Global air quality and public health

a survey of research methods and recent findings

Associated Press, December 2018

Who we are

John Balmes

Ajay Pillarisetti

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Who are you?

Course overview

Date	Details	
Fri Jan 25, 2019	Lecture 1 - Introduction + Overview	8am to 10am
Fri Feb 1, 2019	Lecture 2 - Air Pollutants	8am to 10am
Fri Feb 8, 2019	Lecture 3 - Atm. Chem (Alex Turner)	8am to 10am
Fri Feb 15, 2019	Lecture 4 - Measuring Air Pollution I	8am to 10am
Fri Feb 22, 2019	Lecture 5 - Measuring Air Pollution II	8am to 10am
Fri Mar 1, 2019	Student Presentations - Health Effects	8am to 10am
Fri Mar 8, 2019	Lecture 7 - Air Pollution Epidemiology	8am to 10am
Fri Mar 15, 2019	Lecture 8 - Air Pollution and Occupational Health	8am to 10am
Fri Mar 22, 2019	Lecture 9 - Remote Sensing of Air Pollution (Jason Su)	8am to 10am

Beyond the basics…

Air pollution policy issues in California and India

The impacts of secondhand and active/passive marijuana smoke and vaping

Bringing it all together in the Global Burden of Disease

Grading and Assignments

- **Air pollution event analysis (30%)**. In small groups, students will pick a significant domestic or international air pollution event of interest and describe its impact on air pollutant concentrations (e.g. emissions control strategies during the Beijing Olympics) and health, if applicable. Students will present their findings to the class and submit a two-page summary of findings.

- **Review of air pollution health effects (30%)**. Students will be assigned to groups of 2-3 and will create 20 minute presentations reviewing the associations between air pollution exposure and respiratory, reproductive, cardiovascular, and neurological outcomes.

- **Class participation (20%) + problem sets (20%)**

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Any questions?

Global burden of air pollution

(why we care)

What is air pollution?

(and a lil'history)

Air pollution fundamentals

Perspectives from India

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THE LANCET

COMMISSION ON POLLUTION AND HEALTH

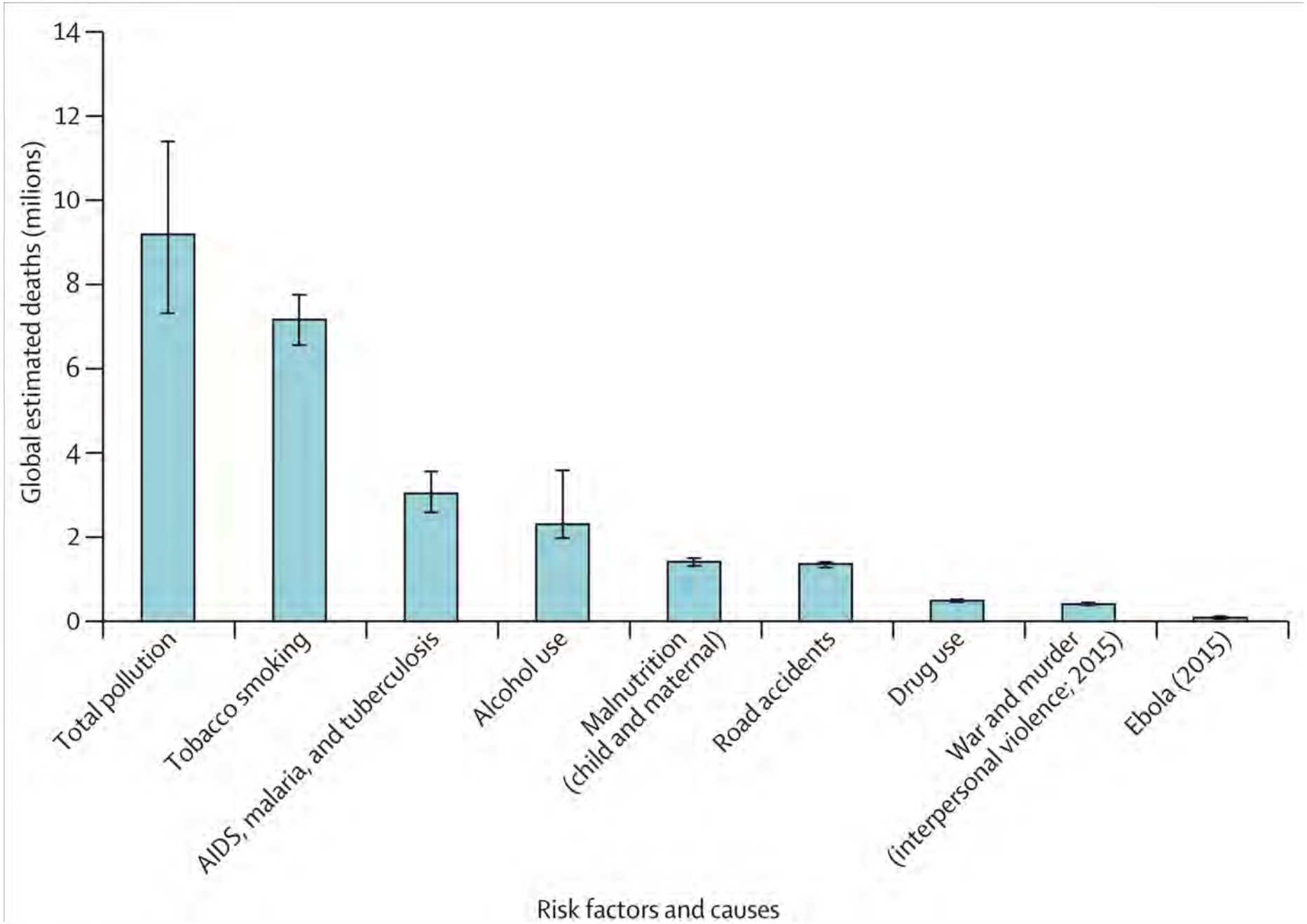
Pollution is the largest environmental cause of disease and premature death in the world today. Diseases caused by pollution were responsible for an estimated 9 million premature deaths in 2015 — 16% of all deaths worldwide — three times more deaths than from AIDS, tuberculosis, and malaria combined and 15 times more than from all wars and other forms of violence. In the most severely affected countries, pollution-related disease is responsible for more than one death in four.

	GBD study best estimate (95% CI)	WHO best estimate (95% CI)
Air (total)	6·5 (5·7–7·3)	6·5 (5·4–7·4)
Household air	2·9 (2·2–3·6)	4·3 (3·7–4·8)
Ambient particulate	4·2 (3·7–4·8)	3·0 (3·7–4·8)
Ambient ozone	0·3 (0·1–0·4)	..
Water (total)	1·8 (1·4–2·2)	0·8 (0·7–1·0)
Unsafe sanitation	0·8 (0·7–0·9)	0·3 (0·1–0·4)
Unsafe source	1·3 (1·0–1·4)	0·5 (0·2–0·7)
Occupational	0·8 (0·8–0·9)	0·4 (0·3–0·4)
Carcinogens	0·5 (0·5–0·5)	0·1 (0·1–0·1)
Particulates	0·4 (0·3–0·4)	0·2 (0·2–0·3)
Soil, heavy metals, and chemicals	0·5 (0·2–0·8)	0·7 (0·2–0·8)
Lead	0·5 (0·2–0·8)	0·7 (0·2–0·8)
Total	9·0	8·4

Note that the totals for air pollution, water pollution, and all pollution are less than the arithmetic sum of the individual risk factors within each of these categories because these have overlapping contributions—eg, household air pollution also contributes to ambient air pollution and vice versa.

Table 1: Global estimated deaths (millions) due to pollution risk factors from the Global Burden of Disease study (GBD; 2015) versus WHO data (2012)[99,101]

Landrigan P, et al, Lancet Commission on Pollution and Health, *The Lancet*, Published online Oct 19, 2017
http://dx.doi.org/10.1016/S0140-6736(17)32345-0



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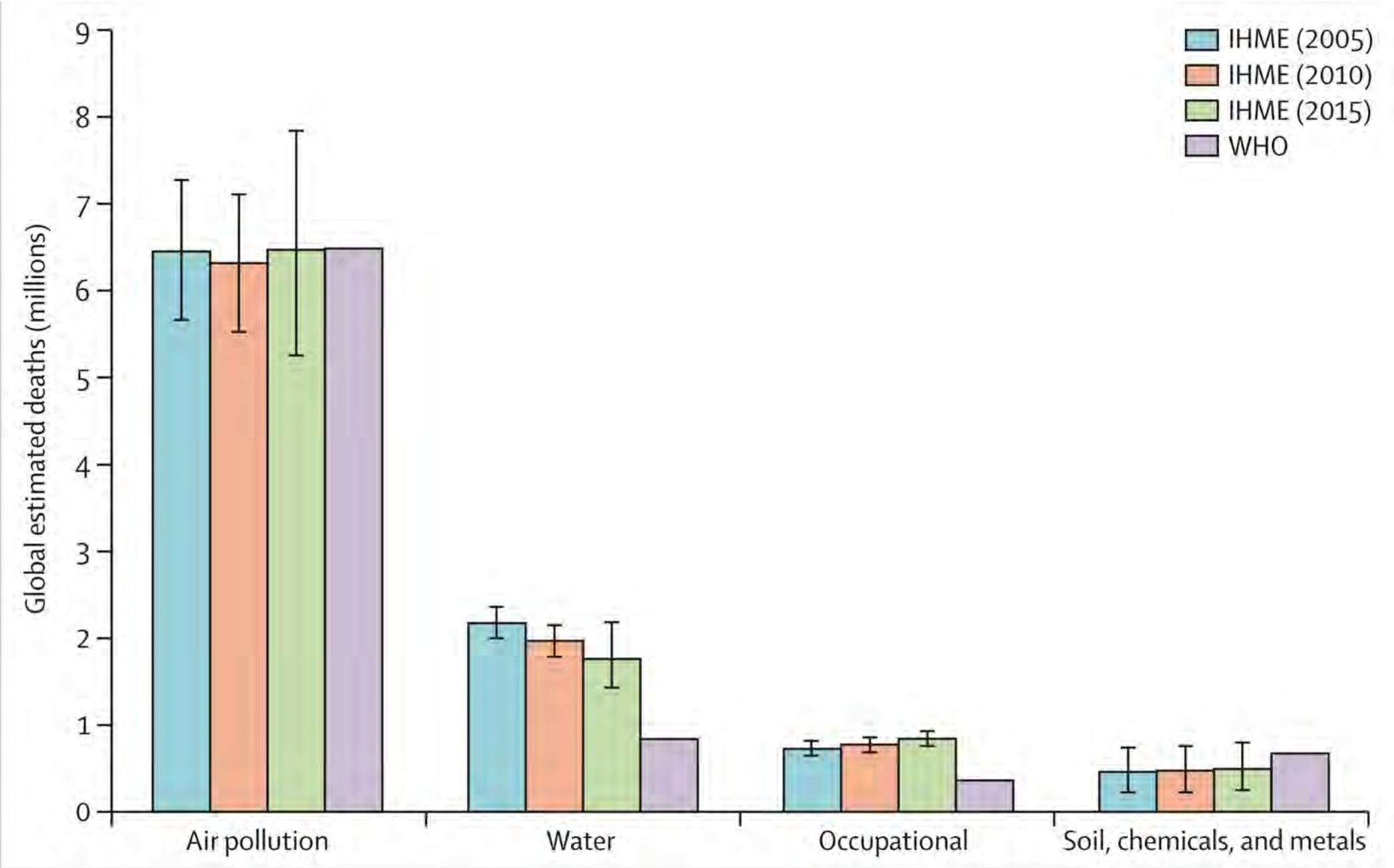
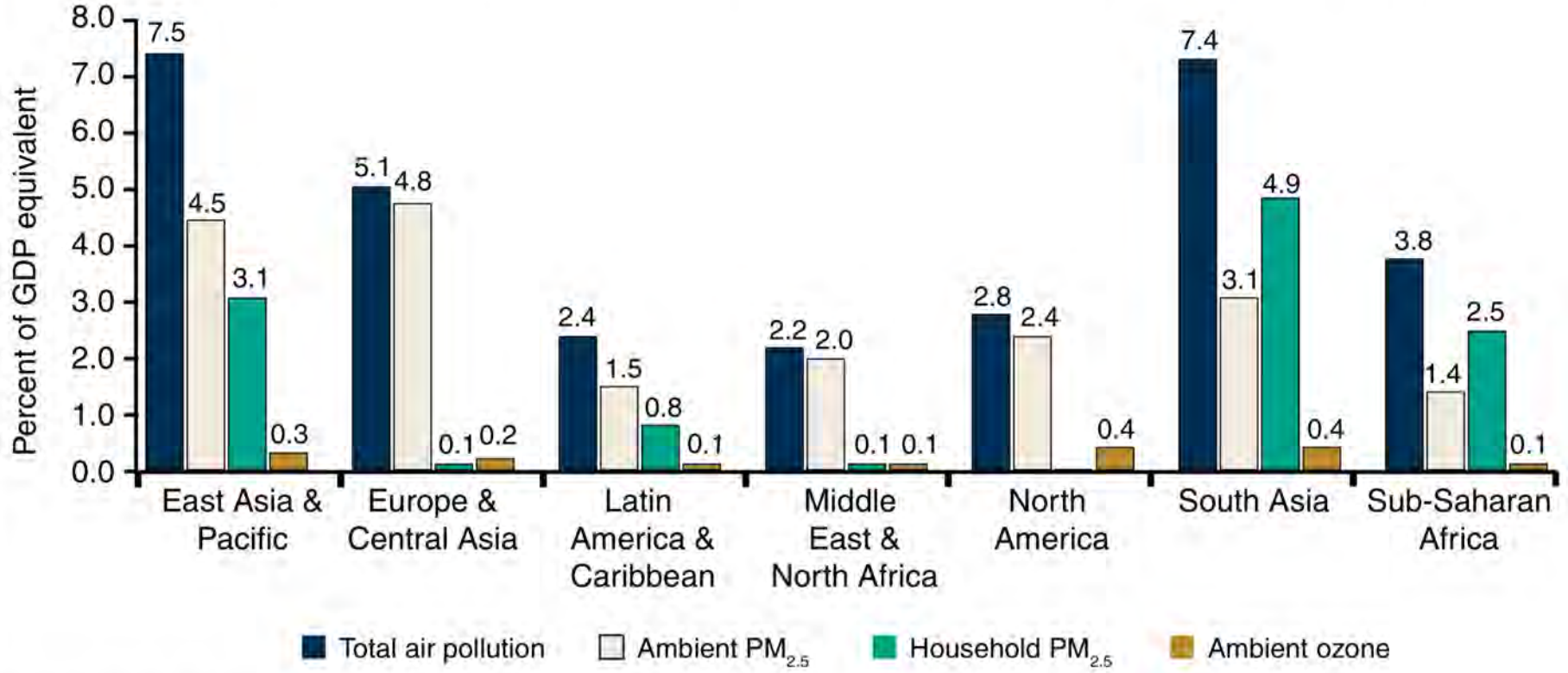
http://dx.doi.org/10.1016/S0140-6736(17)32345-0



