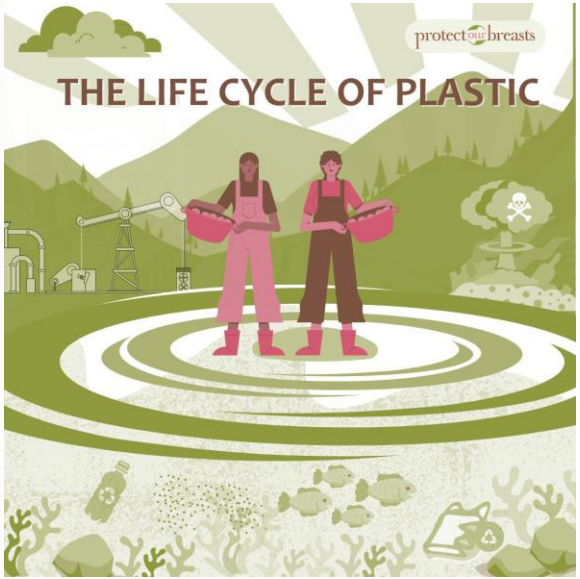
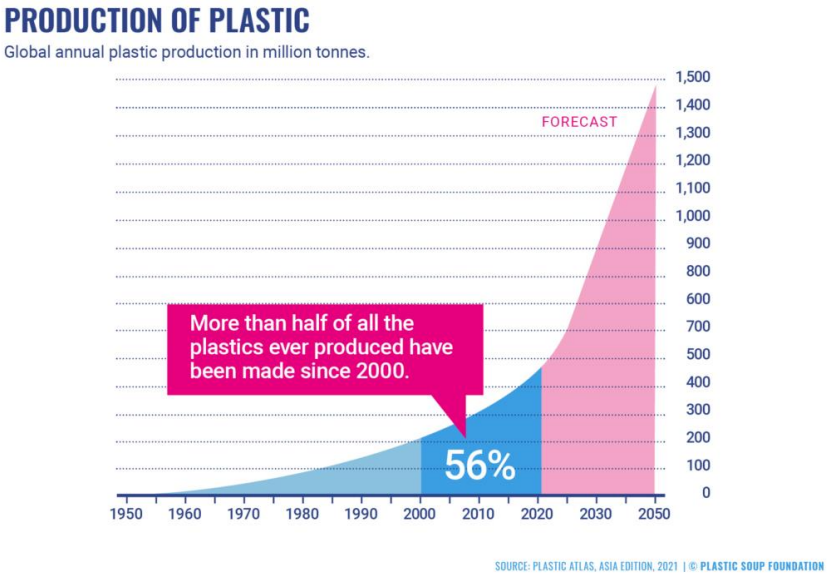
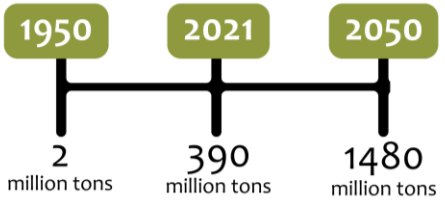
The Plastic Supply Chain

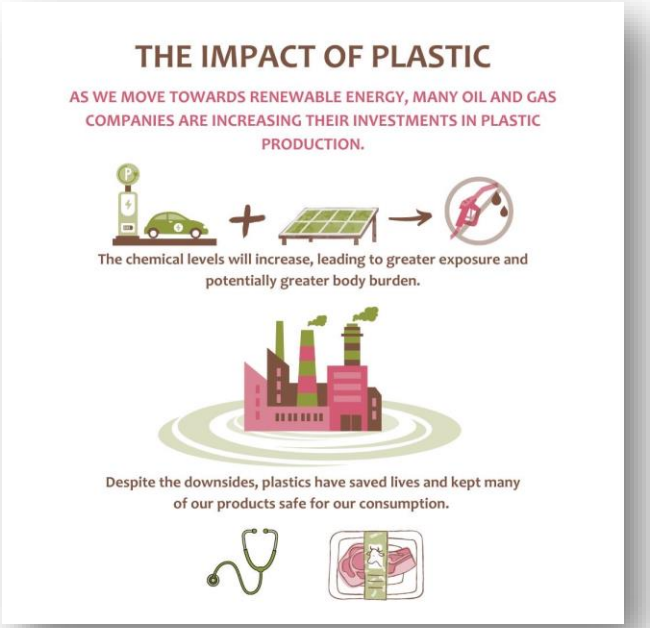


Cynthia Barstow
May 2023

ISENBERG SCHOOL OF MANAGEMENT







- Fossil fuel companies **pivot to plastics**
- Plastics' share of global oil consumption
  2014: 6%
  2050: 20% EST *Landrigan et al 2023*
- 4.5% of global greenhouse gas (GHG) emissions; could almost quadruple by 2050

International Institute for Sustainable Development and Stegmann et al 2022

Plastic Supply Chain

Extraction

Transportation

Refining & Manufacturing

Additives

- Plasticizers
- Flame Retardants
- Stabilizers
- Antioxidants

Plastic Use

- Single Use & Packaging
- Building & Construction
- Synthetic fibers
- Medicine
- Agriculture

