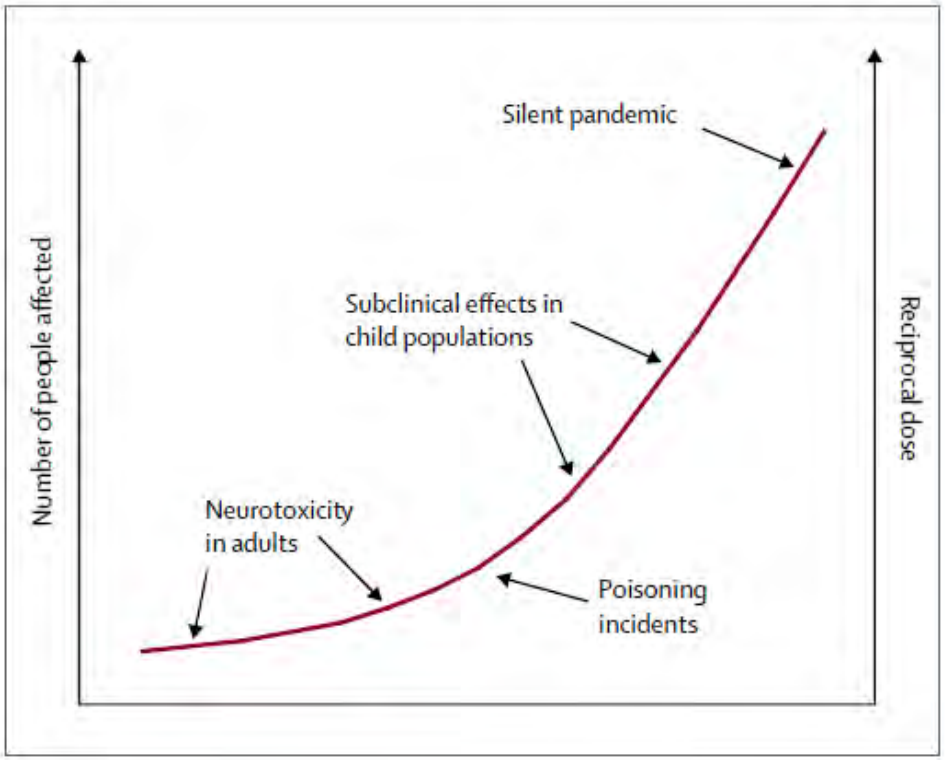
Can we Reduce Inevitable Exposures to Chemicals of Concern?

Miriam Diamond
University of Toronto

25 October, 2023
NCCEH Seminar

To start.... Motivation

Widespread exposure to anthropogenic chemicals, especially during fetal development, contributes significantly to human morbidity and mortality, and is costly for society



Granjean P & PJ Landrigan. 2006 Lancet DOI:10.1016/S0140-6736(06)69665-7
Grandjean P & PJ Landrigan 2014 *Lancet Neurol* 13: 330-338
http://dx.doi.org/10.1016/S1474-4422(13)70278-3

Two examples

Pesticides Globally[1]

- 385 million cases of unintentional acute poisoning (44% of farmers) leading to 11,000 fatalities annually
- Reproductive disorders, cancers, neurological disorders, respiratory illness

PFAS in European Economic Area[2] ($C_{4\text{-}14}$ non-polymer fluorosurfactants)

- 83,627-273,000 occupationally exposed leading to 12,000 deaths (kidney cancer)
- “Moderate” exposure to 3% population or 12.5 million
- Low birth weight, infection (immune system effects), hypertension

[1] Boedeker W et al. *BMC Public Health* 7(2): 1875 doi: 10.1186/s12889-020-09939-0

[2] Goldenman G et al. 2019. The Cost of Inaction. Nordic Council of Ministers

Motivation – Cost of Inaction

PFAS – Health Costs[1]

- EUR 12.7-41.4 million due to occupational exposure in EEA countries[2]
- EUR 52-84 billion due to non-occupational exposure in EEA countries[3]

Non-health Costs

- EUR 821 million to 170 billion[4]

[1]Goldenman G et al. 2019. The Cost of Inaction. Nordic Council of Ministers

[2] kidney cancer; [3] all-cause mortality, low birth weight, infection, hypertension; [4] monitoring, health assessment, upgrading water treatment, remediation

Argument

- Inevitability of exposure
- Inability to sufficiently reduce exposures to protect populations

Why?

- Uncontrolled increasing production & uses
- Uncontrolled proliferation of number of chemicals
- Inability to assess and then control
- Lock-in

What?

- Actions & implementation for harm reduction

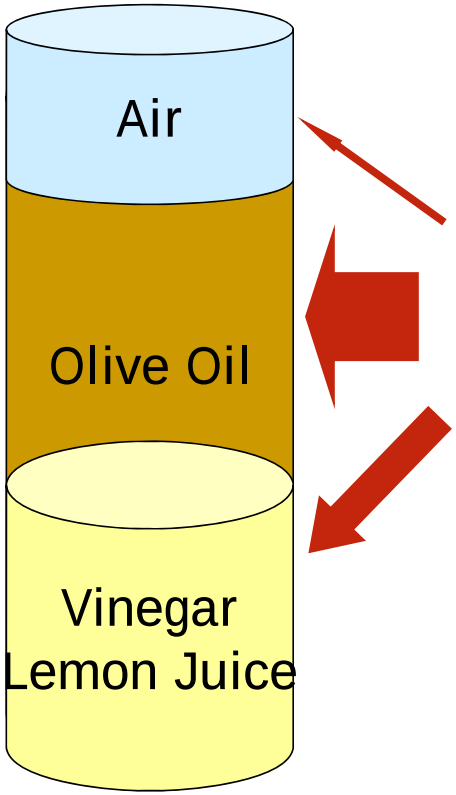
Behind the Argument: Explanations

- Populations are inevitably exposed to anthropogenic chemicals

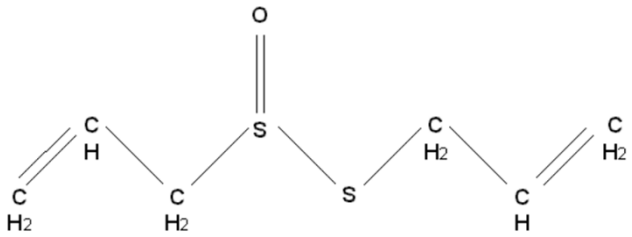
1. Basic thermodynamics - its all about fugacity
2. Chemical production & consumption – total amount, numbers of chemicals & applications
3. We're not all equal

Exposure: 1. Its all about fugacity

Partitioning of neutral chemicals at chemical equilibrium



Allicin from Garlic



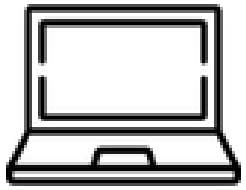
http://www.outtacontext.com/life/images/garlic_icecream.jpg

1a. What is fugacity?

