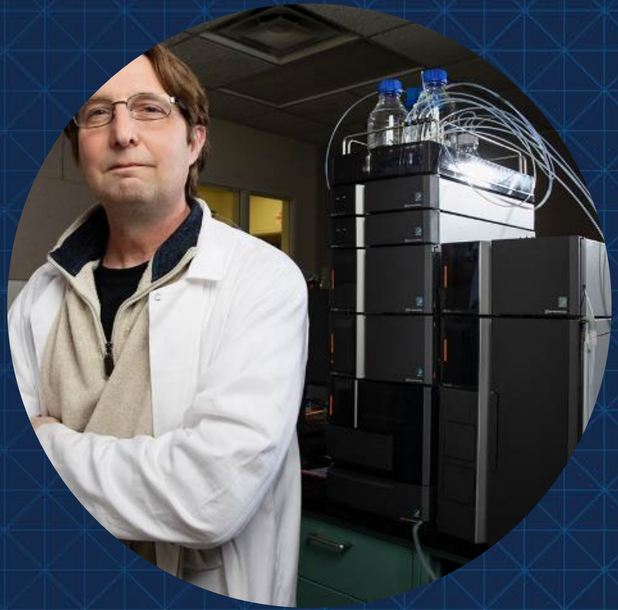
From Additives to Adsorption: Understanding the Full Impact of Plastic Pollution

Great Lakes Microplastics Summit
October 22, 2025

John Scott
Associate Director of ISTC Emerging Contaminant Center



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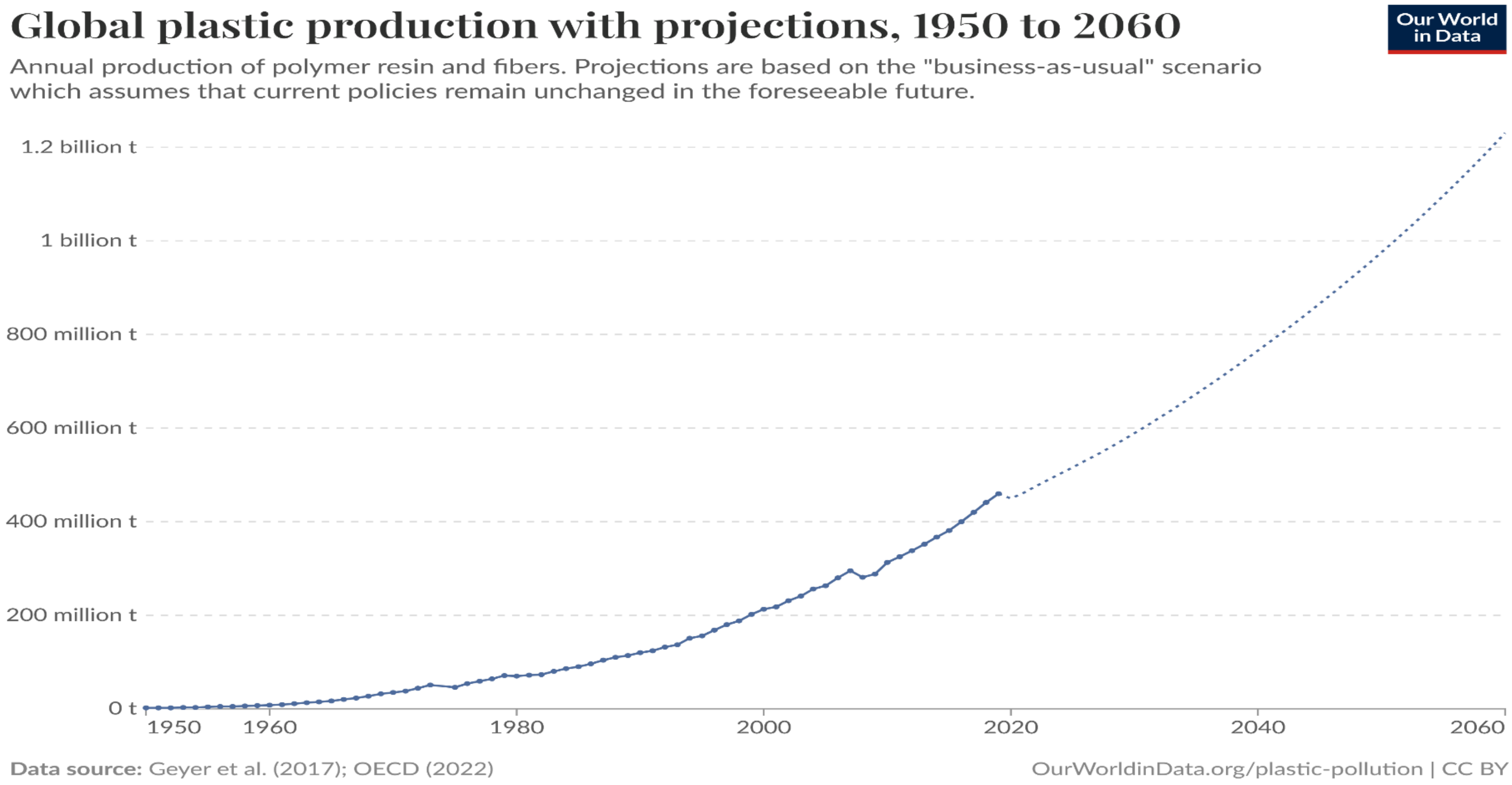
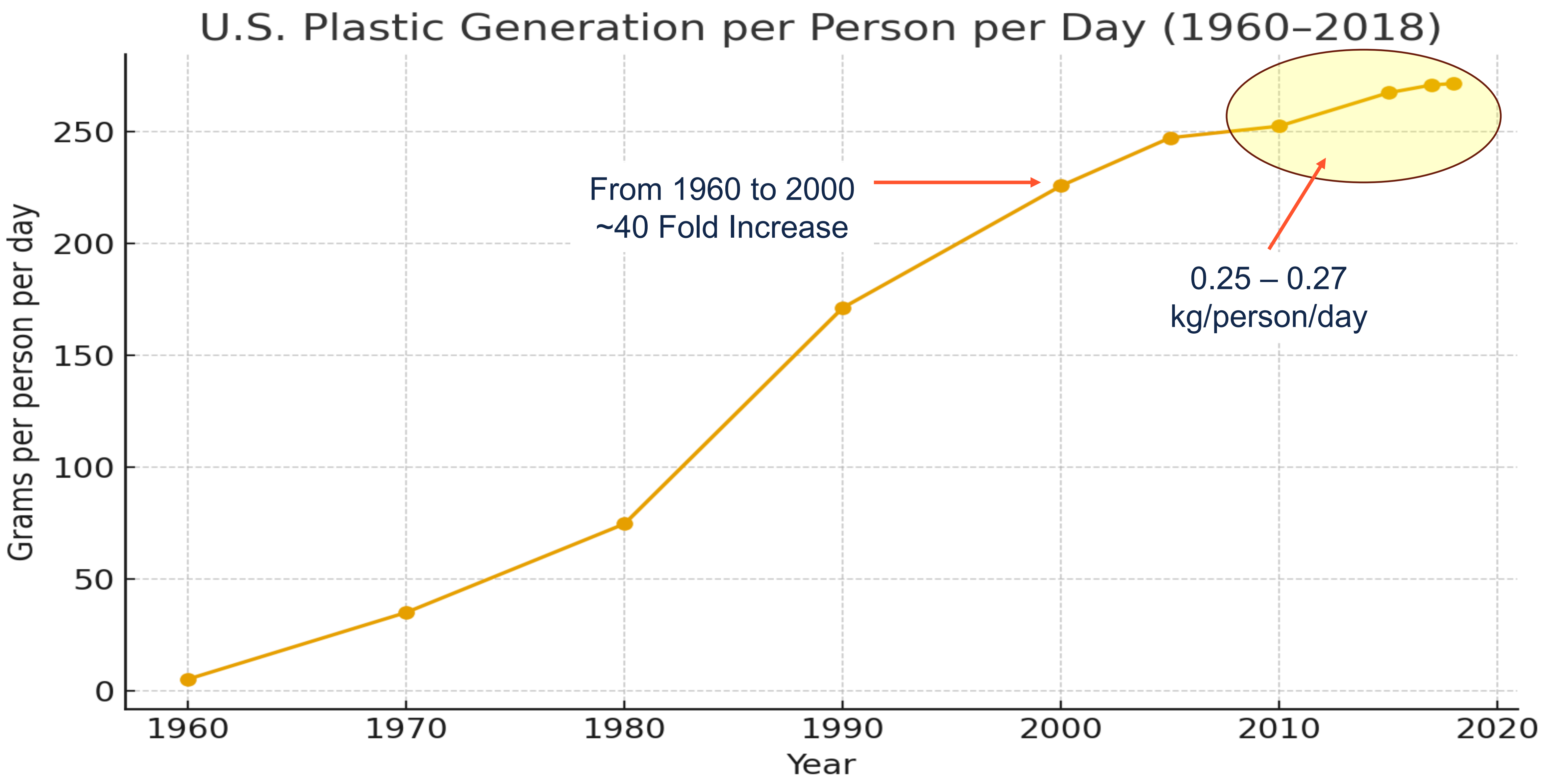