Landrigan P, et al, Lancet Commission on Pollution and Health, *The Lancet*, Published online Oct 19, 2017
http://dx.doi.org/10.1016/S0140-6736(17)32345-0

Enormous costs associated with pollution

FIGURE 3.1 Welfare Losses Due to Air Pollution by Region, 2013

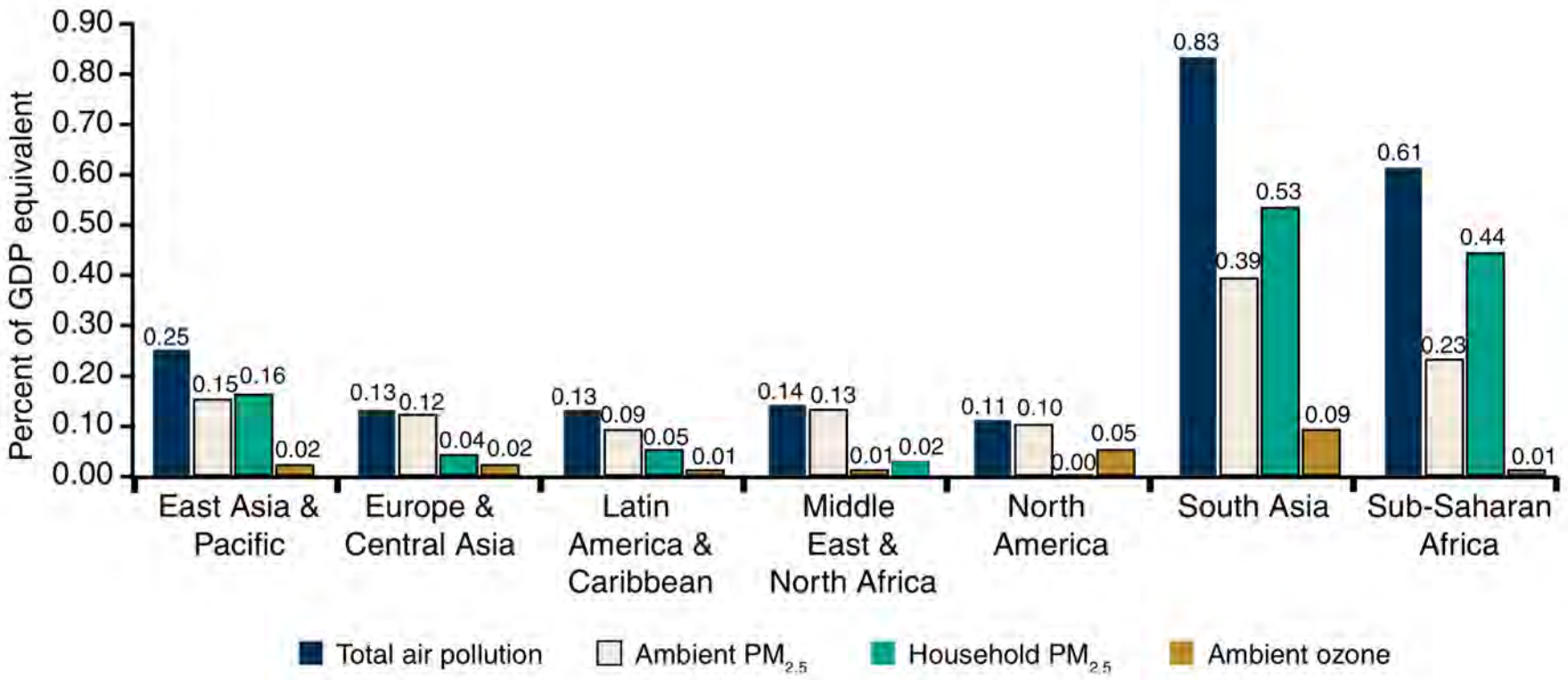


Sources: World Bank and IHME.

Note: Total air pollution damages include ambient $PM_{2.5}$, household $PM_{2.5}$, and ozone. GDP = gross domestic product.

Enormous costs associated with pollution

FIGURE 3.2 Forgone Labor Output Due to Air Pollution by Region, 2013

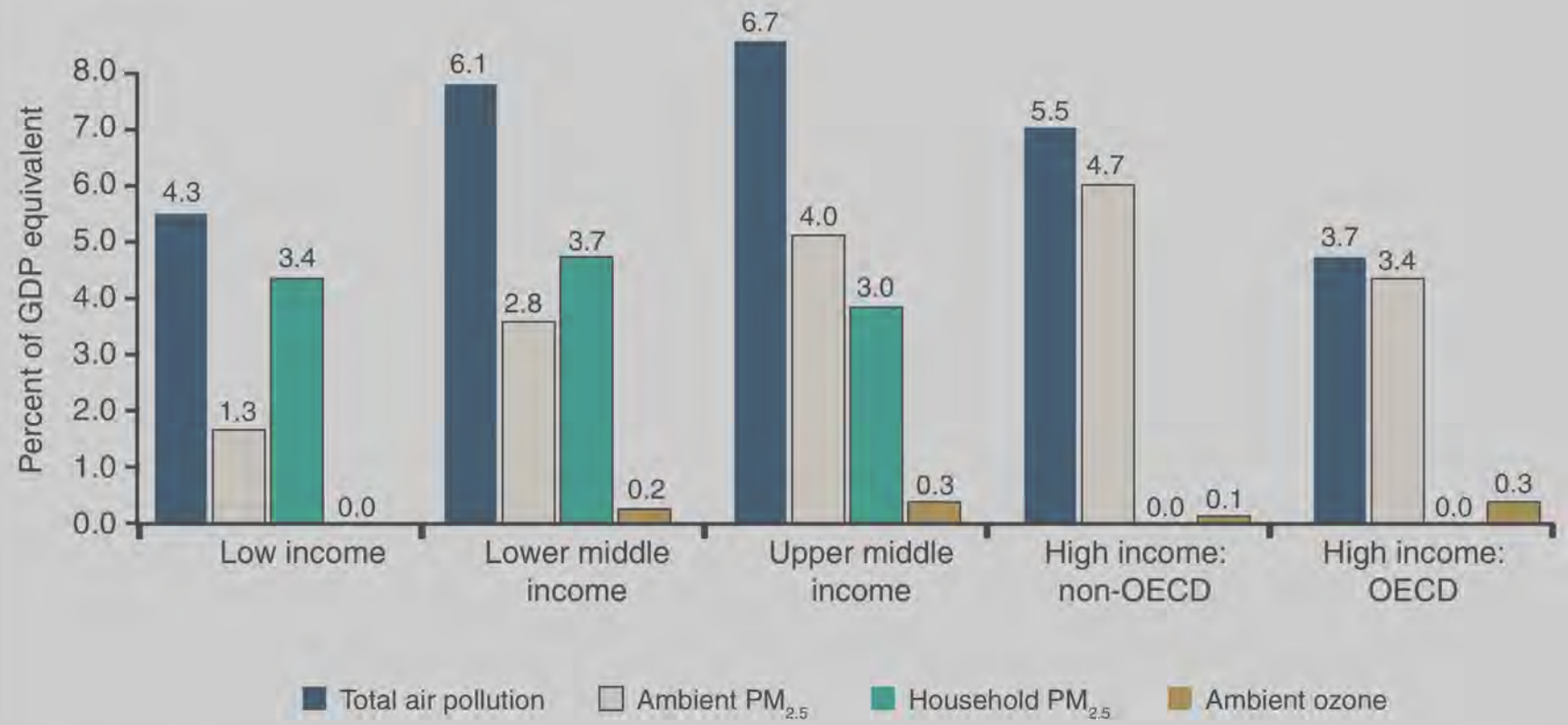


Sources: World Bank and IHME.

Note: Total air pollution damages include ambient $PM_{2.5}$, household $PM_{2.5}$, and ozone. GDP = gross domestic product.

Enormous costs associated with pollution

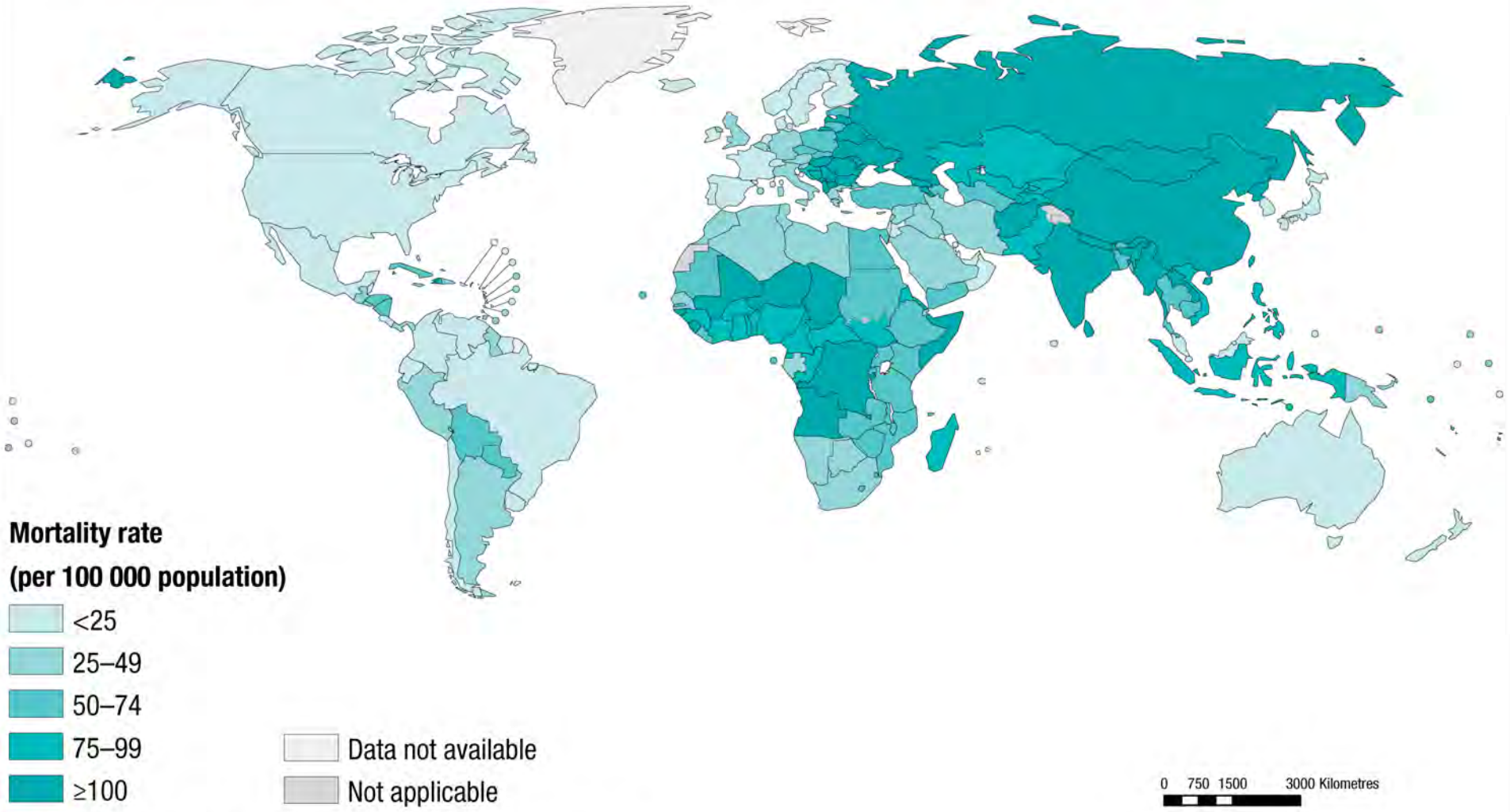
FIGURE 3.5 Welfare Losses Due to Air Pollution by Income Group, 2013



Sources: World Bank and IHME.