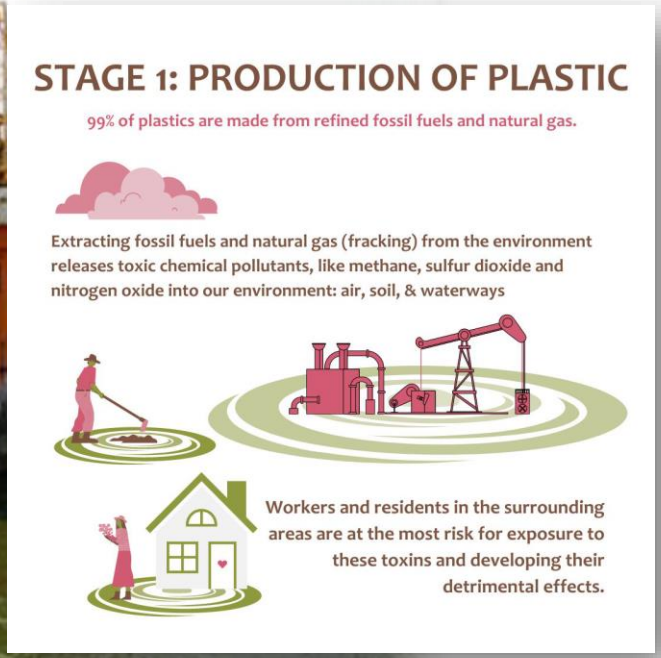
Waste & Recycling

Extraction

- **Coal** (67%), oil (23%), and natural gas (10%) primary feedstocks for more than 99% of global plastic production.

- Contaminants during oil extraction: benzene, toluene, ethylbenzene, and xylene; toxic metals such as arsenic, cadmium, chromium, mercury and PFAS.

Landrigan et al 2023



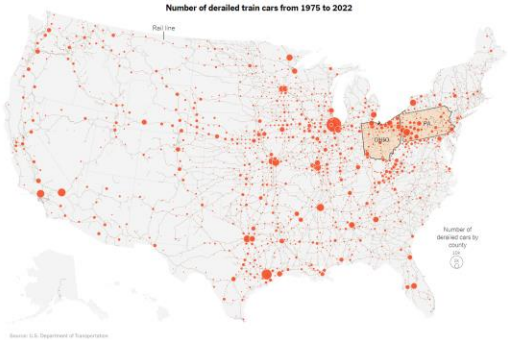
Fracking

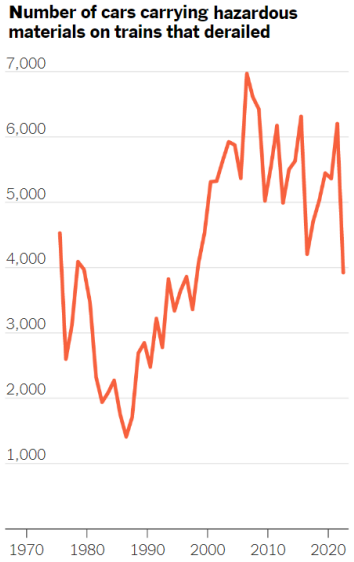
- Hydraulic fracturing extracts large volumes of oil and gas trapped in rock formations/shale.
- Over **1,000 chemicals** in "slick water" (fracking fluids) and/or wastewater
- Additives 0.5%–2%, yet an average injection can total **~18,500 kg of additives** per frack per well
- 52,000 shale gas wells drilled in the US
- 81% of the fracking chemicals used have the potential to damage the brain and nervous system. *Landrigan et al 2023*
- Increased ethane from fracking stimulating plastics production

Transportation

- Tankers transport 50%–60% of the world's crude oil supply and barges transport on inland waterways.
- 24 oil spills 1997 – 2007 with shoreline impacts from 1 km to 3,000 km
- In 2013, US pipeline was used for ~61,000 miles for crude oil and 320,000 miles for gas.

Landrigan et al 2023





Refining & Manufacturing

Oil, gas, and coal transformed into:

- Naphtha, a product of crude oil
- Natural gas liquids
- Syngas, carbon monoxide and hydrogen produced from gasified coal (then converted to methanol)

Landrigan et al 2023

- The predominant components of these feedstocks are ethane, methane, propane and saturated hydrocarbons.

- The EPA estimates that 229 chemical plants dumped over 2 billion pounds of pollution into waterways in 2019.

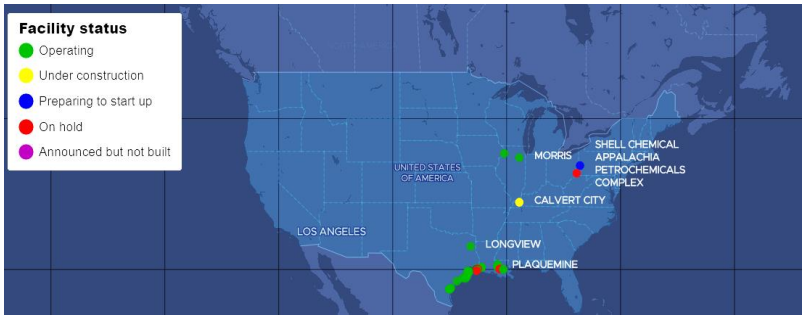
Clean Water Action 2023

- Outdated standards 1984-1993

Cracking

- Cracking: breaking down heavy hydrocarbons into lighter molecules (alkanes/alkenes) using high temperature, pressure and sometimes catalysts
- EPA designated **18/34** ethane crackers as "**high priority violators**" of Clean Air Act ex. Louisiana's "Cancer Alley" *Bernhardt, Oil & Gas Watch 2022*
- Construction costs for ethane cracking plants very high: $6-10 billion for one cracker in Pennsylvania *Tickner et al 2021*
- In 2015, **24/34** ethane crackers had the combined carbon output of **3.8 million passenger vehicles**