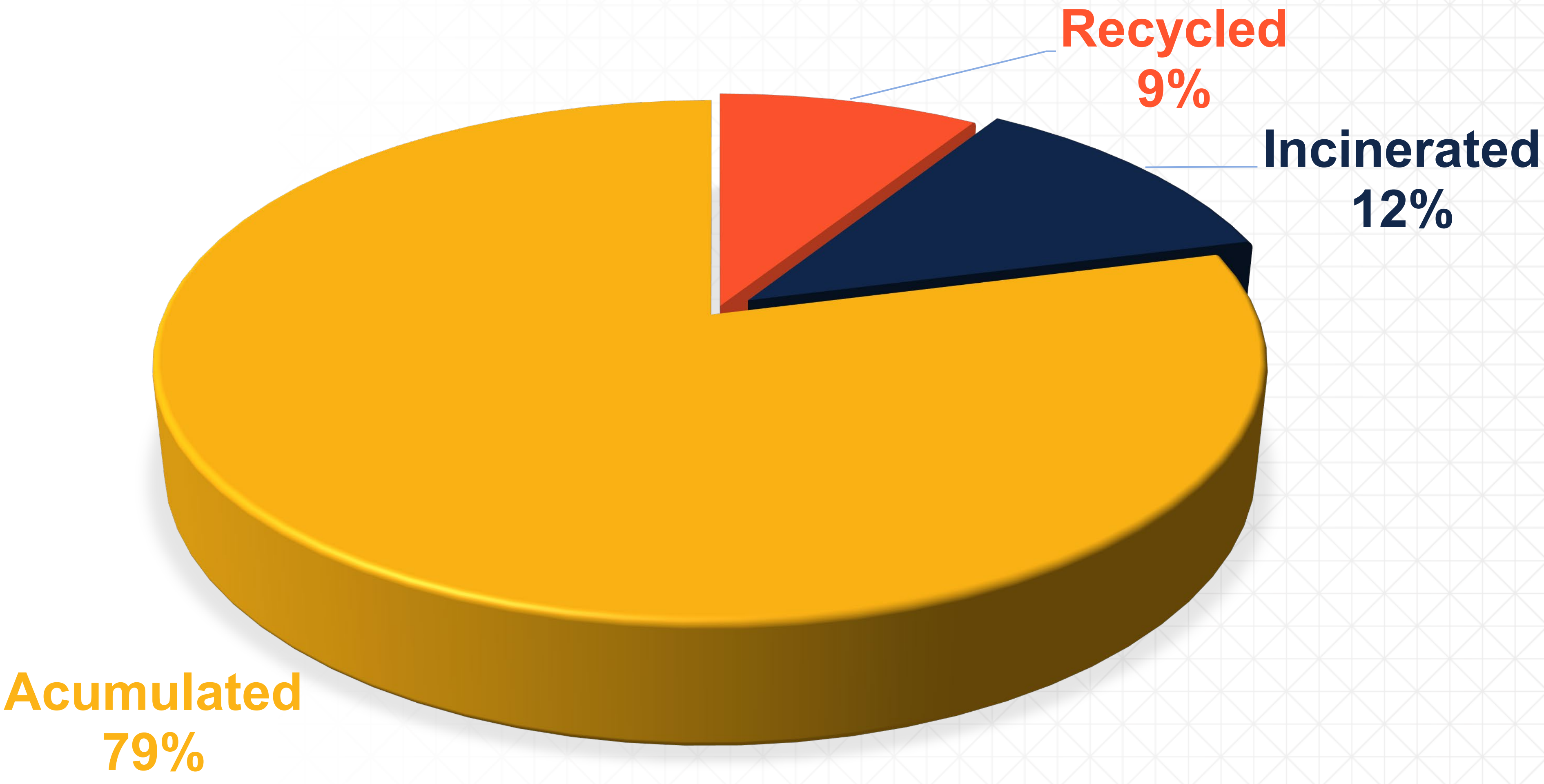
Hannah Ritchie, Veronika Samborska, and Max Roser (2023) - "Plastic Pollution" Published online at OurWorldinData.org. Retrieved from: 'https://ourworldindata.org/plastic-pollution' [Online Resource]



U.S. Environmental Protection Agency. *Plastics: Material-Specific Data.* In *Advancing Sustainable Materials Management: Facts and Figures.* Last modified 2023. Accessed October 7, 2025. https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling

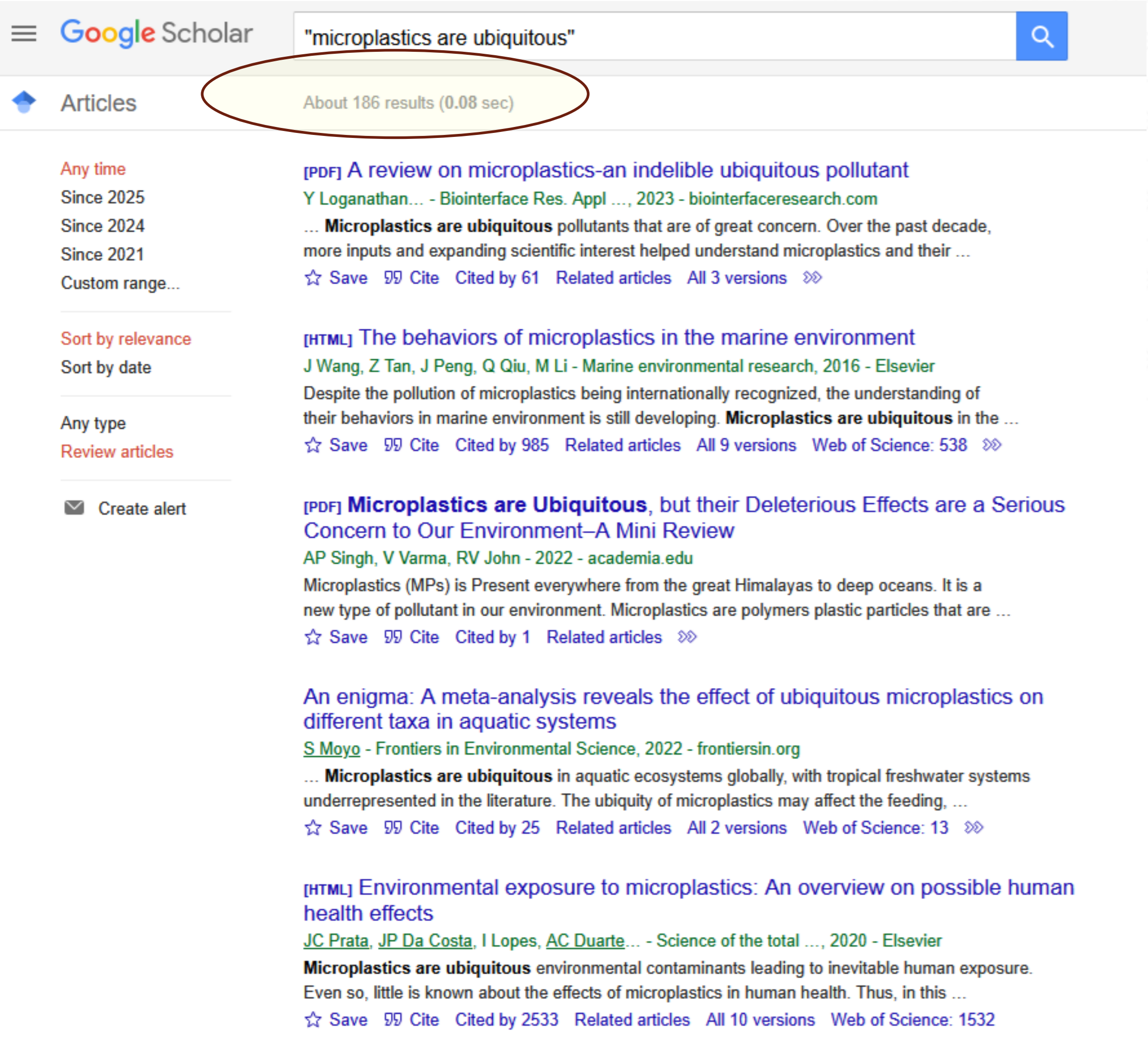
World Bank. *Population, Total – United States.* World Development Indicators. Accessed October 7, 2025. https://data.worldbank.org/indicator/SP.POP.TOTL?locations=US

The Fate of Plastic Waste



Source- Geyer, Roland, Jenna R. Jambeck, and Kara Lavender Law. "Production, use, and fate of all plastics ever made." Science advances 3, no. 7 (2017): e1700782.

The ***Widespread*** Occurrence of Microplastics



Google Scholar
"microplastics are ubiquitous"

Articles
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[PDF] A review on microplastics-an indelible ubiquitous pollutant
Y Loganathan... - Biointerface Res. Appl ..., 2023 - biointerfaceresearch.com
... **Microplastics are ubiquitous** pollutants that are of great concern. Over the past decade, more inputs and expanding scientific interest helped understand microplastics and their ...
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[HTML] The behaviors of microplastics in the marine environment
J Wang, Z Tan, J Peng, Q Qiu, M Li - Marine environmental research, 2016 - Elsevier
Despite the pollution of microplastics being internationally recognized, the understanding of their behaviors in marine environment is still developing. **Microplastics are ubiquitous** in the ...
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[PDF] **Microplastics are Ubiquitous**, but their Deleterious Effects are a Serious Concern to Our Environment–A Mini Review
AP Singh, V Varma, RV John - 2022 - academia.edu
Microplastics (MPs) is Present everywhere from the great Himalayas to deep oceans. It is a new type of pollutant in our environment. Microplastics are polymers plastic particles that are ...
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An enigma: A meta-analysis reveals the effect of ubiquitous microplastics on different taxa in aquatic systems
S Moyo - Frontiers in Environmental Science, 2022 - frontiersin.org
... **Microplastics are ubiquitous** in aquatic ecosystems globally, with tropical freshwater systems underrepresented in the literature. The ubiquity of microplastics may affect the feeding, ...
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[HTML] Environmental exposure to microplastics: An overview on possible human health effects
JC Prata, JP Da Costa, I Lopes, AC Duarte... - Science of the total ..., 2020 - Elsevier
Microplastics are ubiquitous environmental contaminants leading to inevitable human exposure. Even so, little is known about the effects of microplastics in human health. Thus, in this ...
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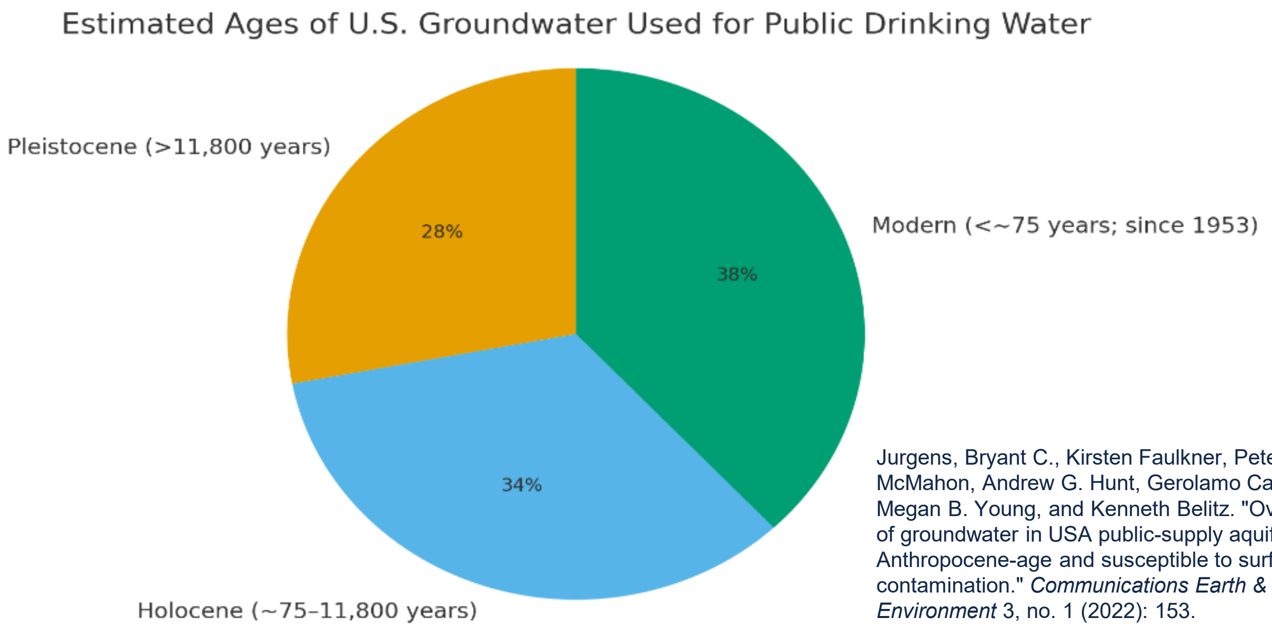
Ubiquitous – found everywhere, all the time.

Yes, microplastics are found in nearly every media we look at.

