Learning from Chemical Flame Retardants: The Life Cycle Questions We Need to Answer

P2 Through Nanotechnology
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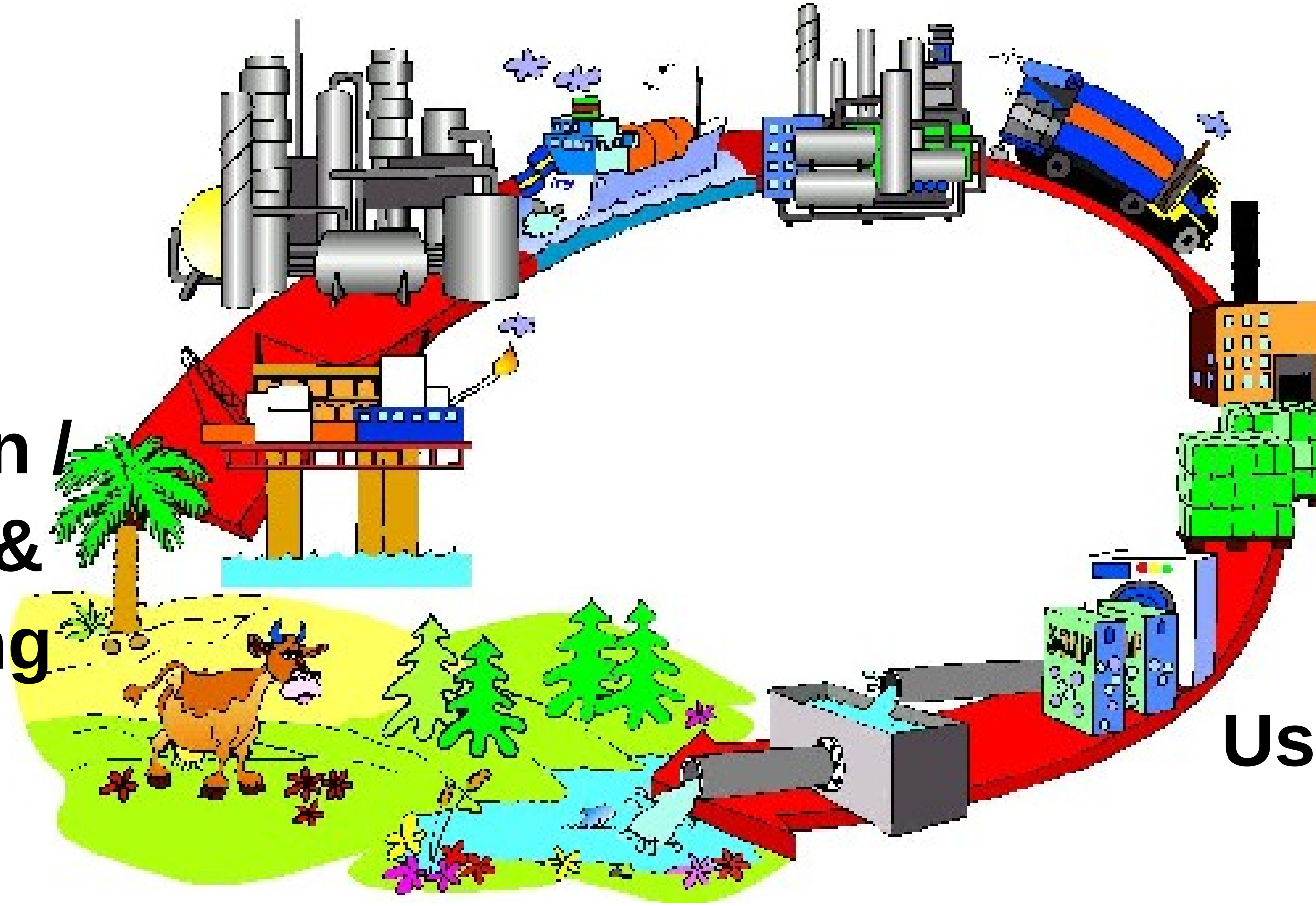
Clean Production Action

Life Cycle Thinking



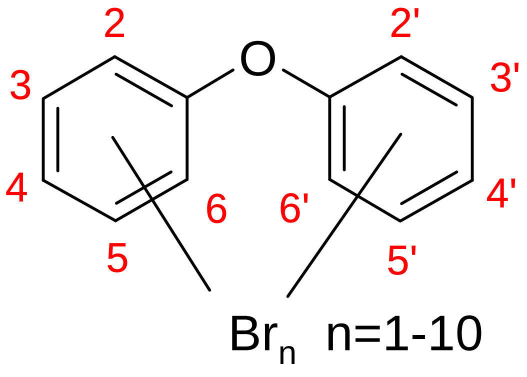
Brominated Flame Retardants (BFRs)

