Chesapeake Bay Program
Scientific & Technical Advisory Committee (STAC)
Chesapeake Bay Commission

Technical Review of Microbeads/Microplastics in the Chesapeake Bay

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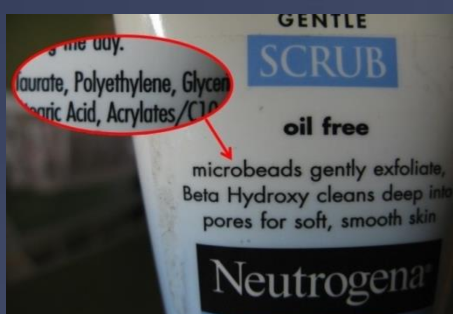
School of Marine Science



Chesapeake Bay Program Toxics Workgroup Meeting: July 13, 2016

Plastic debris in the Environment
- Big effects from big stuff

* **Wildlife Entanglement**
* **Ingestion**

Plastics (mis)conceptions…

All plastics the same
& behave similarly?

- **Float**
- **Biologically/chemically inert**
- **Last forever**

Only a beach & water surface issue?

Most abundant types = biggest problem?

Biggest pieces = largest problem?

- **What about small microbeads/microplastics? <5 mm**

Specific gravity of various plastics

Plastics	Specific gravity
LDPE	0.91~0.93
HDPE	0.94~0.97
PP	0.90~0.91
PS	1.04~1.07
PVC	1.35~1.45
ABS	0.99~1.10
Polyester	1.38~1.39
PC	1.2
Nylon 66	1.13~1.15
Teflon	2.1~2.2

Source: "Polymer dictionary" by Taiseisha Co., Ltd (1970)

STAC/CBC Microbeads Questions

Fate & Transport

What is the proper definition of 'degradable' in regard to microbeads in the aquatic environment, and what factors impact degradability and rate of breakdown?

Is there a concern that contaminants from the water can adhere to synthetic plastic microbeads?

What is the potential geographic range of impact, i.e., is their impact quite local (like sediment) or does their buoyancy allow them to travel great distances (more like air)?

Potential Impact

Are there physical impacts of microplastic to aquatic organisms?

Is there a risk that synthetic plastic microbeads, both with and without sorbed contaminants, could serve as a vector to aquatic organisms?

What is the evidence of bioaccumulation and is it worse in certain types of species such as mollusks, filter feeding forage fish, etc.?

Is there a risk that synthetic plastic microbeads that have sorbed contaminants could serve as a significant health risk for humans?

Are there any research findings on microplastics specific to the Chesapeake Bay and its tributaries?

Wastewater Treatment

What is the expected removal of microbeads/microplastics in conventional wastewater treatment facilities in the Chesapeake Bay watershed? What are the removal mechanisms? What is the fate of the microbeads/microplastics?

What is the extent of microbead/microplastic discharge from combined sewer overflows (CSOs) and sanitary sewer overflows (SSOs)?

Are there emerging technologies that could enhance removal of microbeads/microplastics? What is the potential for the implementation of these emerging technologies? What would be the expected removal of microbeads/microplastics in conventional drinking water treatment plants using surface water supplies? Is additional treatment warranted?

Does it make sense to place most of the burden of microbead/microplastic control on WWTPs?

Potential Urgency

Is there any evidence of the direction of potential impact, i.e., are microplastics being seen in increasing quantities at local or regional scales?

Is this really a problem that rises to the level of taking individual state action? That is, is this having an impact (or is this likely to have an impact) on the Chesapeake Bay and its tributaries?

Microbead-Free Waters Act of 2015

What is beneficial about the federal legislation banning microbeads?

Does the language in the bill allow for novel innovative scientific solutions now and in the future?

Microbeads Technical Review Panel

- Dr. Charles Bott, Hampton Roads Sanitation District
- Dr. Craig Criddle, Stanford University
- Dr. Robert Hale, Virginia Institute of Marine Science
- Dr. Jason McDevitt, College of William & Mary
- Dr. Molly Morse, Mango Materials
- Dr. Chelsea Rochman, University of California, Davis

  - Report at: http://www.chesapeake.org/pubs/352_Wardrop2016.pdf

Congress Takes Action!