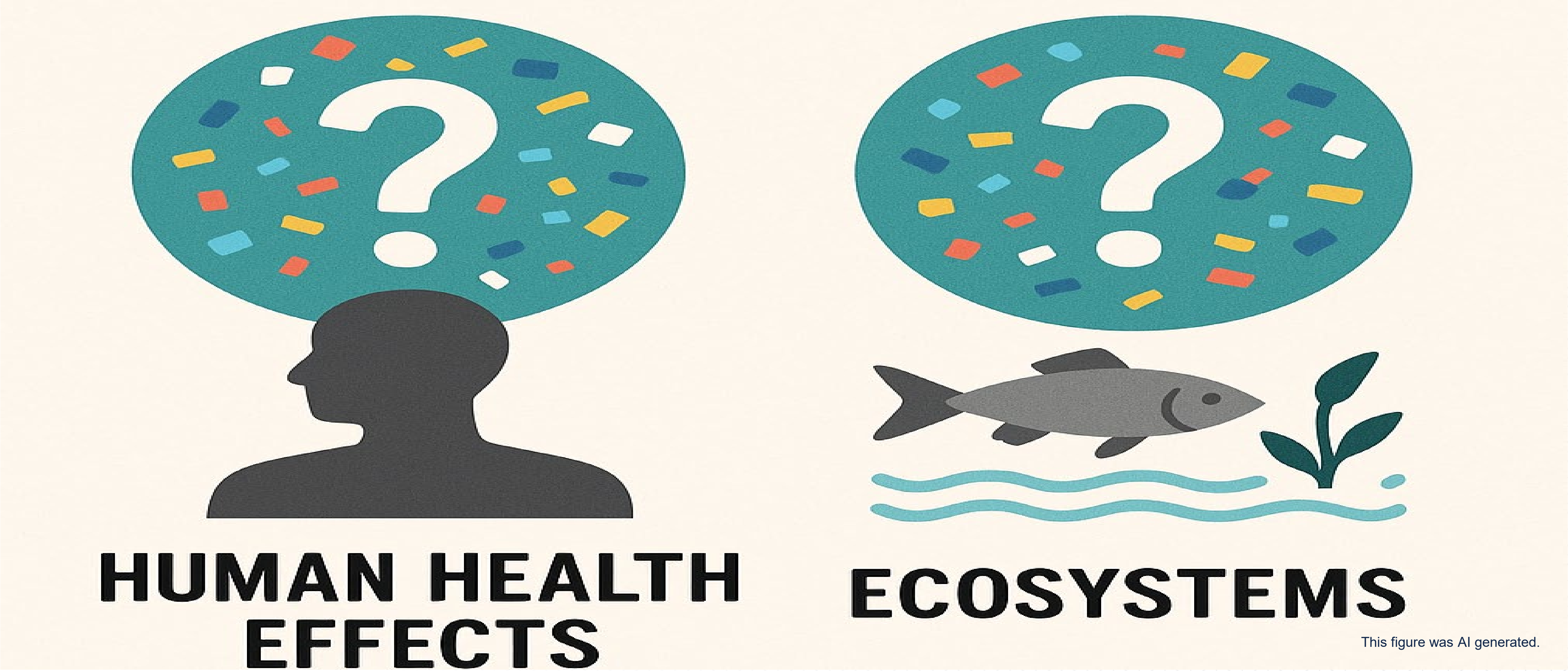
However, is ubiquitous the right term?



Jurgens, Bryant C., Kirsten Faulkner, Peter B. McMahon, Andrew G. Hunt, Gerolamo Casile, Megan B. Young, and Kenneth Belitz. "Over a third of groundwater in USA public-supply aquifers is Anthropocene-age and susceptible to surface contamination." *Communications Earth & Environment* 3, no. 1 (2022): 153.

Tokranov, Andrea K., Zachary R. Hopkins, Bruce D. Lindsey, and Bryant C. Jurgens. "PFAS Are Widespread, Not Ubiquitous: Clarifying Misconceptions About the Prevalence of "Forever Chemicals"." *Environmental Science & Technology* (2025).

Exposure is likely; however, impact is unknown



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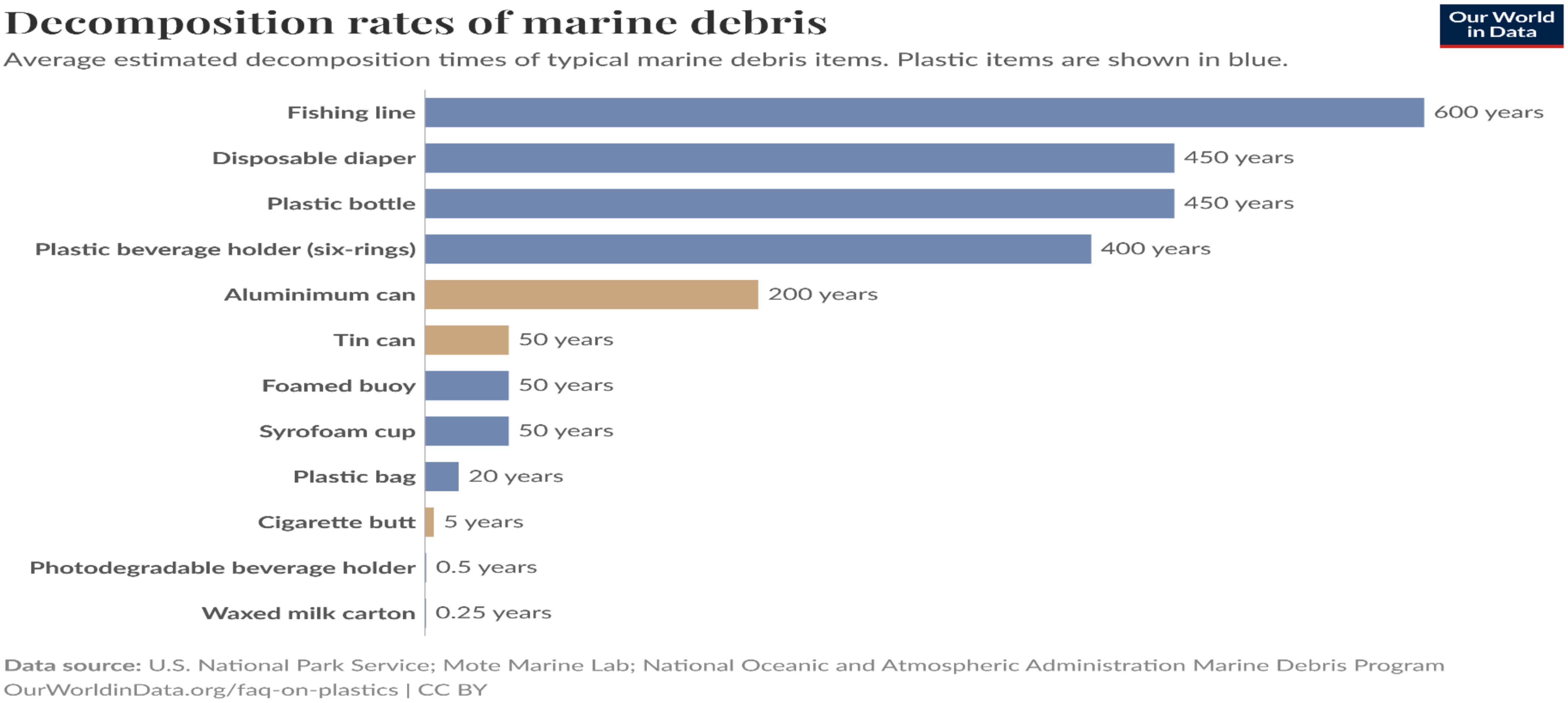
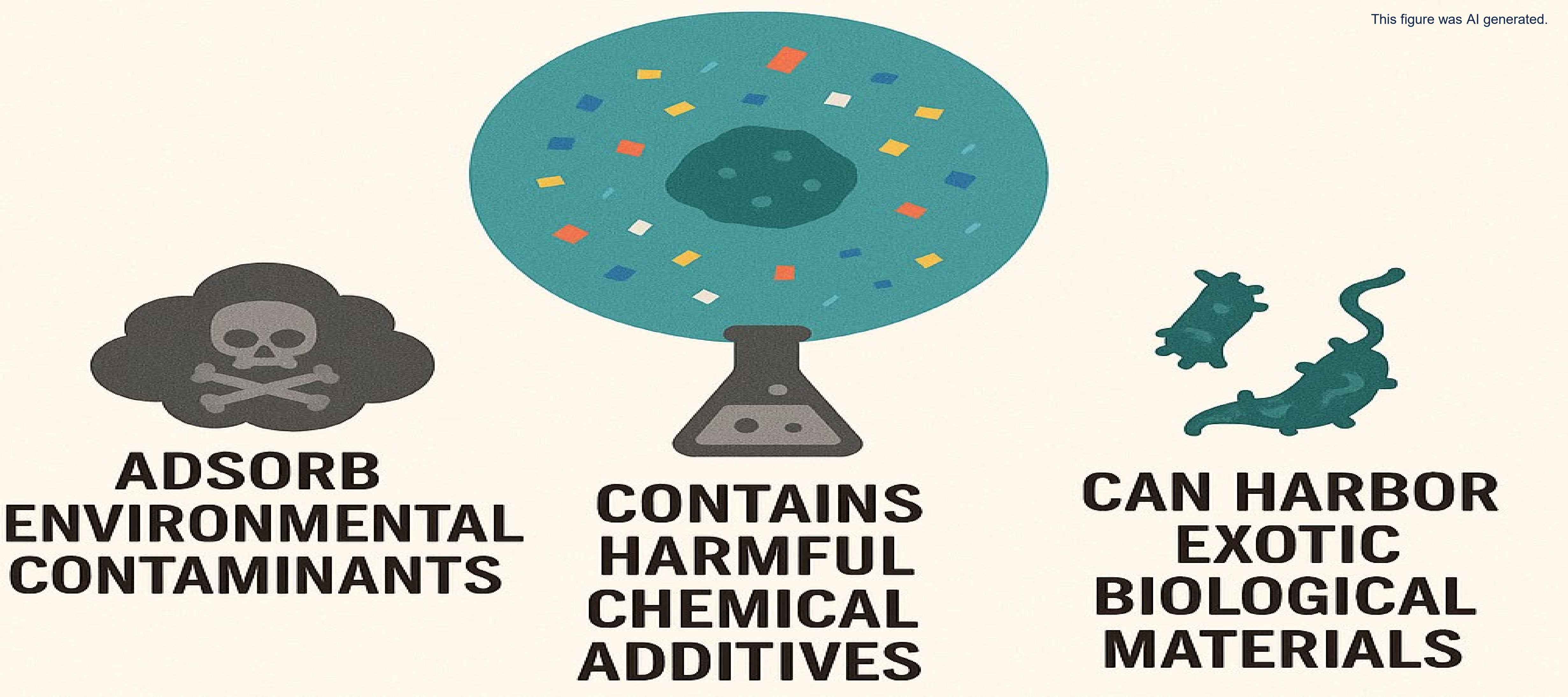
The problem of persistence



Hannah Ritchie, Veronika Samborska, and Max Roser (2023) - "Plastic Pollution" Published online at OurWorldinData.org. Retrieved from: 'https://ourworldindata.org/plastic-pollution' [Online Resource]