Polybrominated diphenyl ethers (PBDEs)

- pentaBDE (pentabromodiphenyl ether – “**Penta**”)
- octaBDE (octabromodiphenyl ether – “**Octa**”)
- decaBDE (decabromodiphenyl ether – “**Deca**”)

Tetrabromobisphenol A (TBBPA)

Hexabromocyclododecane (HBCD)



Polybrominated Diphenyl Ether (PBDE)

Extraction / Growing & Harvesting

- **Environmental concerns from extraction have not been raised during discussions of environmental concerns with flame retardants**

  (yet, we know that the environmental impacts of mining, drilling, and agriculture need to be minimized)

Manufacturing – Questions for Nanotech from FRs

1. How is worker exposure to nanomaterials minimized?

2. What are the emissions to the environment from manufacturing?

3. Is the nanomaterial reactive or additive in polymers?

Manufacturing – Worker Exposure

Occupational Exposure to Commercial Decabromodiphenyl Ether in Workers Manufacturing or Handling Flame-Retarded Rubber

KAJ THURESSON,*,† ÅKE BERGMAN,† AND KRISTINA JAKOBSSON‡ (2005)

Environmental Science & Technology Online

"The results confirm significant uptake of BDE-209 in the workers exposed to DecaBDE and indicate the potential for in vivo formation of lower BDEs"

Manufacturing – Emissions to the Environment – DecaBDE

Toxics Release Inventory Data, lbs (2004)

• On-site Releases	= 92,750
• On-site Disposal	= 151,040
• Off-site Transfers	= 710,697
Total Release & Transfer	**= 954,487**

Manufacturing – Reactive vs. Additive Chemistry

- **<u>Reactive chemical</u>**: integrated into the backbone of a polymer
- **<u>Additive chemical</u>**: mixed into the polymer, but not part of the polymer backbone
- Reactive chemicals are more stable – less likely to be released into the environment – than additive chemicals

However, reactive chemistry is no guarantee to eliminating environmental release:

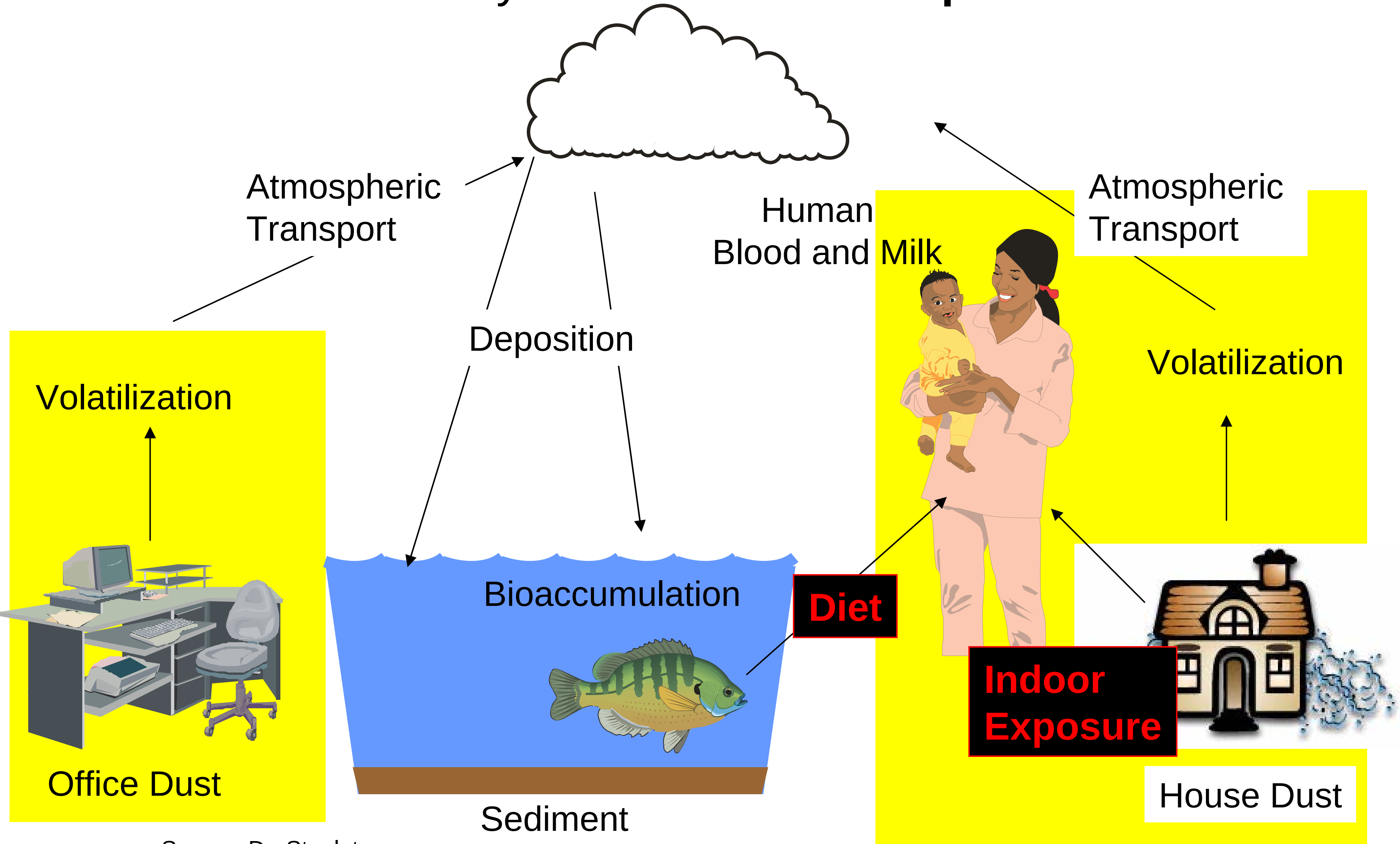
- *TBBPA, for example, is found in the environment*