Note: Total air pollution damages include ambient $PM_{2.5}$, household $PM_{2.5}$, and ozone. GDP = gross domestic product; OECD = Organisation for Economic Co-operation and Development.

Mortality rate attributed to household and ambient air pollution, by WHO region, 2012*



* WHO Member States with a population of less than 250 000 in 2012 were not included in the analysis.

Data Source: World Health Organization
Map production: Information Evidence and Research (IER)
World Health Organization

World Health Organization

What’s this “household air pollution”?

By the numbers

~3 billion people use solid fuels for cooking




While the proportion of the population using these fuels is decreasing, the absolute number has remained relatively constant over the past 30 years

San Lorenzo
Guatemala

KINTAMPO
Ghana


KARGIAKH
Ladakh, India

Household Air Pollution

Results in average exposures higher than recommended guidelines from WHO and US EPA . Exposures are often higher than those of even very polluted cities.

Exposures are typically quantified for particulate matter and carbon monoxide, but hundreds of other compounds have been identified, including carcinogens.

Women and children are most impacted.

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(why we care)

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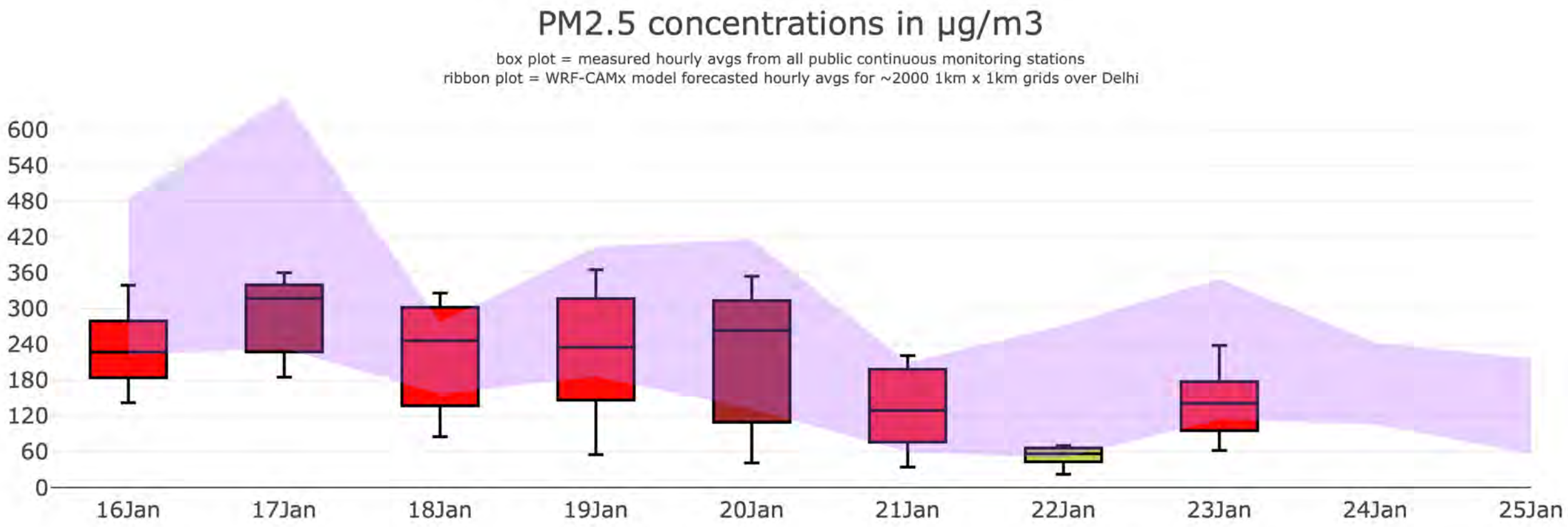
Air quality in and around Berkeley on Tuesday

Parameters	Tuesday, January 22, 2019																							
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
PM2.5	3 -3	3 -1	3 -2	1 -4	3 -2	5 +0	3 -6	10 +2	8 -1	9 +0	6 +0	6 -1	7 +2	7 +3	7 +3	6 +3	5 +3	6 +3	5 +0	13 +4	17 +7	19 +12	13 +11	14 +10
Nitric Oxide (NO)	2 +0	3 -1		6 +2	18 +11	23 +7	39 +17	41 +22	28 +0							21 +15	25 +8	30 +16	14 +3	36 +27	35 +27	27 +27	58 +57	41 +40
Oxides of Nitrogen (NOx)	14 +0	15 +6		19 +11	44 +28	49 +16	71 +27	74 +24	59 -1							40 +23	50 +11	59 +27	45 +17	69 +36	68 +38	58 +51	90 +81	69 +62
Ozone (O3)	16 +0	16 -21		18 -20	9 -25	6 -20	2 -19	2 -11	5 -9							20 -13	14 -7	8 -13	1 -18	0 -10	0 -10	0 -21	0 -20	0 -21
Nitrogen Dioxide (NO2)	12 +0	12 +7		13 +8	26 +17	26 +9	32 +10	33 +2	31 -1							19 +9	25 +3	28 +11	32 +15	33 +9	33 +11	31 +24	32 +24	28 +22
Black Carbon (BC)	0.2 +0	0.2 +0	0.1 +0	0.3 +0	0.7 +0	1.0 +0	1.5 +0	1.6 +1	1.4 +0	1.4 +0	1.6 +1	1.5 +0	1.2 +0	1.3 +0	1.6 +1	1.4 +1	1.2 +0	1.3 +1	1.1 +0	2.0 +1	1.9 +1	1.4 +1	1.8 +2	1.2 +1

Air quality in and around Delhi this week



India 24-hr outdoor standard is 60; WHO 24-hr outdoor guideline is 25; box color corresponds to India AQI code
View the modeled forecasts, maps, time series, and source contributions @ http://www.delhiairquality.info

Air pollution and air quality

- What is air pollution? How do we define these pollutants and who decides on ‘safe’ levels of exposure? How?
- When did we start thinking about air quality?
- What are the scales and types of air quality?
- What are some common pollutants? What is in the air and what can we realistically measure and regulate?

http://www.who.int/topics/air_pollution/en/

Air pollution

Air pollution is contamination of the indoor or outdoor environment by any chemical, physical or biological agent that modifies the natural characteristics of the atmosphere. Household combustion devices, motor vehicles, industrial facilities and forest fires are common sources of air pollution. Pollutants of major public health concern include particulate matter, carbon monoxide, ozone, nitrogen dioxide and sulfur dioxide. Outdoor and indoor air pollution cause respiratory and other diseases, which can be fatal.

http://www.who.int/topics/air_pollution/en/

Air pollution

Air pollution is a mixture of natural and man-made substances in the air we breathe. It is typically separated into two categories: outdoor air pollution and indoor air pollution. **Outdoor air pollution** involves exposures that take place outside of the built environment. **Indoor air pollution** involves exposures to particulates, carbon oxides, and other pollutants carried by indoor air or dust.

https://www.niehs.nih.gov/health/topics/agents/air-pollution/index.cfm

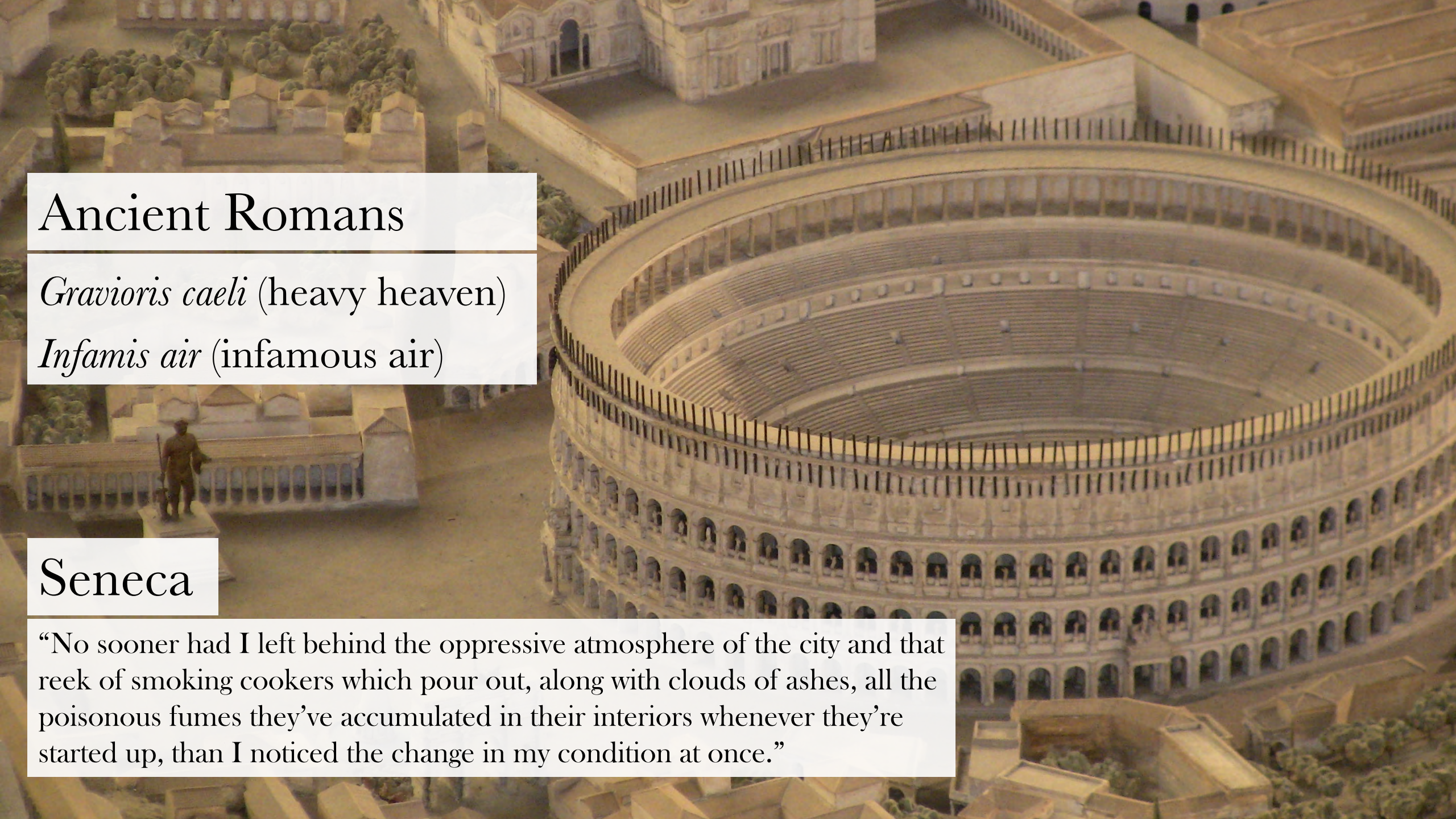
Air pollution

Air becomes polluted when it is changed by the introduction of… substances or energy forms so that the locally, regionally, globally altered atmosphere poses harm to humans, biological systems, materials, or the atmosphere itself

Godish, *Air Quality*

Air pollution historical episodes

http://www.nytimes.com/slideshow/2015/09/23/upshot/a-look-back-at-the-smog/s/23UP-Pollution-ss-slide-2827.html



Ancient Romans

Gravioris caeli (heavy heaven)

Infamis air (infamous air)

Seneca

"No sooner had I left behind the oppressive atmosphere of the city and that reek of smoking cookers which pour out, along with clouds of ashes, all the poisonous fumes they've accumulated in their interiors whenever they're started up, than I noticed the change in my condition at once."

The Kings Edward & their war on coal

Edward I

Edward II

Population growth in London put extensive pressure on forests, leading to the use of abundant coal for fuel

Edward the I implemented a coal ban, which was ignored, revised to include fines, ignored again, and revised to include the death penalty, and ignored again. Edward II tried again, with torture as punishment. No success.