NRDC 2020/CIEL 2019



Monomers to Polymers

HEAL 2020

Over 10,500 different chemicals used to make plastic

Monomers are small molecules used to form polymers

Ethylene (from ethane) used to make PE **~32%** of global plastic production

Propylene used to make PP **~23%**

Other plastic monomers:

- Vinyl Chloride **16%** PVC
- Styrene **7%** PS
- ethylene glycol and terephthalic acid **7%** PET

Landrigan et al 2023

Additives

- 55% of the 10,500 chemicals for functional properties:
  - durability
  - strength
  - flexibility
- Market size:
  - **$48.41 billion in 2020**
  - **$75.20 billion by 2028** *Pinta da Costa et al 2023*

- ~4,000 of the ~10,500 chemicals are high-production volume chemicals HPVC (annual production exceeds 1,000 tons).

- Hazard ranking of 55 HPVC plastic polymers found 16 were Level V (highest) plus 15 Level IV.

- 2023 study demonstrates that both petrochemical and **bio-based** food containers contain harmful additives and that it is not possible to predict material toxicity solely based on chemical analysis.

Akoueson et al 2023

Plasticizers

To make plastics softer, more pliable, and more durable.

30,000 chemicals have been identified as plasticizers, ~100 plasticizers are commercially produced worldwide, **~50 are commercially important**.

Ortho-phthalate diesters comprise up to **85% of the total plasticizer market, of which DEHP and DEP** are the most common.

~97% of DEHP's use is as a plasticizer, with the remainder being used as a solvent in personal care products, such as perfumes and cosmetics.

Flame Retardants

To prevent or slow ignition and combustion.

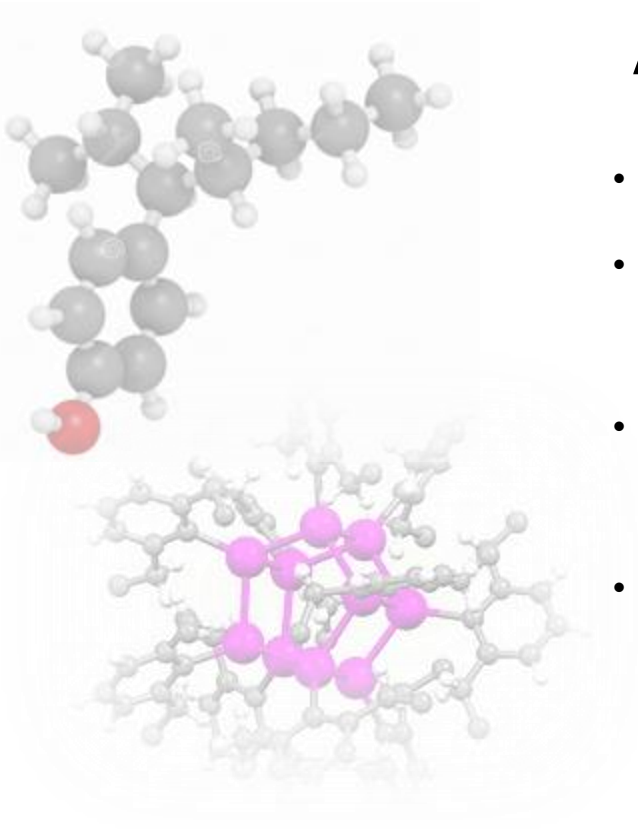
- BFRs - most widely used
- PCBs –have also been widely used.

PBBs - first generation of flame retardants discontinued in 1976 because of their toxicity. **"Regrettable substitutions"** include polybrominated diphenyl ethers (PBDEs).

Many flame retardants are restricted or regulated under the Stockholm Convention and in the US since 2004.

Stabilizers

- Protect plastics from degradation by oxidation, ozone, heat, light (including UV), and bacterial attack
- Benzophenones (BzPs) preservatives in paints and varnishes and in sunscreens in the 1950s. BzPs are also used in cosmetics and personal care products.
- Benzotriazoles are another class used in plastic bottle caps, food packaging, and shopping bags.