Use – Questions for Nanotech from FRs

- What happens to nanomaterials during use?
- Will exposure to light, heat, or abrasion release nanomaterials into household or office dust?
- Will nanomaterials collect in dust, to be picked up by babies and toddlers crawling on floors?

Major Routes of Human Exposure to PBDEs?

- Likely **Diet** and **Indoor Exposure to Dust**



Source: Dr. Stapleton

A Comparison of PBDE Intake Relative to Body Weight Among U.S. Population

Exposure Route	Population	PentaBDE (ng/kg/day)	DecaBDE (ng/kg/day)	Reference
Diet	Adults	1 to 1.4	0 to 0.7[a]	Schecter et al., 2006
Inhalation[b]	Adults	0.12 to 0.18	0.04 to 0.06	Allen et al., 2006
Nursing[c]	Infants	30 to 2020 Mean: 355	0 to 40 Mean 4.4	Schecter et al., 2003
Dust Ingestion[d]	Children 1-4 years of age	10 to 214 Mean: 46	0.2 to 4050 Mean: 30	Stapleton et al., 2005 Allen et al., 2006

a-assuming BDE 209 can be 50% of total PBDE composition in food. (Very dependent on diet)
b-assuming an inhalation rate of 20 m^3/day.
c-assuming milk sampled is 3% lipid and that a 5 kg infant ingests 800 mL milk/day.
d-assuming that children ingest between 0.02 g to 0.2 g of dust/day and weigh approximately 13 kg.

Source: Dr. Stapleton

End of Life - Recycling

Courtesy Basil Action Network

- What happens to nanomaterials in polymers/textiles when recycled?
- How will recycling workers be protected?