Cold

Temperature

Hot



Low

Fugacity

High

Don Mackay

Officer of the Order of Canada

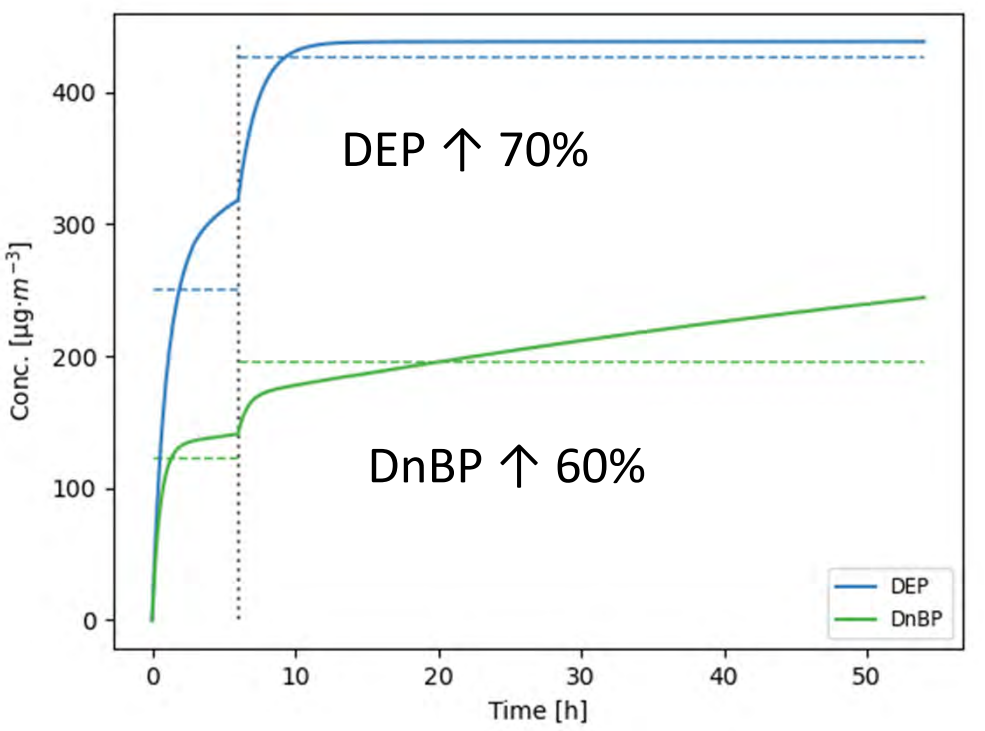
https://www.trentu.ca/newsarchive/pressreleases/mackaybio.html

Food icons created by Freepik - Flaticon
Laptop icons created by Freepik - Flaticon

1. Chemicals strive towards eqi-fugacity

Zhang X et al. 2009. Multimedia modeling of PBDE emissions and fate indoors. *Environ Sci Technol* 43(8): 2845-2850.

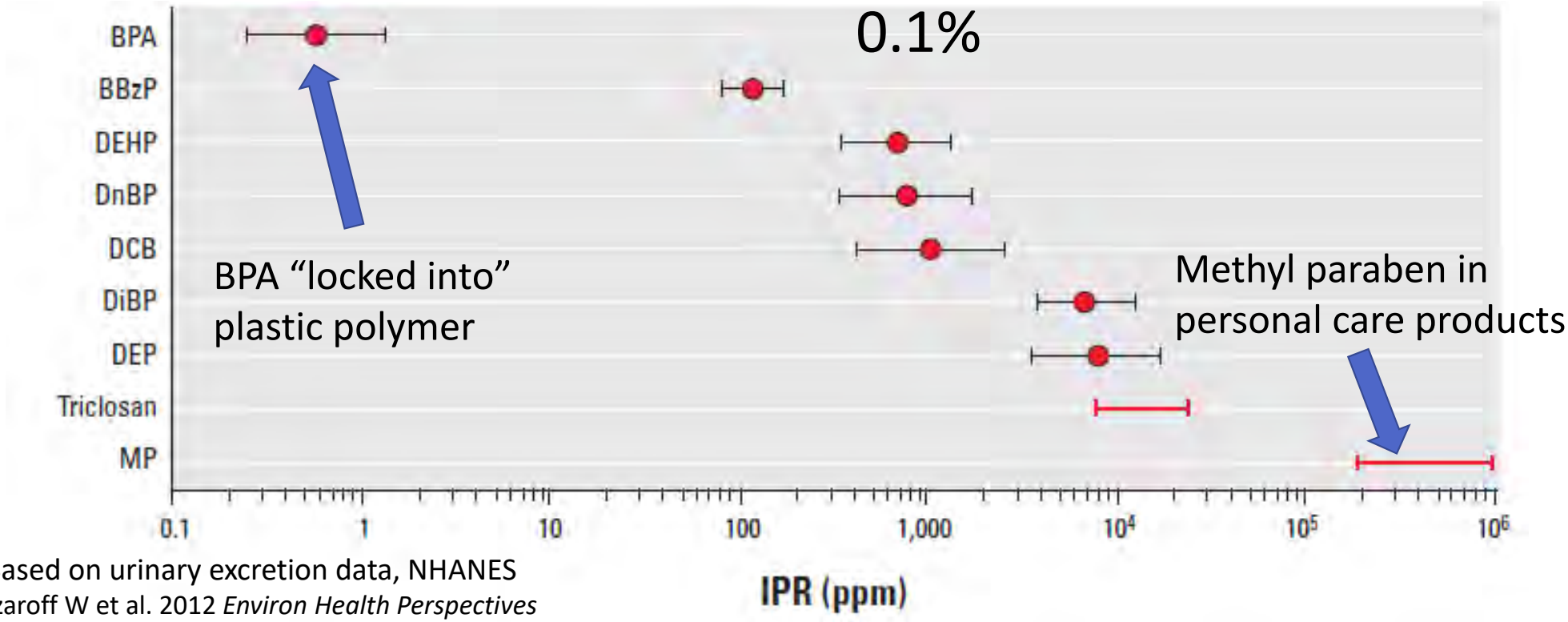
For example… Consider 3 guys in a room with phthalates in air



Weschler CJ et al. 2015. *Env. Health Perspect* **2015**, *123* (10), 928–934.
https://doi.org/10.1289/ehp.1409151
https://eohsi.rutgers.edu/zarblrt-2/

Kvasnicka J et al. *JESEE*, under revision.

Exposure: 2. Chemical Production
Intake* to Production Ratio for US



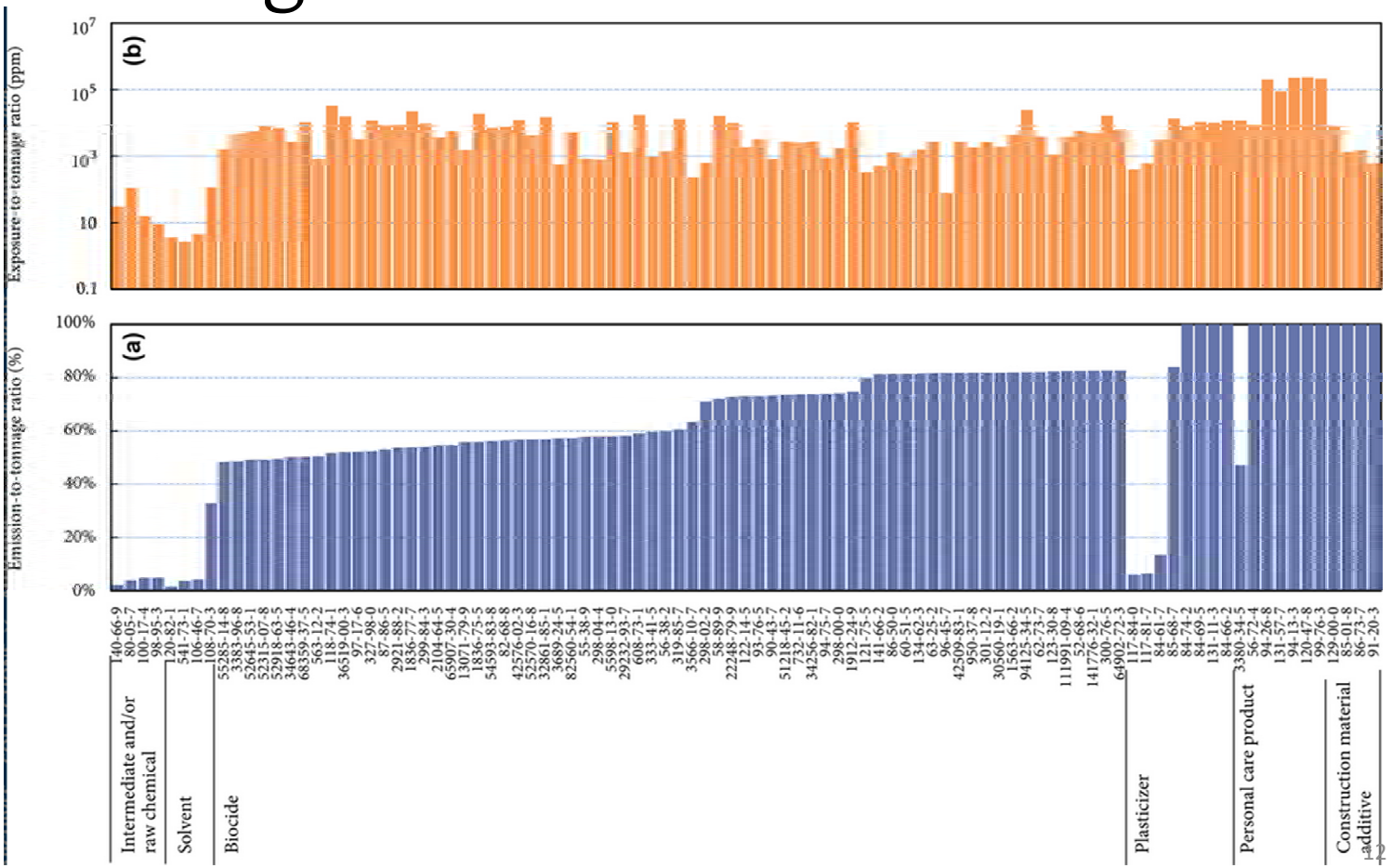
* Based on urinary excretion data, NHANES

