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
Global Causes of Mortality, 2015

Number of Deaths (Millions)

Pollution caused 9 million deaths in 2015

> 90% deaths from pollution in low- and middle income countries

“Unhealthy environments”
12.6 million deaths (23% of total)

Lancet Commission on Pollution and Health, 2017

- “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

Numbers of pollution-related deaths included in GBD estimates by zone:

- Zone 1: 9.0 million
- Zone 2: none at present
- Zone 3: none at present

Landrigan et al. 2017
### Number of deaths by pollution source examined

<table>
<thead>
<tr>
<th>Source</th>
<th>GBD study best estimate (95% CI)</th>
<th>WHO best estimate (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air (total)</td>
<td>6.5 (5.7–7.3)</td>
<td>6.5 (5.4–7.4)</td>
</tr>
<tr>
<td>Household air</td>
<td>2.9 (2.2–3.6)</td>
<td>4.3 (3.7–4.8)</td>
</tr>
<tr>
<td>Ambient particulate</td>
<td>4.2 (3.7–4.8)</td>
<td>3.0 (3.7–4.8)</td>
</tr>
<tr>
<td>Ambient ozone</td>
<td>0.3 (0.1–0.4)</td>
<td>..</td>
</tr>
<tr>
<td>Water (total)</td>
<td>1.8 (1.4–2.2)</td>
<td>0.8 (0.7–1.0)</td>
</tr>
<tr>
<td>Unsafe sanitation</td>
<td>0.8 (0.7–0.9)</td>
<td>0.3 (0.1–0.4)</td>
</tr>
<tr>
<td>Unsafe source</td>
<td>1.3 (1.0–1.4)</td>
<td>0.5 (0.2–0.7)</td>
</tr>
<tr>
<td>Occupational</td>
<td>0.8 (0.8–0.9)</td>
<td>0.4 (0.3–0.4)</td>
</tr>
<tr>
<td>Carcinogens</td>
<td>0.5 (0.5–0.5)</td>
<td>0.1 (0.1–0.1)</td>
</tr>
<tr>
<td>Particulates</td>
<td>0.4 (0.3–0.4)</td>
<td>0.2 (0.2–0.3)</td>
</tr>
<tr>
<td>Soil, heavy metals, and chemicals</td>
<td>0.5 (0.2–0.8)</td>
<td>0.7 (0.2–0.8)</td>
</tr>
<tr>
<td>Lead</td>
<td>0.5 (0.2–0.8)</td>
<td>0.7 (0.2–0.8)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>9.0</td>
<td>8.4</td>
</tr>
</tbody>
</table>

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—e.g., 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)*⁶⁴ versus WHO data (2012)⁹⁸,¹⁰¹
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 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
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

- 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

~ 5 points

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.
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

NOTICE

THIS ARTICLE MEETS ALL FLAMMABILITY REQUIREMENTS OF CALIFORNIA BUREAU OF HOME FURNISHINGS BULLETINS 116 AND 117. CARE SHOULD BE EXERCISED NEAR OPEN FLAME OR WITH BURNING CIGARETTES.

TB 116/117
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

Thyroid Hormone → Fertility
Thyroid Hormone → Birth weight
Thyroid Hormone → Obesity

Neuro-behavioral development
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

1939
DDT discovered

1948
Müller wins Nobel Prize for DDT discovery

1948
Müller wins Nobel Prize for DDT discovery

History of DDT

"DDT is good for me-e-e-e!"

Time Magazine, June 30, 1947
Widespread Use of DDT

DDT being sprayed on Long Island beaches in 1945
History of DDT

- **1939**: DDT discovered
- **1940-1970**: Various years with different events
- **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
- **2005-2010**: Various years with different events
- **2011**: WHO concludes exposure in IRS areas below levels of concern
History of Pyrethroids

- **1800’s...**: Early 19th Century
  - Natural pyrethrum is widely available in Europe

- **1920’s**: Active structure of pyrethroids is discovered

- **1960**: 1st generation synthetic pyrethroids created

- **1970**: 2nd generation pyrethroids are created

- **1980**: Pyrethroids comprise 20% of the total insecticide market

- **2002...**: 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-Cyhalothrin
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

Venda Health Examination of Mothers, Babies and their Environment

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

Out with the old, in with the old...

Bisphenol-A

\[
\begin{array}{c}
\text{HO-} \\
\text{CH}_3 \text{-} \\
\text{HO-}
\end{array}
\]

\[
\begin{array}{c}
\text{CH}_3 \\
\text{OH}
\end{array}
\]

Bisphenol-F

\[
\begin{array}{c}
\text{HO-} \\
\text{H} \quad \text{H} \\
\text{OH}
\end{array}
\]
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”


Impact of Climate Change on Human Health

- Injuries, fatalities, mental health impacts
- Asthma, cardiovascular disease
- Severe Weather
- Air Pollution
- Malaria, dengue, encephalitis, hantavirus, Rift Valley fever, Lyme disease, chikungunya, West Nile virus
- Respiratory allergies, asthma
- Forced migration, civil conflict, mental health impacts
- Extreme Heat
- Changes in Vector Ecology
- Increasing Allergens
- Malnutrition, diarrheal disease
- Water and Food Supply Impacts
- Water Quality Impacts
- Cholera, cryptosporidiosis, campylobacter, leptospirosis, harmful algal blooms
- Heat-related illness and death, cardiovascular failure
- Environmental Degradation
- Increasing CO2 Levels
- Rising Temperatures
- More Extreme Weather
We conduct population-wide experiments
Outline for today

- Global burden of disease due to pollution (chronic exposure)
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- 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

- 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
Looking for students!

McGill
Department of Epidemiology, Biostatistics and Occupational Health
APPLICATION DEADLINE DEC 15
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