Introduction to Global Environmental Health

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Types of environmental risks

- Chemical
  - Air pollution, pesticides, plasticizers (e.g. phthalates) and plastic components (e.g. bisphenol A), flame retardants, disinfection byproducts, toxic waste
- Biological
  - Bacteria, viruses, parasites
- Physical
  - Noise
  - Ionizing and non-ionizing radiation
  - Built environment
- Socioeconomic
  - Neighborhood safety
  - Accessibility and connectivity

What is pollution?

"Unwanted, often dangerous, material that is introduced into the Earth's environment as the result of human activity, that threatens human health, and that harms ecosystems."

WHO, 2014

Outline for today

- Global burden of disease due to pollution (chronic exposure)
  - Quantification, distribution, cost
- Emerging threats / Results from our group
- Environmental policy
- Where do we go from there?

Quantification of disease burden due to pollution

Main causes of mortality globally, 2015

1) Ischaemic heart disease
2) Stroke
3) Lower respiratory infections
4) Chronic obstructive pulmonary disease
5) Trachea, bronchus and lung cancers

…

9) Tuberculosis
13) HIV/AIDS
26) Malaria

Similar in lower-middle income countries

WHO Global Health Estimates , 2016

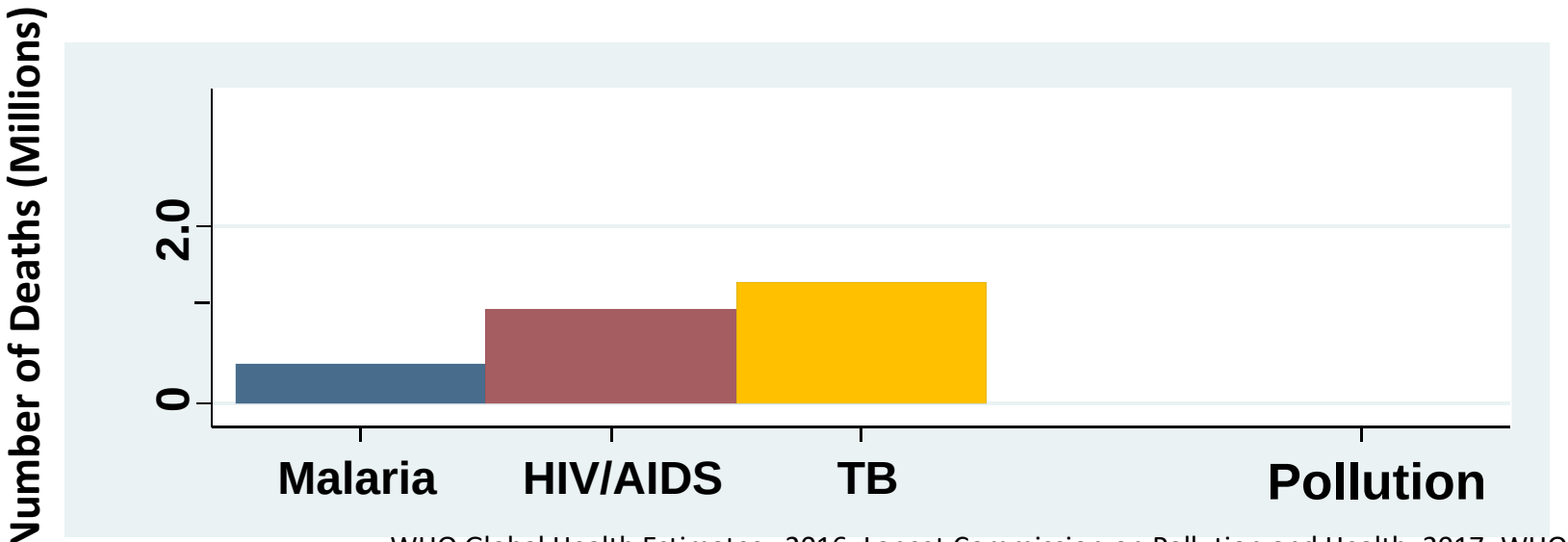
Main causes of mortality in low-income countries, 2015

1) Lower respiratory infections
2) Diarrhoeal diseases
3) Stroke
4) Ischaemic heart disease
5) HIV/AIDS
6) Tuberculosis
7) Malaria

Major investments in research and prevention on these, for good reasons

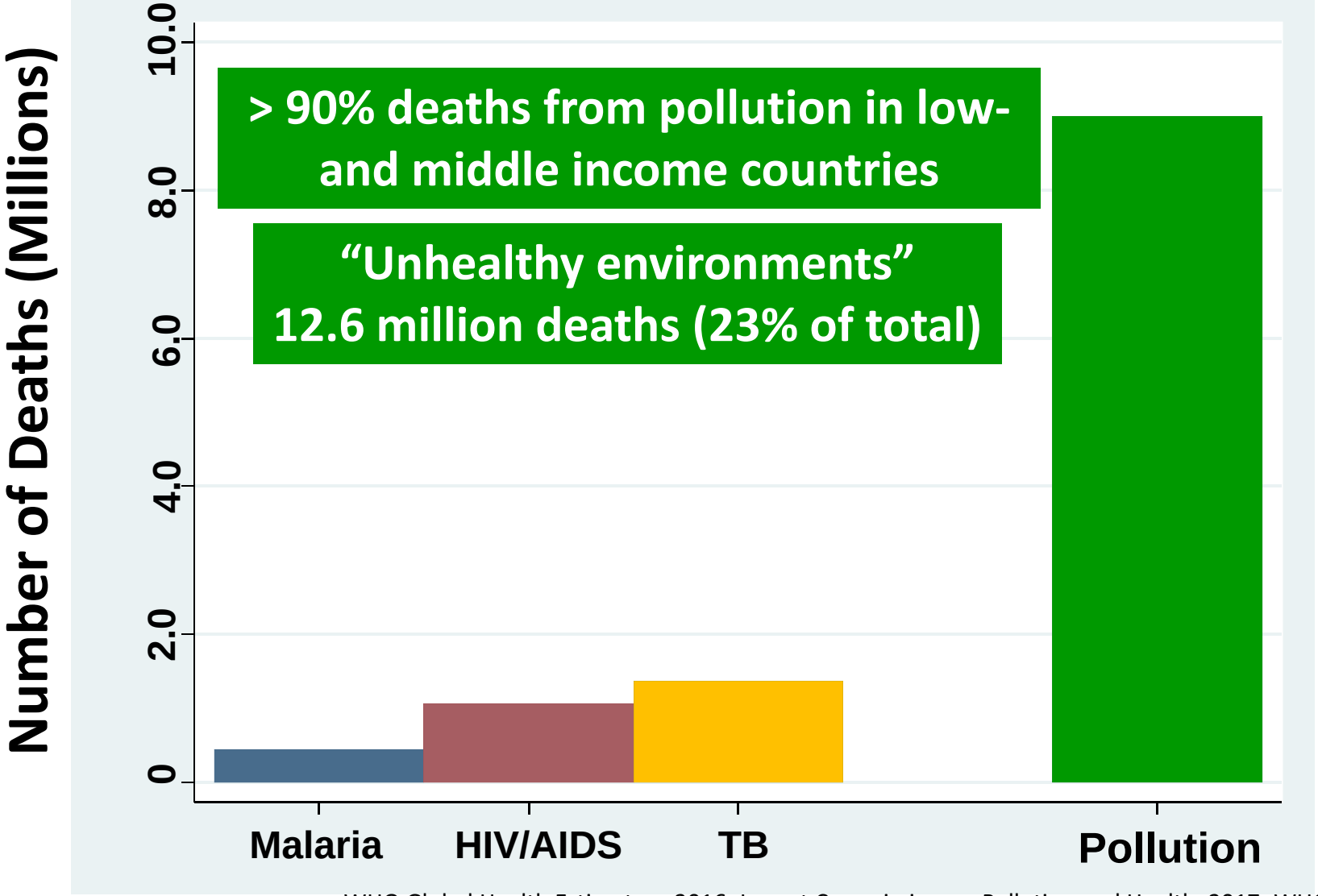
WHO Global Health Estimates , 2016

Global Causes of Mortality, 2015



WHO Global Health Estimates , 2016; Lancet Commission on Pollution and Health, 2017; WHO, 2014

Pollution caused 9 million deaths in 2015



WHO Global Health Estimates , 2016; Lancet Commission on Pollution and Health, 2017; WHO, 2014

Lancet Commission on Pollution and Health, 2017

The *Lancet* Commission on pollution and health

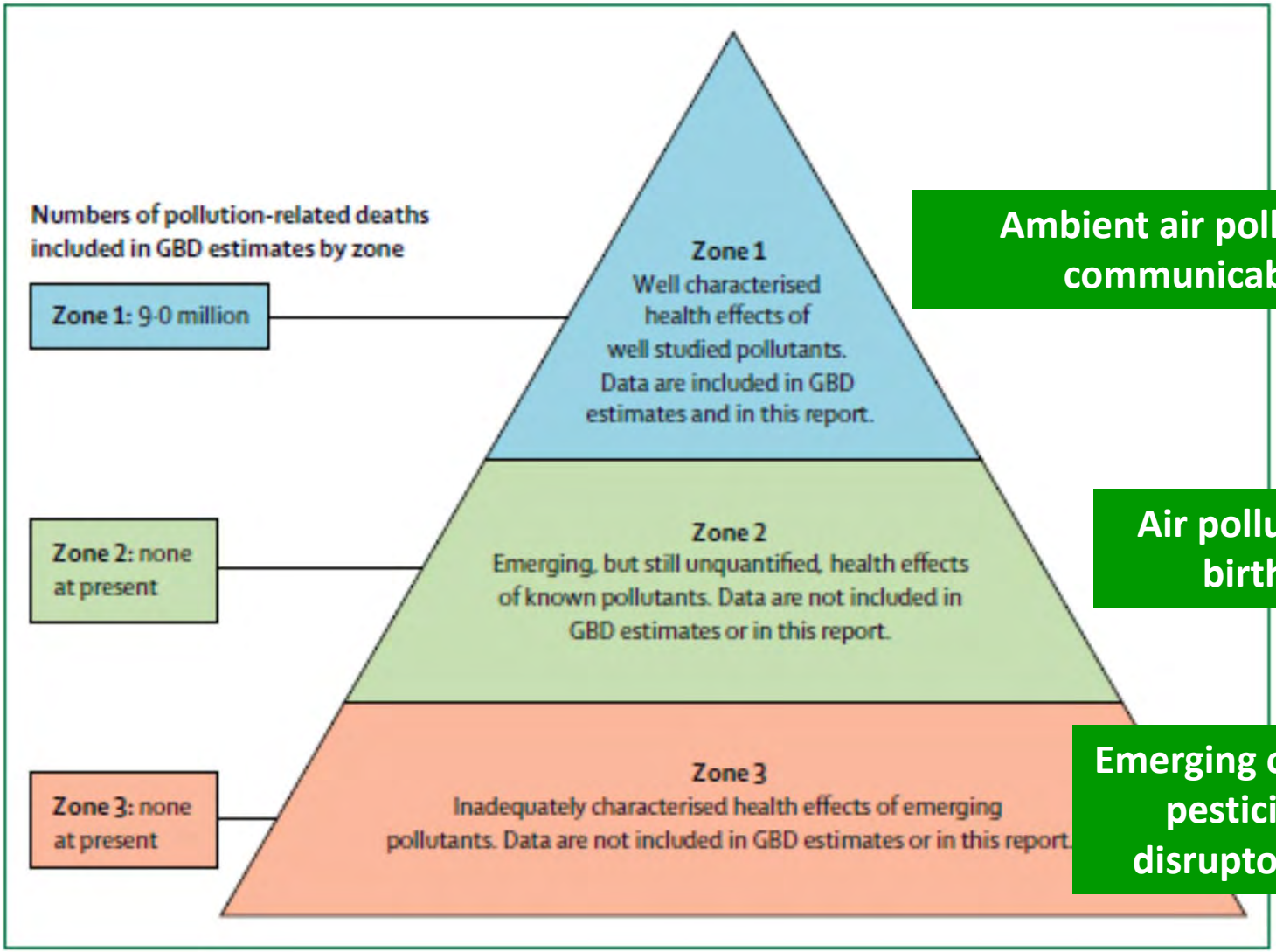
Philip J Landrigan, Richard Fuller, Nereus J R Acosta, Olusoji Adeyi, Robert Arnold, Niladri (Nil) Basu, Abdoulaye Bibi Baldé, Roberto Bertollini, Stephan Bose-O'Reilly, Jo Ivey Boufford, Patrick N Breysse, Thomas Chiles, Chulabhorn Mahidol, Awa M Coll-Seck, Maureen L Cropper, Julius Fobil, Valentin Fuster, Michael Greenstone, Andy Haines, David Hanrahan, David Hunter, Mukesh Khare, Alan Krupnick, Bruce Lanphear, Bindu Lohani, Keith Martin, Karen V Mathiasen, Maureen A McTeer, Christopher J L Murray, Johanita D Ndahimananjara, Frederica Perera, Janez Potočnik, Alexander S Preker, Jairam Ramesh, Johan Rockström, Carlos Salinas, Leona D Samson, Karti Sandilya, Peter D Sly, Kirk R Smith, Achim Steiner, Richard B Stewart, William A Suk, Onno C P van Schayck, Gautam N Yadama, Kandeh Yumkella, Ma Zhong

- "Pollution is one of the great existential challenges of the Anthropocene epoch."
- "Like climate change, biodiversity loss, ocean acidification, desertification, and depletion of […] water supply, pollution endangers the stability of the Earth's support systems and threatens the continuing survival of human societies."
- "Yet, despite its great and growing magnitude […] pollution has been largely overlooked in […] global health agendas and [… has] received little attention from either international agencies or philanthropic donors."