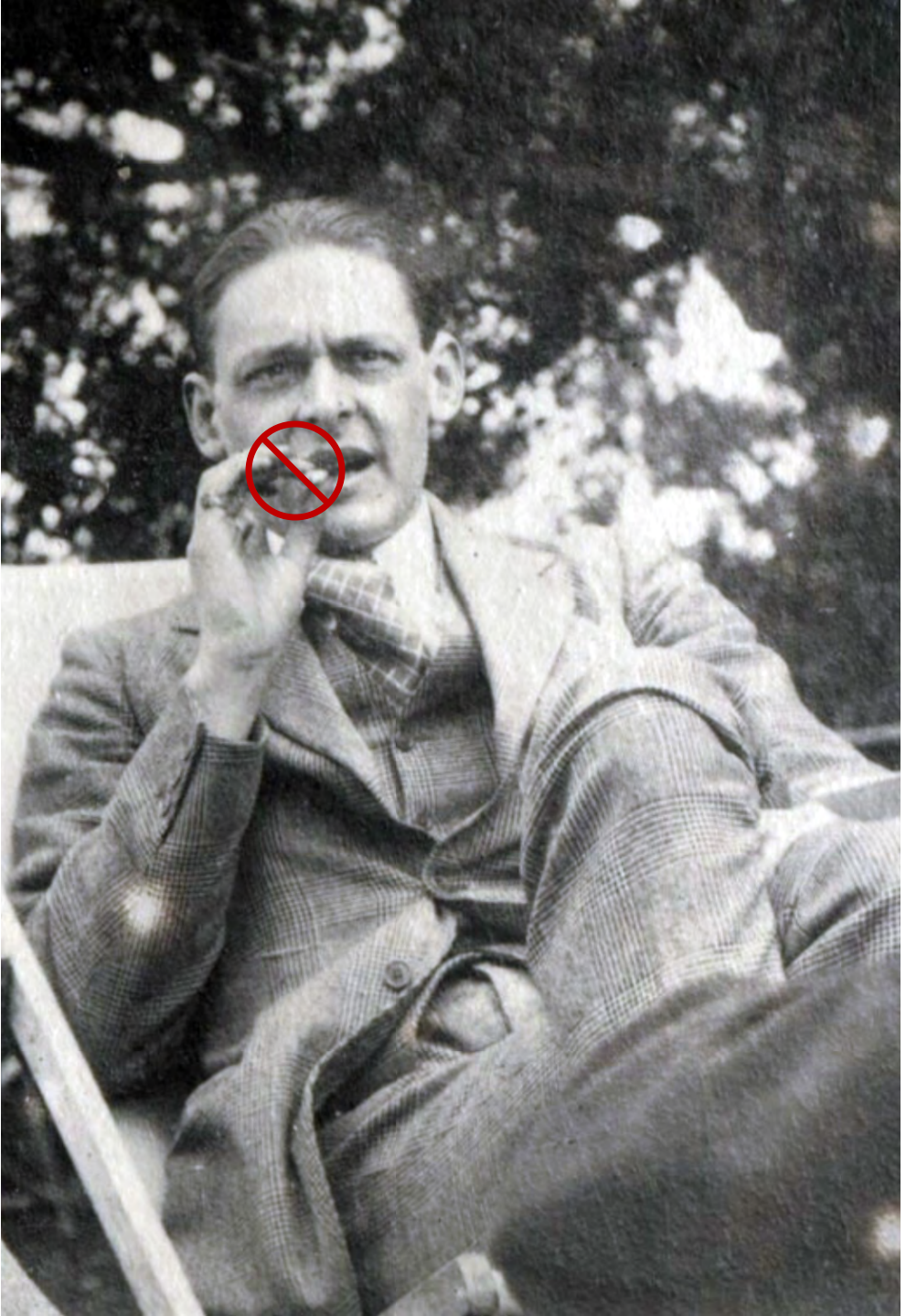
https://www.epa.gov/history/topics/perspect/london.htm (retrieved from archive.org)

Monet and the London Fogs

“Paintings from Monet’s London series have been analysed for the quantitative [info] they contain. The results are consistent with the known period Monet was in London… and may potentially be considered as a proxy indicator for the Victorian smogs and atmospheric states they depict.”

Paintings made in and around 1900

Baker and Thornes, doi:10.1098/rspa.2006.1754, 2006



T.S. Eliot

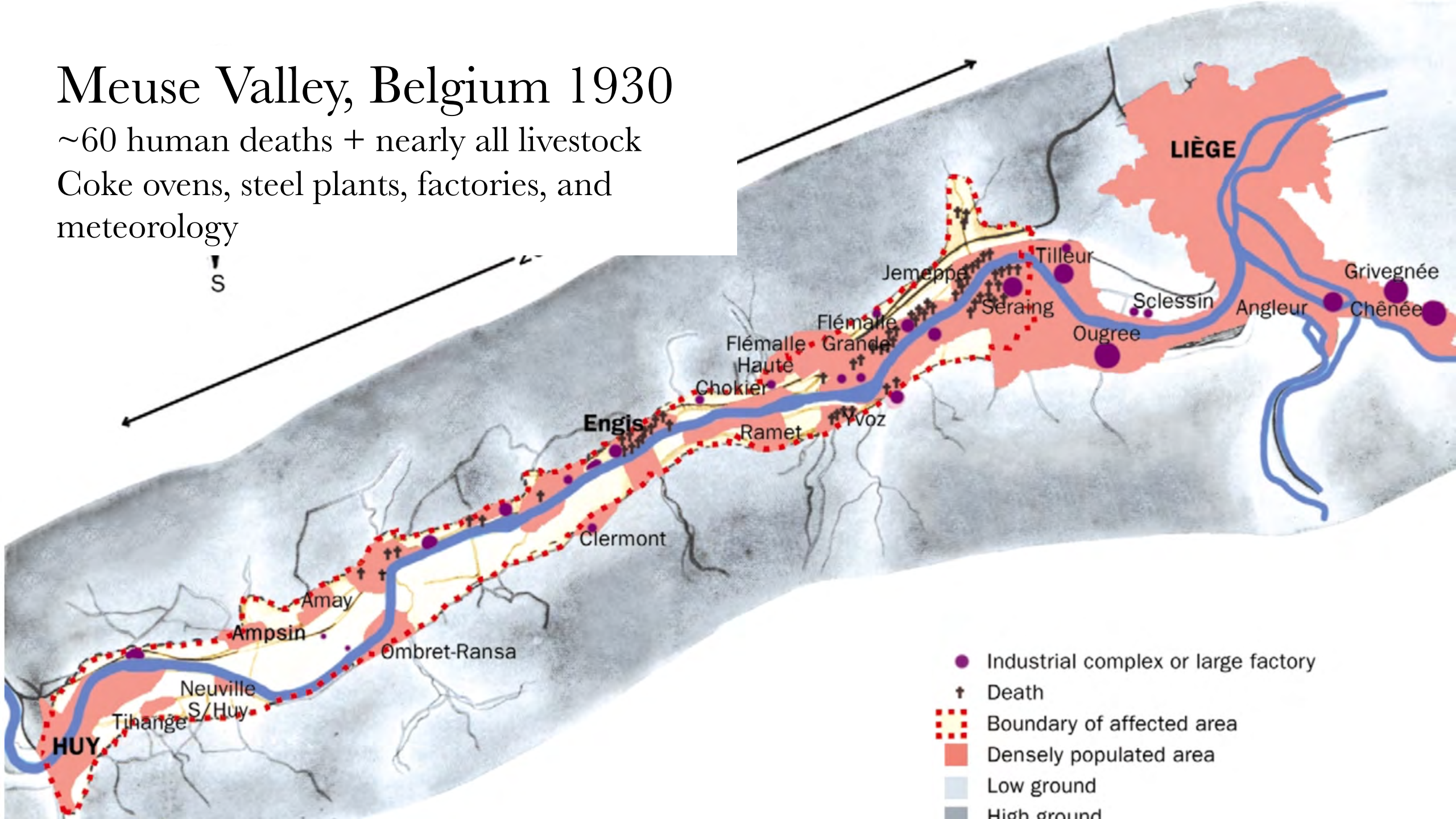
The Love Song of J. Alfred Prufrock (1917)

The yellow fog that rubs its back upon the window-panes,
The yellow smoke that rubs its muzzle on the window-panes
Licked its tongue into the corners of the evening,
Lingered upon the pools that stand in drains,
Let fall upon its back the soot that falls from chimneys,
Slipped by the terrace, made a sudden leap,
And seeing that it was a soft October night,
Curled once about the house, and fell asleep.

Meuse Valley, Belgium 1930

~60 human deaths + nearly all livestock

Coke ovens, steel plants, factories, and meteorology



Donora, PA 1948

Similar meteorology, steel mill and zinc smelters –
17 deaths, 2000 hospitalized Resulted in first state and
federal rules trying to control air pollution

London

The “Great Smog” of 1952

- At least 4000 deaths, though perhaps as many as 12000
- Mortality remained elevated for months after the event
- Resulted in substantial recognition of the problem and passing of legislation
- Established “smokeless zones”
- Estimated at 3000 $\mu g/m^3$ of PM_{10}

PATHE NEWS

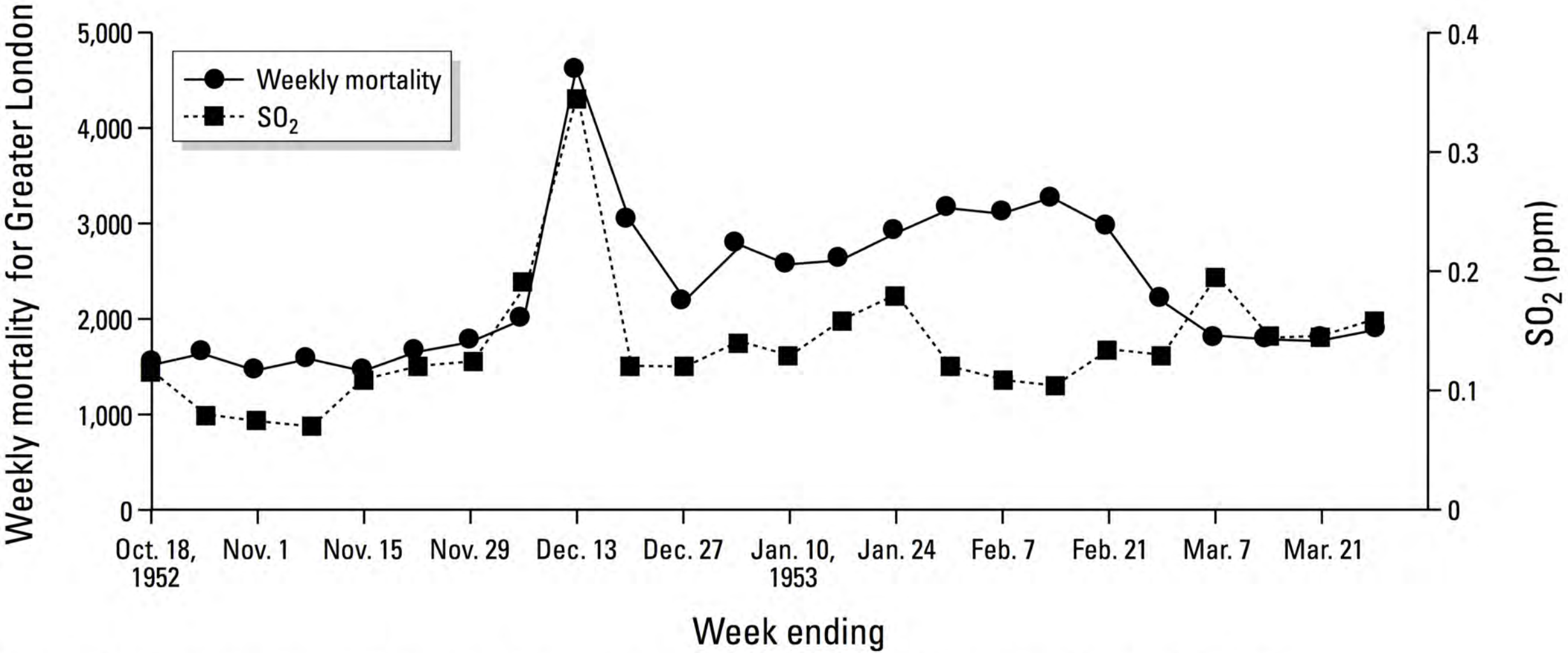


Figure 1. Approximate weekly mortality and SO_2 concentrations for Greater London, 1952–1953.