Nazaroff W et al. 2012 *Environ Health Perspectives*

https://ehp.niehs.nih.gov/doi/10.1289/ehp.1204992

Exposure: 2. Chemical Production
Exposure to Tonnage Ratio

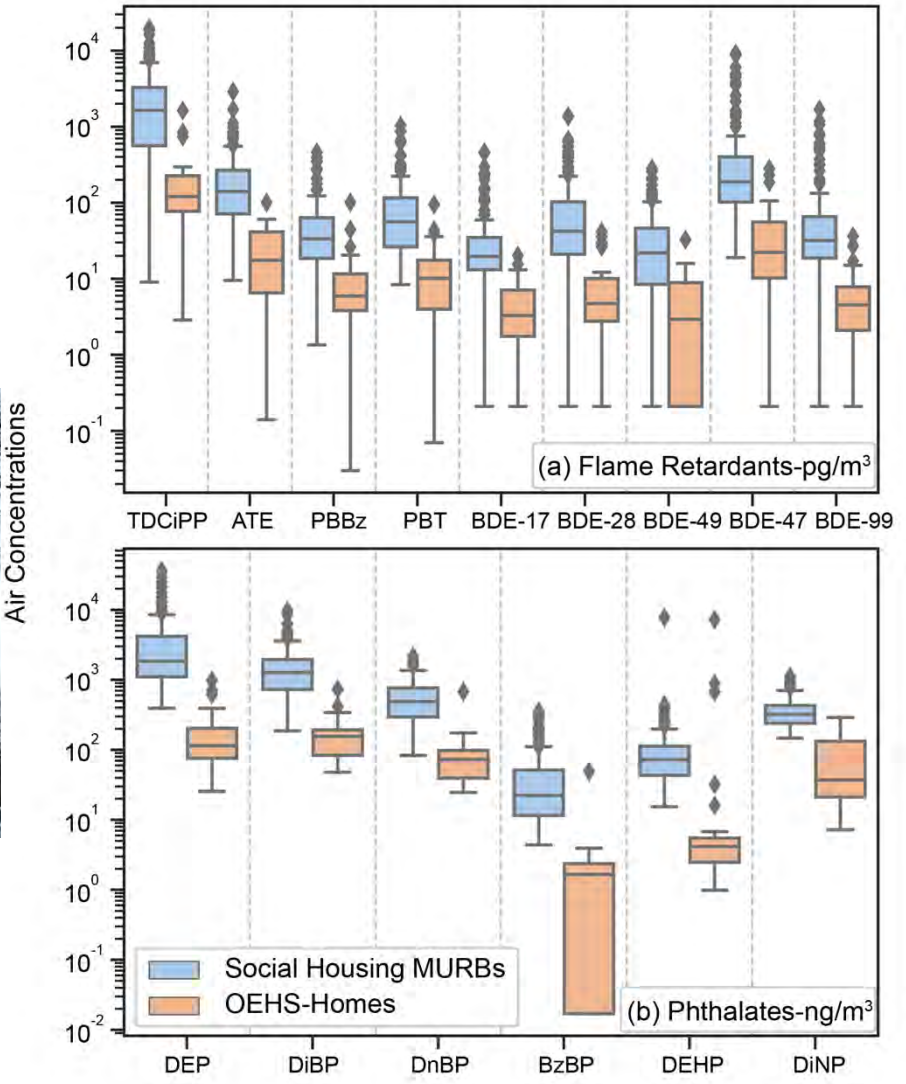
0.1%



Li Li et al. 2021. *Environ Health Perspec* CID: 127006 https://doi.org/10.1289/EHP9372

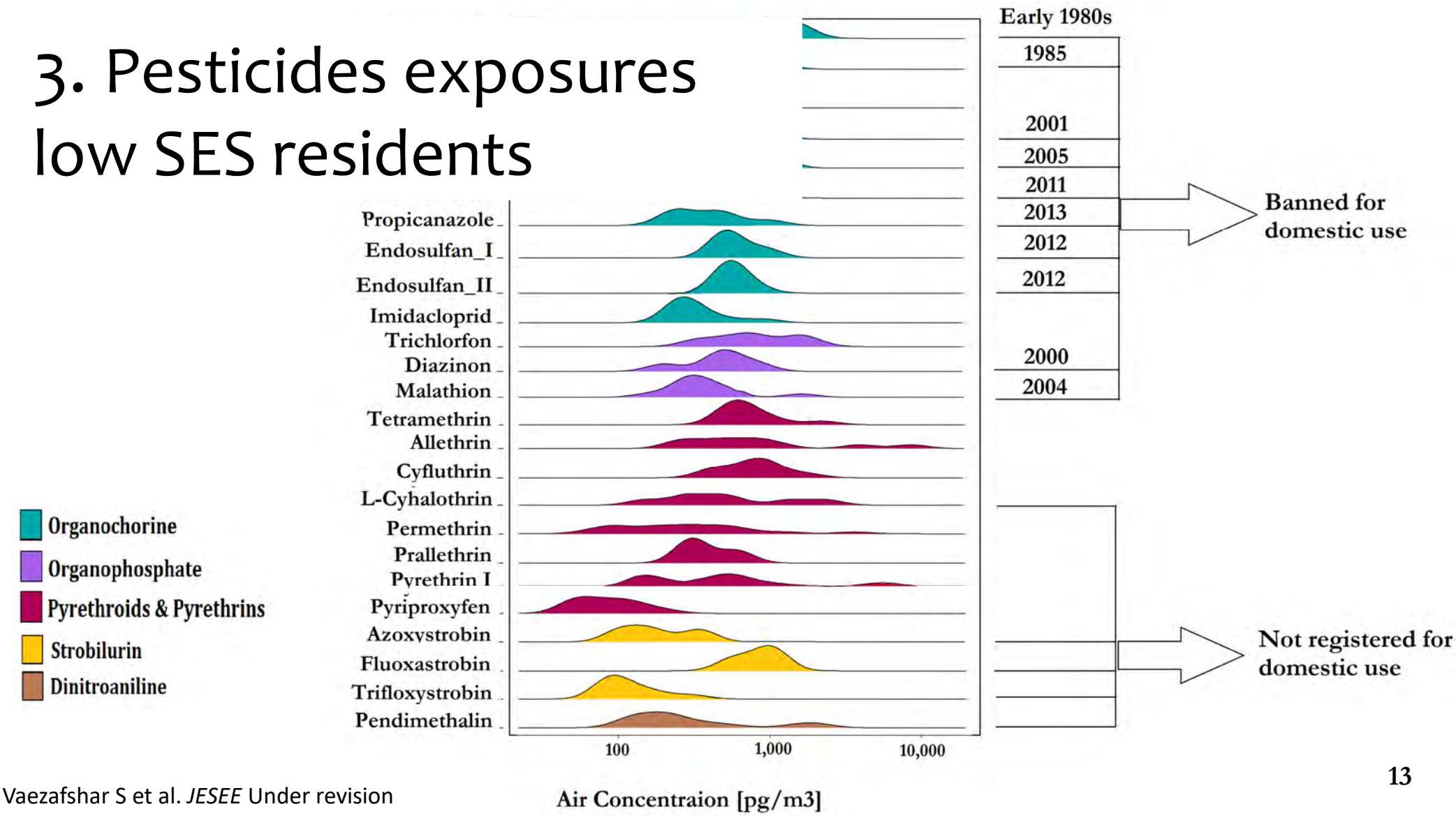
3. We're not all equal

Low SES residents have higher exposures



Wan et al. 2020. *Environ Sci Technol Lett* 7(3): 191-197.
https://doi.org/10.1021/acs.estlett.0c00068