Pollution risk factors examined by the Lancet Commission

- Air Pollution
  - Household air pollution
  - Ambient fine particulate and ozone pollution
- Water Pollution
  - Unsafe sanitation
  - Unsafe water sources (chemical risks not included)
- Soil Pollution
  - Chemicals, lead and mercury in known contaminated sites
- Occupational pollution
  - Carcinogens
  - Particulates, gases and fumes

The health effects of few pollutants has been well-characterized – Is this the tip of the iceberg?



Ambient air pollution and non-communicable diseases

Air pollution and preterm birth, diabetes, IQ

Emerging chemicals including pesticides, endocrine disruptors, nanoparticles

Landrigan et al. 2017

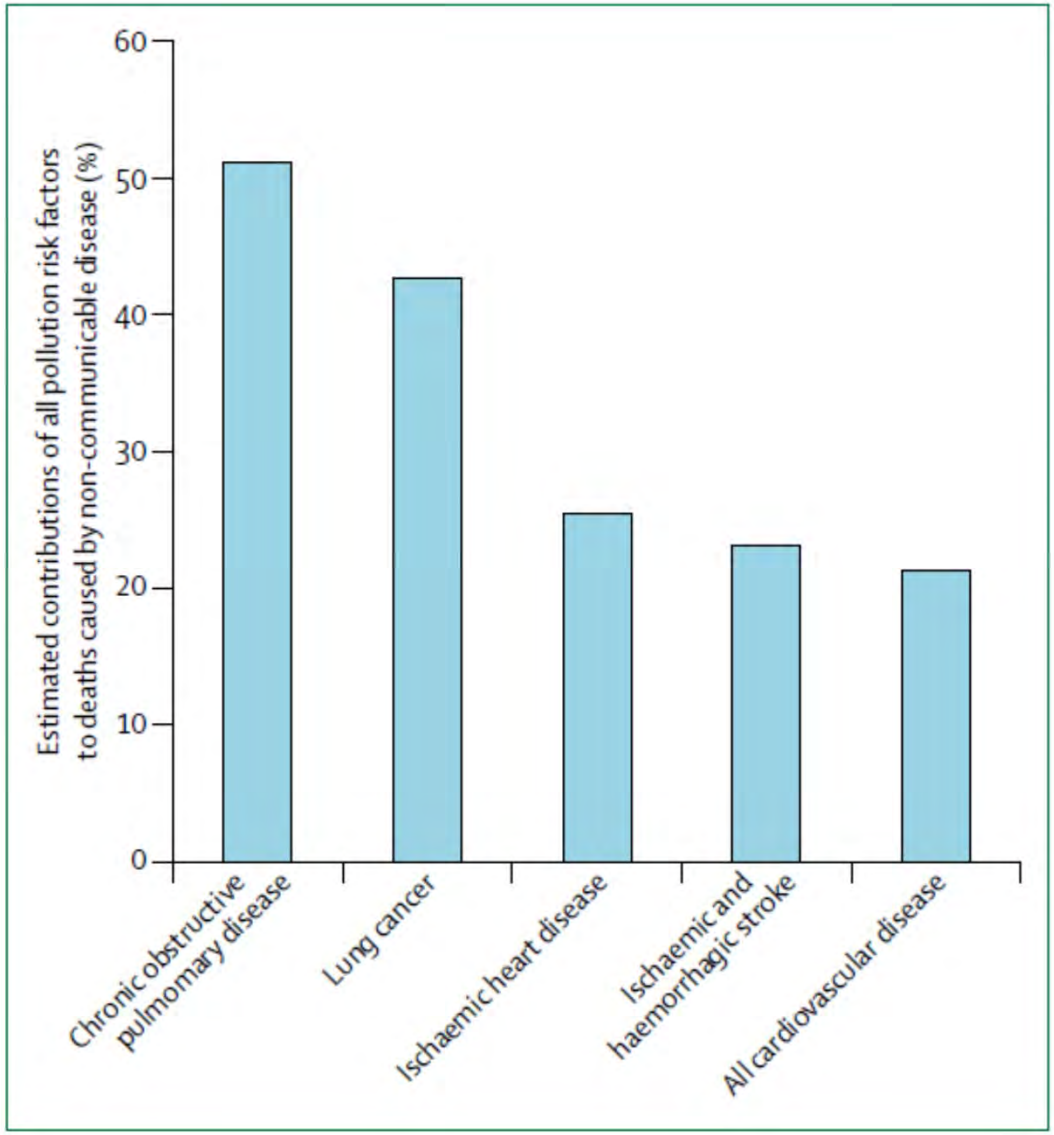
Number of deaths by pollution source examined

	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)[42] versus WHO data (2012)[99,101]**

Contribution of pollution to mortality due to non-communicable diseases, 2015

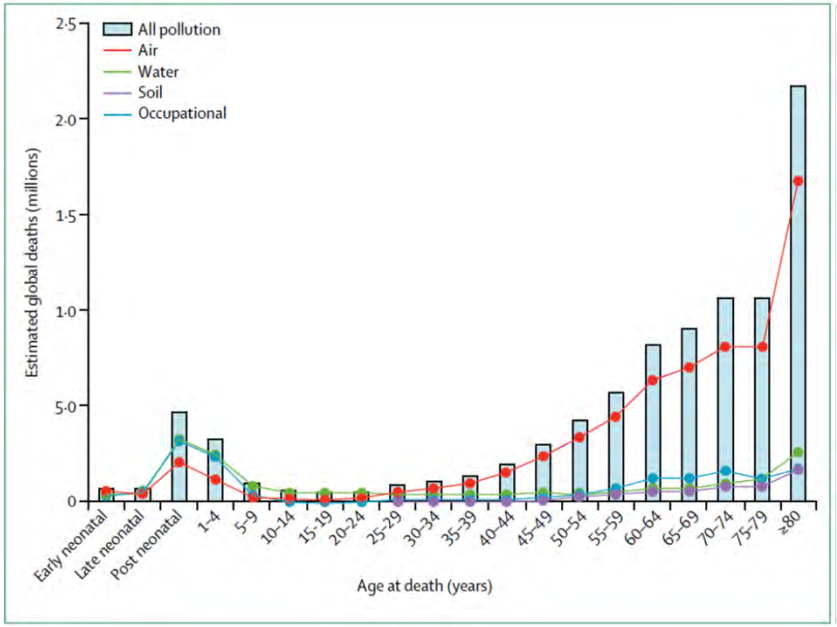


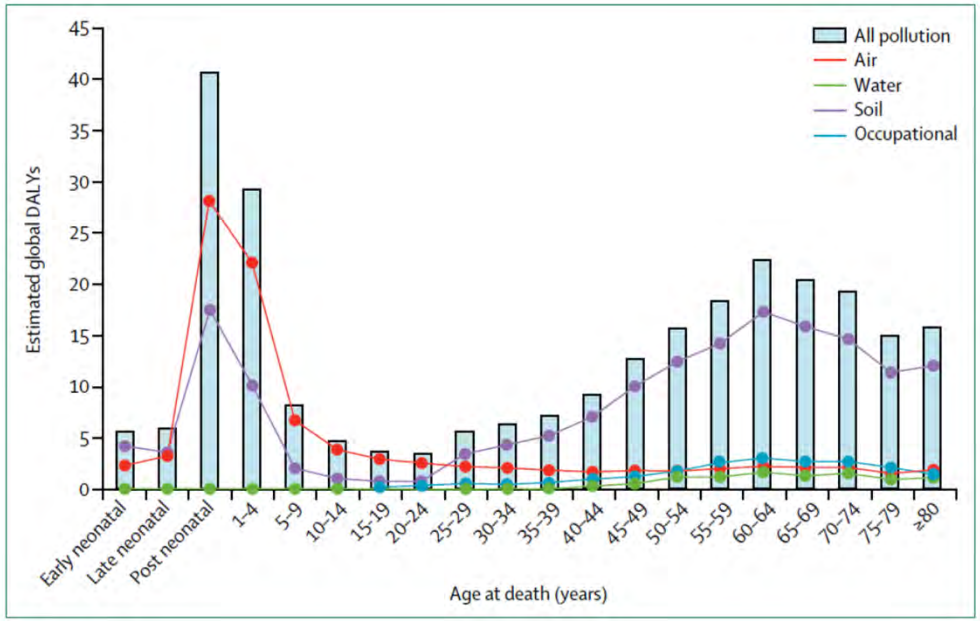
GBD Study, 2016; Figure from Landrigan et al. 2017

Global DALYs by pollution source and age of death

- Air pollution: Primarily kills older people but disease burden larger in children

- Water pollution: Primarily kills children





Health effects of air pollution ($PM_{2.5}$)

- Strong evidence for:
  - Myocardial infarction
  - Hypertension
  - Congestive heart failure
  - Arrhythmia
  - Cardiovascular mortality
  - Chronic obstructive pulmonary disease
  - Lung cancer

- Emerging evidence
  - Premature birth
  - Low birth weight
  - Diabetes
  - Impaired cognition (children) neurodegenerative disease (adults)
  - Attention-deficit/hyperactivity disorder
  - Autism

Water pollution

- 2.4 billion people use inadequate sanitation facilities

- Total deaths: 1.8 million in 2015 (mostly children < 5 years)
  - Diarrhoeal disease (70% of deaths)
  - Parathyphoid and thyphoid fever (28% of deaths)
  - Lower respiratory tract infections (2% of deaths)

Chemicals in water not considered

GBD 2015 Risk Factors Collaborators, 2016

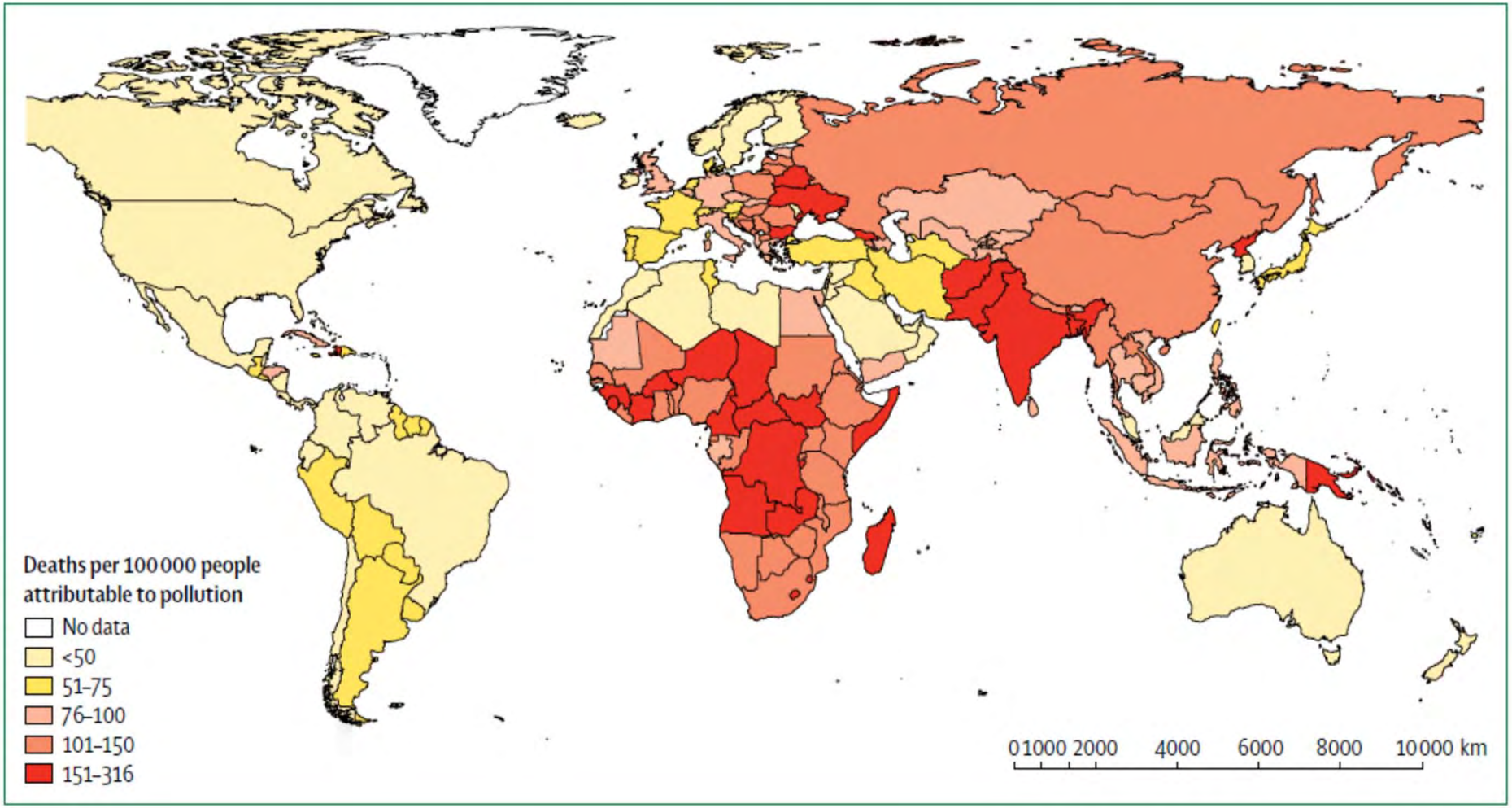
Chemicals found in water

- Chemicals found in water may include:
  - Pharmaceuticals
  - Hormones
  - Pesticides
  - Industrial chemicals
  - “Household” chemicals (detergents, bisphenol A, phthalates)
  - Endocrine disruptors