Bell and Davis, 2001

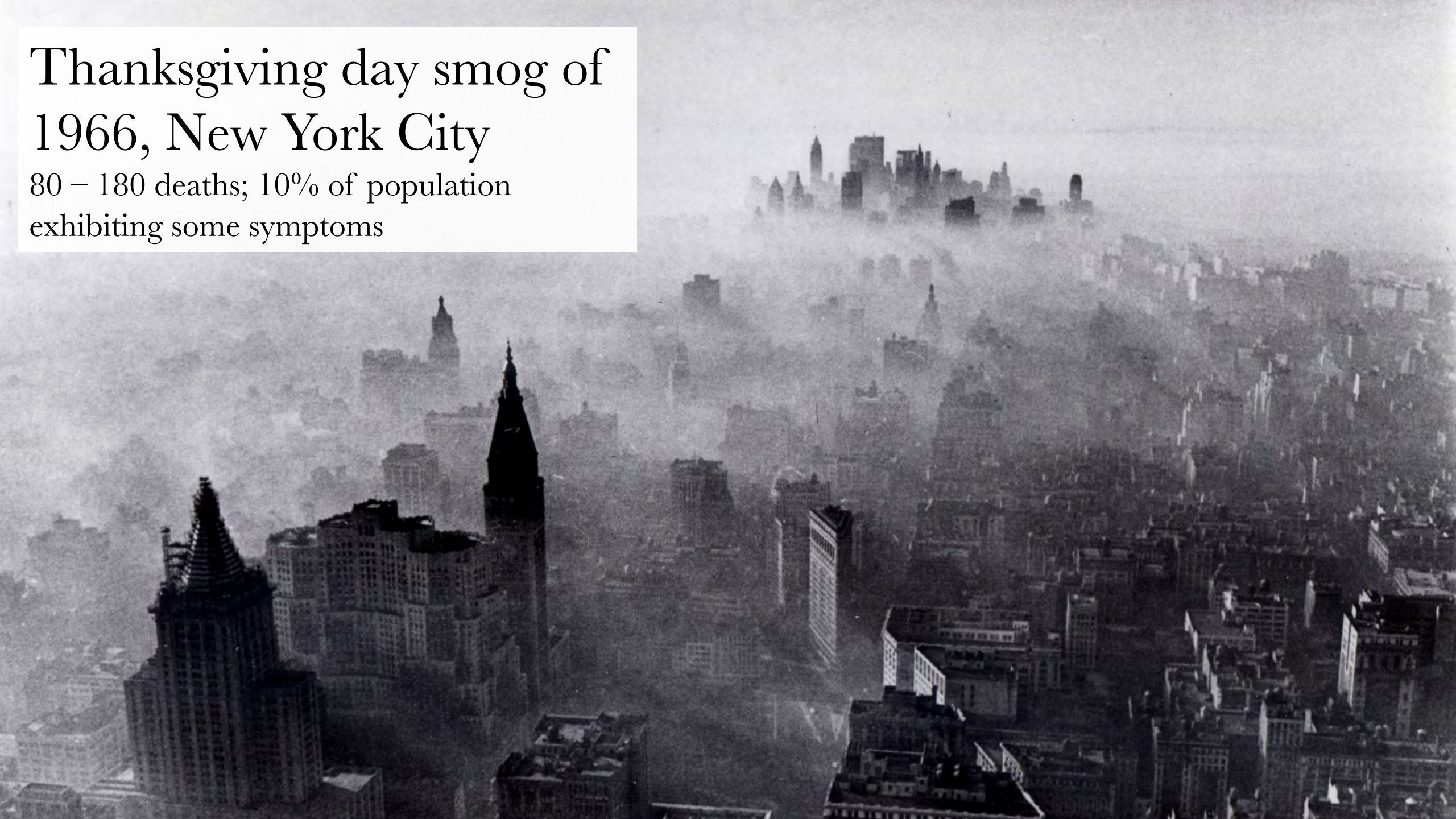
How do we study exposures at 'normal' levels? Are there levels that are safe?

Figure 1. Approximate weekly mortality and SO_2 concentrations for Greater London, 1952–1953.

Bell and Davis, 2001

Thanksgiving day smog of 1966, New York City

80 – 180 deaths; 10% of population exhibiting some symptoms



Dozens of more recent examples

Beijing, Delhi, Riyadh, Peshawar


While urban air pollution is an old problem, HAP is older and persistent

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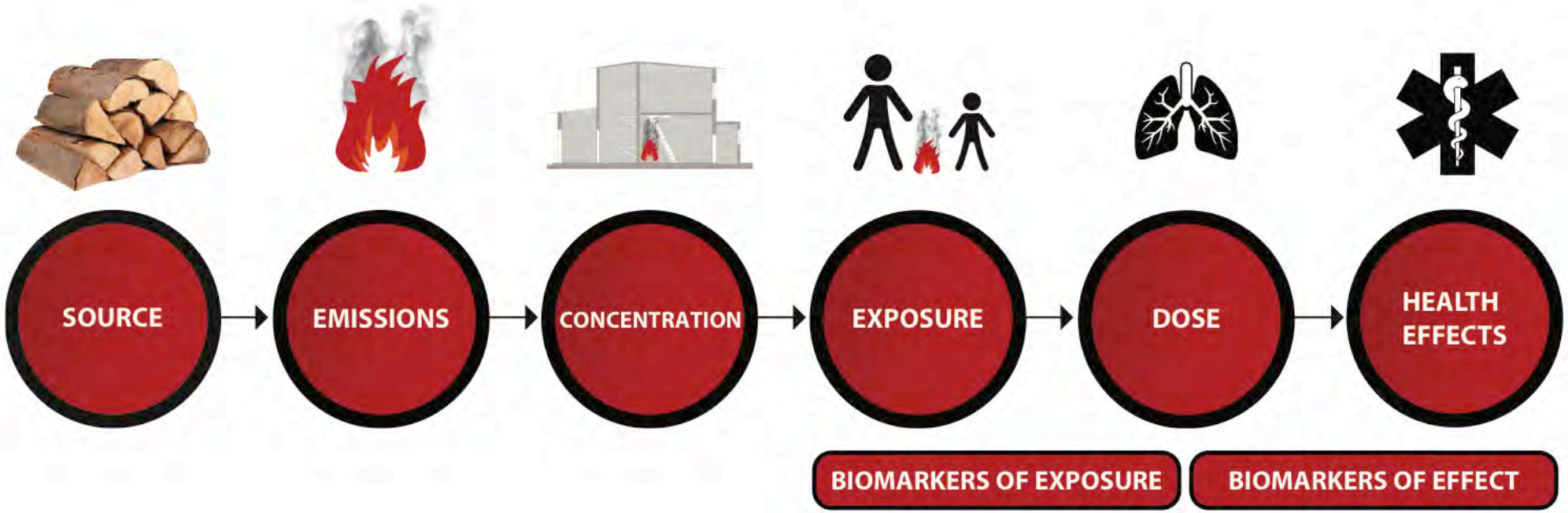
Environmental Health Pathway



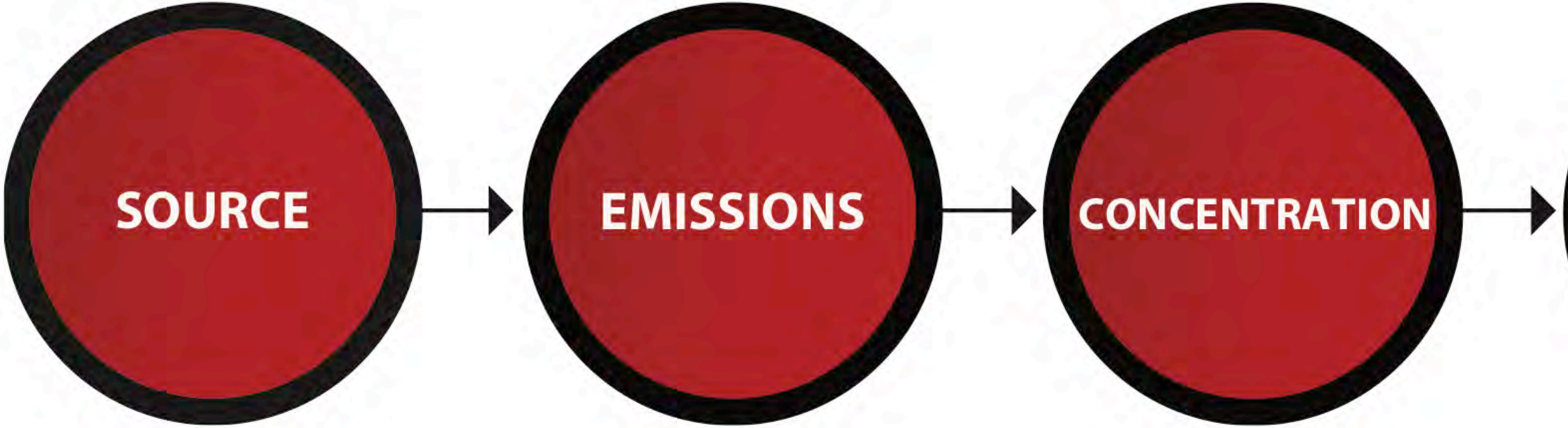
Instructional for conceptualizing environmental harms

Exists in many different forms depending on the specific discipline

Same basic concepts

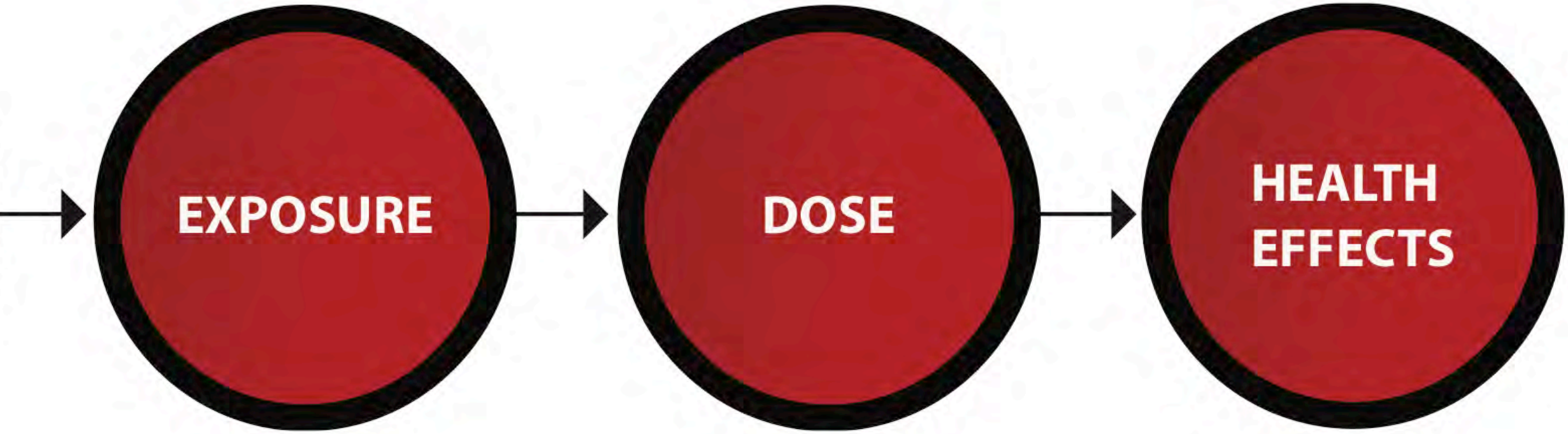
Linear approximation not necessarily accurate