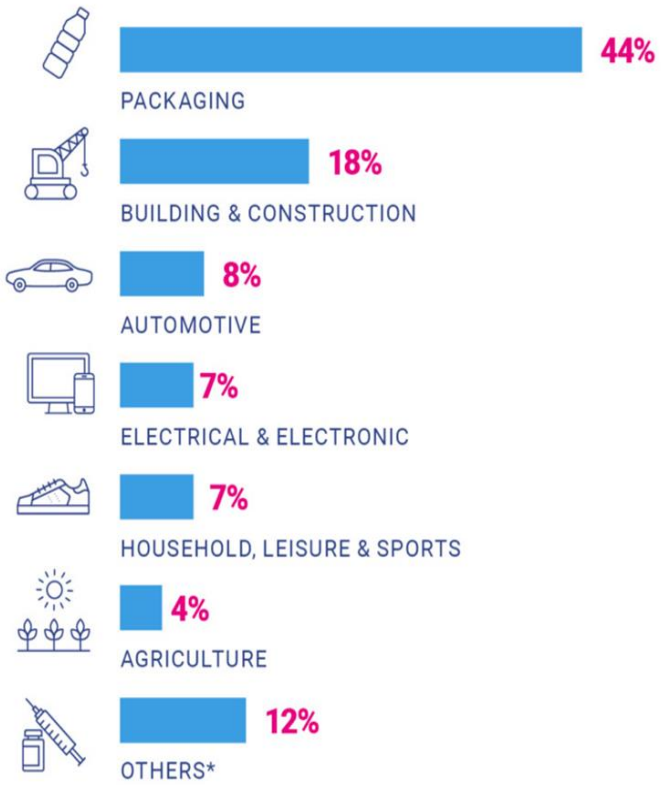


Antioxidants

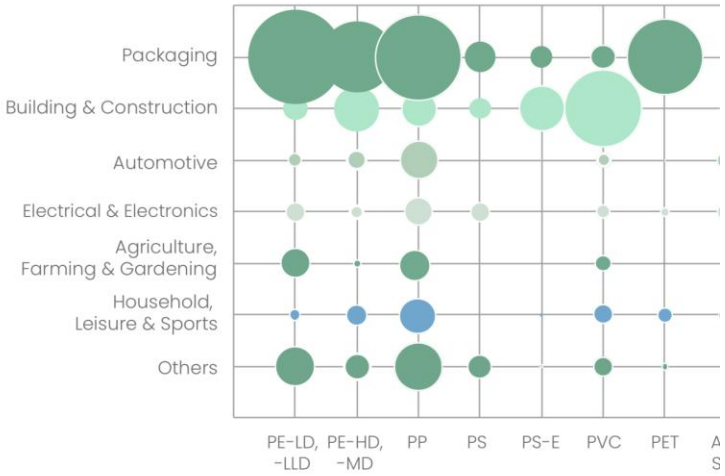
- Inhibit degradation
- Nonylphenols used as antioxidants (and plasticizers) in various resins
- Concern about the endocrine-disrupting properties of nonylphenols
- Migration of nonylphenols from HDPE and PVC bottles and caps into the water

Landrigan et al 2023

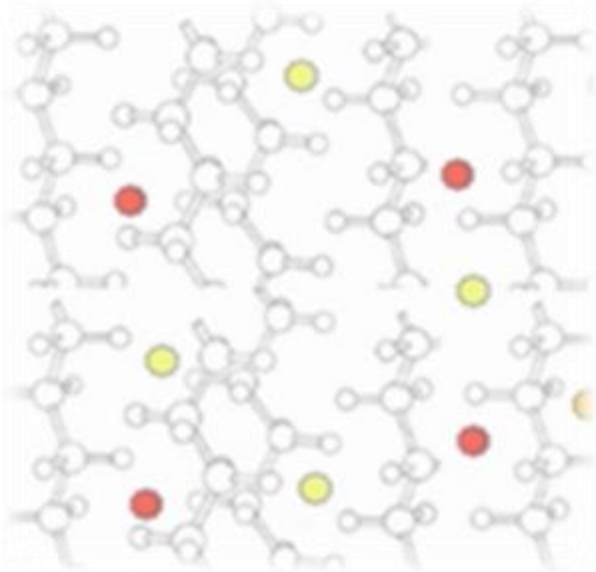
Plastic Use


44%
PACKAGING
18%
BUILDING & CONSTRUCTION
8%
AUTOMOTIVE
7%
ELECTRICAL & ELECTRONIC
7%
HOUSEHOLD, LEISURE & SPORTS
4%
AGRICULTURE
12%
OTHERS*


STAGE 2: THE USE OF PLASTIC
How many plastic products did you come in contact with today?
We rely on the substance for everything from food preservation to medical devices. The benefits are significant!
ICE COFFEE


Packaging
Building & Construction
Automotive
Electrical & Electronics
Agriculture, Farming & Gardening
Household, Leisure & Sports
Others
PE-LD, -LLD
PE-HD, -MD
PP
PS
PS-E
PVC
PET