Standard water treatment not effective in removing chemicals

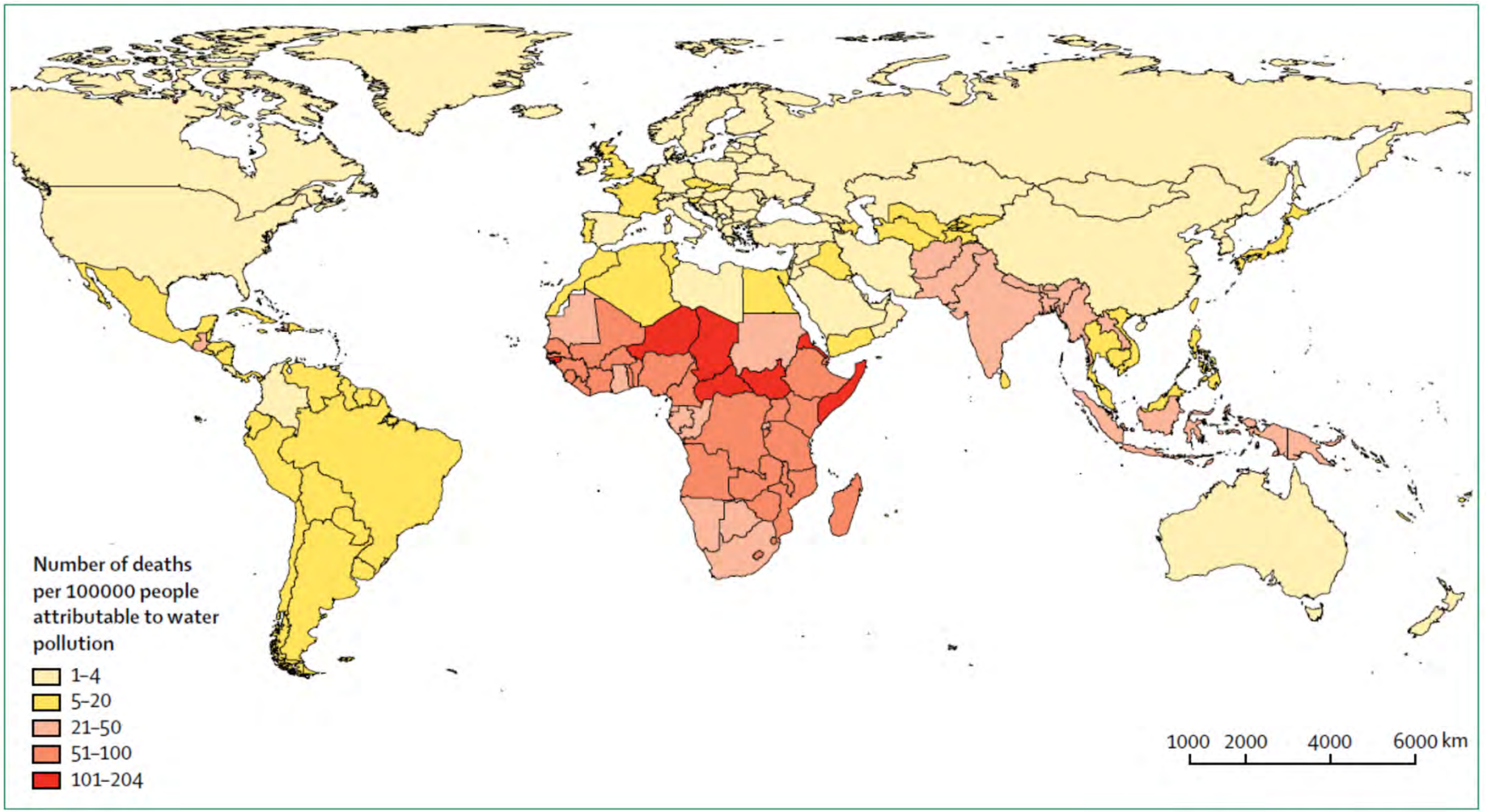
Distribution of disease burden due to pollution

Most deaths due to pollution occur in vulnerable populations

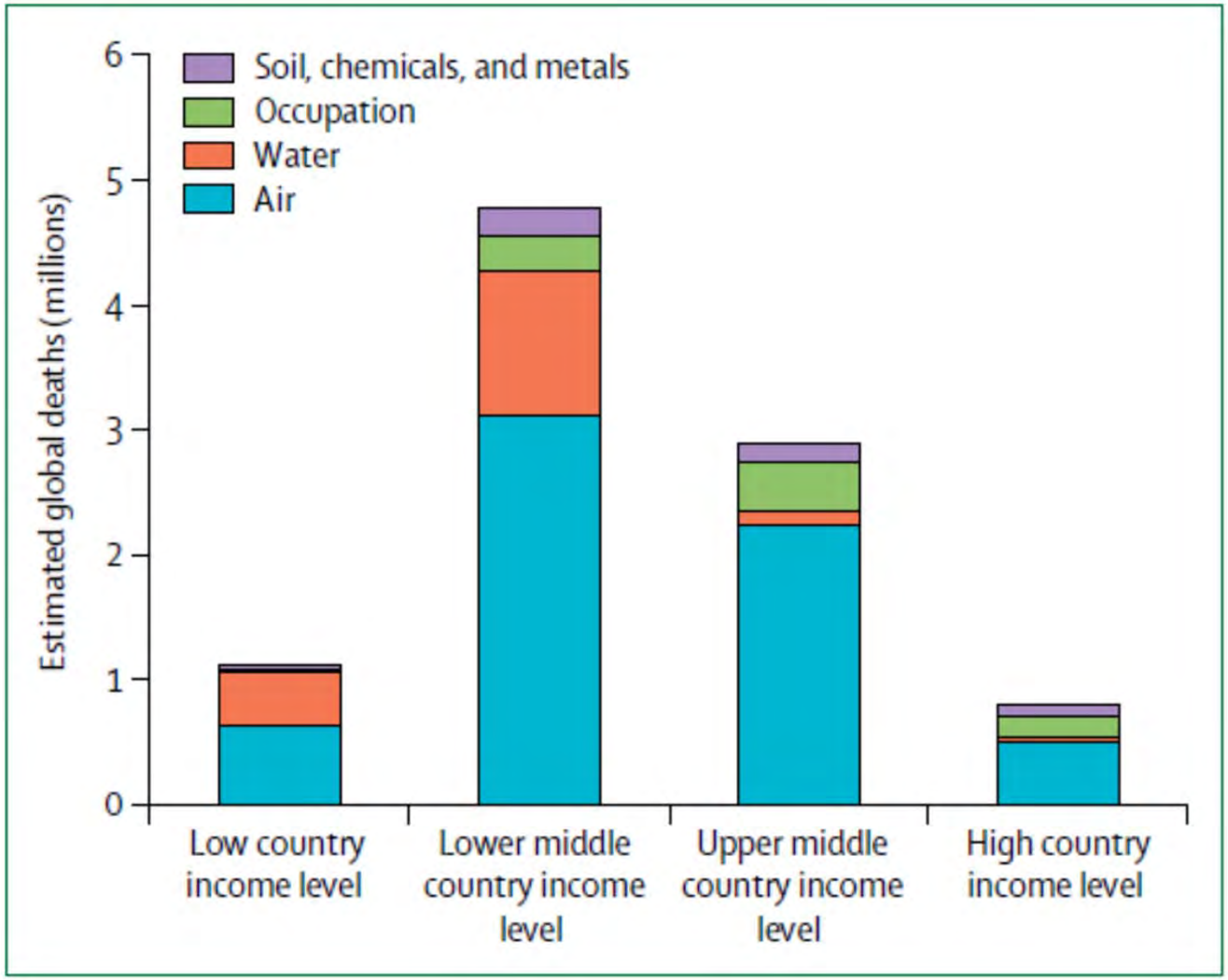


Landrigan et al. 2017

Most deaths due to water pollution occur in sub-Saharan Africa



Most deaths in rapidly-developing lower-middle income countries



Lower-middle income countries

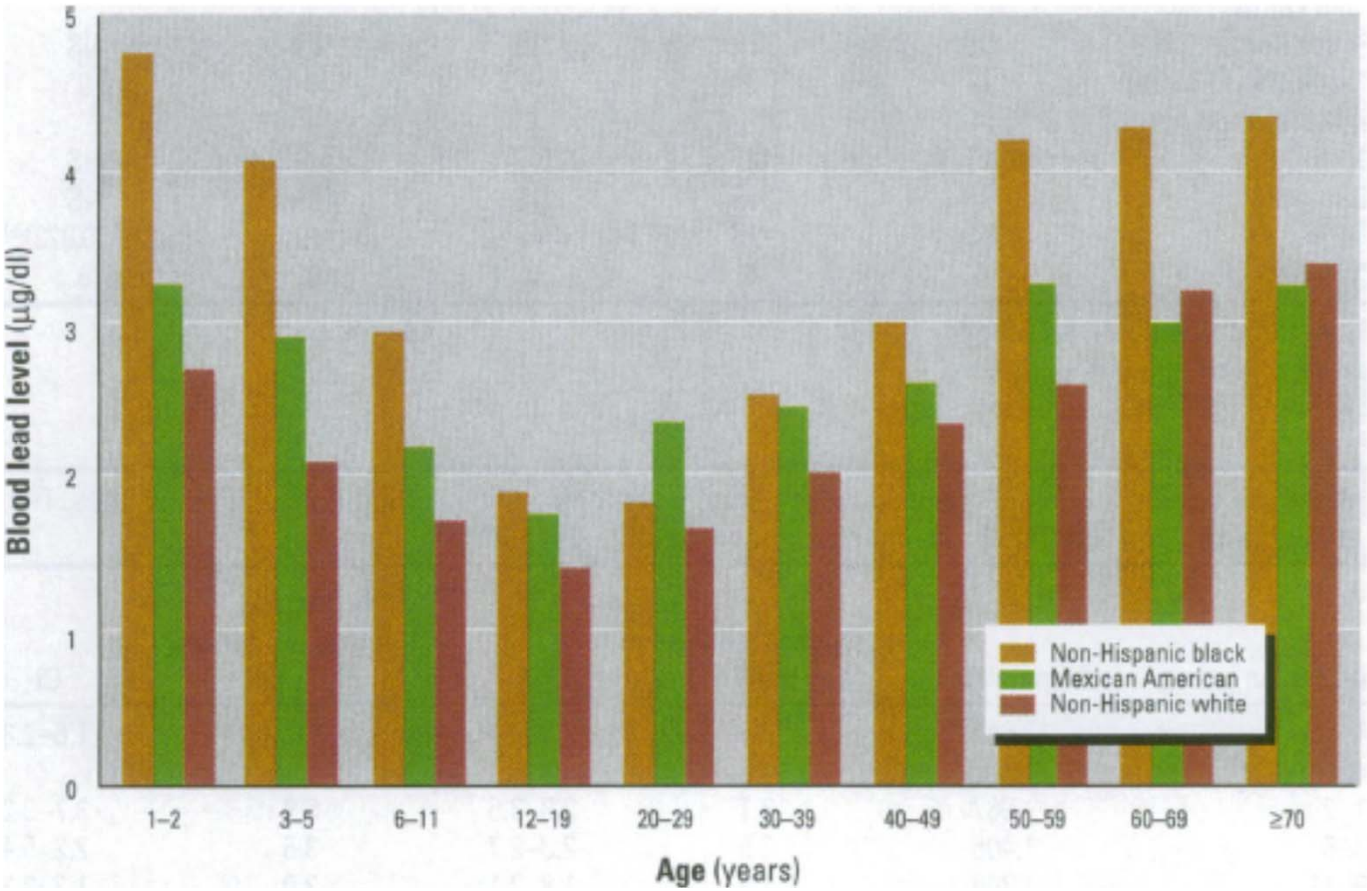
- Bangladesh
- Cambodia
- Cameroon
- Ghana
- Honduras
- Indonesia
- Kenya
- Pakistan
- Philippines
- Ukraine
- Vietnam