3. Pesticides exposures low SES residents



Vaezafshar S et al. *JESEE* Under revision

Argument

- Inevitability of exposure
- Inability to sufficiently reduce exposures to protect populations

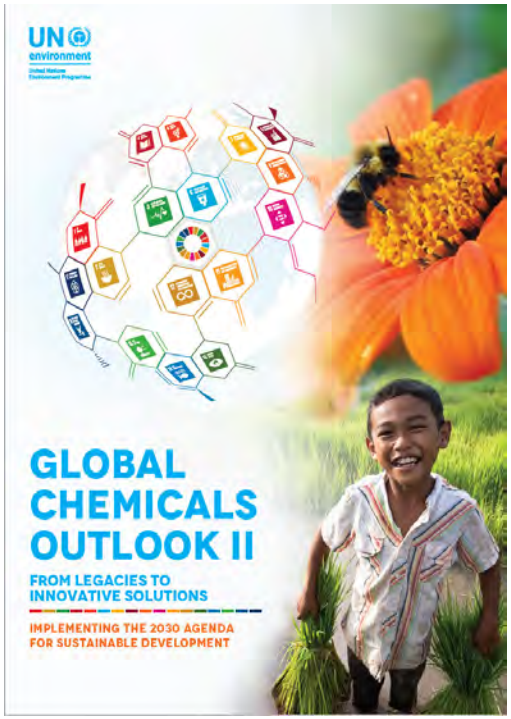
Why?

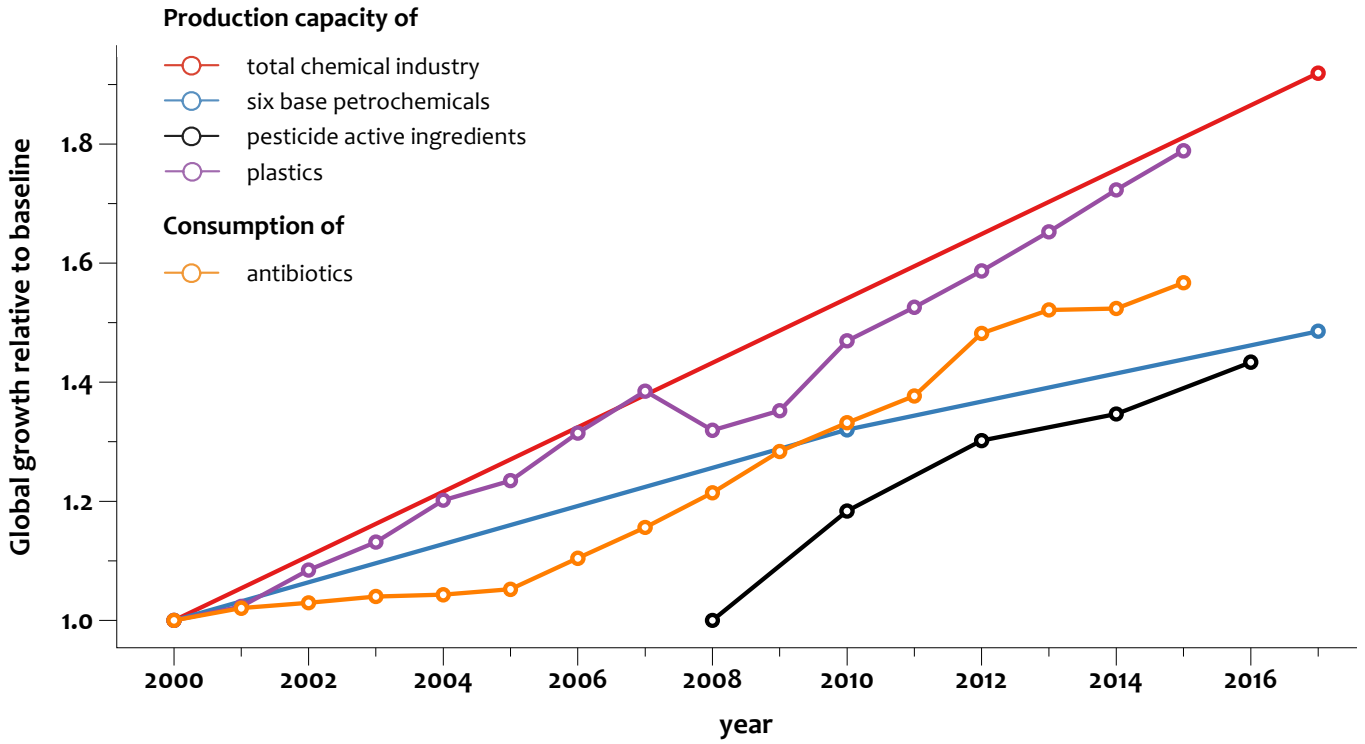
1. Uncontrolled increasing production & uses
2. Uncontrolled proliferation of chemicals
3. Inability to assess and control
4. Lock-in

What?

- Actions & implementation for harm reduction

1. Growth of chemical production/consumption

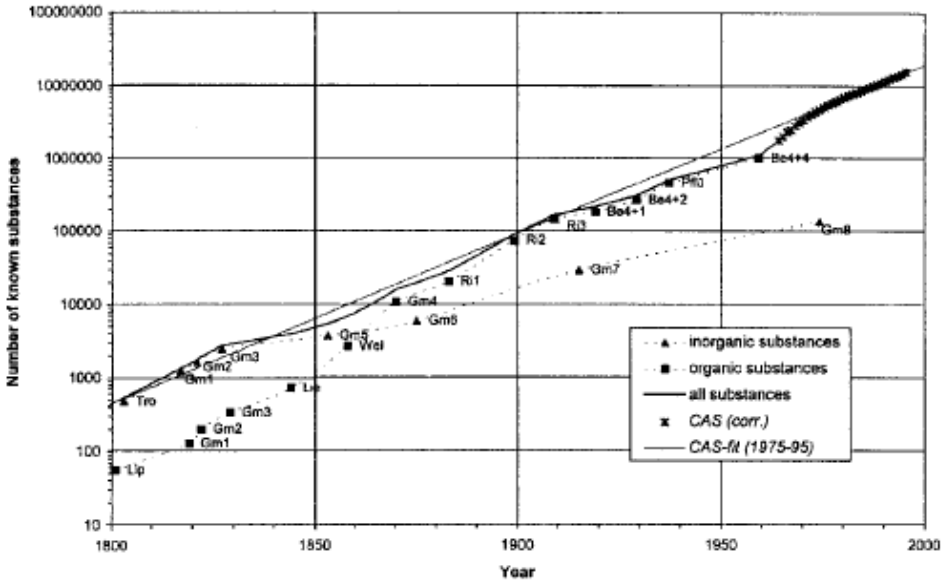




L. Persson et al., 2022. *Environ Sci &Technol* 56: 1510-1521 https://doi.org/10.1021/acs.est.1c04158

2. Uncontrolled proliferation of chemicals

- 350,000 substances registered for use globally
  - 70,000 registered 2010-2020
  - 30,000 registered in emerging economies
  - 50,000 confidential
  - 70,000 ambiguous



Wang Z et al. 2020. Towards a global understanding of chemical pollution. *Environ Sci Technol* 54: 2575-2584.