Environmental Health Pathway



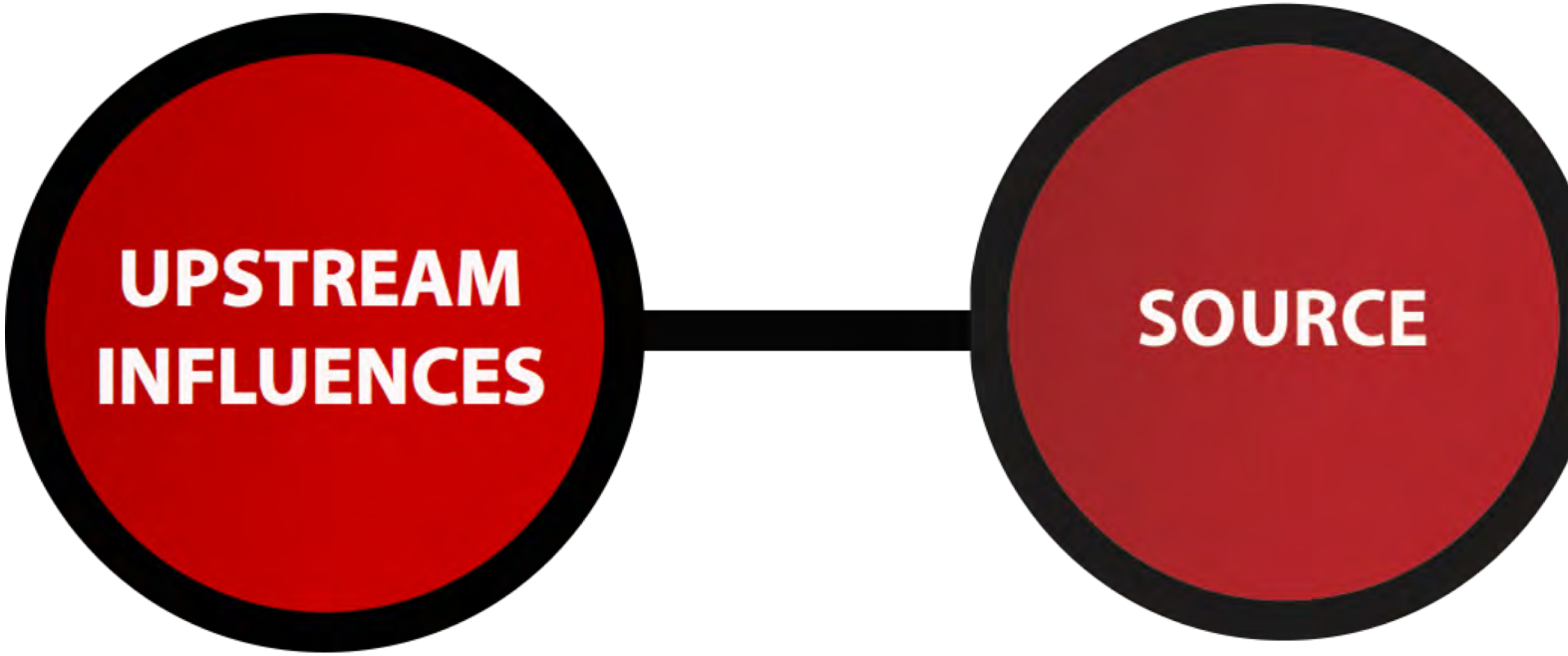
Environmental Components

Environmental Health Pathway



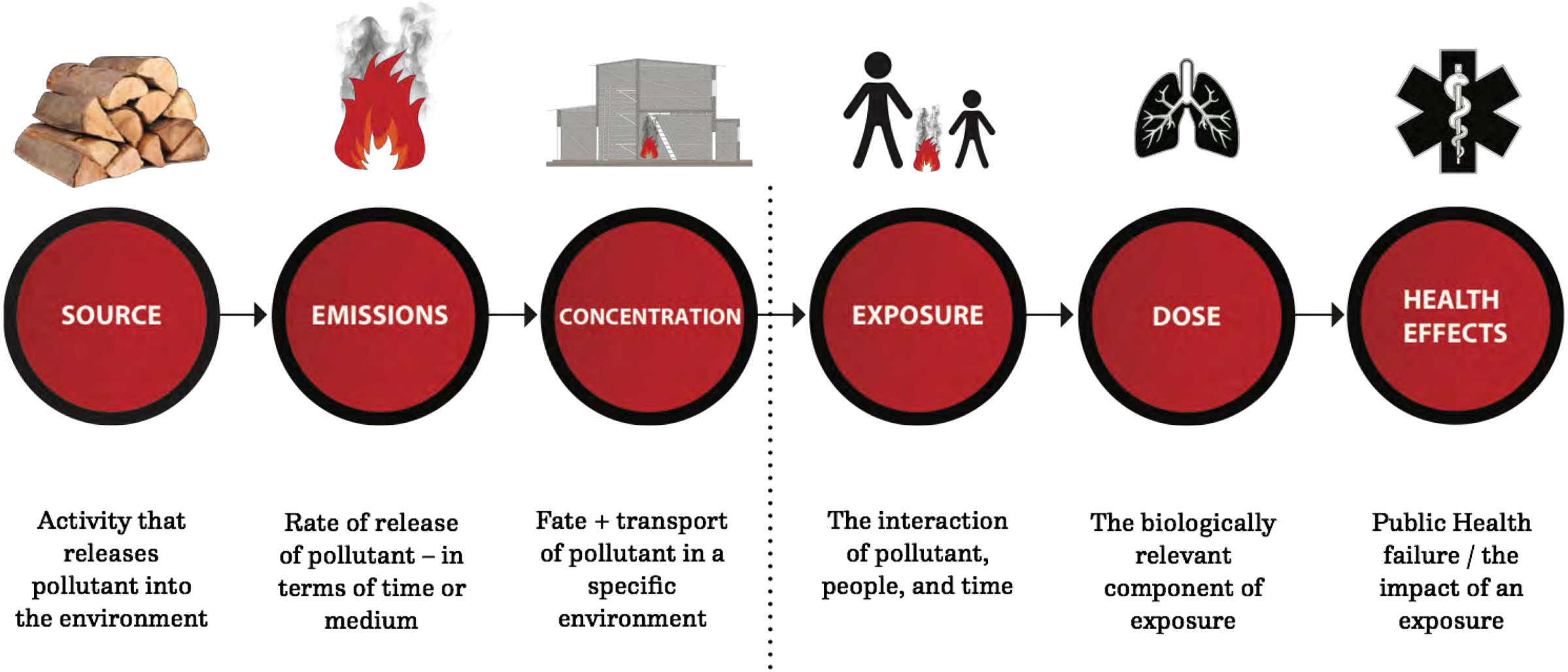
Organism-level components

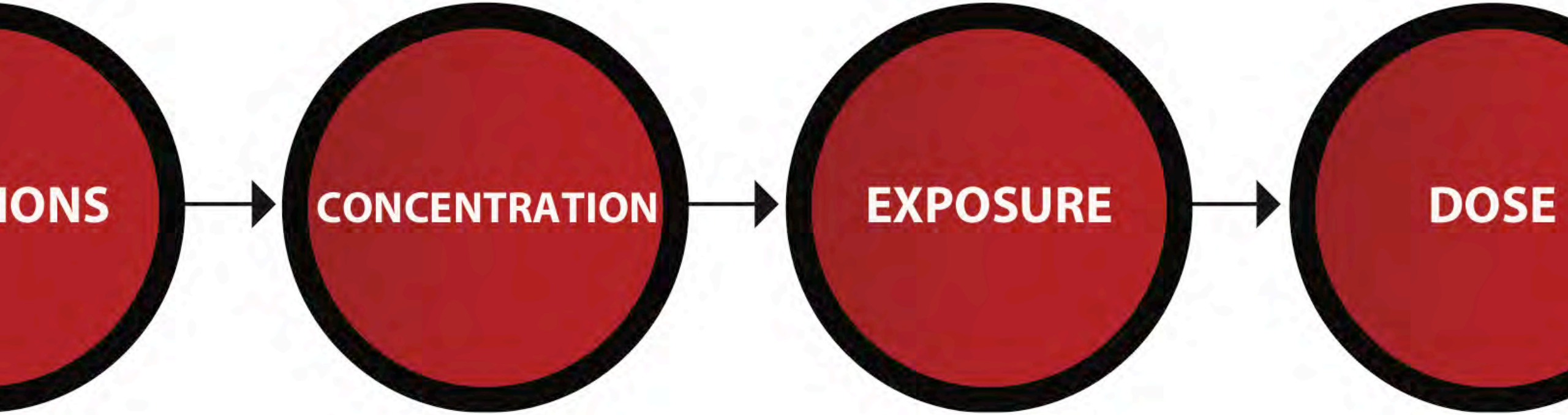
Environmental Health Pathway



Socioeconomic + Behavioral Factors

Environmental Health Pathway





Describing pollutant levels

Mass per volume air

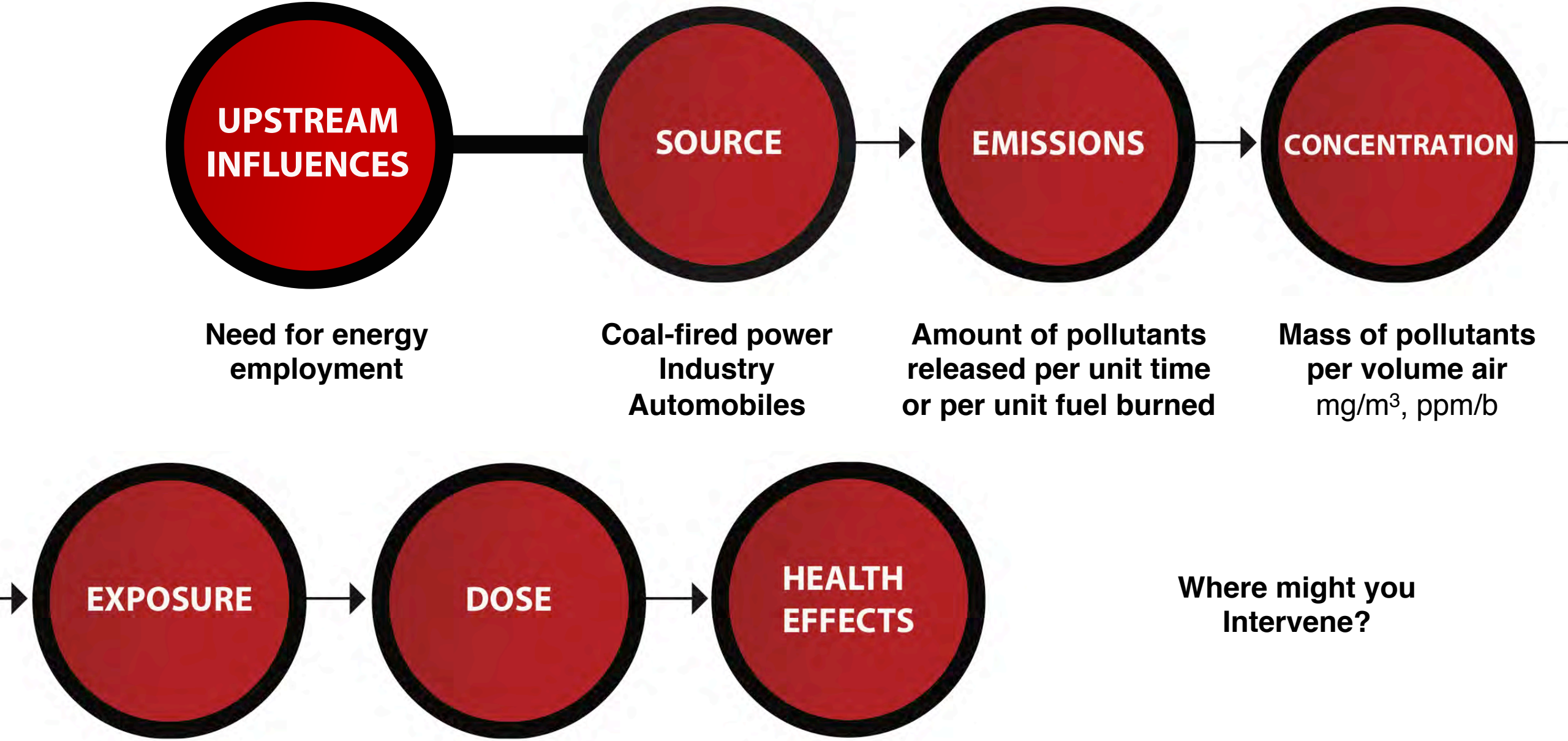
- ng, ug, mg per cubic meter of air (mg/m^3)
- commonly seen for particles and some gasses

Parts per million, billion, or trillion

- Volume of pollutant per million volumes of air
- Often expressed as ppmv, ppbv

Thanksgiving Day Smog

New York City - 1966



Where might you Intervene?

?

Any questions?

What causes an air pollutant to be noticed?

- Detectable presence in the atmosphere
  - Measurable / quantifiable
  - Sometimes qualitatively observable (Monet, Delhi)

- Toxicity

- Environmental effects

- Media coverage due to visibility, hospitalizations, etc

http://www.who.int/topics/air_pollution/en/

Sources of Air Pollution

Natural Sources

Anthropogenic Sources

Stationary

Mobile

Anthropogenic Sources

Stationary

- Point sources, like stacks or cookstoves
- Area sources, like pesticide applications
- Fugitive sources, like industrial leaks or wind-exposed plots

Mobile sources

- Cars, trucks, buses
- Ships
- Airplanes

Distribution of Pollutants

- Pollutant distributions are impacted by their sources and background concentrations in the atmosphere

- Pollutants in the atmosphere undergo changes due to interaction with other chemical species and with sunlight

- Removal mechanisms
  - chemical reactions
  - Physical removal, like deposition

- Dispersion due to wind (outdoors) and/or ventilation (indoors)

Temporal and Spatial Considerations

- Pollutants exist at varying temporal and spatial scales, depending on their residence time in the atmosphere

- Spatial
  - Microscale (0 – 100 m)
  - Urban (1 – 100 km)
  - Regional (10 – 1000s km)
  - Global (> 5000 km)