GBD Study, 2016; Figure from Landrigan et al. 2017

Blood lead levels in U.S. 1991-1994

Blood lead higher in:

- **Children and elderly**
- **Minorities**



Pirkle, 1998

Children are not little adults

In comparison with adults, children…

- Have higher breathing rates
- Consume more food per unit body weight
- Have higher skin surface to volume ratios
- Have lower detoxifying capabilities

Costs of disease burden due to pollution

Costs of pollution likely high but insufficient data for full accounting

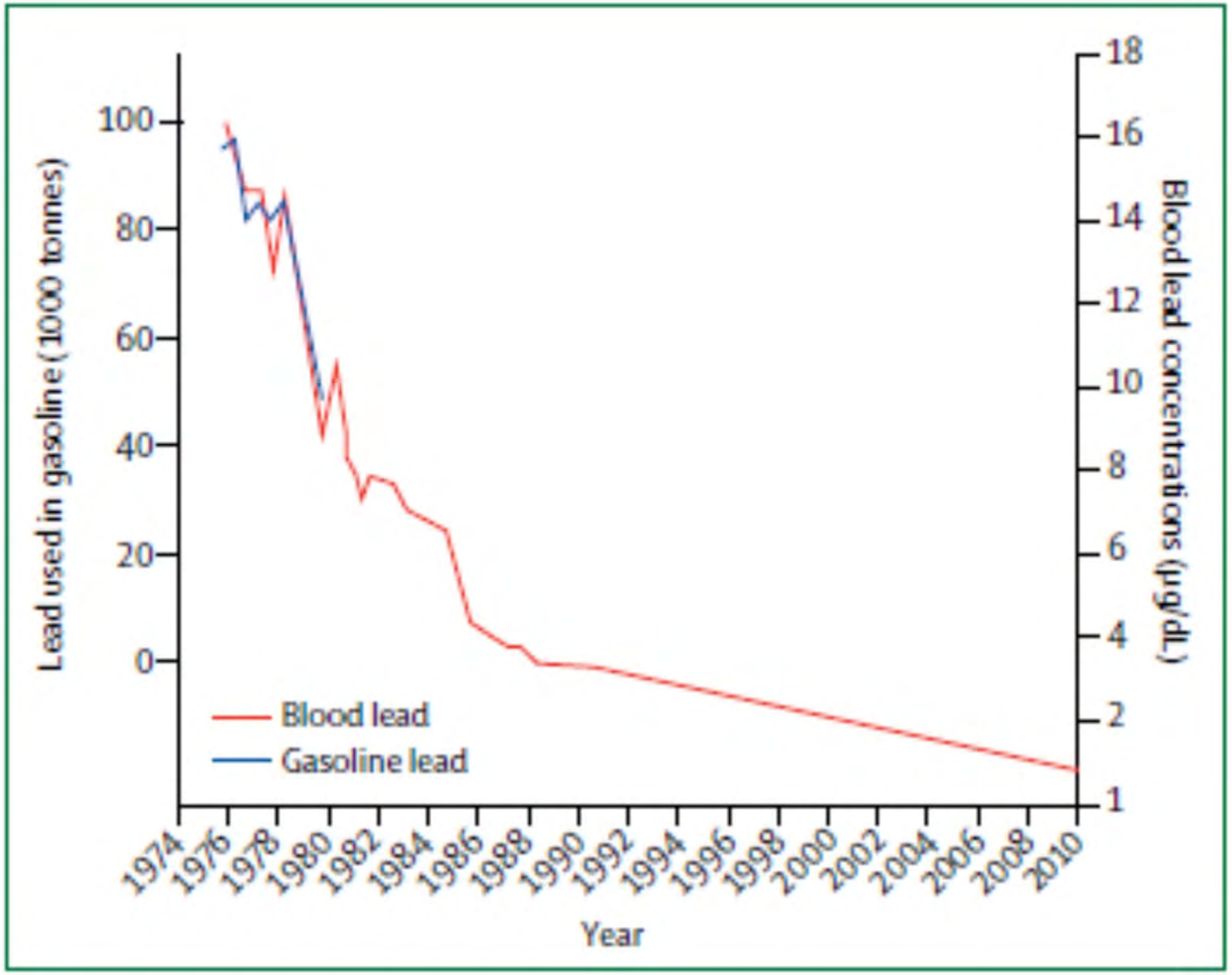
- Health care costs due to air pollution $US 100 billion in 2013 for high-income countries

- Costs of lost productivity due to pollution $US 53 billion in 2015 for high and upper-middle income countries

Controlling pollution is cost-effective

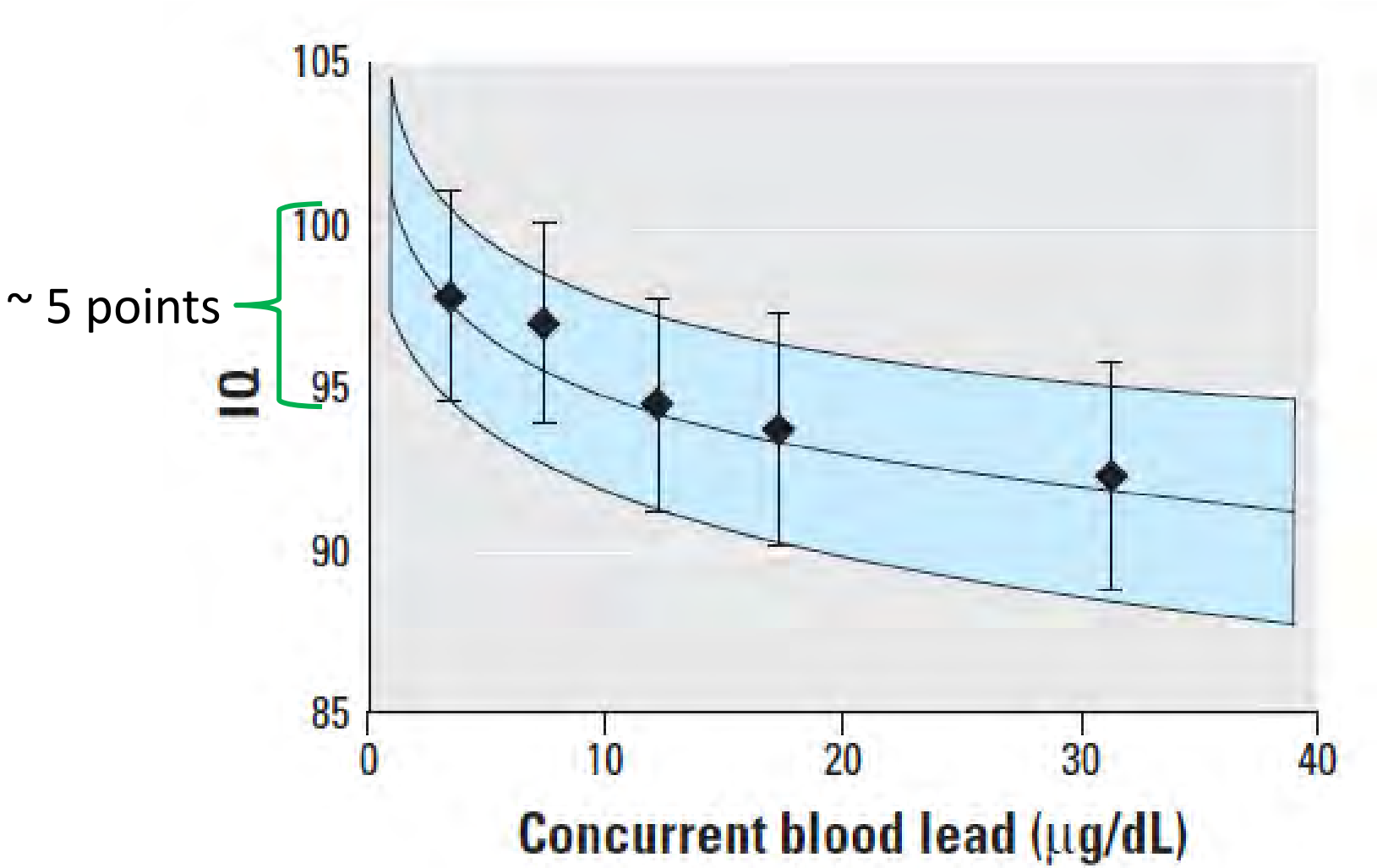
- In USA, US$ 30 in benefits per US$ 1 invested in air pollution control
  - Total benefit since 1970: $1.5 trillion

A well-known public health success: The removal of lead in gasoline



Centers for Disease Control and Prevention, 2016

Lead related to reduced IQ in children aged 5 – 10 years



Lanphear et al., 2005

Benefits of removing lead from gasoline

- Lead removal increased IQ by 2-5 points in children born since 1980
- Gain represents US$ 200 billion for each annual cohort
  - Total to date: US$ 6 trillion

Grosse et al., 2002; Pirkle et al. 1998; Annest et al., 1983

Consequences of inaction

- Under “business as usual” scenario, mortality due to air pollution estimated to increase by 2.4 million (50% increase)

- Consequences of inaction not evaluated for other environmental risks.

Lelieveld et al. 2015

Outline for today

- Global burden of disease due to pollution (chronic exposure)
  - Quantification, distribution, cost
- **Emerging threats / Results from our group**
- Environmental policy
- Where do we go from there?

Chemical contaminants

- How many chemicals synthesized since 1950s?
  - **140,000**
- We are exposed to about 5,000 of these
- How many of these 5,000 chemicals have been tested for safety?

Some emerging contaminants

- Bisphenol A
  - Hard plastics and food and beverage cans
- Flame retardants (polybrominated diphenyl ethers; PBDEs)
  - Stuffed furniture, construction materials, electronics
- Phthalates
  - Soft plastics, personal care products
- Perfluorinated compounds
  - Anti-stain and anti-stick products (Scotchguard, Teflon, Gore-Tex)
  - Microwaveable popcorn!

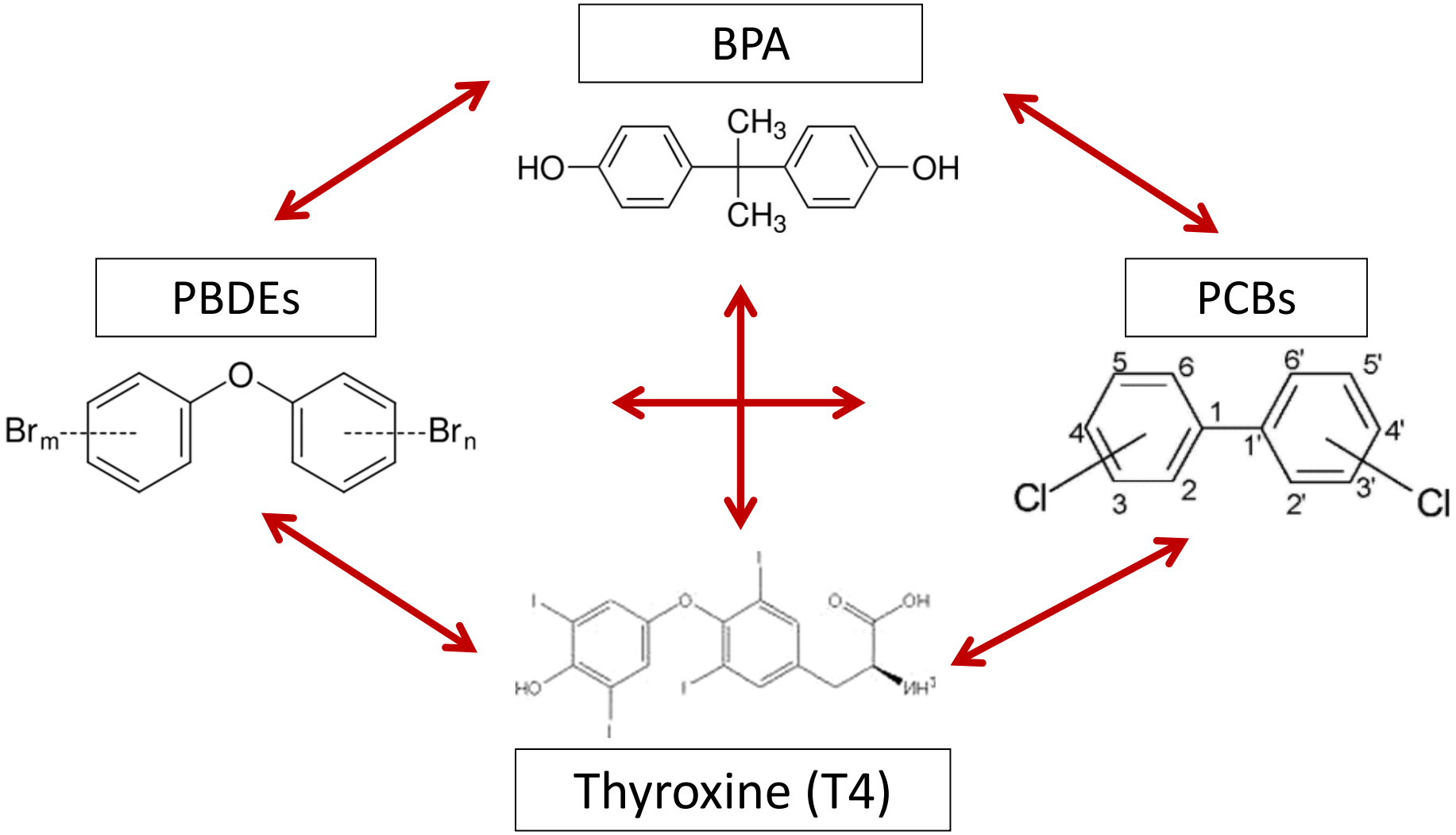
Endocrine Disruption Hypothesis

- Proposes that some chemicals may **interfere** with hormones synthesis, elimination and/or action

- Hormones act at **very low** concentrations (part per trillion)

- Exposure to **very small** amounts of certain chemicals may have **profound and permanent** effects on child development.