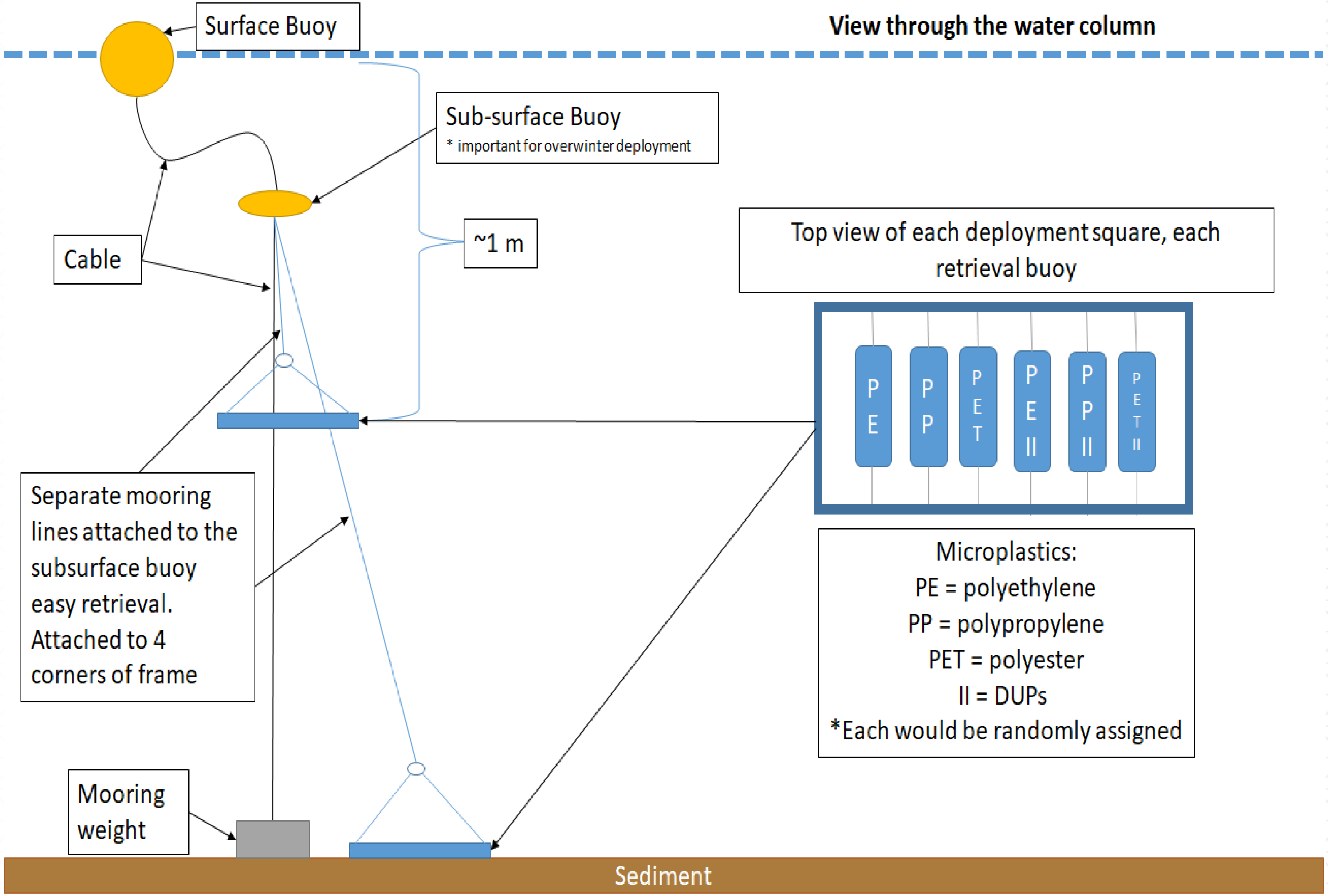
It's more than just plastic



Muskegon Lake – Microplastics Field Study

Approximate Deployment Sites

Microplastic Deployment Rack

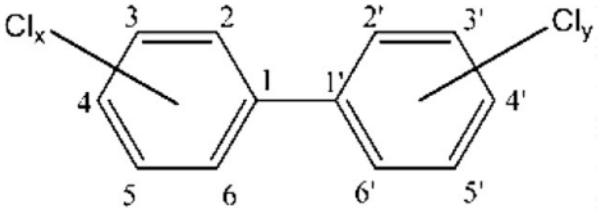


Steinman, Alan D., John Scott, Lee Green, Charlyn Partridge, Maggie Oudsema, Michael Hassett, Emily Kindervater, and Richard R. Rediske. "Persistent organic pollutants, metals, and the bacterial community composition associated with microplastics in Muskegon Lake (MI)." *Journal of Great Lakes Research* 46, no. 5 (2020): 1444-1458.

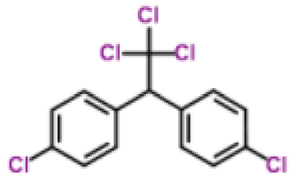
Muskegon Lake– Microplastics Field Study

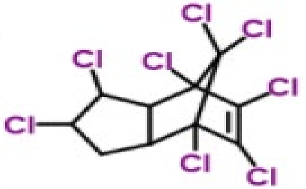
- **10 Elements (RCRA Metals)**
- **85 Persistent Organic Pollutants (POP)**
- **Microbial Diversity**

Polychlorinated Biphenyls (PCB)

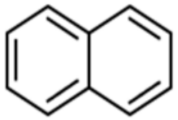


Chlorinated Pesticides (OC)

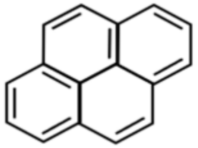




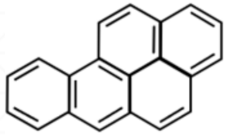
Polyaromatic Hydrocarbons (PAH)



Naphthalene

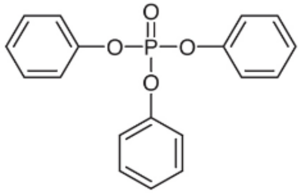


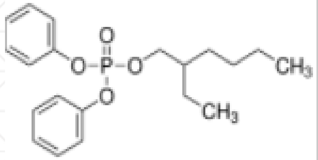
Pyrene



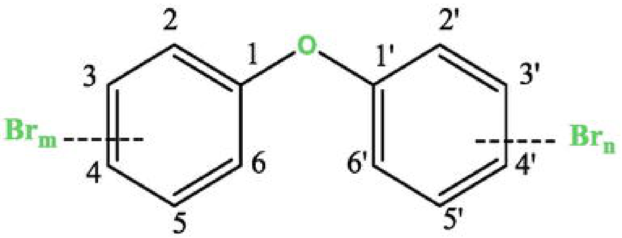
Benzo[a]pyrene

Organophosphate Esters (OPE)

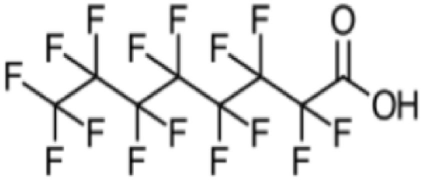




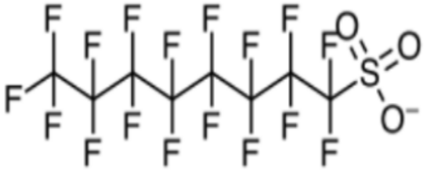
Polybrominated Biphenyl Ethers (PBDE)



Per- and Polyfluoroalkyl Substances (PFAS)



Perfluorooctanoic acid (PFOA)



Perfluorooctane sulfonate (PFOS)

Steinman, Alan D., John Scott, Lee Green, Charlyn Partridge, Maggie Oudsema, Michael Hassett, Emily Kindervater, and Richard R. Rediske. "Persistent organic pollutants, metals, and the bacterial community composition associated with microplastics in Muskegon Lake (MI)." *Journal of Great Lakes Research* 46, no. 5 (2020): 1444-1458.

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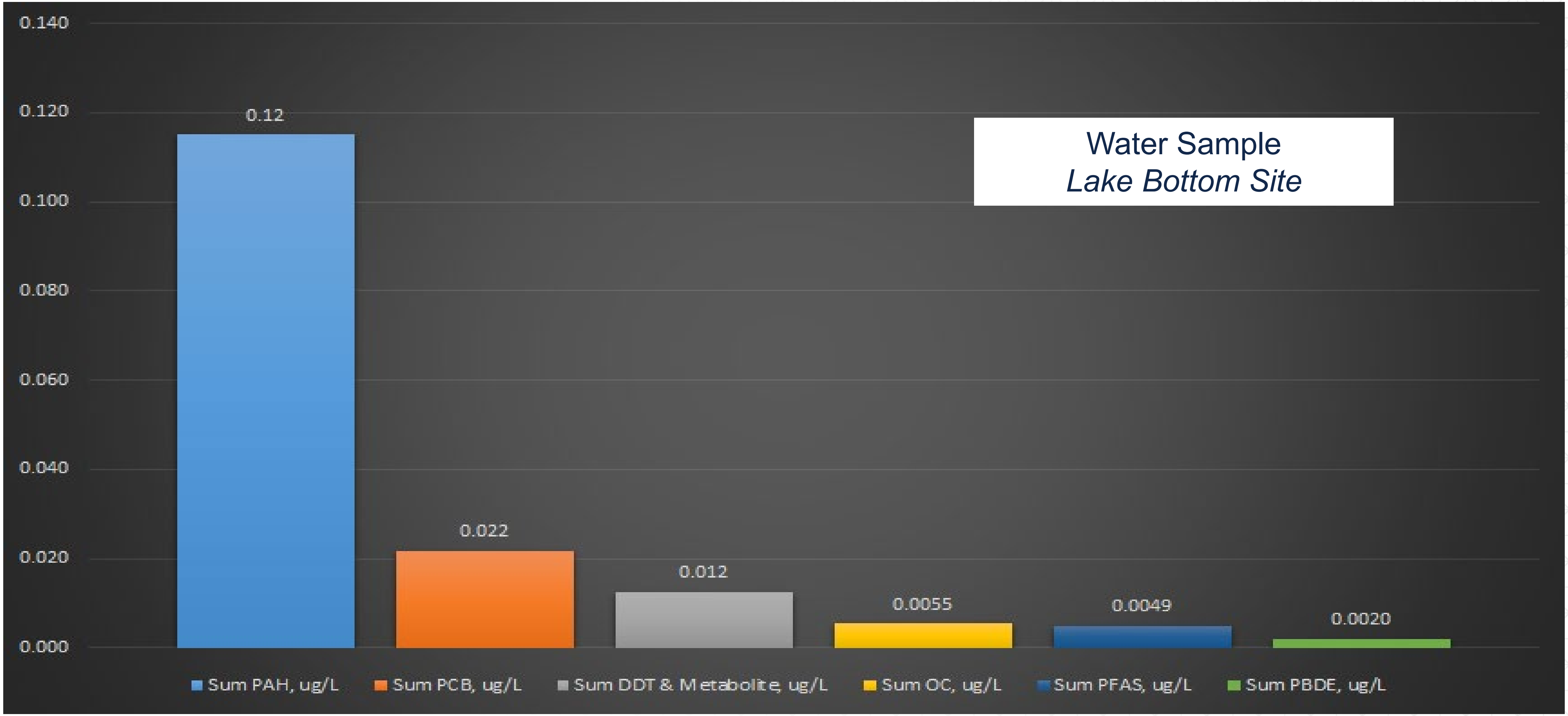