Schummer J. 1997. Scientometric studies on chemistry I: The exponential growth of chemicals substances 1800-1995. *Scientometrics* 39: 107-123.

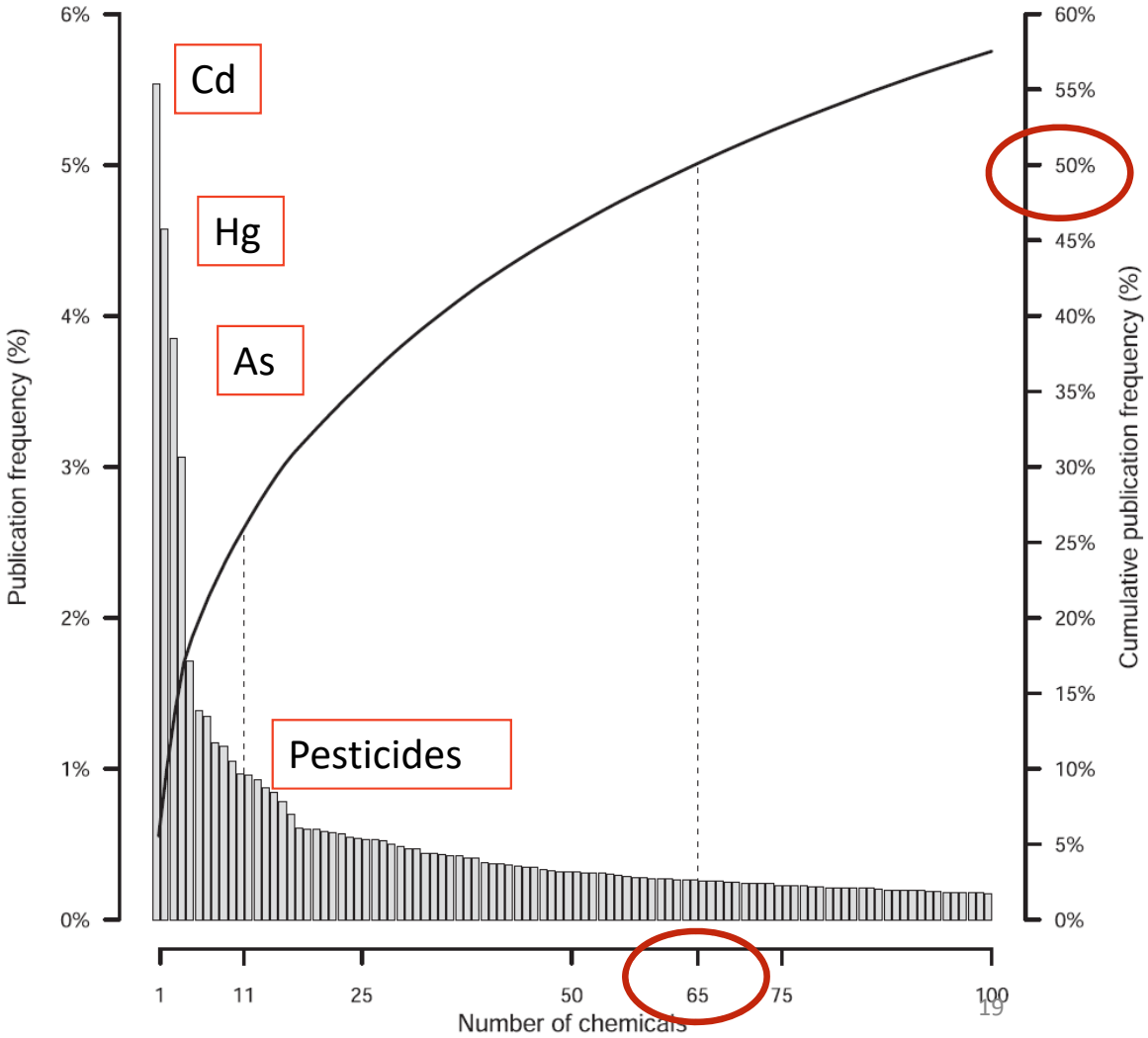
2. Uncontrolled Proliferation of Chemicals - Plastics

- 10,000 substances used in plastics[1]
  - 2,400 are chemicals of concern
- 400 Mt of additives[2]

[1] Wiesinger H et al. 2021. Deep dive into plastic monomers… *Environ Sci Technol* https://doi.org/10.1021/acs.est.1c00976
[2] Geyer r. 2020. Production, use, and fate of synthetic polymers. Pages 13–32 *Plastic Waste and Recycling*. Elsevier.
https://www.nationalgeographic.org/society/

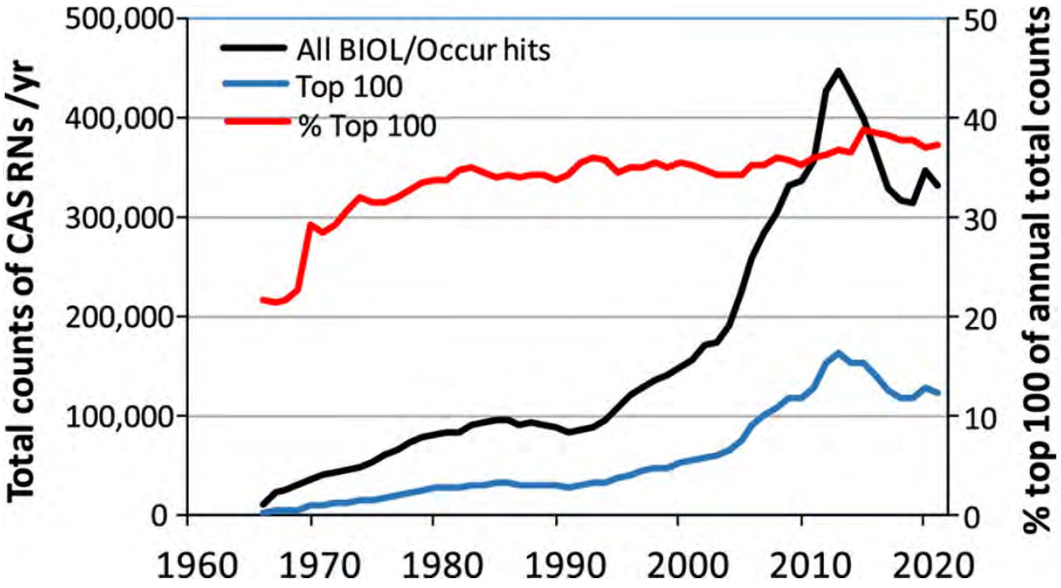
3. Inability to assess:
We know a lot about very few chemicals.
Part I. Ecotoxicity

- Half of 130,000 papers considered 65 out of 3500 chemicals



Kristiansson E et al. 2021 *Environ Sci & Policy* 126: 90-98
https://doi.org/10.1016/j.envsci.2021.09.007

3. Inability to assess:
We know a lot about very few chemicals
Part II. All chemicals - citations

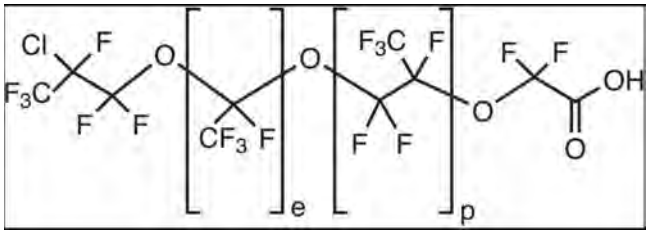


- 34% of citations were 100 most reported chemicals
- 50-60% were metals, pharmaceuticals & pesticides
- 5% were industrial chemicals

