Mean Surface-Air Temperature, 1880–2016.




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Hunter DJ et al. N Engl J Med 2017;376:1605-1607.

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# Air Pollution and climate change

- Average temperatures are predicted to rise by1.7 to 5.6°C within the lifetimes of children now being born
- Summer heat waves increase mortalityHigher temperatures also increase ozone levels, compromising lung function and exacerbating asthma.
- Earlier and longer pollen seasons elevate exposure to allergens, increasing allergic sensitization and asthma episodes

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# Air Pollution and climate change

- Warmer water temperatures - facilitate the growth of pathogenic waterborne organisms
- The distribution of vector borne diseases such as Lyme disease,West Nile virus, Rocky Mountain spotted fever, plague, and tularemia expands as the range of their vectors changes
- The mosquito vectors of pathogens such as dengue, chikungunya, and Zika, may find more favorable conditions.
- Food production — crops, livestock, and fisheries — is projected to decline in some regions of the world

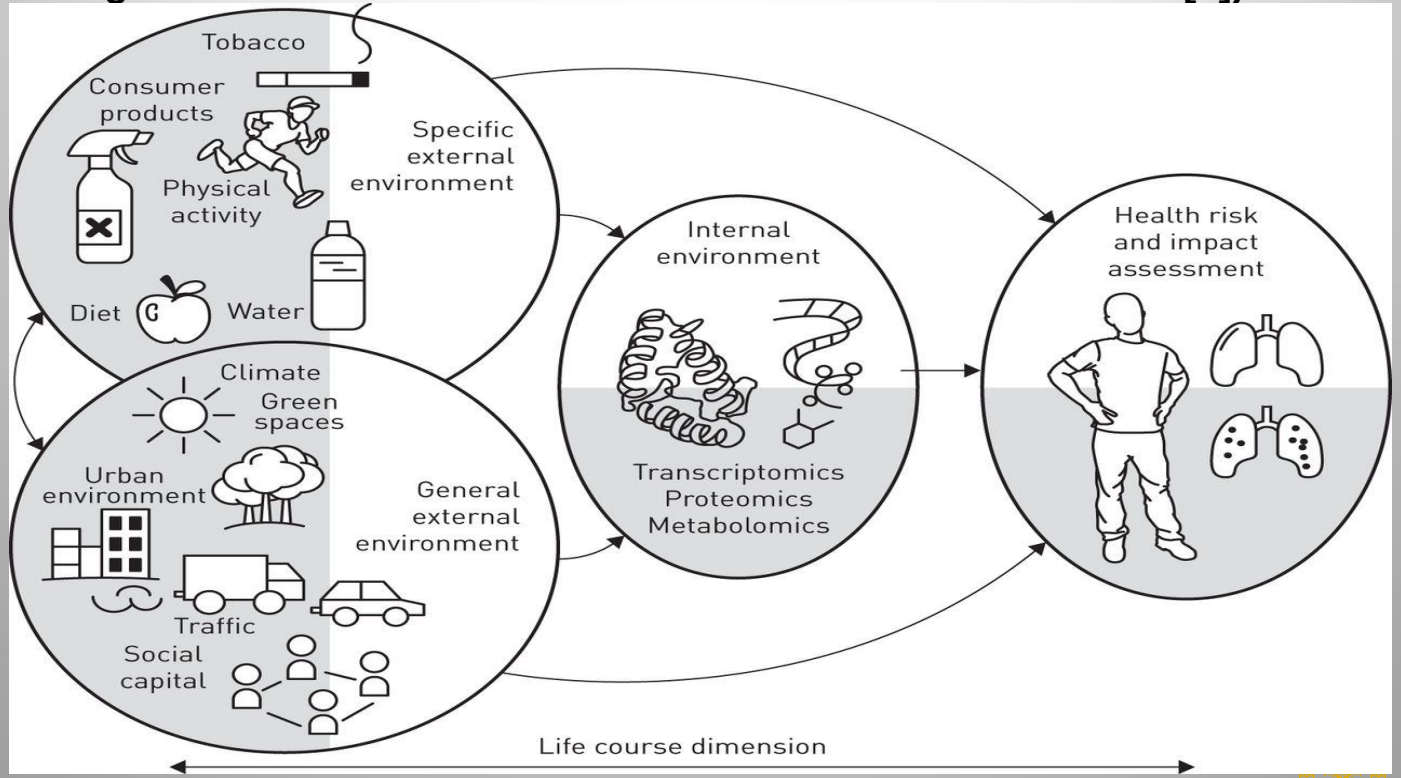
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# Air Pollution and climate change

- Extreme heat leads to more aggression and violence
- Extreme weather events can cause stress and anxiety, exacerbating depression and other mental illnesses.