PCBs, PBDEs, BPA & Thyroid Hormone

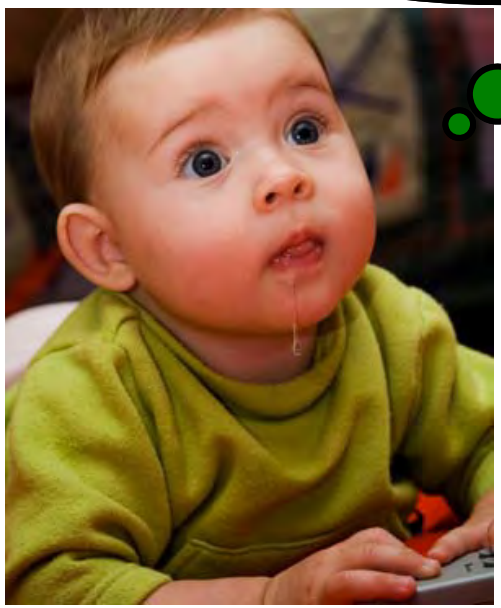


Developmental Effects of Hypothyroidism

Cretinism: Caused by iodine deficiency-related hypothyroidism

Objective

Is maternal exposure to PCBs, PBDEs and/or BPA associated with thyroid function in pregnant women and neonates?

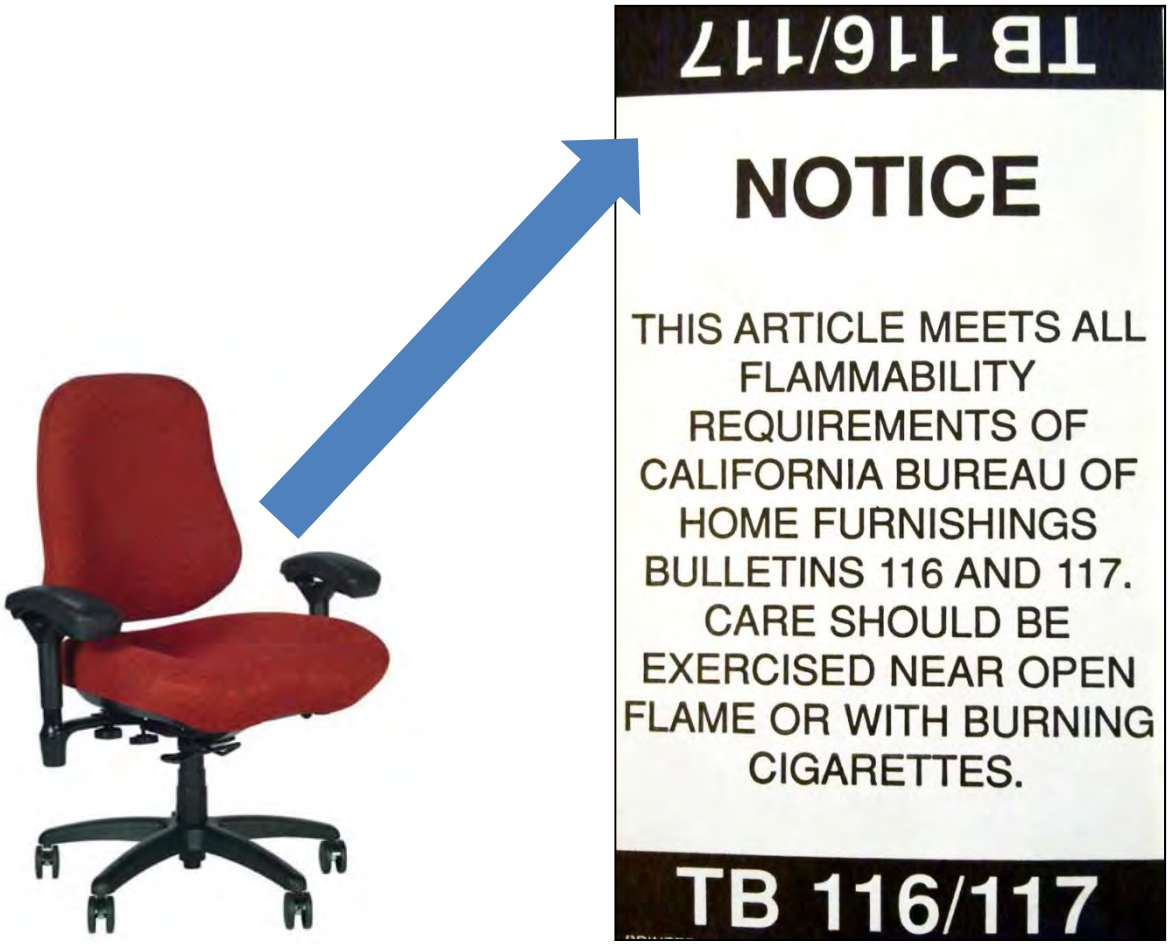


CHAMACOS Study Location

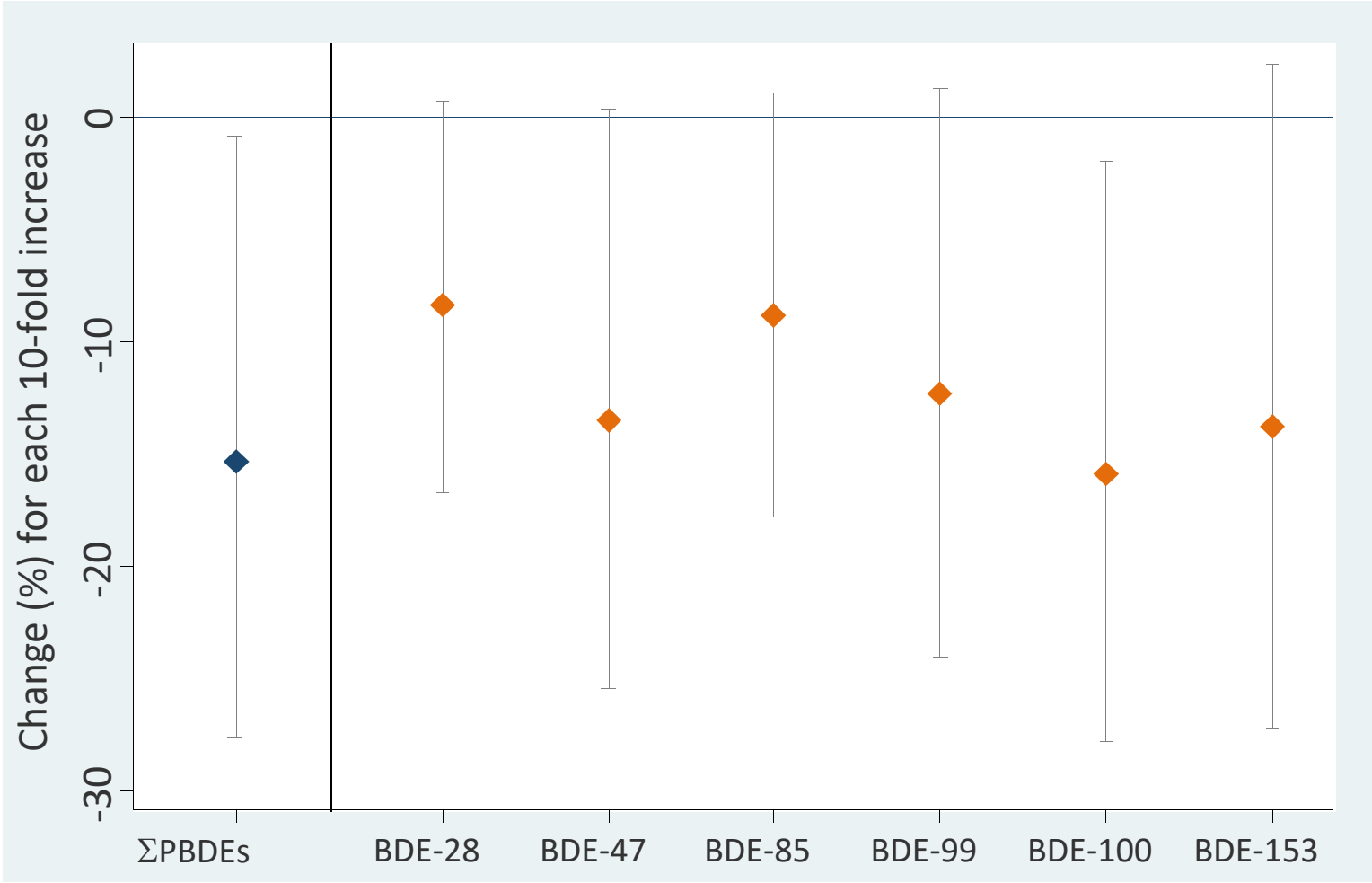
Who is at greatest risk of exposure to PBDEs?

- North American Residents
- Californians in Particular

Technical Bulletin 117



Association of Serum PBDEs & Maternal TSH

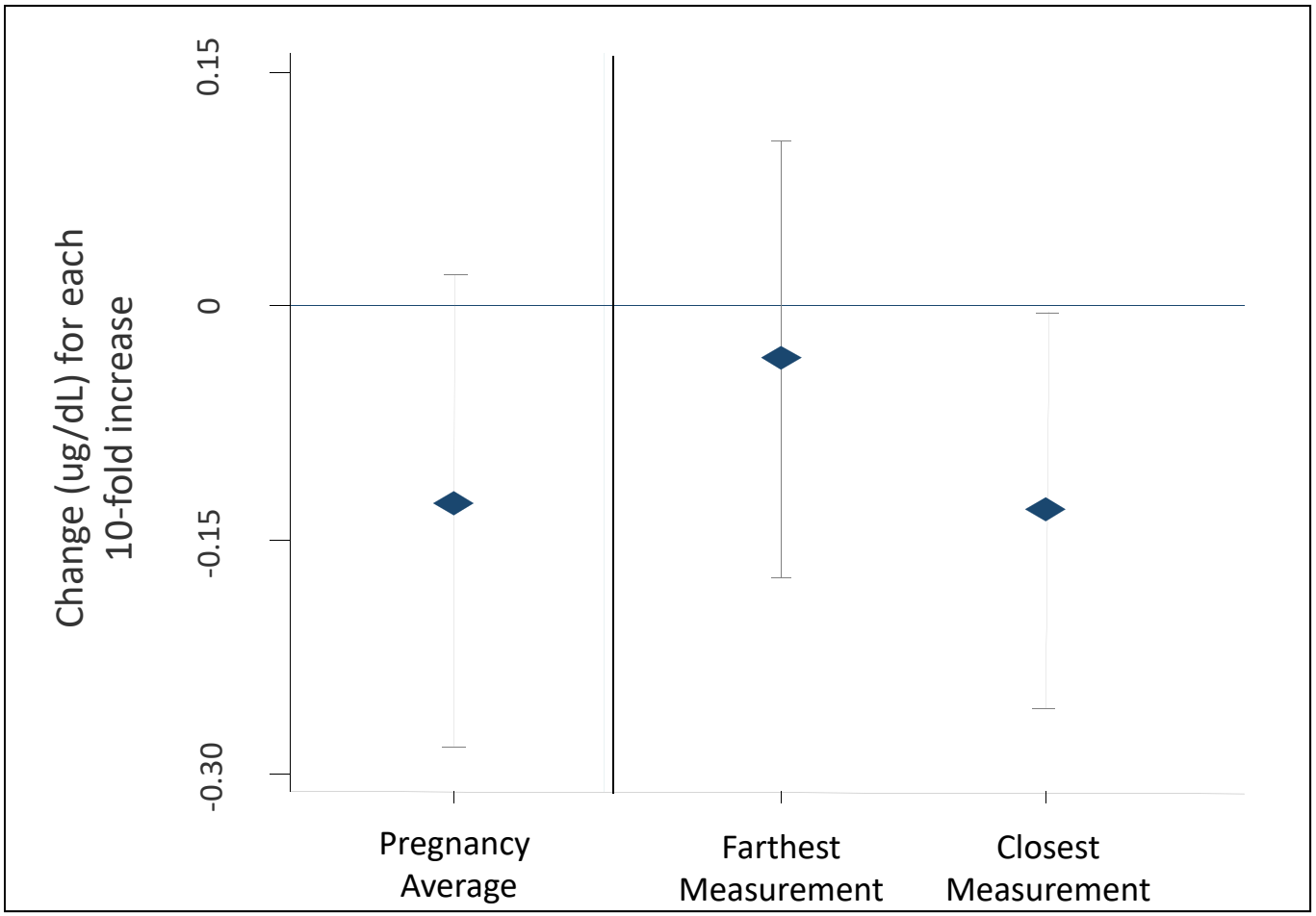


Adjusted for maternal age, race, education, income, country of birth, time lived in the U.S., pre-pregnancy BMI, gestational age at blood collection. Results were unchanged after the removal of outliers, selection bias correction and were independent of the lipid adjustment method.