Muir DCG et al 2023. *Environ Sci Technol* 57: 9119-9129.
https://doi.org/10.1021/acs.est.2c09353

3. Too many chemicals to assess

- EU REACH
  - ~23,000 substances; 80% yet to be assessed
- Case study: Chloroperfluoropolyether carboxylate compounds (ClPFPECAs)
  - High enough and long enough production volumes to be widely distributed (Washington et al. 2020)
- US EPA – no data
- ECHA – acute toxicity
- EFSA – not mutagenic



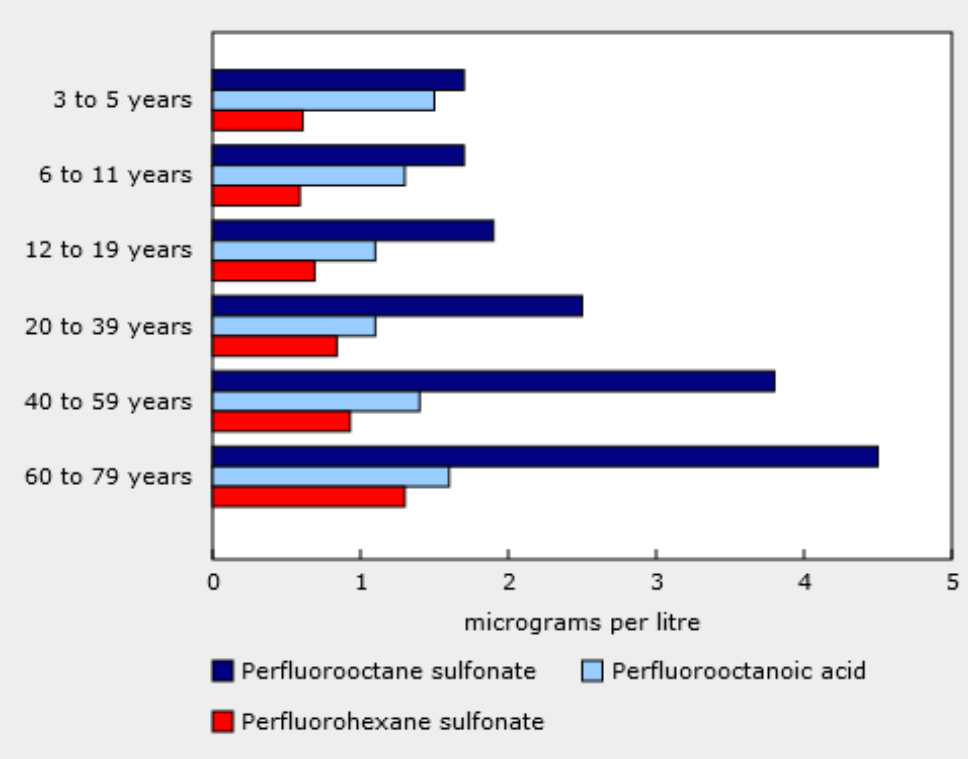
Where are the data?

The EPA Comptox chemical-toxicological database includes an entry for the ClPFPECAs, but indicates that no data or values are available for any of the categories of information. See (*16*).

- ⊗ Quantitative Risk Assessment Values
- ⊗ Quantitative Hazard Values
- ⊗ Cancer Information
- ⊗ Reproductive Toxicology
- ⊗ Chronic Toxicology
- ⊗ Subchronic Toxicology
- ⊗ Developmental Toxicology
- ⊗ Acute Toxicology
- ⊗ Subacute Toxicology
- ⊗ Neurotoxicology
- ⊗ Endocrine System
- ⊗ Absorption, Distribution, Metabolism, and Elimination
- ⊗ Fate and Transport
- ⊗ Exposure
- ⊗ Adverse Outcome Pathway Information
- ⊗ Water Quality
- ⊗ Air Quality
- ⊗ Occupational Exposure

Washington JW et al 2020. *Science* https://www.science.org/doi/10.1126/science.aba7127
Gold SC & WE Wagner. 2020. *Science* https://www.science.org/doi/10.1126/science.abc1250

3. Inability to control exposure through risk-based chemicals management

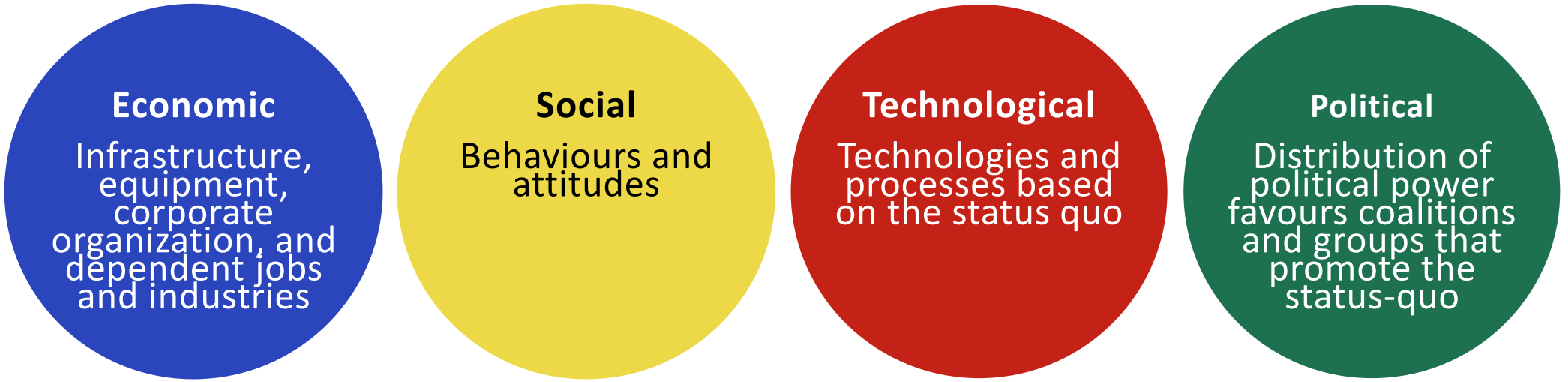


- 98.5% of Canadians have/had measurable blood PFOS, PFOA & PFHxS at low µg/L
- US EPA proposed drinking water guideline 4 ng/L
- **PFOS** regulations in 2008, 2016, 2022 (CEPA)

Canadian Health Measure Survey, Cycle 5 (2016-2017)
https://www150.statcan.gc.ca/n1/daily-quotidien/191113/cg-a003-eng.htm

4. Lock-in

What is it?



Slide courtesy of Jonathan Blumenthal

Blumenthal J et al. 2022. Time to break the "lock-in" impediments to chemicals management. *Environ Sci Technol* 56(7): 3863-3870. https://doi.org/10.1021/acs.est.1c06615

PFOS: The timeline

1977-1990s
3M found evidence of toxicity, bioaccumulation, but continued to produce PFOS

1999-2002
3M reached voluntary agreement w/ US EPA to stop producing PFOS

2002-2006
Chinese production grew 2002-2006 from 30 to 247 tons/year

2009
PFOS listed under Stockholm Convention (with exemptions)

2011-present
2017-2023 Global Environment Facility (GEF) > $150 million USD to reduce production in China

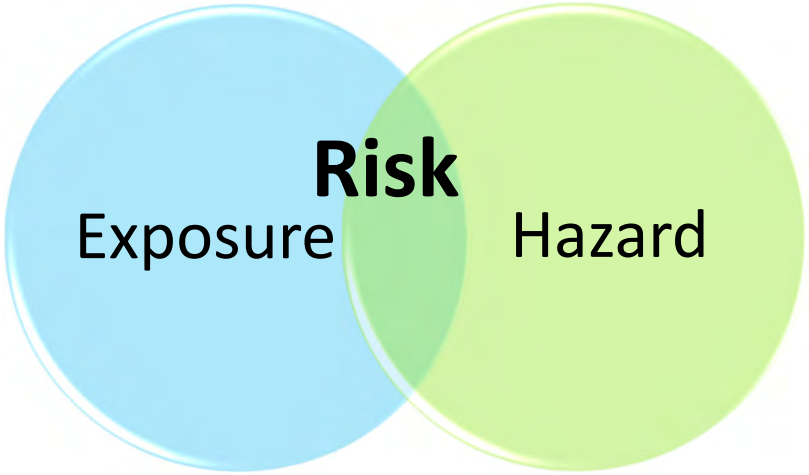
Slide courtesy of Jonathan Blumenthal

Key failure: Restrict supply without addressing demand

Actions & Implementation for Harm Reduction

1. Hazard and not risk assessment
2. Chemical “simplification”
   - To enable assessment
   - To enable circular economy
3. Cap chemical emissions & production
4. Break “lock-in”
5. Sufficiency