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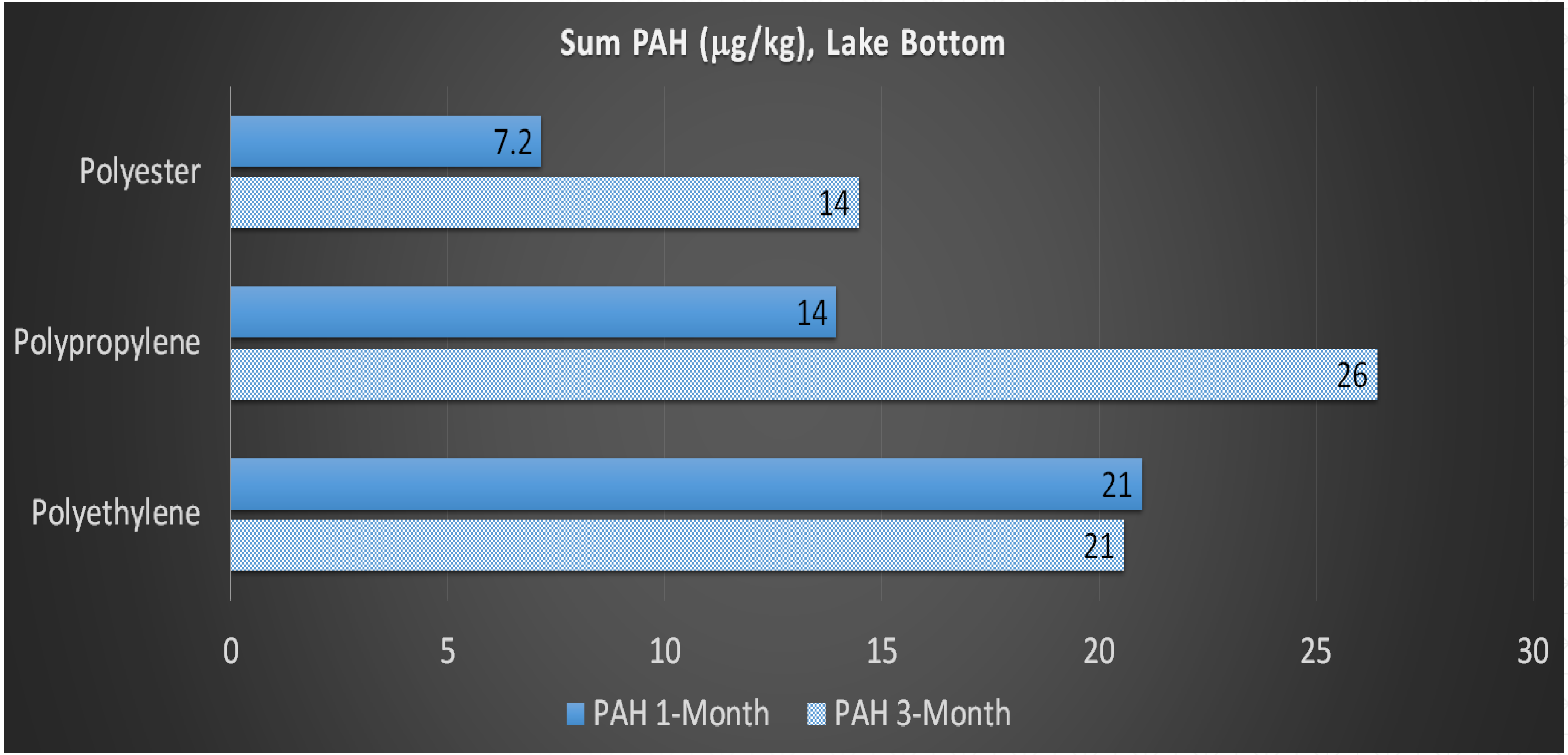


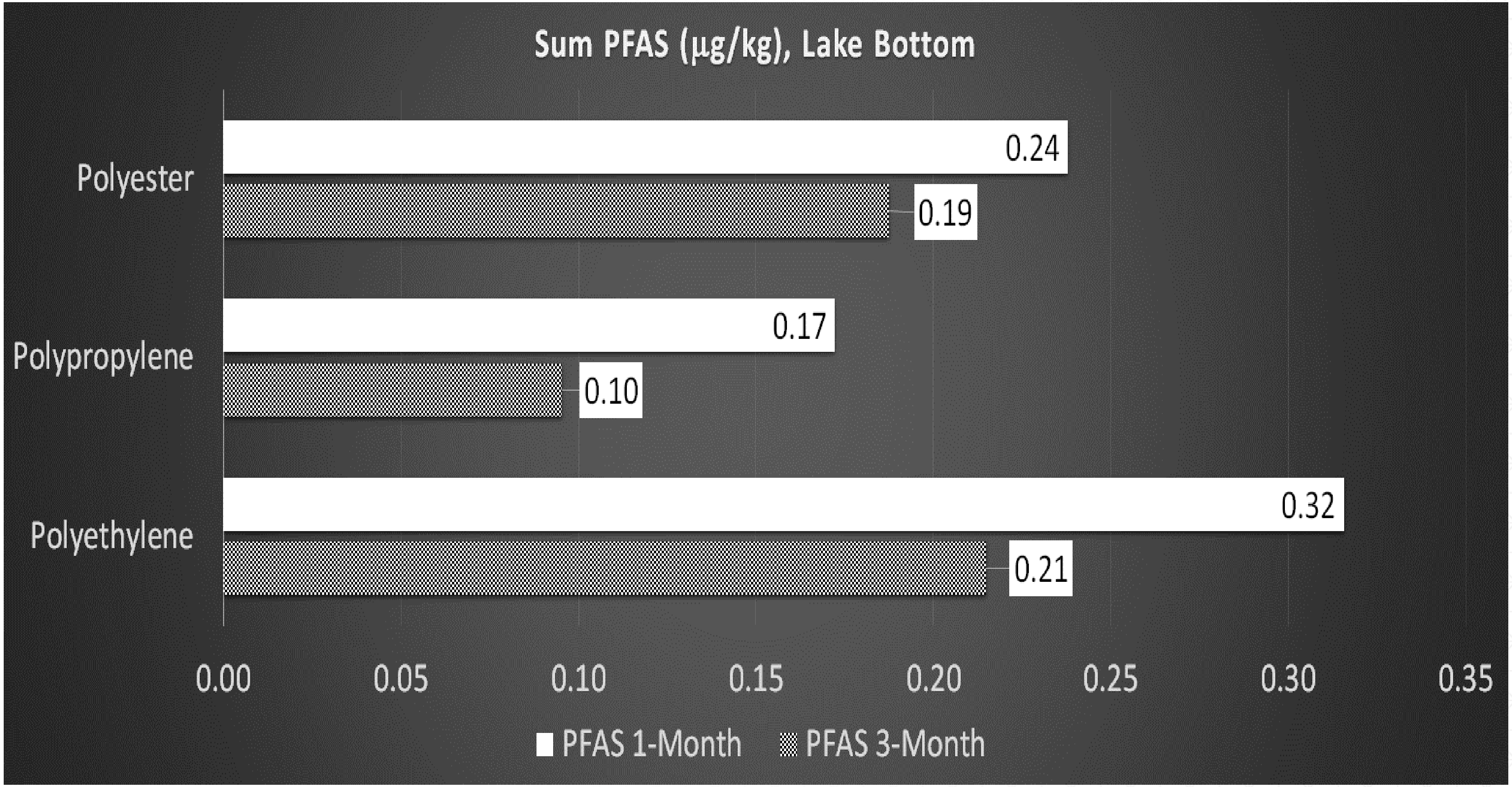
60X to 120x increase

60X to 220X increase

180X increase

Steinman, Alan D., John Scott, Lee Green, Charlyn Partridge, Maggie Oudsema, Michael Hassett, Emily Kindervater, and Richard R. Rediske. "Persistent organic pollutants, metals, and the bacterial community composition associated with microplastics in Muskegon Lake (MI)." *Journal of Great Lakes Research* 46, no. 5 (2020): 1444-1458.

Muskegon Lake– Microplastics Field Study



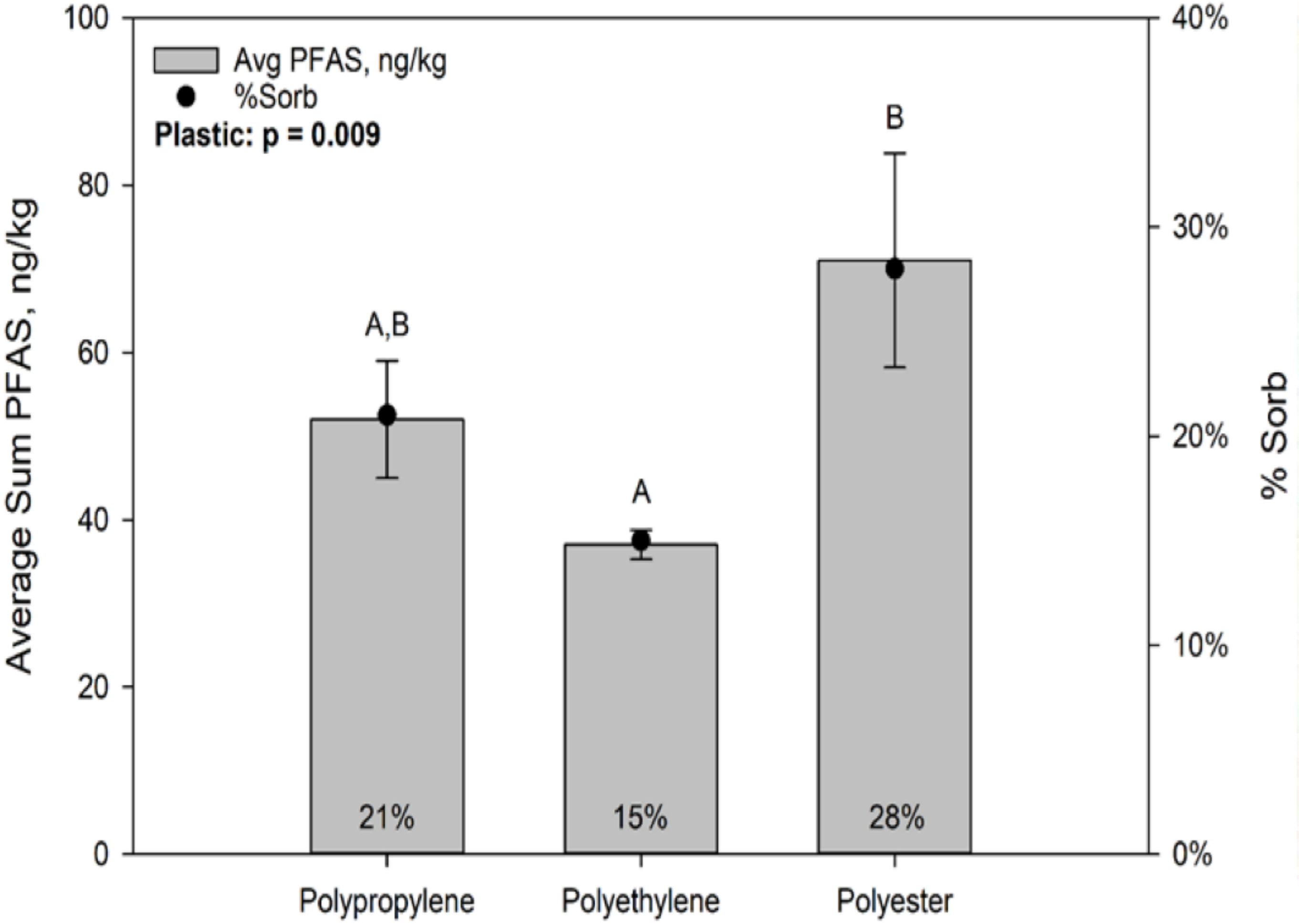
95X to 120x increase

50X to 85X increase

105X to 160X increase

Scott, John W., Kathryn G. Gunderson, Lee A. Green, Richard R. Rediske, and Alan D. Steinman. "Perfluoroalkylated substances (PFAS) associated with microplastics in a lake environment." *Toxics* 9, no. 5 (2021): 106.