Chevrier et al., 2010

Bisphenol A (BPA)

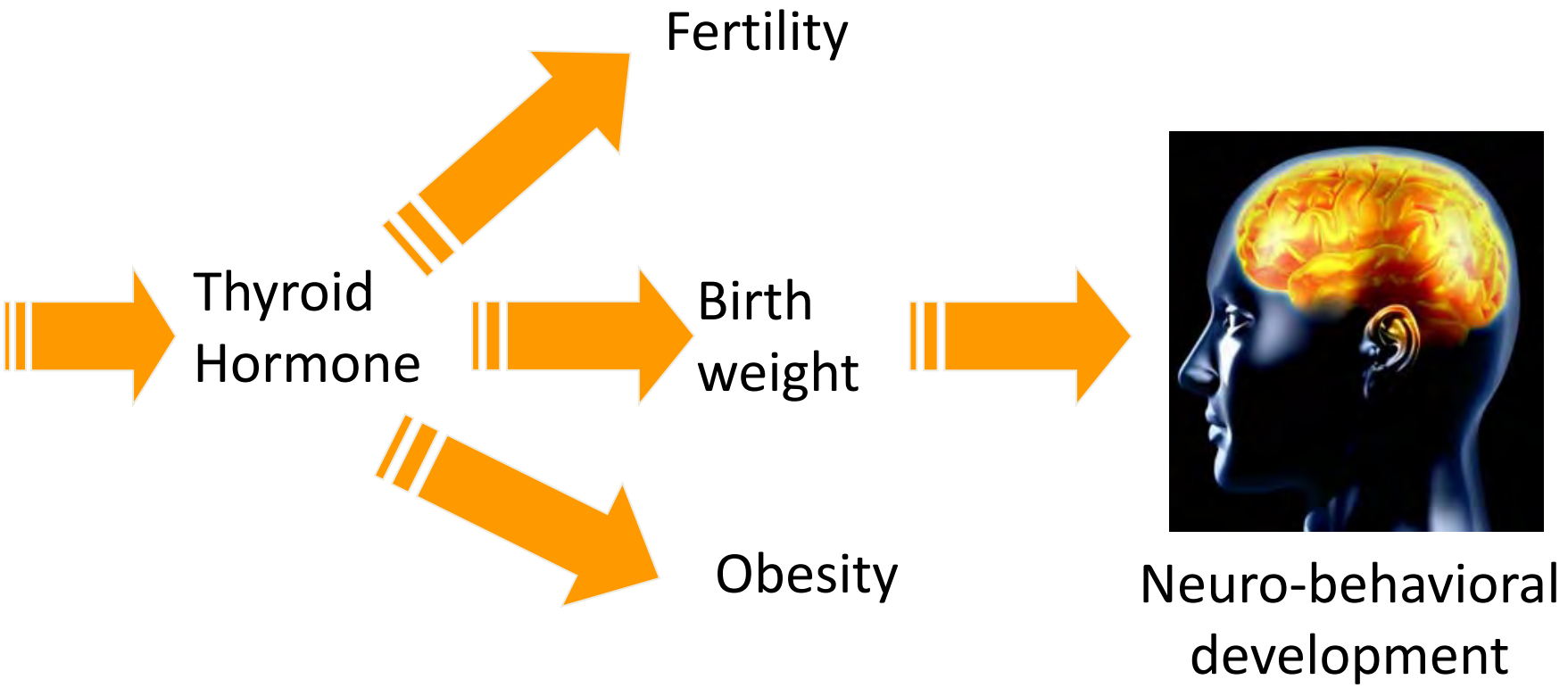
BPA & Maternal T4



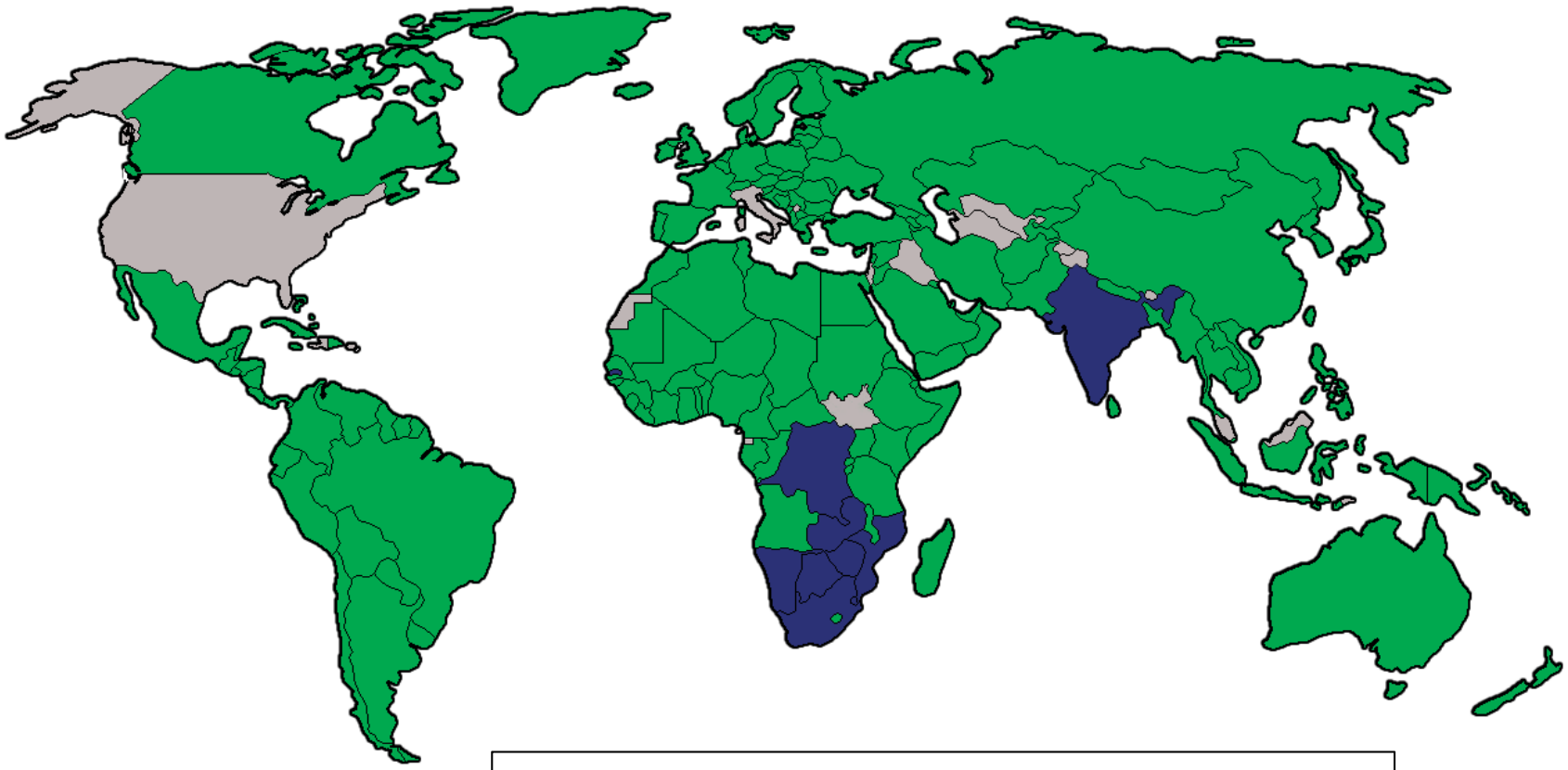
Models adjusted for maternal age, education level, country of birth, poverty level,, alcohol and drug consumption during pregnancy, iodine intake, and HCB and PCB serum concentrations.

Chevrier et al., 2013

Simplified Causal Diagram



DDT Use Under Stockholm Convention, 2014



Green: Party to Stockholm Convention
Grey: Not party to Stockholm Convention
Blue: Countries notifying of DDT use

History of DDT

1940 1950 1960 1970 … 2000 2005 2010

1939
DDT discovered

Shortly after its invention in 1939, DDT was promoted as a miricle pesticide all around the world.

1948
Müller wins Nobel Prize for DDT discovery

History of DDT

Time Magazine, June 30, 1947

Widespread Use of DDT

DDT being sprayed on Long Island beaches in 1945

History of DDT

1940 1950 1960 1970 … 2000 2005 2010

1939
DDT discovered

1948
Müller wins Nobel Prize for DDT discovery

1962
Rachel Carson's *Silent Spring* published

1970s
DDT banned in Western countries

2001
Stockholm Convention on POPs

2006
WHO recommends scaling up IRS

2007
WHO announces reevaluation of DDT safety and calls for ultimate elimination

2011
WHO concludes exposure in IRS areas below levels of concern

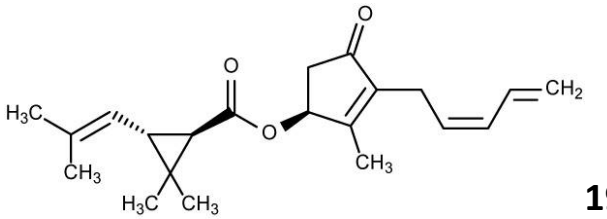
World Health Organization

History of Pyrethroids

1800's… 1920... 1960 1970 1980 2002 …

Early 19th Century
Natural pyrethrum is widely available in Europe

1920's
Active structure of pyrethroids is discovered



1966
1st generation synthetic pyrethroids created

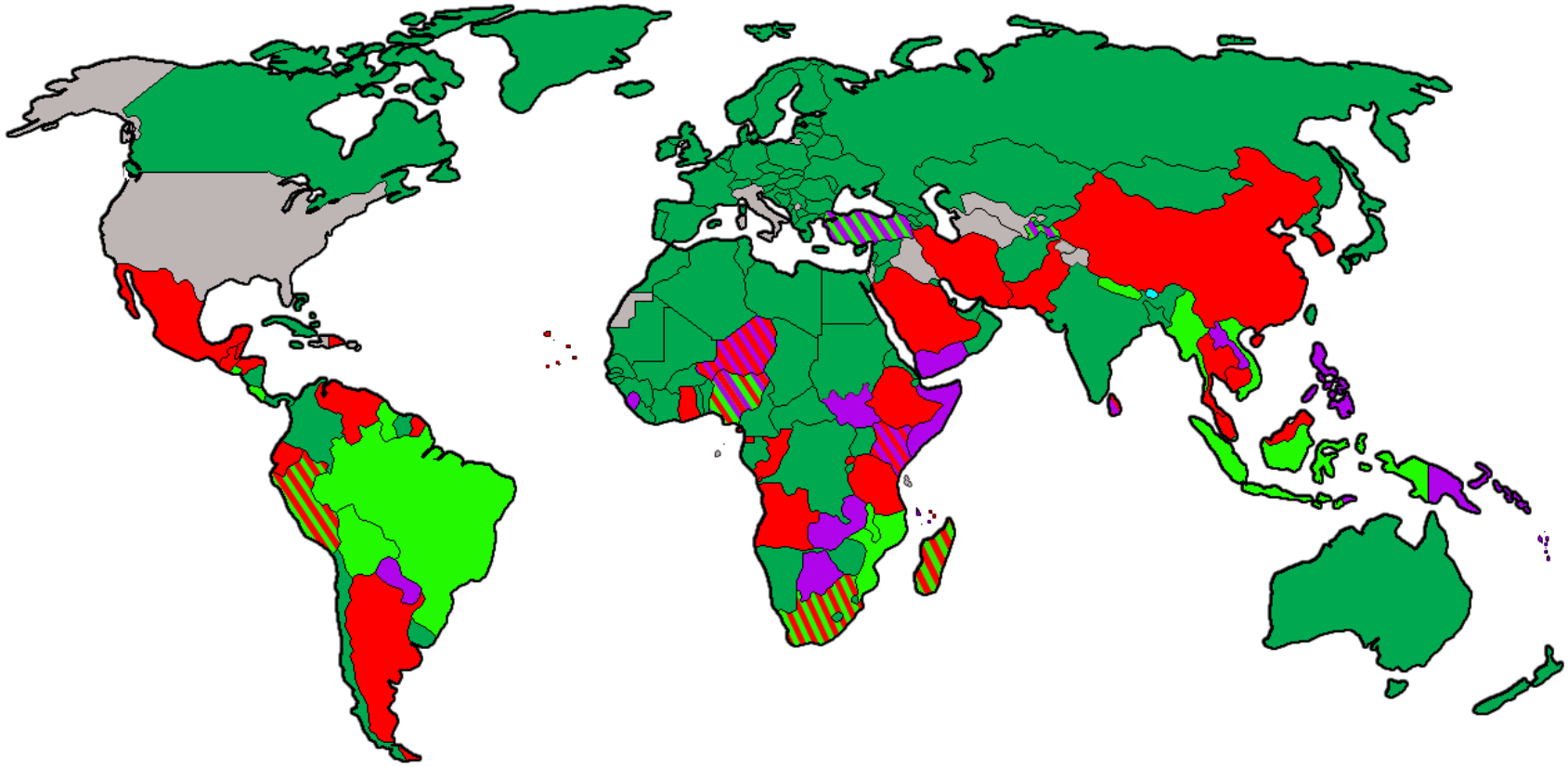
1972
2nd generation pyrethroids are created