Migration - Leaching



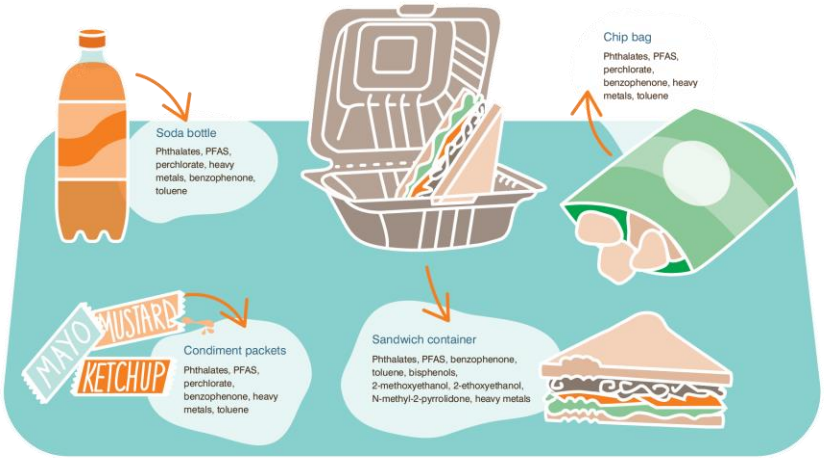
- Additives and NIAS (non-intentionally added substances) leach from everyday plastic products – **not covalently bound.**
- DEHP, DBP, BPA, DEHA, and 2,4-di-tert-butylphenol as the **five most frequently detected** plastic-associated chemicals leaching from food contact materials. *Maffini et al*
- Inhalation is another route of exposure with PAHs, phthalates, organophosphates, and BFRs in household products shown to vaporize into **indoor air**.

Landrigan et al 2023

Single-Use & Packaging

- 99% of single use is packaging.

- Single-use plastics produced 450 million metric tons of greenhouse gases in 2021, just below the annual emissions of Britain. *NYTimes 2/7/23*



Environmental Defense Fund

Building & Construction

- PVC most used plastic in the building and construction sector - 43% of EU plastics
- ~2/3 global organotin consumption used in PVC
- Flexible PVC is plasticized by DEHP/DINP and have been detected in air and dust in homes.

Synthetic Fibers

- Synthetic fiber production increased to almost 65 Mt per year ~ 2/3 of all textile fibers produced globally, dominated by polyester
- Dyeing, impregnating, coating, and plasticizing, involve azo dyes, formaldehyde and more

Medicine

- Phthalates can account for 30%–40% of medical-use plastics by weight and are used in medications to control GI drug delivery.
- Intensive-care patients showed 100–1,000 times higher levels of DEHP, and levels of BPA, than the general population.
- Plastics comprise 70% of sanitary waste and 34% of general waste in hospitals. Covid waste increased ~350%

Landrigan et al 2023

Agriculture

- Chemicals of concern that leach into soil from plastics include phthalates and BPA.
- A study in Spain estimated plastic waste to be almost 250,000 kg over 1,500 hectares per year.
- Fluorescently labeled PS beads revealed their uptake by wheat and lettuce roots, with transfer to the epidermis and xylem.
- Analysis of farmland soils in China has revealed that flame retardants, including OPFRs and BFRs such as PBDEs, are widely detected.
- Plastic packaging for animal feedstock has been found to contain several bisphenol compounds (BPA).