Muskegon Lake– Microplastics Lab Study



Scott, John W., Kathryn G. Gunderson, Lee A. Green, Richard R. Rediske, and Alan D. Steinman. "Perfluoroalkylated substances (PFAS) associated with microplastics in a lake environment." *Toxics* 9, no. 5 (2021): 106.

Muskegon Lake– Microplastics Lab Study

Key Findings

- Microplastics deployed in Muskegon Lake accumulated persist organic pollutants up to several hundred times the background concentrations.

- Microplastics exposed in Muskegon Lake accumulated PFAS much greater than those exposed to similar PFAS concentrations in the laboratory. Suspected to be related to biofilm.

- Although microplastics do accumulate environmental contaminants, wildlife would have to ingest very large masses of microplastics to substantially increase exposure.

Example Sum PAH, 26 ng/g x 1g / 1000 mg = 0.026 ng for every milligram of microplastic

Concentrations of microplastics in aqueous samples typically on the microgram scale

Steinman, Alan D., John Scott, Lee Green, Charlyn Partridge, Maggie Oudsema, Michael Hassett, Emily Kindervater, and Richard R. Rediske. "Persistent organic pollutants, metals, and the bacterial community composition associated with microplastics in Muskegon Lake (MI)." *Journal of Great Lakes Research* 46, no. 5 (2020): 1444-1458.

Scott, John W., Kathryn G. Gunderson, Lee A. Green, Richard R. Rediske, and Alan D. Steinman. "Perfluoroalkylated substances (PFAS) associated with microplastics in a lake environment." *Toxics* 9, no. 5 (2021): 106.

Plastic Additives

More than 10,000 plastic additives in use.

2,400 have been identified as potentially hazardous

Types of Additives

- Colorants
- Fillers
- Antioxidants
- Heat & UV stabilizers
- Antistatic
- Flame retardants
- Cross-linking agents
- Processing aids
- Stability modifiers
- Anti-microbial agents
- Lubricants
- Etc.

Environmental Science & Technology

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Deep Dive into Plastic Monomers, Additives, and Processing Aids

Helene Wiesinger,* Zhanyun Wang,* and Stefanie Hellweg

Cite This: *Environ. Sci. Technol.* 2021, 55, 9339–9351 Read Online

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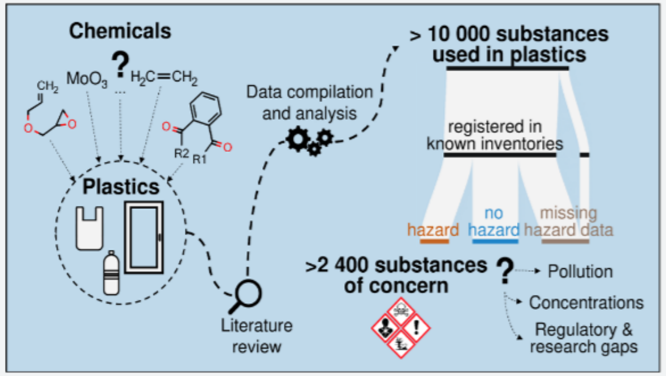
ABSTRACT: A variety of chemical substances used in plastic production may be released throughout the entire life cycle of the plastic, posing risks to human health, the environment, and recycling systems. Only a limited number of these substances have been widely studied. We systematically investigate plastic monomers, additives, and processing aids on the global market based on a review of 63 industrial, scientific, and regulatory data sources. In total, we identify more than 10'000 relevant substances and categorize them based on substance types, use patterns, and hazard classifications wherever possible. Over 2'400 substances are identified as substances of potential concern as they meet one or more of the persistence, bioaccumulation, and toxicity criteria in the European Union. Many of these substances are hardly studied according to SciFinder (266 substances), are not adequately regulated in many parts of the world (1'327 substances), or are even approved for use in food-contact plastics in some jurisdictions (901 substances). Substantial information gaps exist in the public domain, particularly on substance properties and use patterns. To transition to a sustainable circular plastic economy that avoids the use of hazardous chemicals, concerted efforts by all stakeholders are needed, starting by increasing information accessibility.



KEYWORDS: *plastic products, plasticizers, plastic pollution, chemical inventory, production volume, substances of concern, circular economy, regulatory status*

Source: Wiesinger, Helene, Zhanyun Wang, and Stefanie Hellweg. "Deep dive into plastic monomers, additives, and processing aids." *Environmental science & technology* 55, no. 13 (2021): 9339-9351.

Plastic Additives – U.S Regulations

(Level 1) Core Chemical Oversight
EPA (Toxic Substances Control Act - TSCA): Governs all chemicals & additives

- Must be on TSCA Inventory or get Premanufacture Notice (PMN)
- Risk management for PBTs, PFAS, etc.

(Level 2) Use-Specific "Gates"

- See Table

Use Case	Key Regulator / Rule	Main Requirements
Food Contact	FDA – 21 CFR Parts 174–178 (+ FCS program)**	Additives must be FDA-cleared, meet migration & purity limits
Toys / Kids' Products	CPSC / CPSIA / ASTM F963	Phthalates ≤ 0.1%; heavy-metal migration limits
Medical Devices	FDA CDRH / ISO 10993	Biocompatibility & chemical characterization required
Pharma Packaging	USP <661.1>/<661.2>	Extractables, identity, additive safety
Drinking Water	NSF/ANSI 61 & 372	Health-effects extraction limits, lead content
General Consumer Goods	CPSC FHSA + State Laws (e.g., Prop 65)	Hazard labeling & exposure warnings

This table was AI generated.

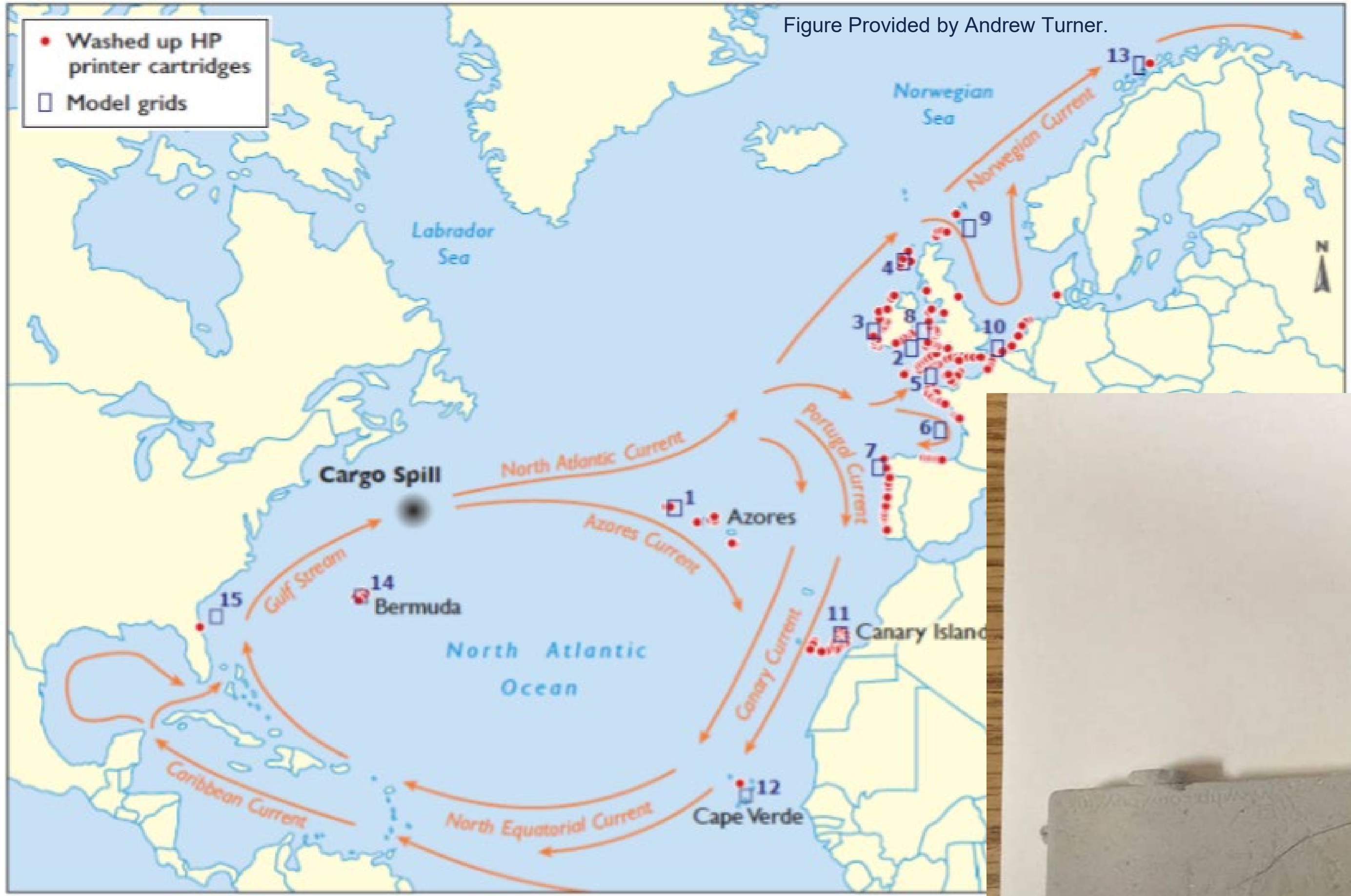
U.S. rules are **use-based**, not polymer-based — the same additive may be legal in one application and banned in another.