End of Life - Combustion

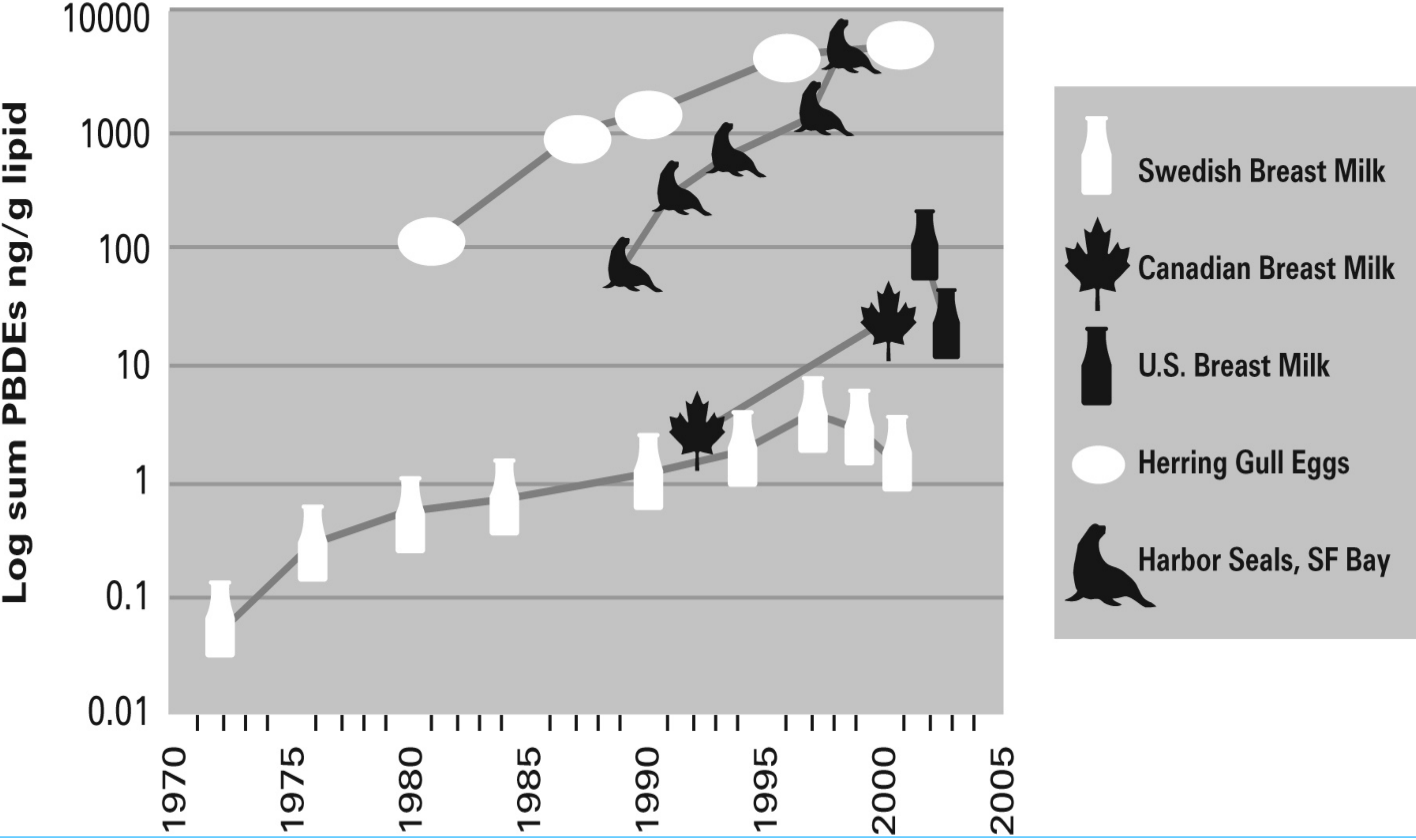
- What happens to nanomaterials during combustion?
- Will nanomaterials alter the formation of combustion byproducts from other chemicals in the product?

"A concern with chemicals introduced into foam products is the ***formation of hazardous combustion byproducts either during a residential fire or if the consumer product is ultimately disposed to an incinerator***. For example, halogenated flame retardants have the potential to combine with other organic compounds during combustion and ***form halogenated dioxins and furans***. The formation of other hazardous combustion byproducts should also be considered." (US EPA, 2005)

Environmental Fate & Transport

- What happens to nanomaterials in the environment?
- Are they persistent and/or bioaccumulative?
- Are they capable of long range transport?
- Are they present in the environment – water, air, soil or animals?
- Or do they safely degrade?

Human and Wildlife Levels of PBDEs



Toxicological Characteristics

- What are the potential toxic effects from exposure to nanomaterials?
- Have they been tested for:
  - Ecotoxicity?
  - Carcinogenicity, Mutagenicity, or Reproductive Toxicity (CMR)?
  - Sensitization of skin or respiratory system?
  - Neurotoxicity?
  - Endocrine disruption?

Health Effects – Polybrominated Diphenyl Ethers (PBDEs)

- **Neurodevelopmental**: Exposure to PBDEs (Penta, Octa, Deca) during critical windows of brain development results in decreased memory and learning that worsens with age and is irreversible. (Viberg, 2003)
- **Reproductive development**: Penta-BDE exposure at levels similar to those found in humans was associated with decreased sperm counts in rodents. (Kuriyama, et al. 2005 and Lilienthal, et al. 2005)
- **Cancer**: US EPA considers decaBDE a possible human carcinogen.

Environmental Impact Assessment: Summary for PBDEs

Extraction	??
Manufacturing	Concerns with: worker exposure & environmental releases
Use	Concerns: release into indoor environments, exposure of babies and toddlers
End of Life	Concerns with: exposure of recyclers & combustion byproducts
Environmental Fate & Transport	Persistence, Bioaccumulation, Long-range Transport, Presence in Environment
Toxicological Characteristics	Neurotoxicity, Reproductive toxicity, Carcinogenicity, Endocrine Disruption

Lessons Learned from Flame Retardant (FR) Chemistry – Part 1

<u>Expect the Unexpected</u>

- ***Expect chemicals or nanomaterials to "leak" into the environment***
- ***Expect degradation + exposure*** from use
- ***Expect combustion byproducts***
- ***Expect exposures and toxicological effects*** greater than anticipated

Lessons Learned from Flame Retardant Chemistry – Part 2

Perform an <u>“Environmental Impact Assessment”</u>

- ***Identify potential environmental concerns at each life cycle stage***
- ***Assess fate & transport potential***
- ***Assess toxicological characteristics*** of the material -- **untested ≠ safe**

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