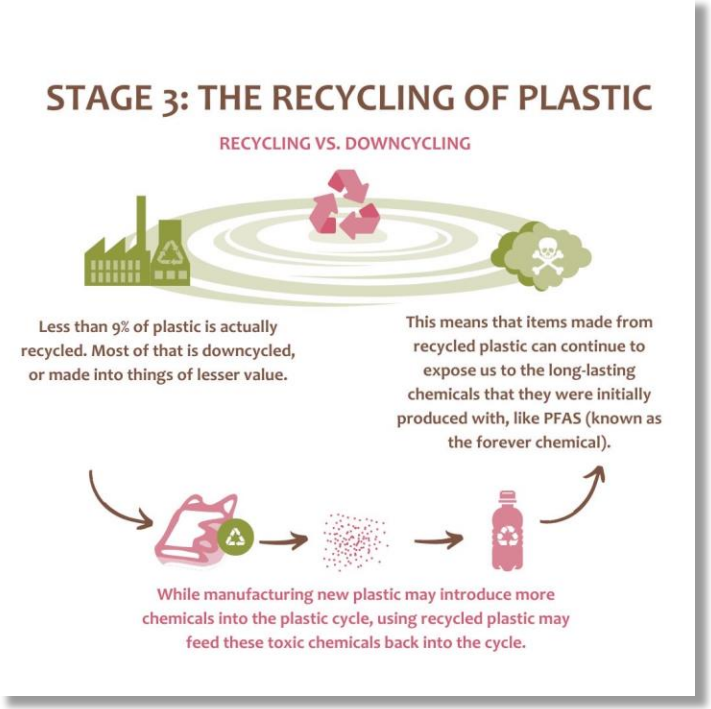
Waste & Recycling

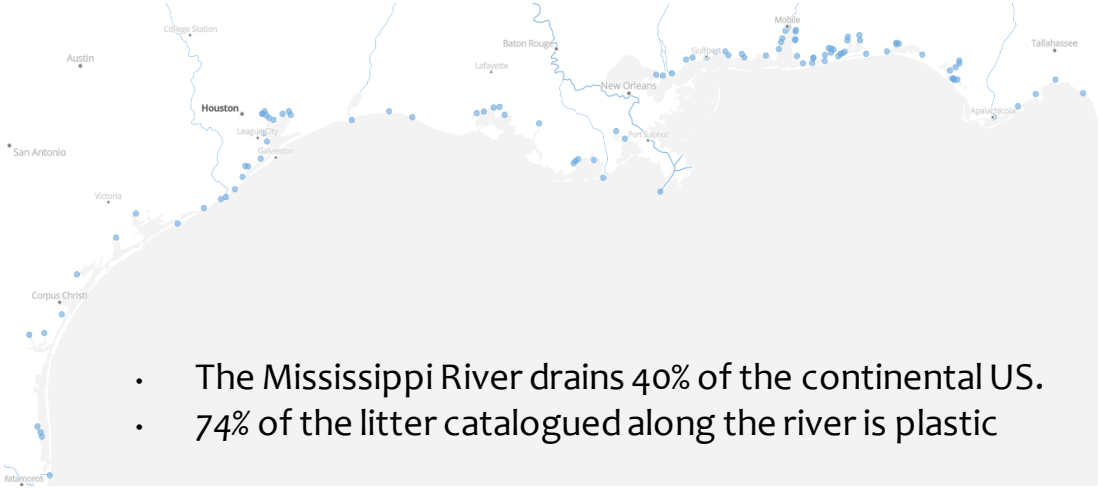
- Plastic recovery and recycling rates: below 9-10% globally

- Plastic trash: 139 million metric tons in 2021 *NYTimes 2/7/23*
- Of the plastic waste produced globally in 2019:
  - ~50% sanitary landfills
  - 19% incinerated
  - 9% recycled
  - 22% burned or leaked to the environment.

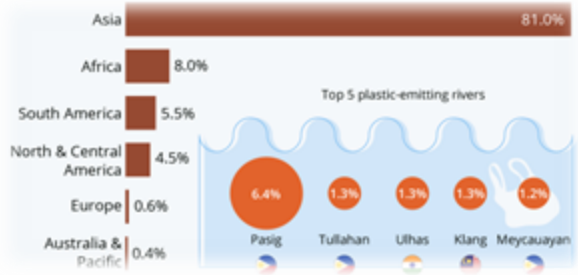
- The "New Plastics Economy Global Commitment" from the Ellen McArthur Foundation unites 850+ signatories – to recycle in practice and at scale by 2025.
  However, it is important to note that these recycled content commitments are made without specifying how to address chemicals in recycled plastics.

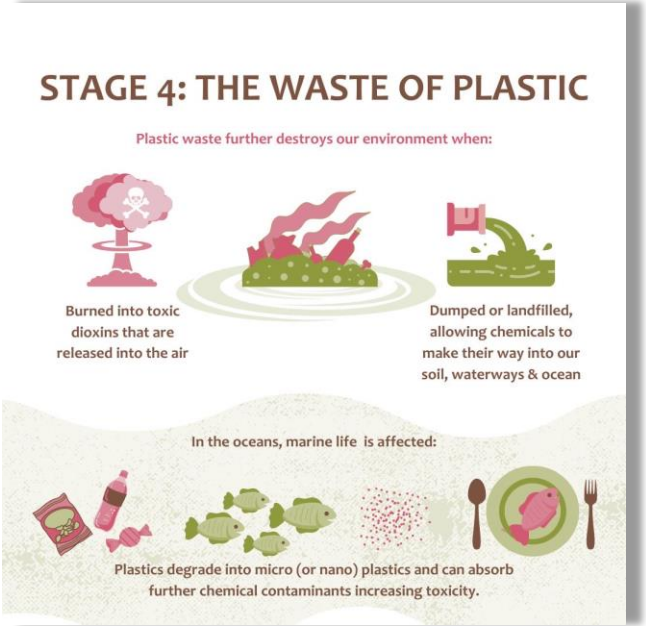
- "When plastics are recycled, it is highly likely that these compounds will be integrated into the newly manufactured product." *Akoueson et al 2023*





- The Mississippi River drains 40% of the continental US.
- 74% of the litter catalogued along the river is plastic





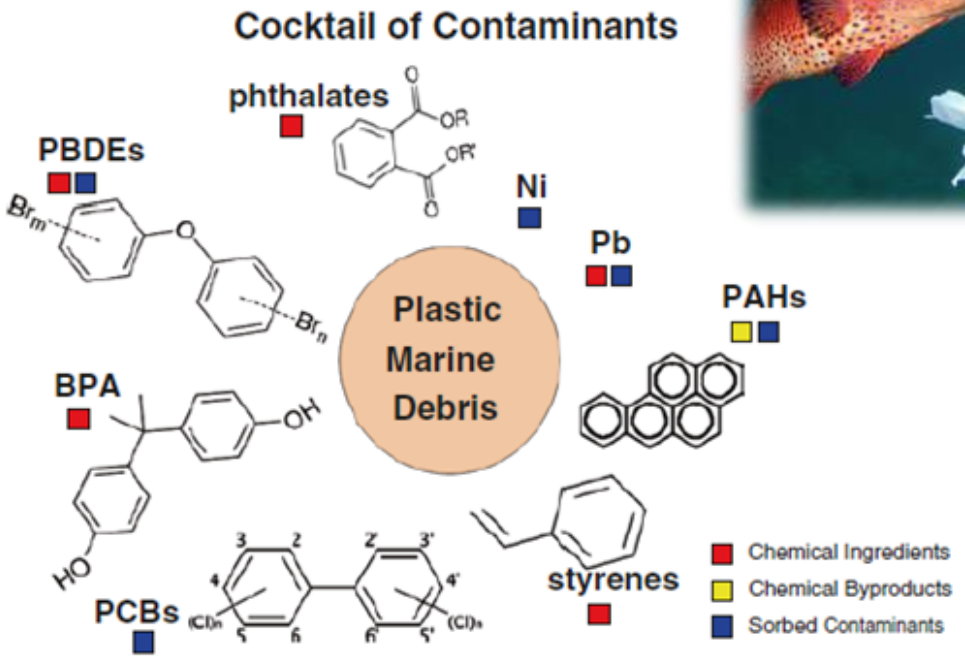
It is estimated that by 2030 up to 53 million metric tons (Mt) of plastics per year could be emitted into our waterways, and that the volume of global plastic waste could nearly triple by 2060, if the upward trend is not curtailed by the forthcoming **Global Plastics Treaty.**