Plastic Additives – Heavy Metals

Function	Metals Commonly Used	Example Compounds	Status / Trend
Heat stabilizers	Pb, Cd, Sn, Ba, Zn	Lead stearate, Cd laurate, organo-tins	Lead & Cd banned; Ca/Zn replacing
Pigments	Pb, Cd, Cr, Co	$PbCrO_4$, CdS, CdSe	Phased out; organic pigments replacing
Flame retardants	Sb, Sn	Sb_2O_3	Still used, under review
UV stabilizers	Ni, Co, Mn, Zn	Nickel chelates	Declining use
Fillers / catalysts	Ti, Al, Fe, Cu	TiO_2, Al_2O_3	Generally safe/inert
Antimicrobials	Ag, Cu, Zn	Ag nanoparticles, ZnO	Still used, regulated by EPA FIFRA

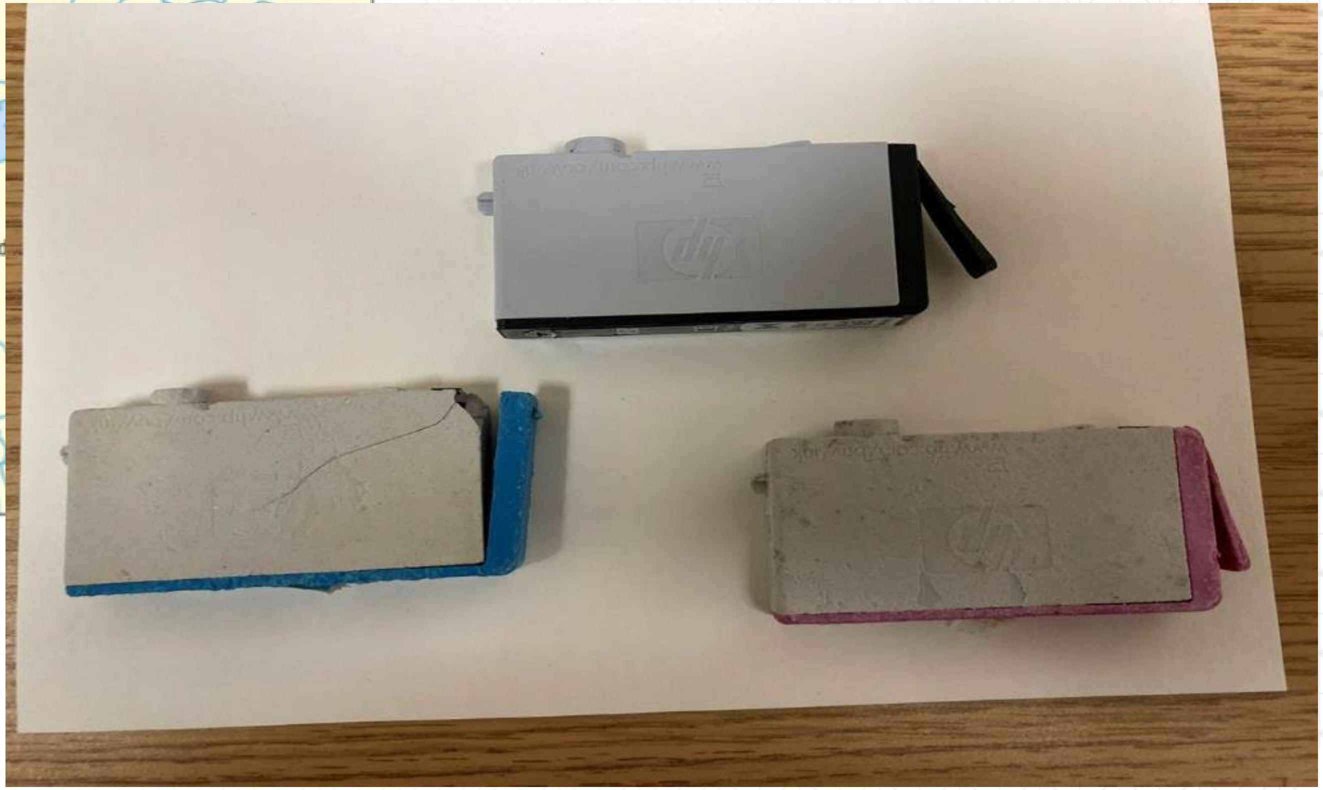
Example Beach Plastics Analyzed at ISTC

Plastic Additives – Titanium Dioxide (TiO_2)



Most widely used plastic additive

- White pigment
- UV blocker (Surface-treated rutile)
- Aesthetics (makes plastics look glossy)
- Protects light sensitive products



Scott, John W., Andrew Turner, Andres F. Prada, and Linduo Zhao. "Heterogeneous weathering of polypropylene in the marine environment." *Science of The Total Environment* 812 (2022): 152308.

Plastic Additives – Black Colored Plastics

- Screening of 1000 consumer plastics found that black colored plastics had the greatest occurrence of bromine.
- Bromine most detected in electronic associated plastics (42%) but did show up in 18% of non-electronic items (toys, jewelry).
- Antimony and lead commonly associated with bromine.
- Suggests that electronic waste in likely contaminating plastic recycling systems.

Science of the Total Environment 601–602 (2017) 374–379

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

ELSEVIER

Bromine in plastic consumer products – Evidence for the widespread recycling of electronic waste

Andrew Turner [a,*], Montserrat Filella [b]

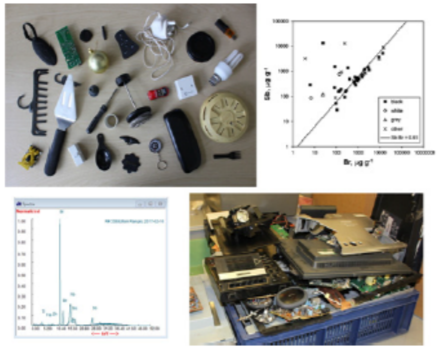
[a] School of Geography, Earth and Environmental Sciences, Plymouth University, Drake Circus, Plymouth PL4 8AA, UK

[b] Institute F.-A. Forel, University of Geneva, Boulevard Carl-Vogt 66, CH-1205 Geneva, Switzerland

HIGHLIGHTS

- XRF has been used to determine Br in 1000 plastic consumer products.
- Br was detected in 42% of electronic and 18% of non-electronic samples.
- Its presence is attributed to brominated flame retardants (BFRs).
- The results suggest that plastics from WEEE are widely recycled.
- The occurrence of BFRs in toys and food-contact items are of concern.

GRAPHICAL ABSTRACT



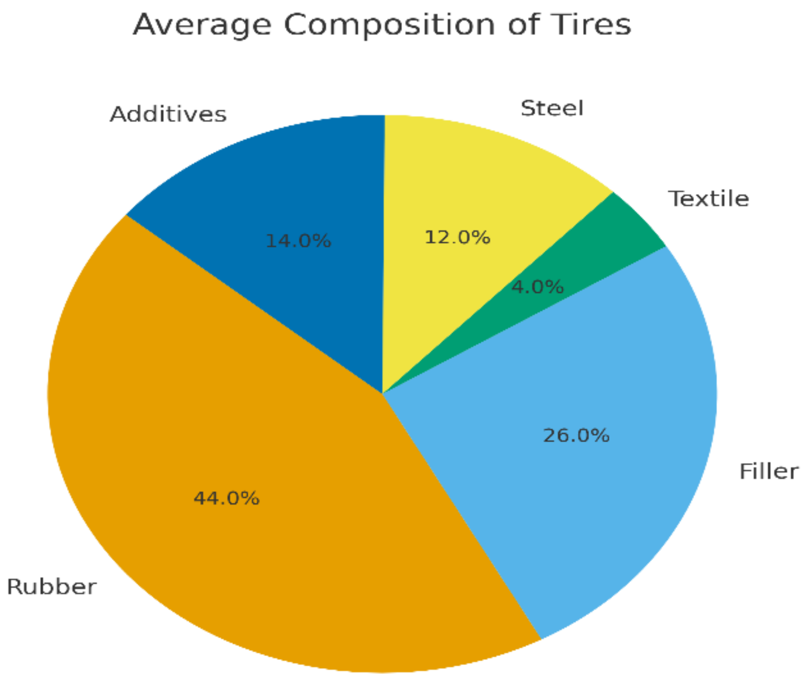
Turner, Andrew. "Black plastics: Linear and circular economies, hazardous additives and marine pollution." *Environment international* 117 (2018): 308-318.

Turner, Andrew, and Montserrat Filella. "Bromine in plastic consumer products–Evidence for the widespread recycling of electronic waste." *Science of the Total Environment* 601 (2017): 374-379.

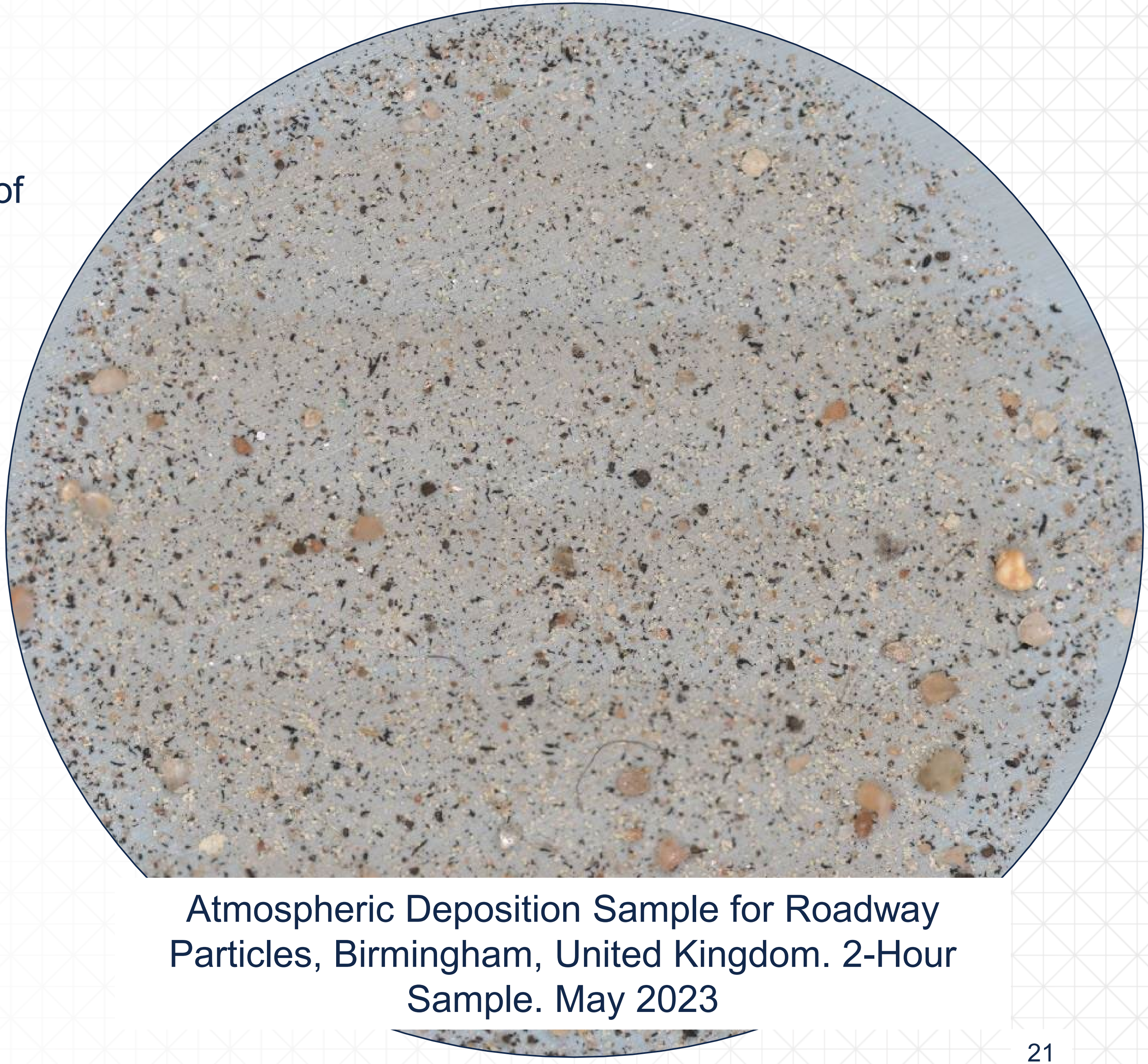
Tyre Wear Particles

- A major contributor to environmental loading of microplastics

- Tyres are extremely complex materials



Source: Utrera-Barrios, Saul, Raquel Verdejo, Miguel Ángel López-Manchado, and Marianella Hernández Santana. "Self-Healing Elastomers: A sustainable solution for automotive applications." *European Polymer Journal* 190 (2023): 112023.