Fed supersedes multiple state actions

Size: 0.1 um - 5 mm
"rinse-off" products only

MicroBeads
0.001%

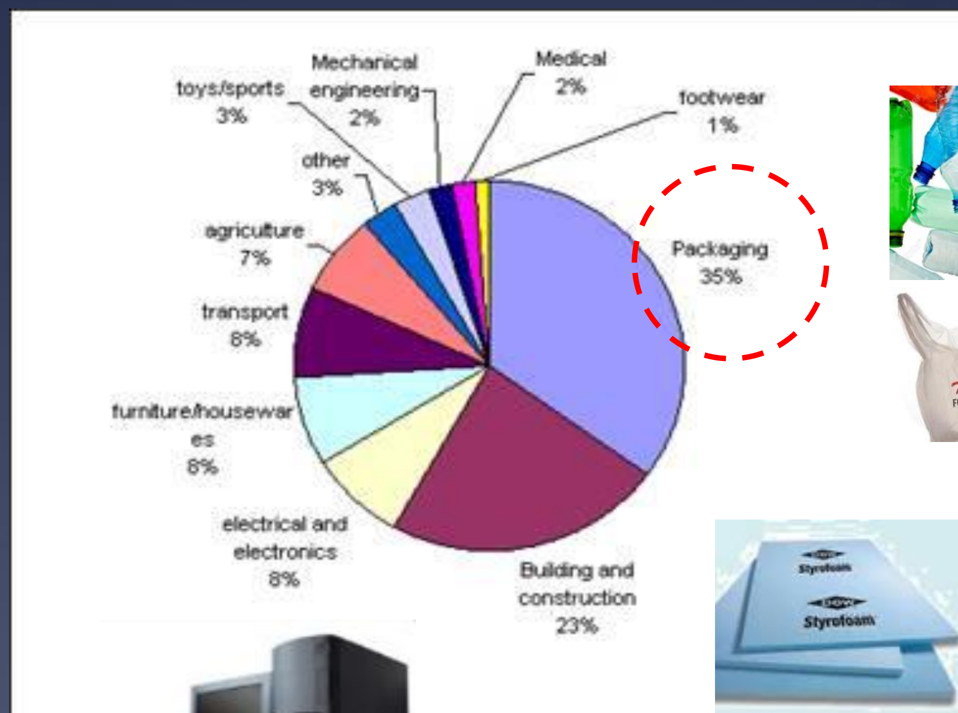
What about Microbeads in…
cleaning products
paints, printer toners
abrasive media (e.g., plastic blasting)
oil and gas exploration
textile printing
anti-slip, anti-blocking applications
medical applications….

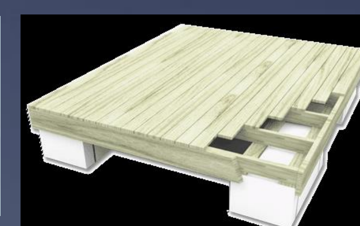
Plastics Production + Uses + End of life = Exposure

Plastics Make it Possible

Microbeads
Personal care

MicroBeads 0.001%

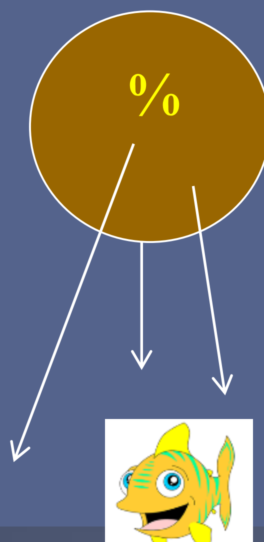




Synthetic polymer additives at % levels in plastics!!!

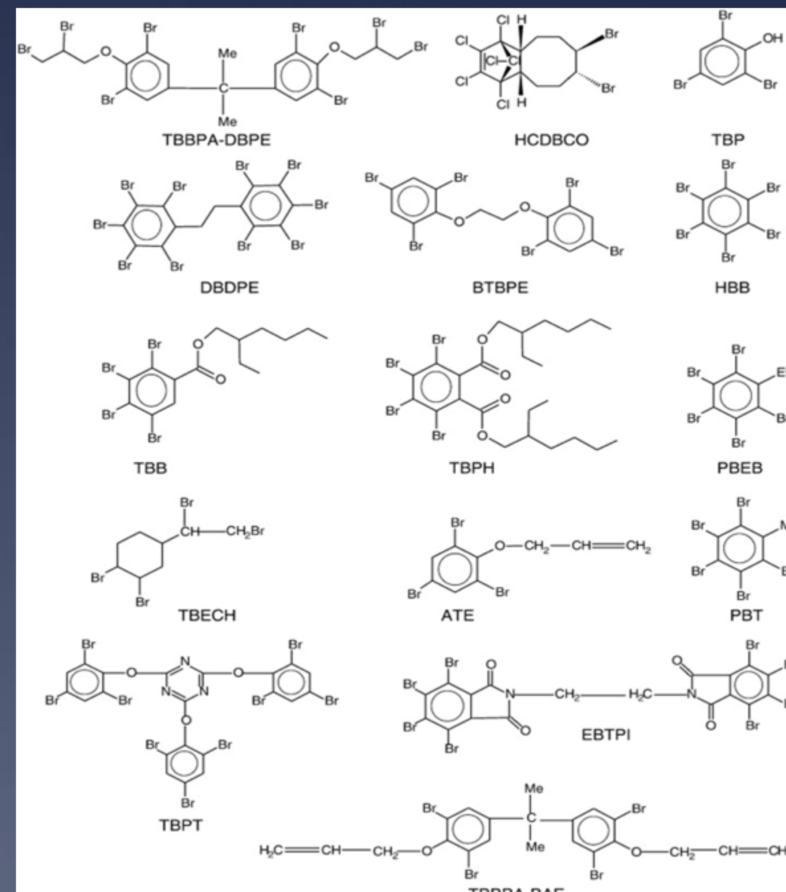
- Antimicrobials
- Antioxidants
- Antistatic Agents
- Biodegradable Plasticisers
- Blowing Agents
- External Lubricants
- Fillers/Extenders
- Flame Retardants
- Fragrances
- Heat Stabilisers
- Impact Modifiers
- Internal Lubricants
- Light Stabilisers
- Pigments
- Plasticisers
- Process Aids
- Reinforcements