- Temporal lifetime can span between seconds to years

Temporal & Spatial Considerations

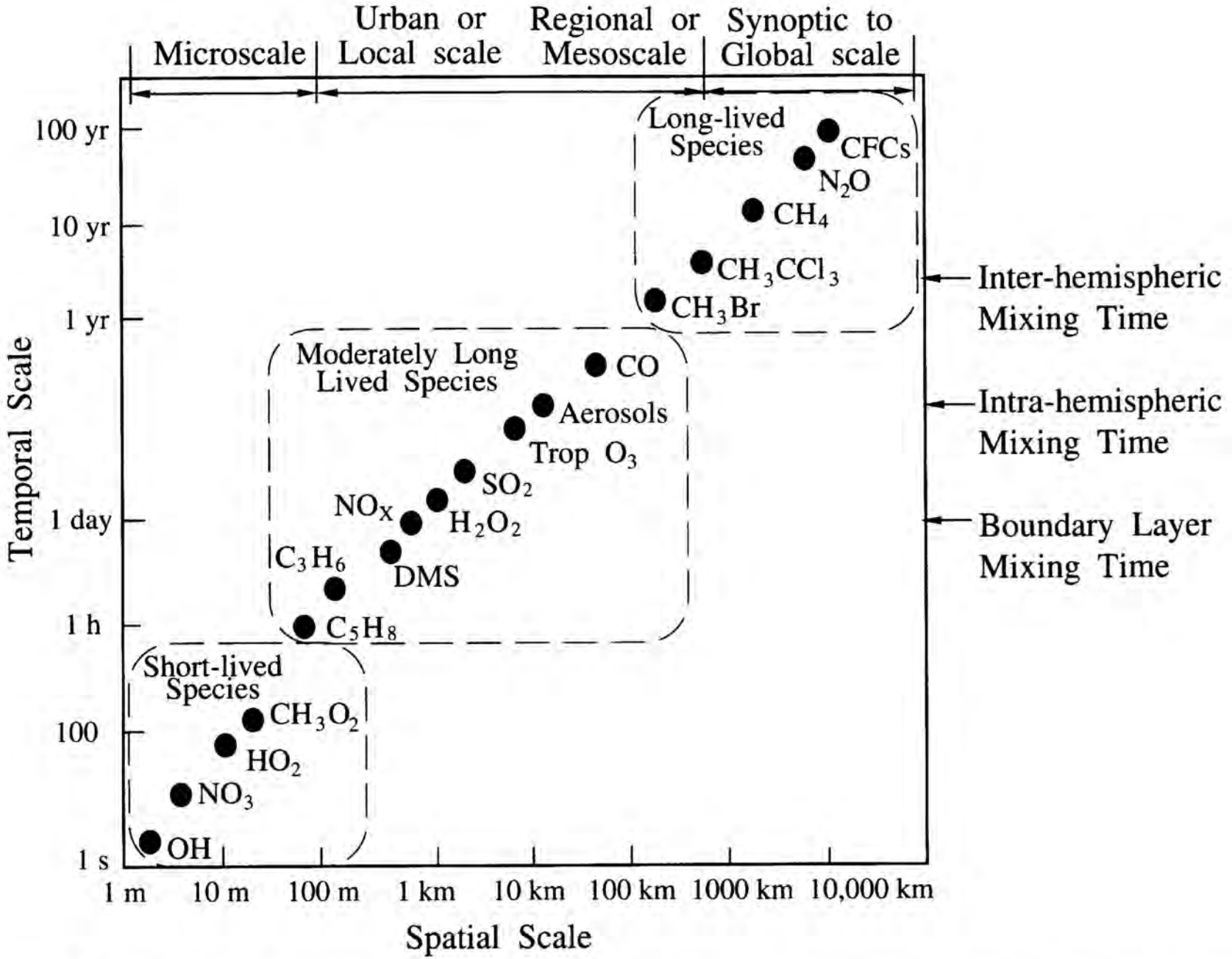
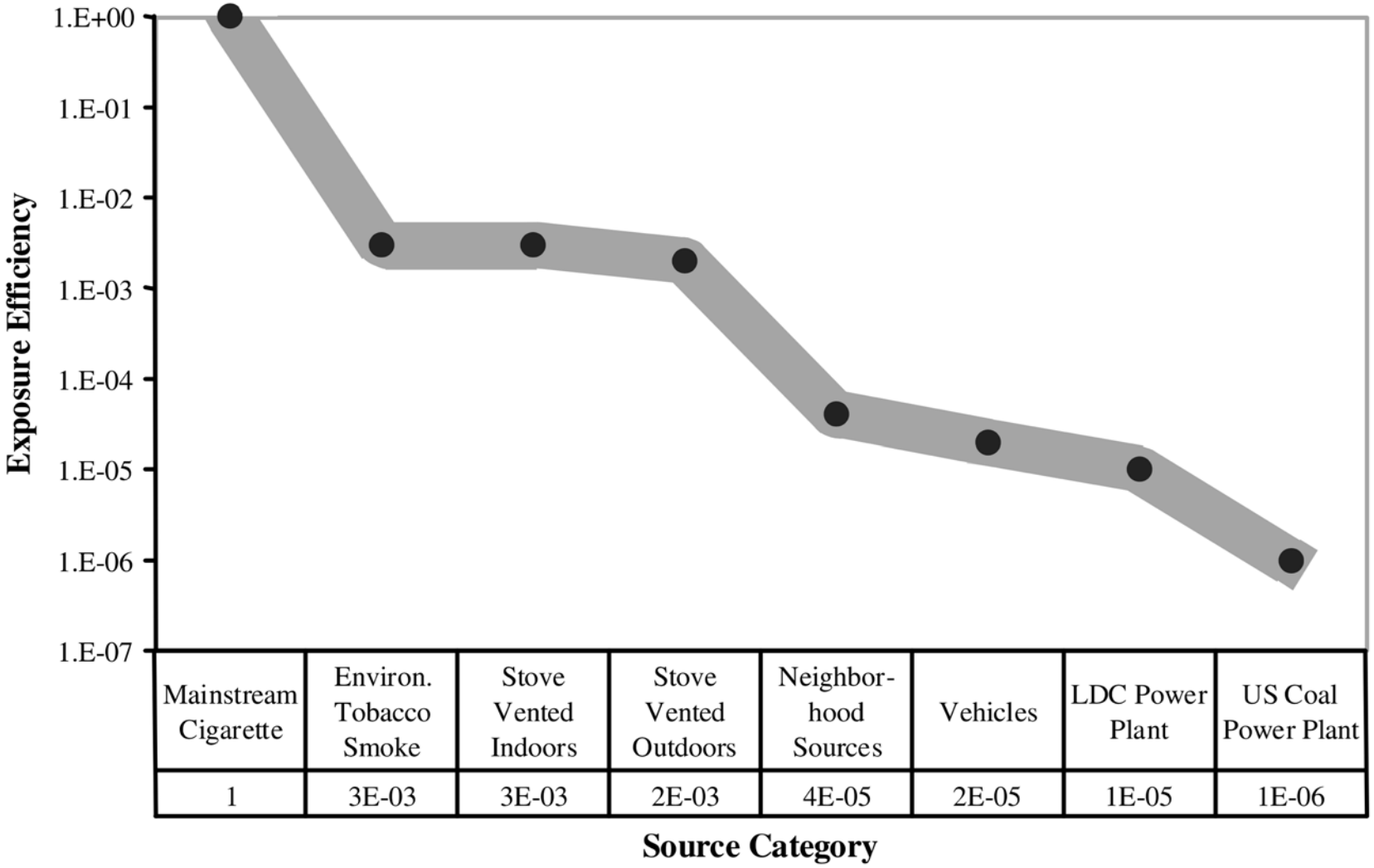


FIGURE 1.4 Spatial and temporal scales of variability for atmospheric constituents.

Seinfeld and Pandis

Relating Sources and Exposure

Intake Fraction or Exposure Efficiency

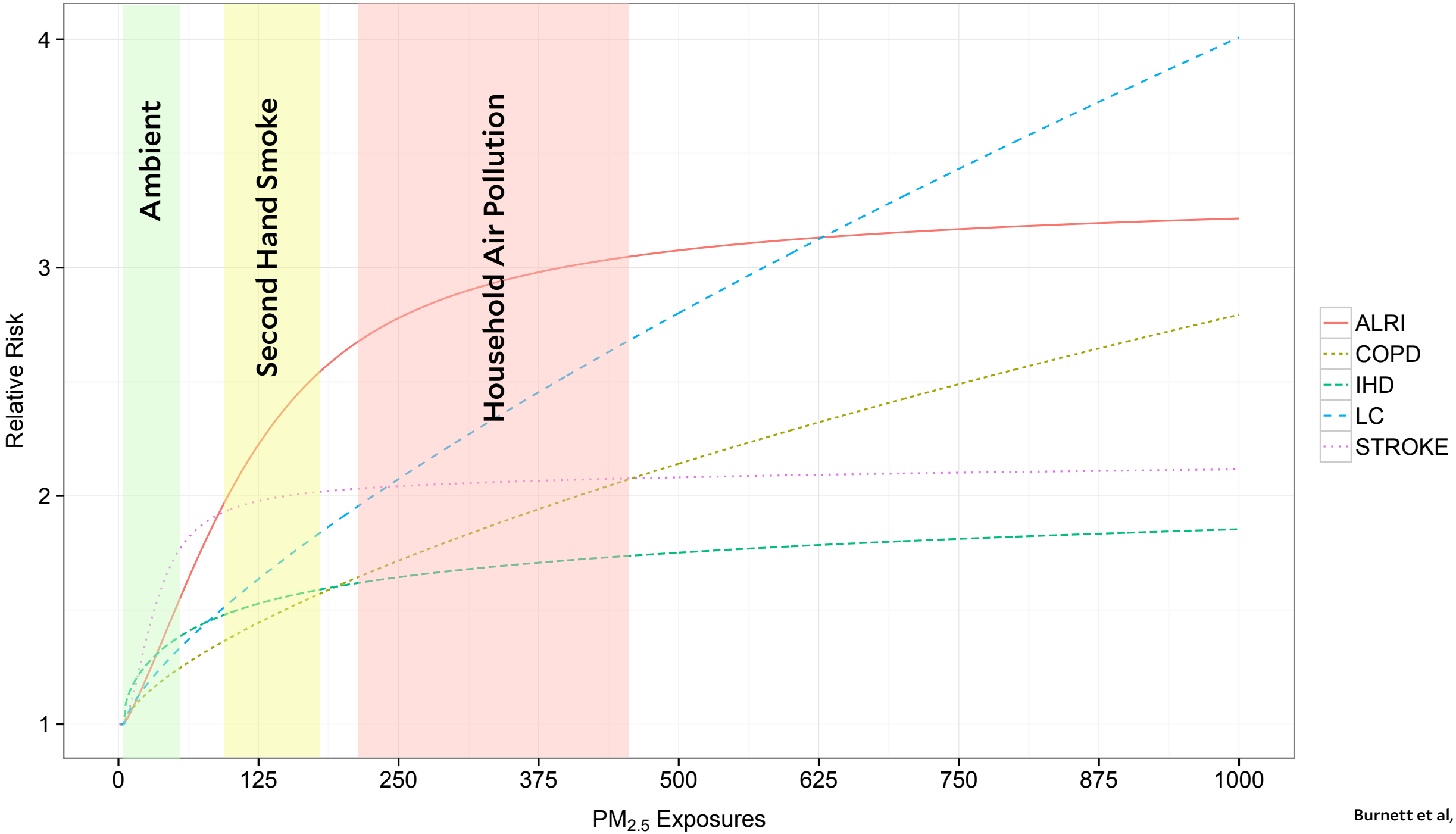


Mainstream Cigarette	Environ. Tobacco Smoke	Stove Vented Indoors	Stove Vented Outdoors	Neighbor-hood Sources	Vehicles	LDC Power Plant	US Coal Power Plant
1	3E-03	3E-03	2E-03	4E-05	2E-05	1E-05	1E-06

The fraction of material released from a source that is inhaled

Air Pollution Trends

- New evidence indicates that there may be no safe level for exposure to PM2.5

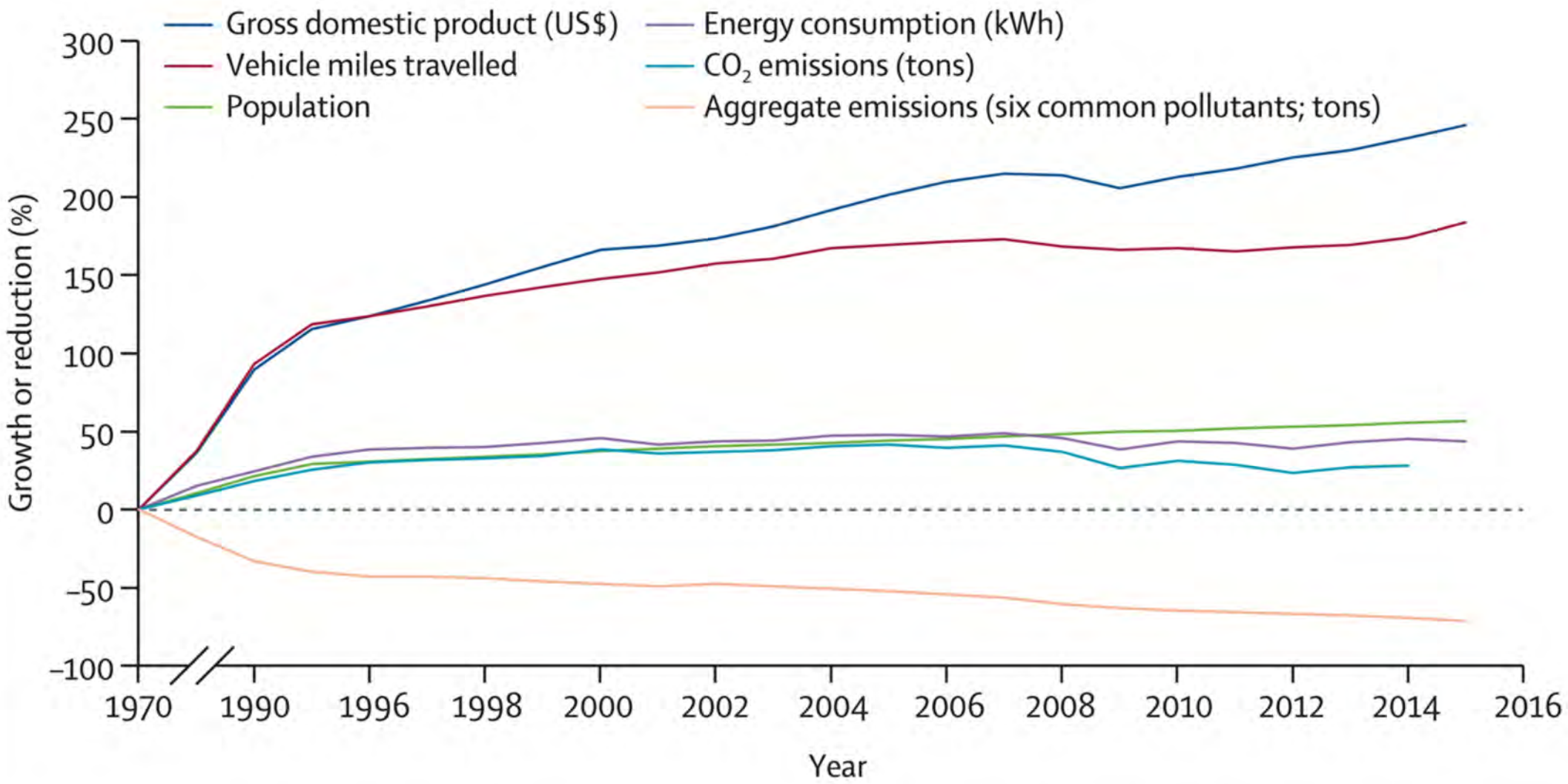


Burnett et al, 2014

Air Pollution Trends

- New evidence indicates that there may be no safe level for exposure to $PM_{2.5}$
- In the developed world, for the most part, air quality is improving through a combination of legislation and technological development