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**The effects and interactions between the different domains constituting the exposome (specific and general external environments and internal environment [2]) and health risk.**

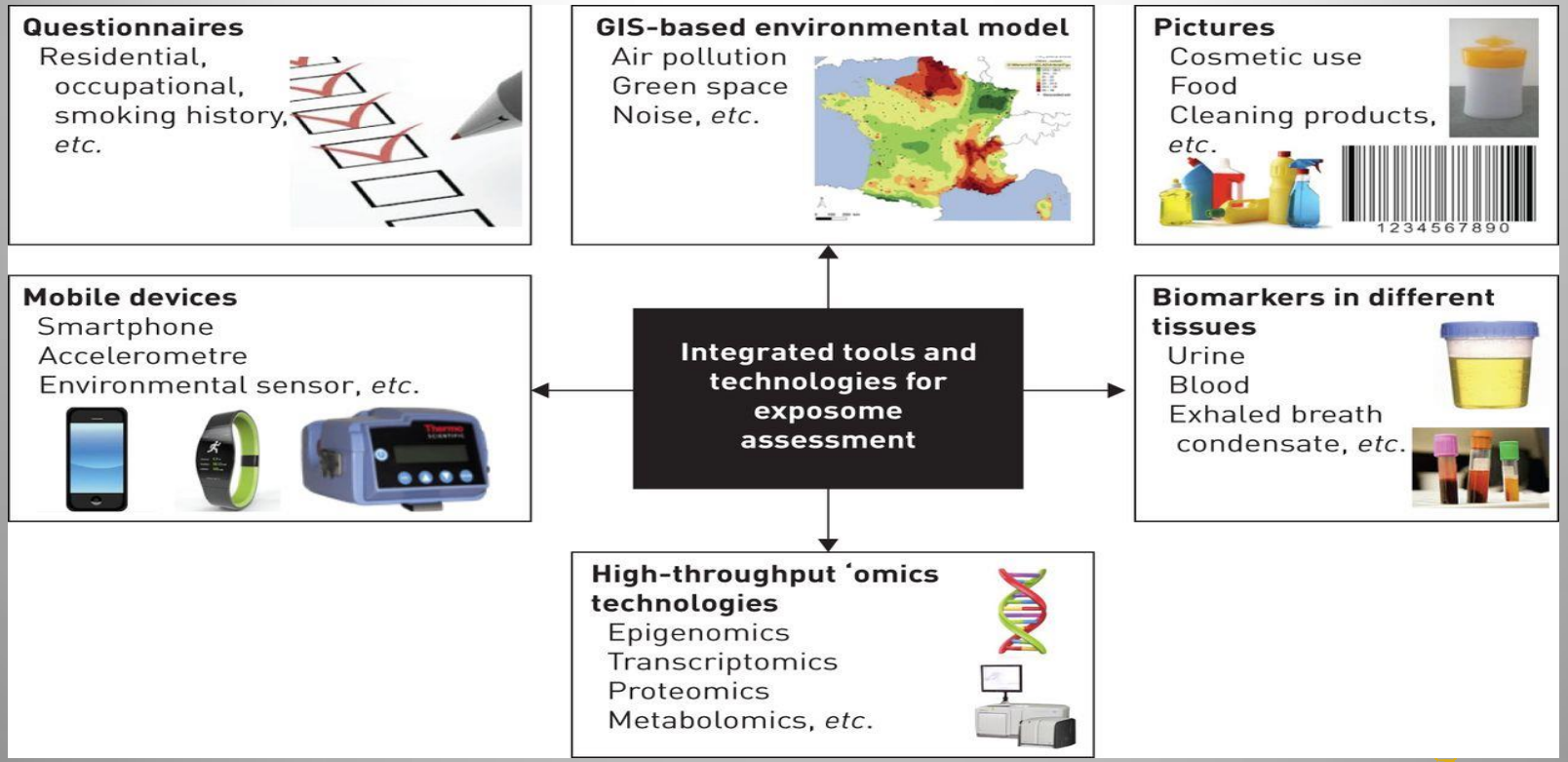



**Valérie Siroux et al. Eur Respir Rev 2016;25:124-129**

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## Tools for the assessment of the exposome.