1986
Pyrethroids comprise 20% of the total insecticide market

Today
Pyrethroids use at its highest in history

A $6 billion industry by 2021

Pyrethroid use for malaria control



Light Green: alpha-Cypermethrin
Red: Deltamethrin
Purple: lambda-Cyalothrin
Blue: Cyfluthrin

World Malaria Report, 2015

Some facts about DDT/DDE and pyrethroids

- DDT/DDE are persistent in humans and the environment
  - Half-life: 4-12 years
- DDT/DDE bioconcentrate in fat and biomagnify up the food chain
- Pyrethroids are nonpersistent
  - Half-life: 5-13 hours

- DDT/DDE **and** pyrethroids cross the placenta
  - Fetuses are exposed
- DDT/DDE **and** pyrethroids are excreted in breast milk
  - Infants are exposed

An Important Piece of the Puzzle is Missing: Health Effects in Children from IRS Areas

The **VHEMBE** Study

V enda

H ealth

E xamination of

M others,

B abies and their

E nvironment

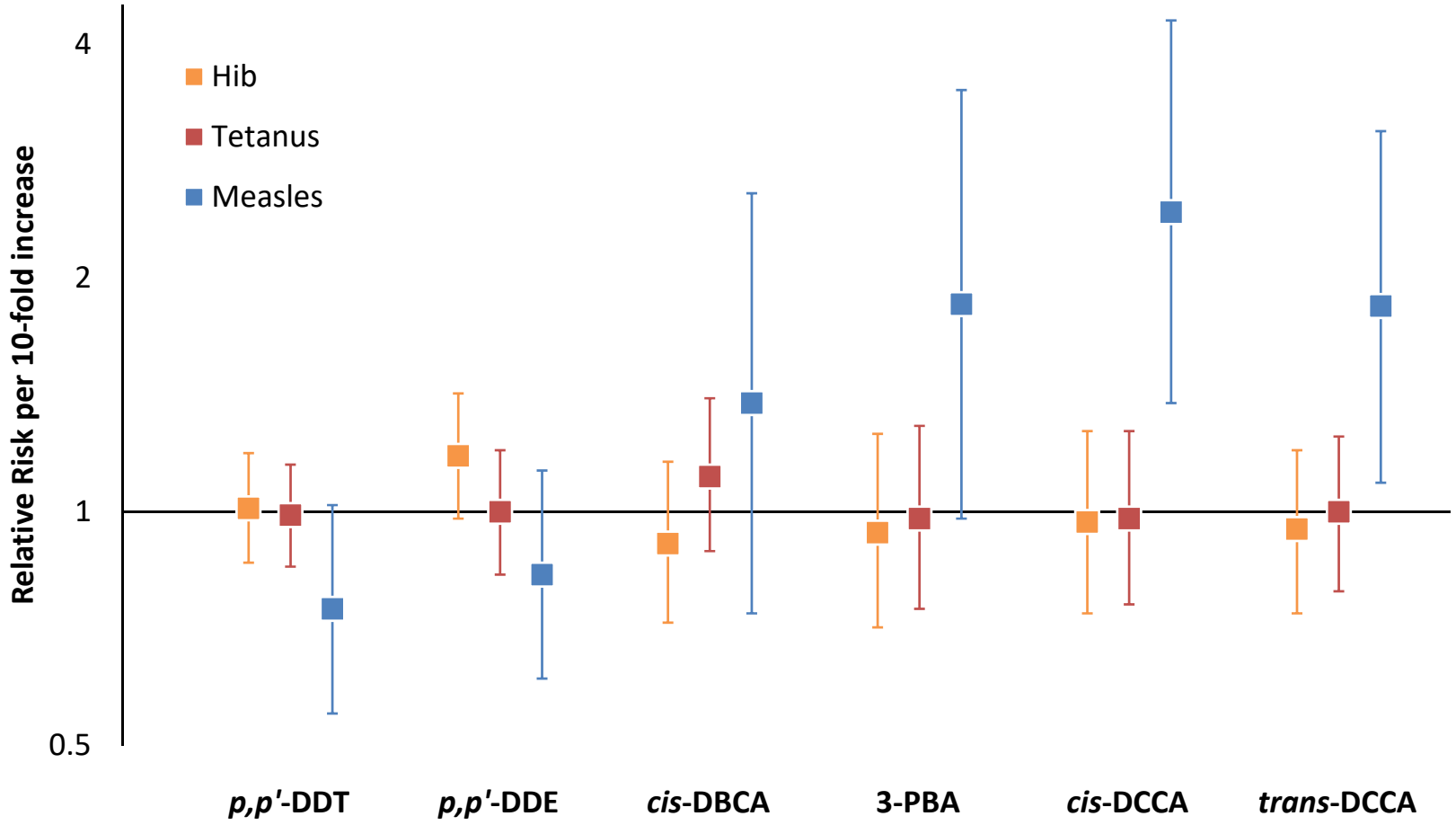
A birth cohort study located in the Vhembe district of Limpopo, South Africa

VHEMBE study objectives

- To determine whether exposure to pyrethroids and/or DDT is associated with:
  - Fetal growth (birth size, gestational duration)
  - Disruption of the endocrine system
  - Altered growth/body composition
  - Impaired neurodevelopment
  - Altered immune function (increased infection and allergies, inhibited vaccine response)

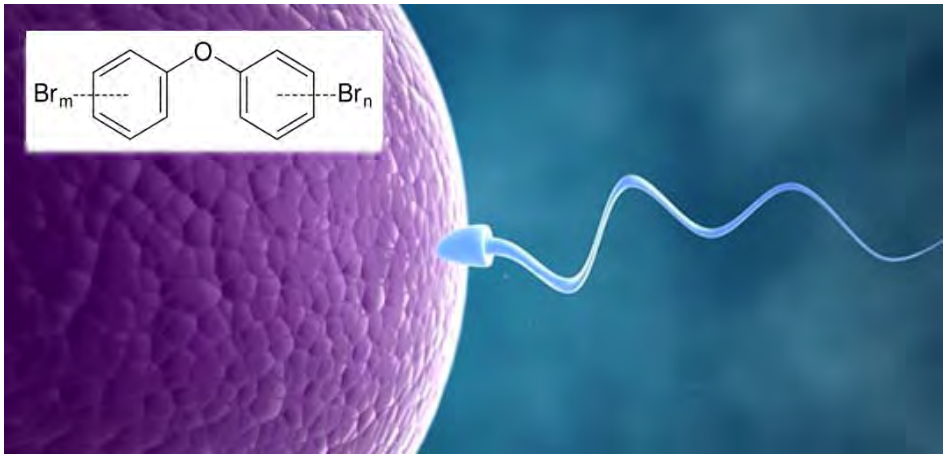
Study Site: Thohoyandou, Vhembe district

Pyrethroid metabolites associated with higher risk of measles antibodies below protective levels



Adjusted for time since last vaccine (restricted cubic spline), child age (months), sex, breastfeeding duration (months), household income per capita, and maternal HIV status during pregnancy

Other studies

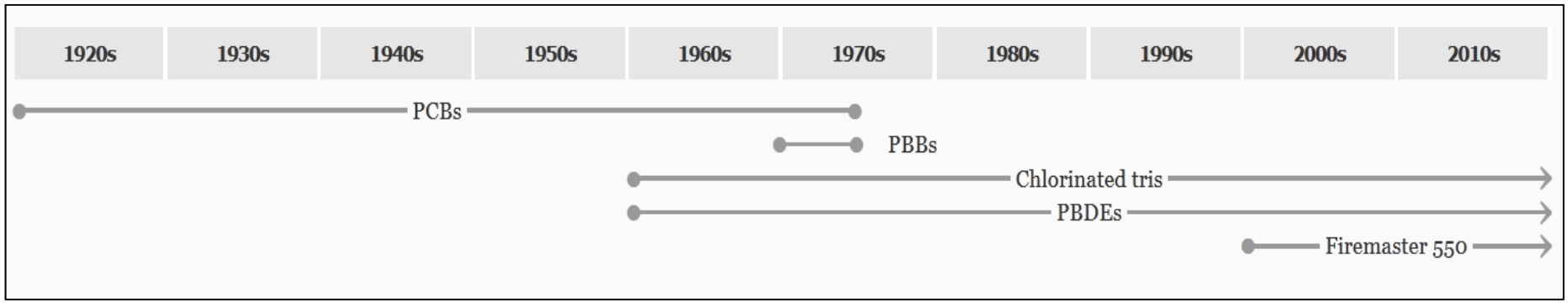


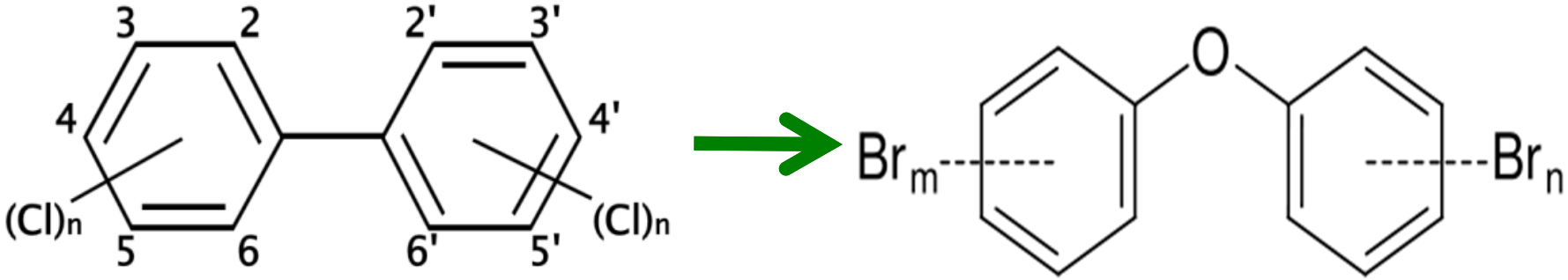
Join us!

Outline for today

- Global burden of disease due to pollution (chronic exposure)
  - Quantification, distribution, cost
- Well-known environmental disasters (acute exposure)
- Emerging threats / Results from our group
- **Environmental policy**
- Where do we go from there?

Out with the old, in with the old…

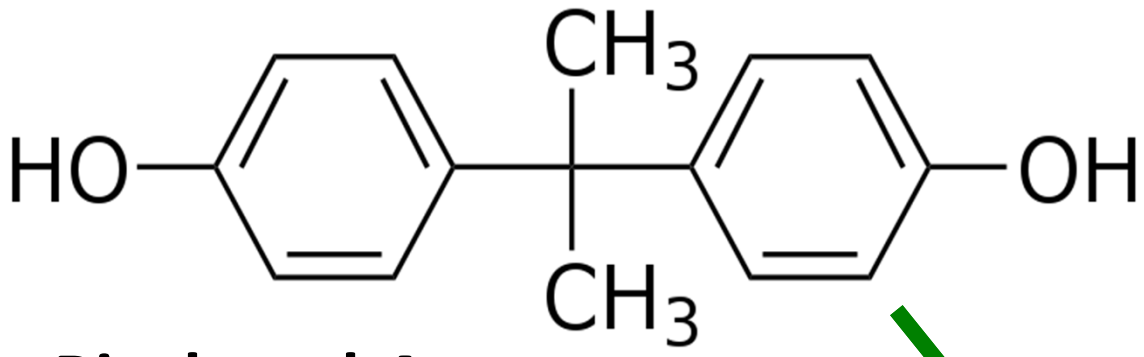




PCBs/PBBs **PBDEs**

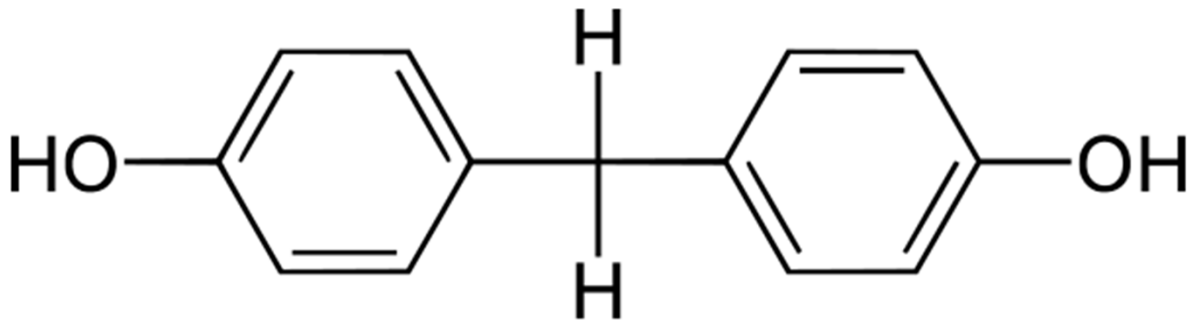
http://media.apps.chicagotribune.com/flames/chemical-similarities-and-history-of-flame-retardants.html

Out with the old, in with the old…



Bisphenol-A

Bisphenol-F



Is BPA the Tip of the Iceberg?