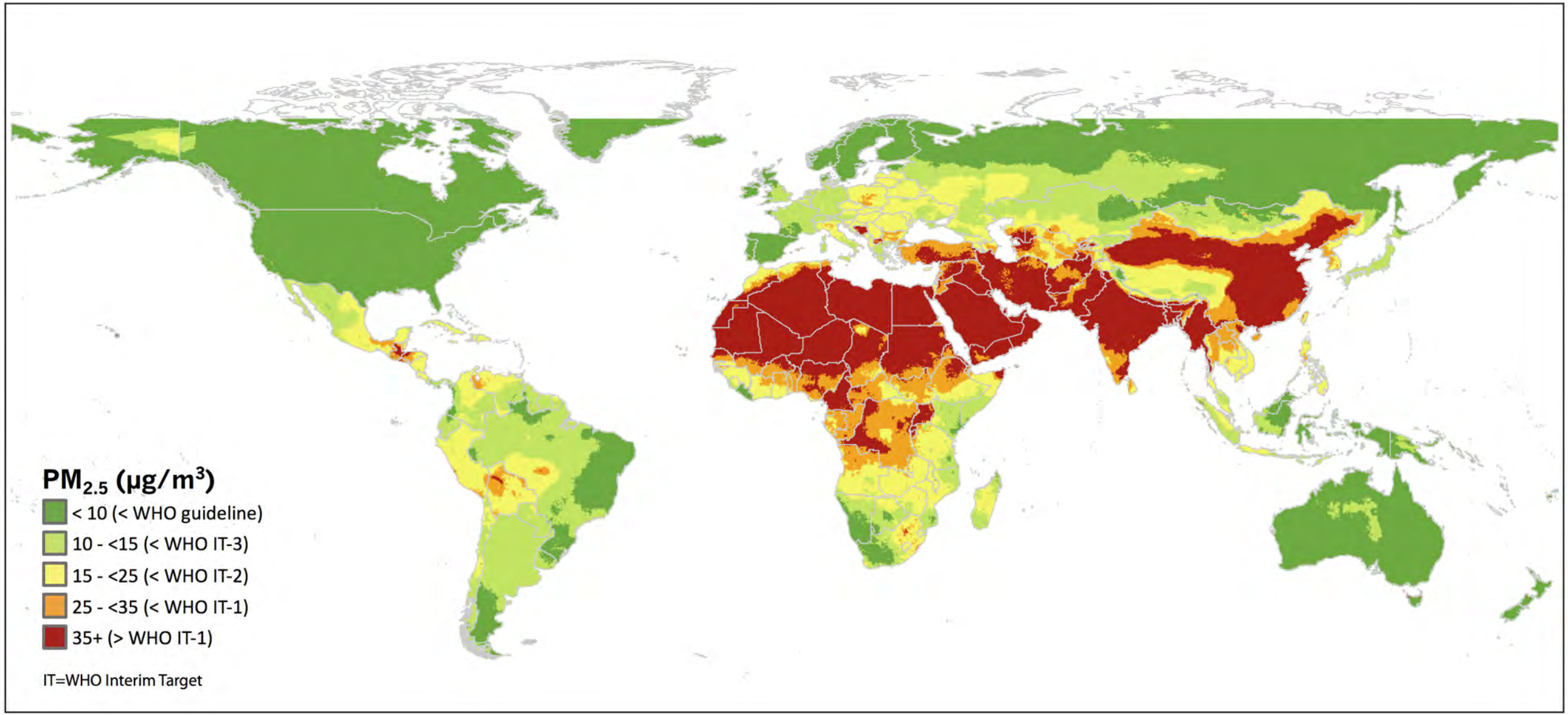
Air Pollution Trends



Landrigan P, et al, Lancet Commission on Pollution and Health, *The Lancet*, Published online Oct 19, 2017
http://dx.doi.org/10.1016/S0140-6736(17)32345-0

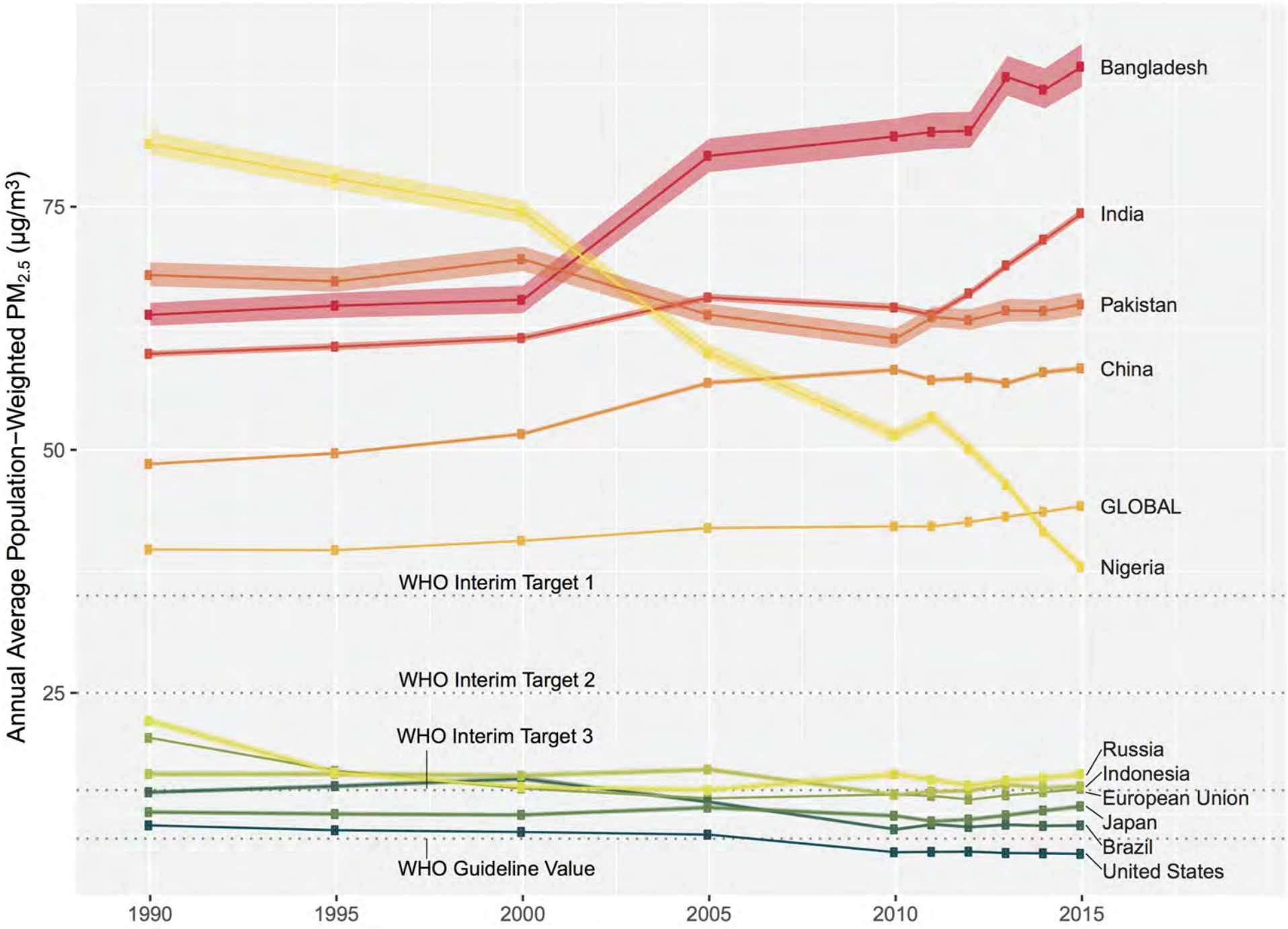
Air Pollution Trends

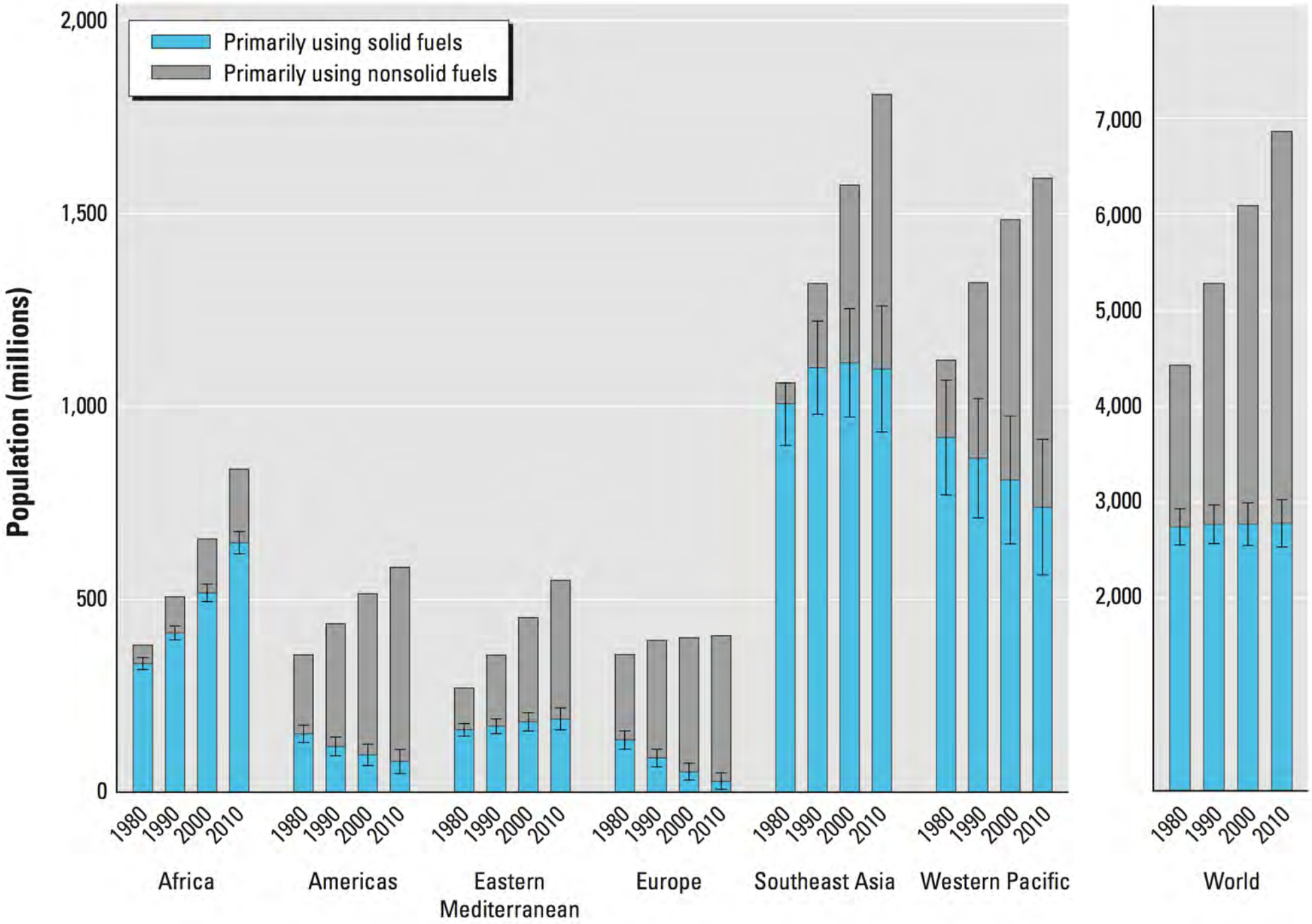
- New evidence indicates that there may be no safe level for exposure to $PM_{2.5}$
- In the developed world, for the most part, air quality is improving through a combination of legislation and technological development
- The story is different in the developing world, where air quality is worsening; in many regions, solid fuel use is constant and in some areas it is increasing



Half the world's population exceeds WHO's IT-1

State of Global Air 2017


Annual Average Population−Weighted $PM_{2.5}$ (µg/m³)
75
50
25
1990
1995
2000
2005
2010
2015
Bangladesh
India
Pakistan
China
GLOBAL
Nigeria
WHO Interim Target 1
WHO Interim Target 2
WHO Interim Target 3
WHO Guideline Value
Russia
Indonesia
European Union
Japan
Brazil
United States



Bonjour et al 2013

Air Pollution Trends

- New evidence indicates that there may be no safe level for exposure to $PM_{2.5}$
- In the developed world, for the most part, air quality is improving through a combination of legislation and technological development
- The story is different in the developing world, where air quality is worsening; in many regions, solid fuel use is constant and in some areas it is increasing
- Innovative, inter-ministerial policy work across the globe seeks ways to mitigate this burden

Global burden of air pollution

(why we care)

What is air pollution?

(and a lil'history)

Air pollution fundamentals

Perspectives from India and China