Environ. Sci.: Processes Impacts, 2023

Adsorption

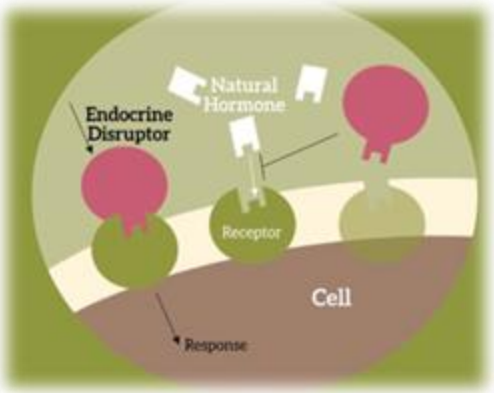
- Plastic marine litter is a cocktail containing chemicals added during manufacture as well as those adsorbed from polluted water.
- Includes phthalates, PBDEs, BPA, PCBs, styrenes, PAHs, and metals such as lead and nickel
- Hydrophobic additives ingested by marine organisms can leach when introduced to oily components in digestive fluid.

Landrigan et al 2023

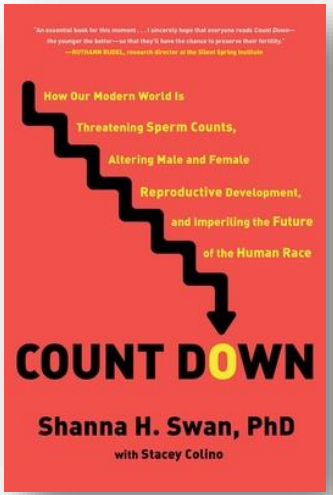


Endocrine Disruptors

Plastics contain and leach hazardous chemicals, including EDCs, which disturb the body's hormone systems and can cause cancer, diabetes, reproductive disorders, and neurological damage in fetuses and children.



International Institute for Sustainable Development 2021



W. Yi *et al.*
DEHP exposure destroys blood-testis barrier (BTB) integrity of immature testes through excessive ROS-mediated autophagy
Genes & diseases (2018)

L. Yang *et al.*
DEHP induces ferroptosis in testes via p38α-lipid ROS circulation and destroys the BTB integrity
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Prenatal bisphenol a and phthalate exposure are risk factors for male reproductive system development and cord blood sex hormone levels
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Toxicol. Appl. Pharmacol. (2017)

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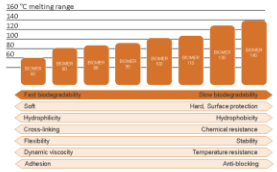
Paternal preconception phthalate exposure alters sperm methylome and embryonic programming
Environ. Int. (2021)

X. Liu *et al.*
Chronic exposure of BPA impairs male germ cell proliferation and induces lower sperm quality in male mice
Chemosphere (2021)

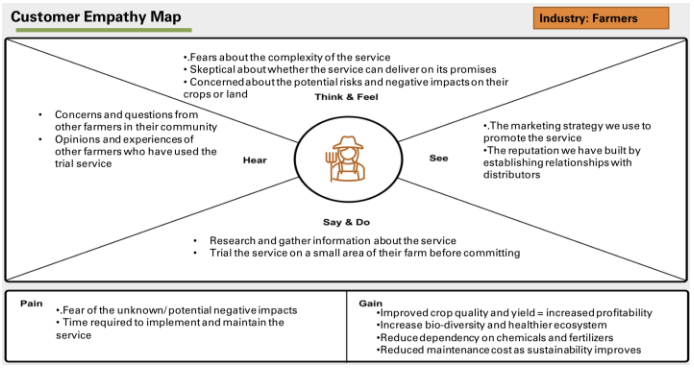
What to do?