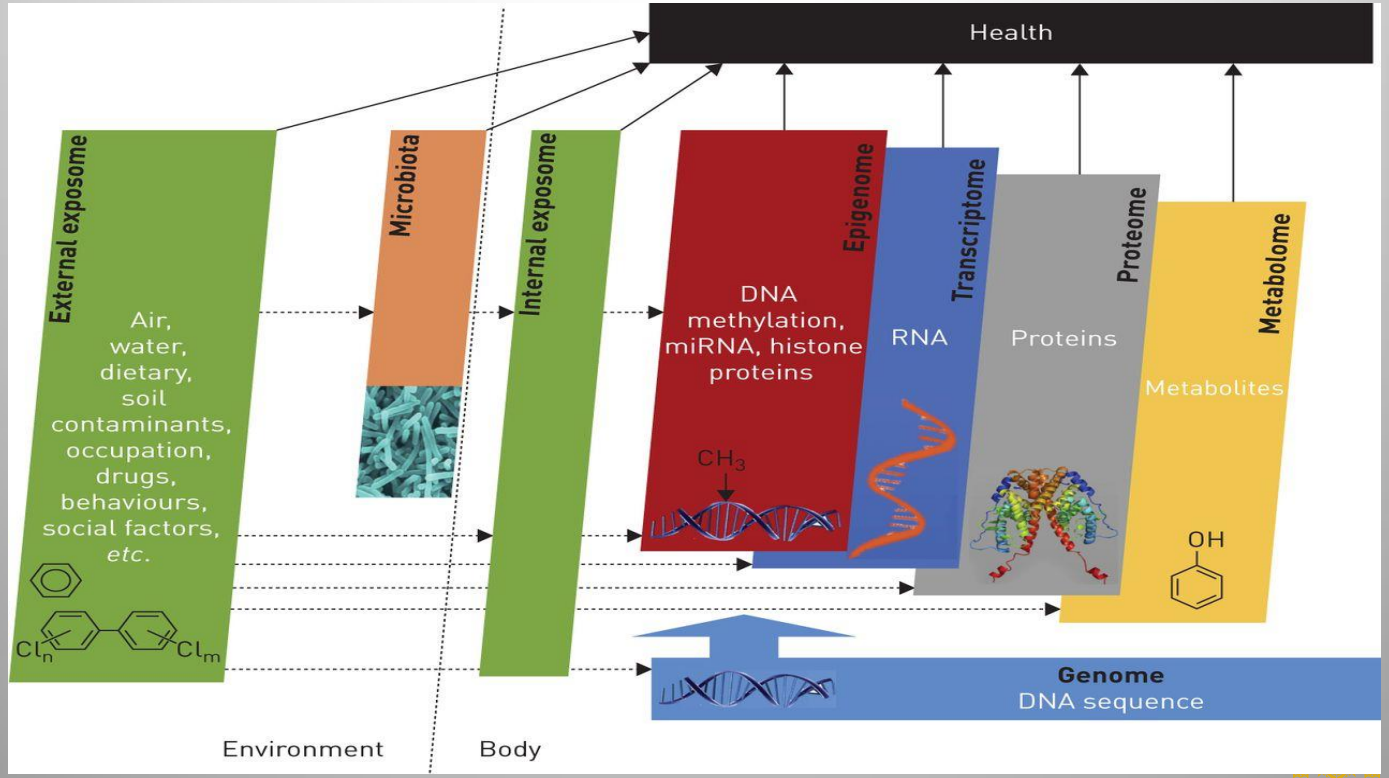



**Valérie Siroux et al. Eur Respir Rev 2016;25:124-129**

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**Schematic diagram of some of the ‘omics layers and pathways of influence of the exposome on health.**




**Valérie Siroux et al. Eur Respir Rev 2016;25:124-129**

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# Conclusions

- Air pollution has significant impact on mortality and morbidity
- International co-operation is required - distant impacts of pollution
- Individual choices are also important
- Understanding of mechanisms of effects is progressing

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