1. Hazard and Not Risk Assessment



Because of lock in

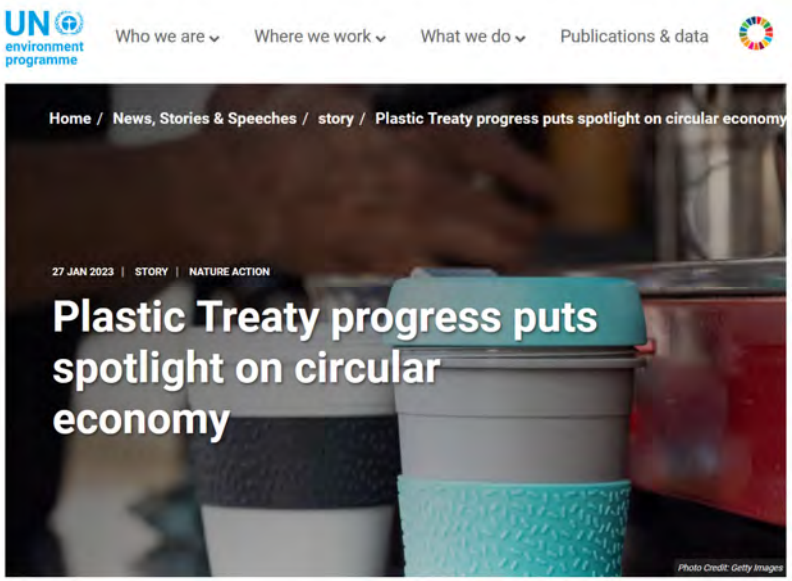
Canadian Chemicals Management Plan

- Schedule of “Toxic” compounds from risk assessment
- List of high hazard

EU - REACH

- E.g., Hazard classification - CMR (carcinogenic, mutagenic, reproductive toxicity)

2. Chemical Simplification

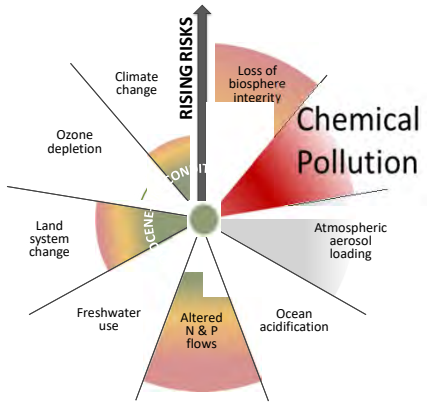


https://www.unep.org/news-and-stories/story/plastic-treaty-progress-puts-spotlight-circular-economy

- > 10,000 substances in plastic production & processing
  - 2,400 are chemicals of concern
- Need simpler polymer composition for managing plastic waste
  - Harmonized plastic formulation of PET bottles

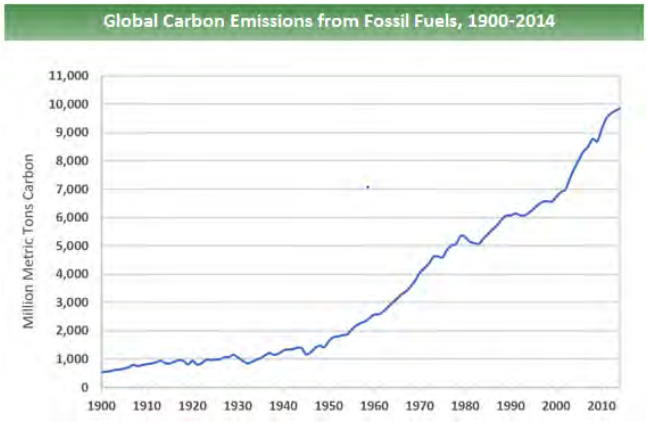
Wiesinger H et al. 2021. Deep dive into plastic monomer, additives, and processing aids. *Environ Sci Technol* 55: 9339-9351.
Wang Z & A Praetorius. 2020. Integrating a chemicals perspectives into the Global Plastics Treaty. *Environ Sci Tech Lett* 9(12): 1000-1006.
https://resource-recycling.com/plastics/2020/12/02/pet-bottle-recycling-rate-drops-in-us/

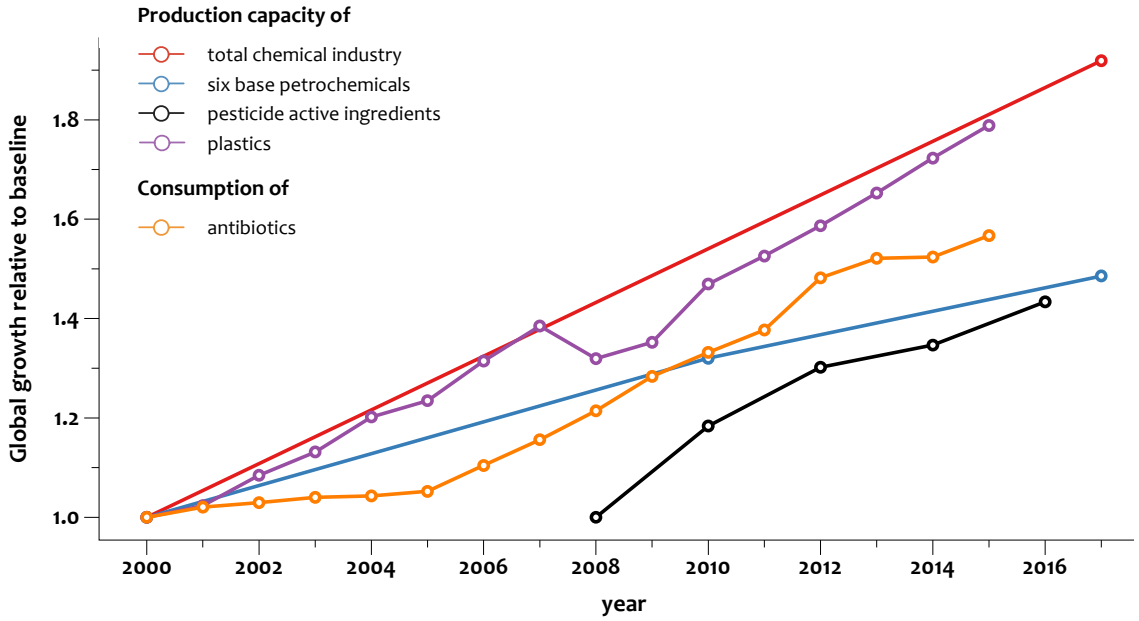
3. Cap on Chemical Production Planetary Boundary Proposal



- Global cap on emissions (Persson et al. 2022)
  - Move from "activity-based" to "fixed cap" emission limits

- Global cap on production





https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data
https://ourworldindata.org/exports/global-plastics-production_v2_850x600.svg

4. Break Lock-In: Manage Supply & Demand

1: Broaden the scope of regulations

+

2: Engage all stakeholders early

+

3: Long-term, proactive thinking

Restrictions need to reflect global interconnections to prevent unwanted market responses

Need comprehensive plans for transition, e.g., economic supports

Prevent lock-in before it happens, e.g., safer alternatives, **hazard- (not risk-) based management**