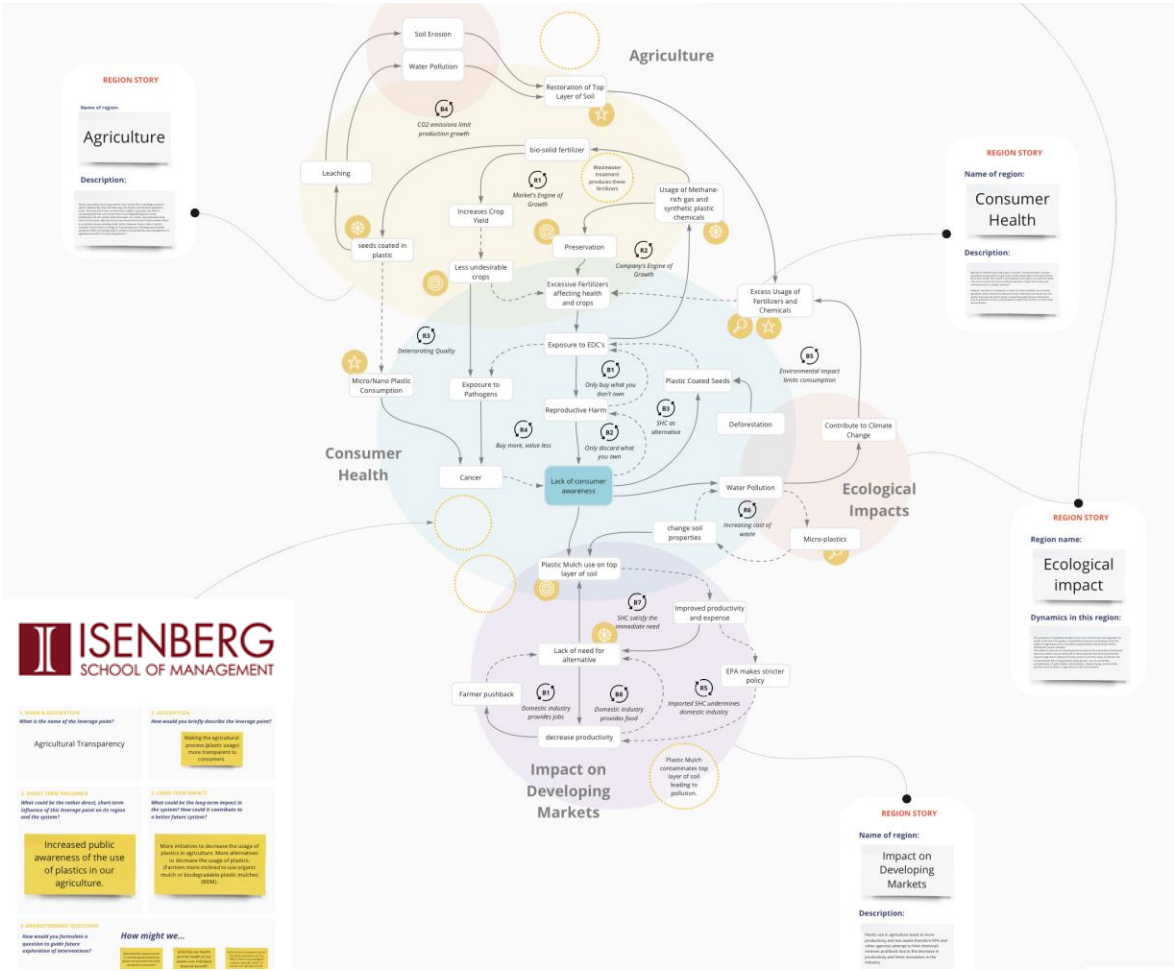
HOW MELTING POINT OF WAX COATING EFFECTS QUALITY OF CROPS



The wax seed is made to postpone emergence until environmental conditions are favorable for germination and development. Farmers would be able to plant crops earlier than usual without sacrificing quality thanks to this delay in emergence. (Instead of plastic, substitute polymer seed coats.)

1. **Slow-release of water:** A thin layer of wax coating can be applied to the surface of seeds to create a water barrier, which slows down the release of water from the seed. This can help the seedlings to survive with less frequent watering.
2. **Retain soil moisture:** Wax coatings can help seeds to retain moisture in the soil by reducing evaporation from the soil surface. This can help to reduce the frequency of watering required.
3. **Protect seeds from drought:** The wax coating can protect the seeds from drought stress by reducing water loss from the seed. This can help to ensure that the seeds are able to germinate and establish even in arid conditions.
4. **Reduce water runoff:** When seeds are planted in soil with a wax coating, the water is absorbed more slowly, reducing the amount of water runoff. This can help to conserve water resources.
5. **Enhance seedling growth:** Wax coatings can help to enhance the growth of seedlings by providing a protective barrier against environmental stresses, such as high temperatures and low humidity.





HOW DO WE CHANGE THE SYSTEM TO PRESERVE THE BENEFITS AND REMOVE THE DAMAGE?

Every opportunity you can choose products and packaging that are not plastic (glass or paper), you are helping to change the system.

Support businesses working towards a safer marketplace, like our brand partners!

"Yes, we are doing quite a bit. In March we became certified plastic negative and carbon neutral. We already use little to no plastic in our supply chain as our primary packaging is aluminum, and we use a sugar cane film instead of other methods."

protect our breasts Brand Partner

All Protect Our Breasts' brand partners have signed a commitment to improve the safety of their packaging!

Sources

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