BPA substitutes and structurally related compounds:

- Bisphenol AF
- Bisphenol AP
- Bisphenol B
- Bisphenol C
- Bisphenol F
- Bisphenol S
- BPA diglycidyl ether (BADGE)

How harmful are these chemicals to humans?

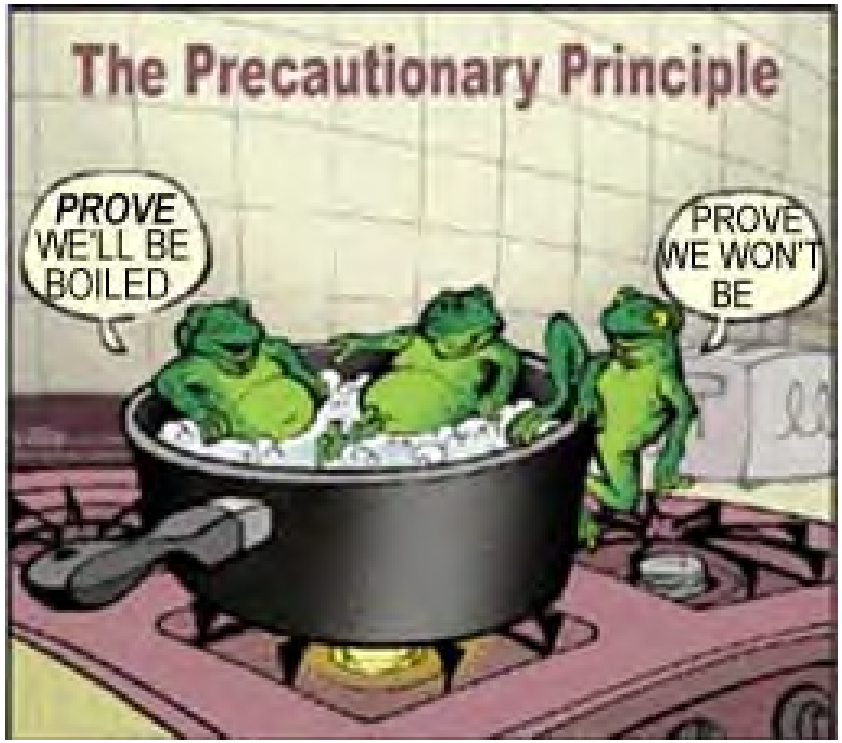
Uncertainty remains

- Association is not causation
- Human literature inconsistent, particularly regarding BPA
- Chance findings
- Uncontrolled confounding

How much evidence is enough to act?

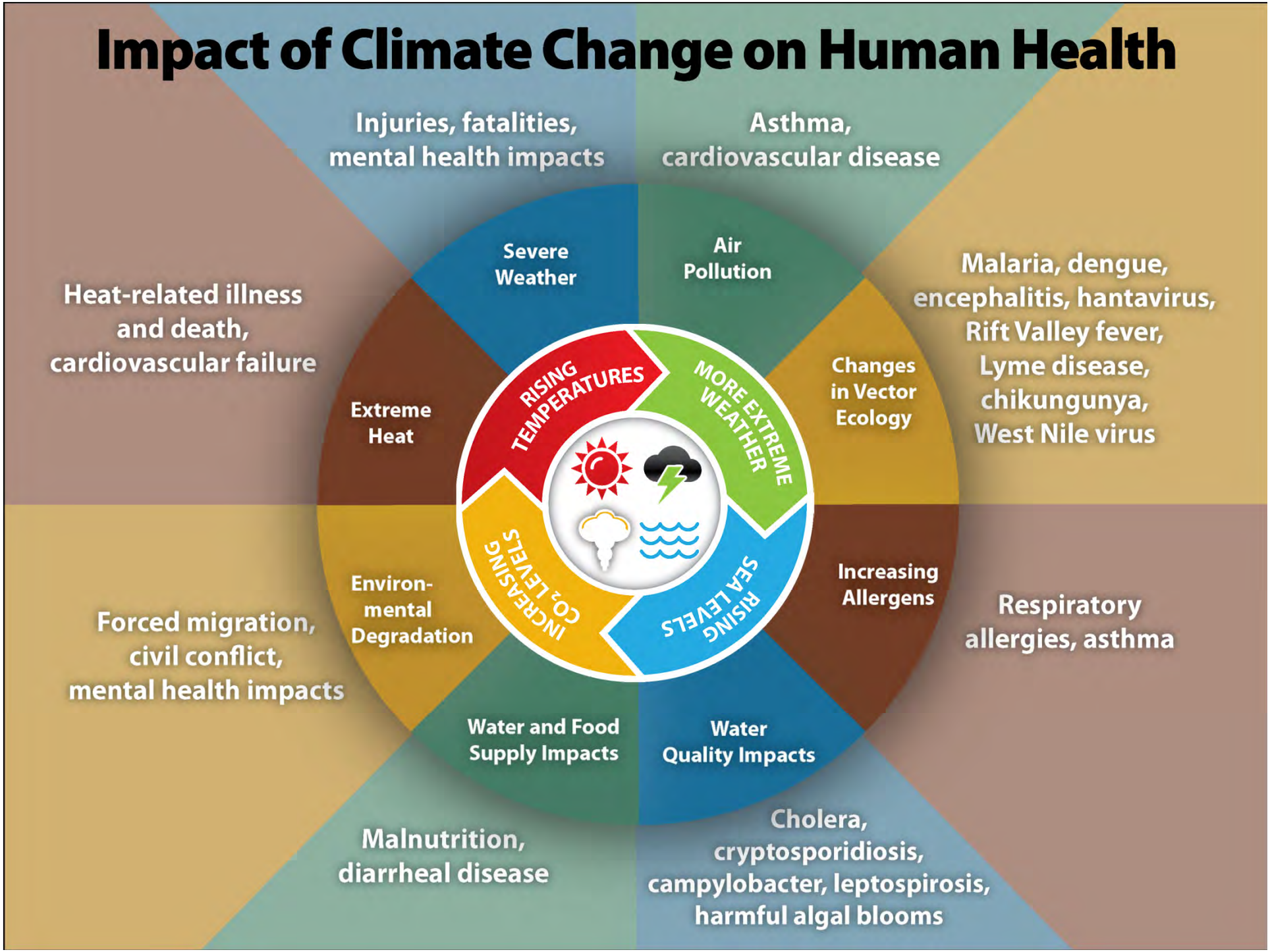
Precautionary principle

"When an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established"



-- Wingspread Conference on the Precautionary Principle, 1998

http://praxisfound.wordpress.com/2010/03/11/pondering-the-precautionary-principle/


Impact of Climate Change on Human Health
Injuries, fatalities, mental health impacts
Asthma, cardiovascular disease
Heat-related illness and death, cardiovascular failure
Malaria, dengue, encephalitis, hantavirus, Rift Valley fever, Lyme disease, chikungunya, West Nile virus
Forced migration, civil conflict, mental health impacts
Respiratory allergies, asthma
Malnutrition, diarrheal disease
Cholera, cryptosporidiosis, campylobacter, leptospirosis, harmful algal blooms
Severe Weather
Air Pollution
Extreme Heat
Changes in Vector Ecology
Environ-mental Degradation
Increasing Allergens
Water and Food Supply Impacts
Water Quality Impacts
RISING TEMPERATURES
MORE EXTREME WEATHER
INCREASING CO2 LEVELS
RISING SEA LEVELS

We conduct population-wide experiments

Outline for today

- Global burden of disease due to pollution (chronic exposure)
  - Quantification, distribution, cost
- Emerging threats / Results from our group
- Environmental policy
- **Where do we go from there?**

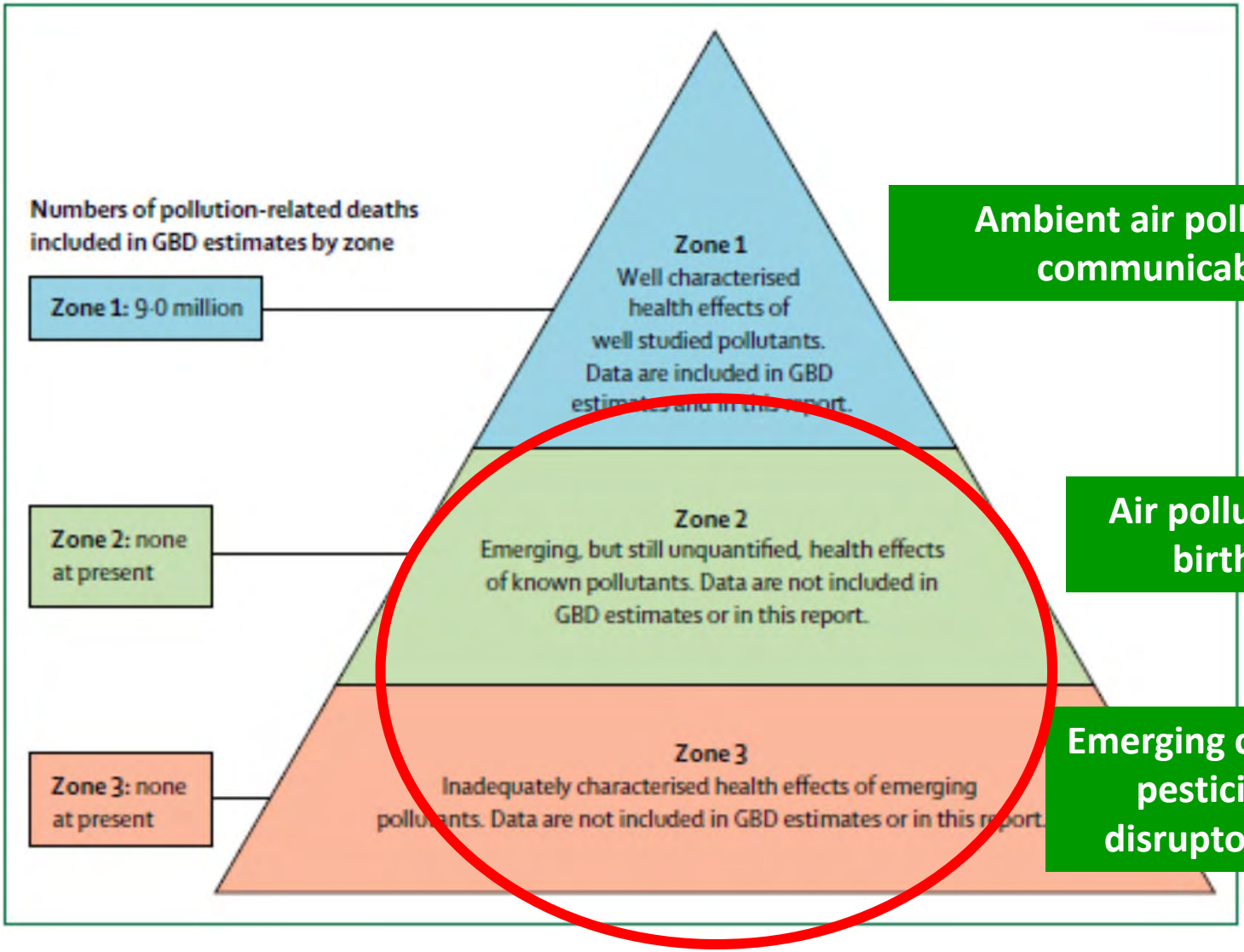
Canadian Environmental Protection act of 1999

- Changes to the law supported by hundreds of scientists
  - Reverse burden of proof for substances of very high concern
  - Ensure that toxic substances are replace with safer alternatives
  - Create national air quality standards that are legally binding
  - Mandatory labeling of toxic substances in consumer products
  - Take vulnerable populations into account in risk assessment

Major need for action now!

- Policy changes
- Enforcing regulations
- Funding to develop and apply technological solutions
- And…

Major need for research on health effects on emerging health risks



Landrigan et al. 2017

Looking for students!

For more information…

- Center for Environmental Research and Children's Health (CERCH) **www.cerch.org**
- Environmental Working Group **www.ewg.org**
- Pesticide Action Network **www.panna.org**
- Collaborative on Health and the Environment **www.healthandenvironment.org**
- Environmental Health News **www.environmentalhealthnews.org**