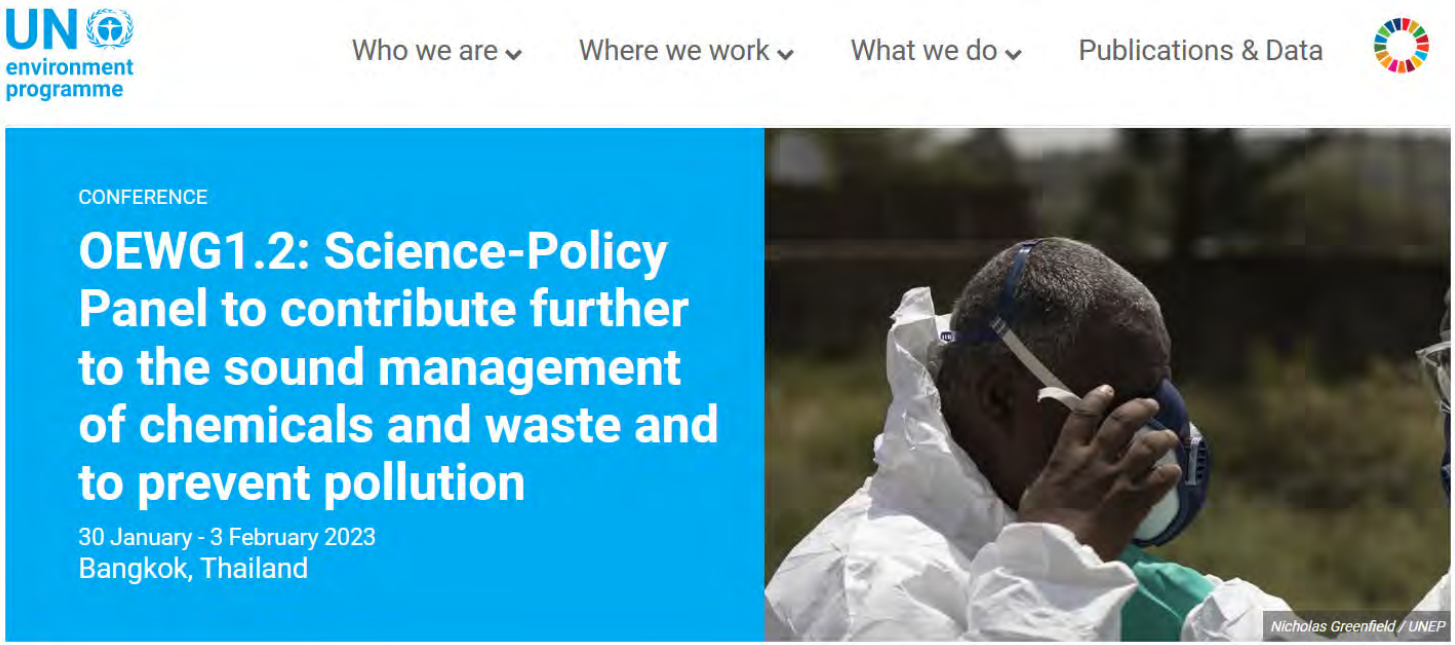
Slide courtesy of Jonathan Blumenthal

Blumenthal J et al. 2022. Time to break the "lock-in" impediments to chemicals management. *Environ Sci Technol* 56(7): 3863-3870. https://doi.org/10.1021/acs.est.1c06615

Multi-lateral Environmental Agreements

Intergovernmental fora

https://www.pops.int/



https://www.unep.org/oewg1.2-ssp-chemicals-waste-pollution

5. Precaution & Sufficiency

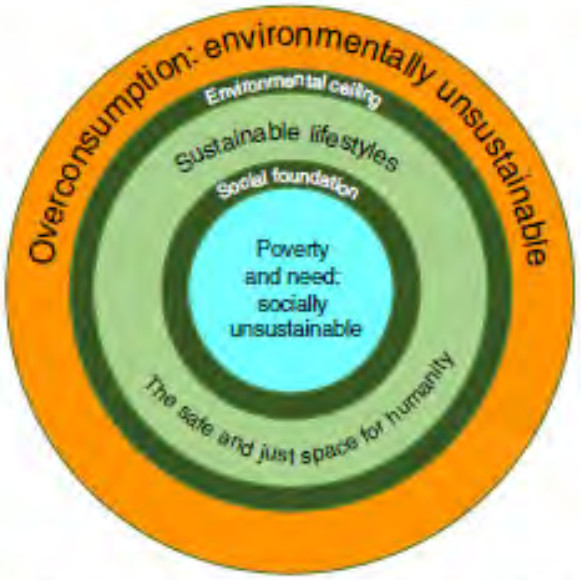


Fig. 2 The safe and just space for humanity. Sustainable lifestyles are situated between an upper limit of permissible use ("Environmental ceiling") and a lower limit of necessary use of environmental resources ("Social foundation") (figures from ref. [49] and ref. [84] combined and adapted).

Wiedmann et al. 2020. Scientists' warning on affluence. Nature Comm. 11: 3107
https://www.nature.com/articles/s41467-020-16941-y

Table 1. Key components of a Wellbeing Economy.

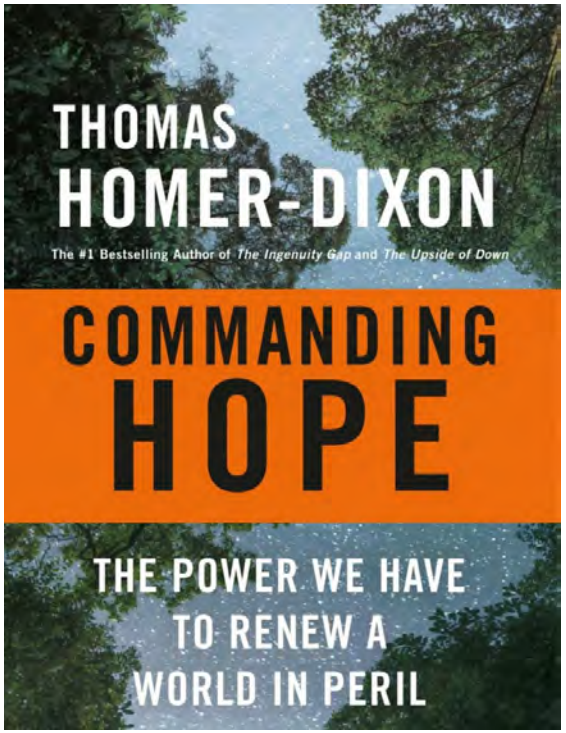
Adaptability to context	
Multi-dimensional approach	
Personal	Social
• Work-Life Balance	• Cohesion
• Psycho-Physical Health	• Equality
• Empowerment	• Community Engagement
Economic	Natural
• Customization	• Healthy Ecosystem Functions
• Localized Production	• Urban-Rural-Wild Balance
• Prosumer Approach	
• Total Cost and Benefit Accounting	

Fioramonti et al. 2022. From growth to degrowth to well being *Ecol Econ*
https://doi.org/10.1016/j.ecolecon.2021.107261

Thomas Homer-Dixon

…a **commanding hope** that's honest about the dangers ahead and astute about the strategies we should use to face those dangers, and one that powerfully motivates us… Let's not aim for what's merely feasible and falsely hope it will be enough. … With commanding hope, let's aim for what we'd *all* consider enough – a future in which our children and life on this planet can flourish.

Commanding Hope. 2022. Knopf Canada. p. 374



Acknowledgements

Funding

- NSERC, Environment & Climate Change Canada, Ontario Ministry of Environment etc., Health Canada

People

- My lab group!
- IPCP crew: Martin Scheringer, Marta Venier, Penny Vlahos, Marlene Ågerstrand et al.
- Lock-in crew: Zhanyun Wang, Jonathan Blumenthal
- Planetary Boundary crew: Linn Persson, Bethanie Carney Almroth, Cynthia de Wit, Sarah Cornell, Zhanyun Wang, et al.
- Arlene Blum (Green Science Policy Inst)