Atmospheric Deposition Sample for Roadway Particles, Birmingham, United Kingdom. 2-Hour Sample. May 2023

Plastic Additives – Tyre Wear Particles

Additive Type	Function	Typical Compounds / Notes
Plasticizers & Softeners	Increase flexibility, reduce Tg, improve processability	Aromatic, naphthenic, or paraffinic oils; esters
Resins	Improve tack, adhesion, and hysteresis control	Phenolic, terpene, or hydrocarbon resins
Processing Aids	Improve mixing and extrusion	Fatty acids (e.g., stearic acid), waxes, surfactants
Waxes (Antiozonants)	Protect surface from ozone cracking	Microcrystalline and paraffin waxes that bloom to surface
Antioxidants	Prevent oxidation and thermal degradation	Amine-based (6PPD, IPPD) or phenolic antioxidants
Antiozonants	Scavenge ozone radicals; prevent cracking	p-Phenylenediamines (PPDs) like 6PPD

This table was AI generated.

Additive Type	Function	Typical Compounds / Notes
Curing Agents	Enable vulcanization (crosslinking)	Sulfur (elemental) + accelerators
Accelerators	Control rate and efficiency of curing	MBT (*2-Mercaptobenzothiazole*), CBS (*N-Cyclohexyl-2-benzothiazolesulfenamide*), TMTD (*Tetramethylthiuram disulfide*), TBBS (*N-tert-Butyl-2-benzothiazolesulfenamide*)
Activators	Enhance sulfur vulcanization	Zinc oxide (ZnO) + stearic acid
Retarders	Prevent premature curing ("scorch")	CTP (*N-Cyclohexylthiophthalimide*)
Adhesion Promoters	Improve bonding to steel and textiles	Cobalt salts, RFL (resorcinol–formaldehyde–latex) resins, brass coatings
Desiccants / Anti-hydrolysis Agents	Control moisture and stability	Silica gels, calcium oxide
Colorants / Pigments	Provide appearance and UV protection	Carbon black, titanium dioxide (TiO_2) for whitewalls

This table was AI generated.

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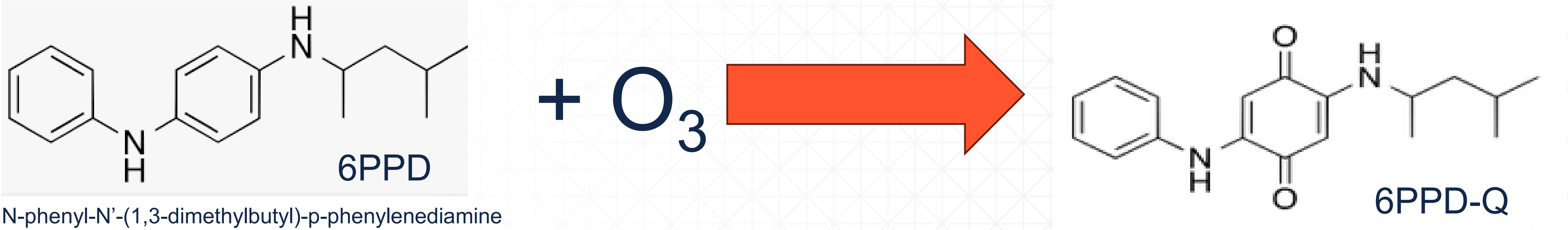
Retarders	Prevent premature curing ("scorch")	CTP (*N-Cyclohexylthiophthalimide*)
Adhesion Promoters	Improve bonding to steel and textiles	Cobalt salts, RFL (resorcinol–formaldehyde–latex) resins, brass coatings
Desiccants / Anti-hydrolysis Agents	Control moisture and stability	Silica gels, calcium oxide
Colorants / Pigments	Provide appearance and UV protection	Carbon black, titanium dioxide (TiO_2) for whitewalls

This table was AI generated.

Plastic Additives – 6PPD & 6-PPD-Q



N-phenyl-N’-(1,3-dimethylbutyl)-p-phenylenediamine

6-PPD-Q is a strong aquatic toxicant!

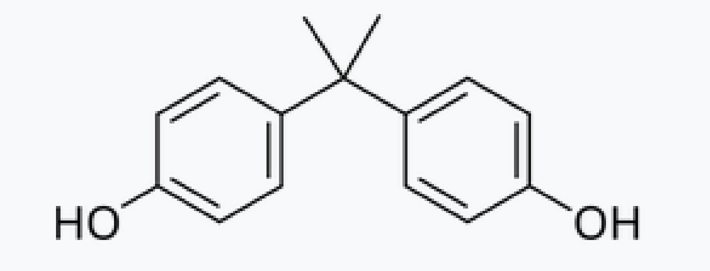
<u>Published Lethal Concentrations</u>

- Coho salmon: LC_{50} = 95 ng/L
- Brook Trout: LC_{50} = 590 ng/L
- Rainbow Trout: LC_{50} = 1000 ng/L

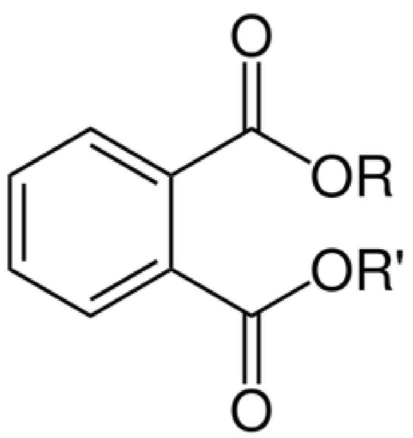
Source: Brinkmann, Markus, David Montgomery, Summer Selinger, Justin GP Miller, Eric Stock, Alper James Alcaraz, Jonathan K. Challis et al. "Acute toxicity of the tire rubber-derived chemical 6PPD-quinone to four fishes of commercial, cultural, and ecological importance." *Environmental Science & Technology Letters* 9, no. 4 (2022): 333-338.

Plastic Additives – Others

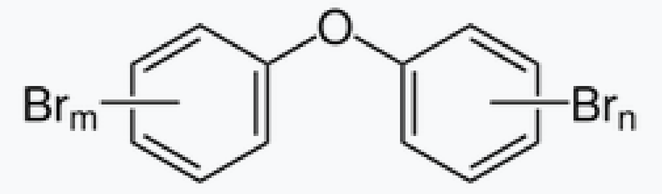
Bisphenol A
(Co-monomer of Polycarbonate, endocrine disruptor)



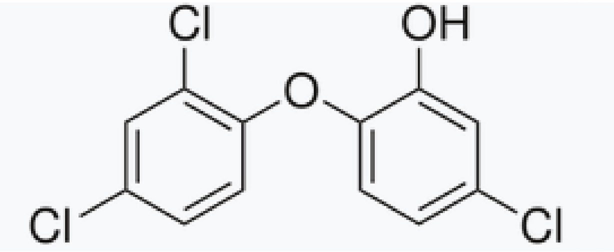
Phthalates
(Plasticizers, PVC, endocrine disruptors)



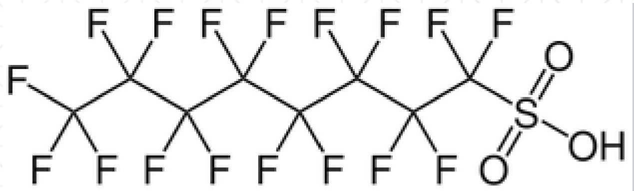
Flame Retardants
(Halogenated, persistent, bioaccumulative, and endocrine disruptors)



Triclosan
(Antimicrobial)



Per- and polyfluoroalkyl substances - PFAS (Surface Coatings & processing aid, persistent and bioaccumulative)



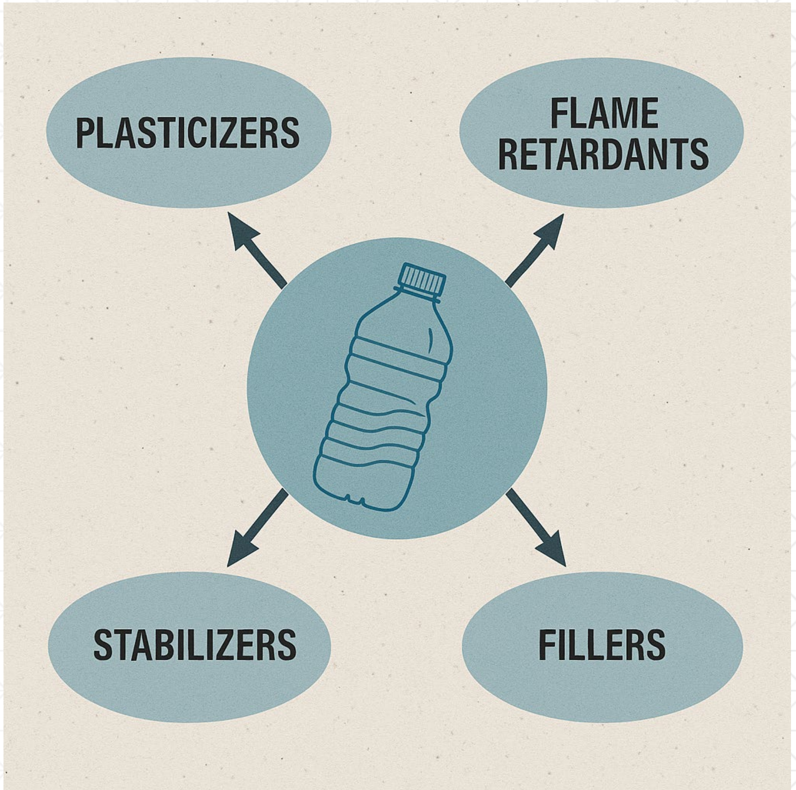
Etc., etc., etc……..

Plastic Additives – Summary

- Additives are typically present in plastics at high concentrations (percent level)
- Many of the additives used are known to be persist, bioaccumulative, and toxic
- Many additives hinder the ability to recycle or recover energy from these materials

Plastic in the Environment

When evaluating plastic pollution in the environment, it is essential to consider all associated factors, as these parameters can significantly influence the transport, fate, and toxicity of plastics.



These images were AI generated.

Questions?

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