Myth: Additives locked in plastics forever



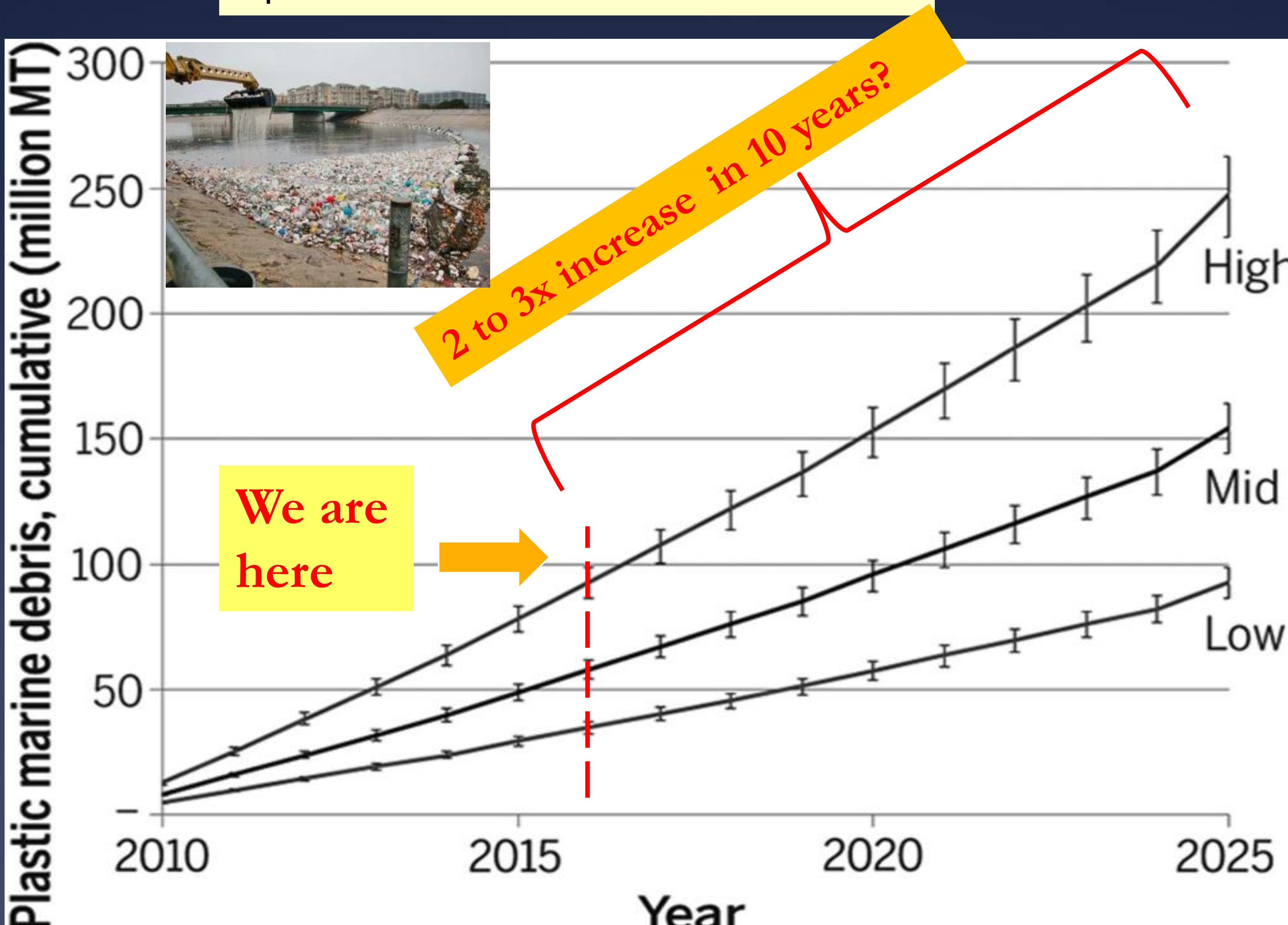
Partial list of known brominated flame retardants (BFRs)

Identity of many *confidential business information* (CBI)?



Estimated mismanaged plastic waste input to the ocean by populations living <50 km of a coast (192 countries), plotted as cumulative sum: 2010 to 2025.

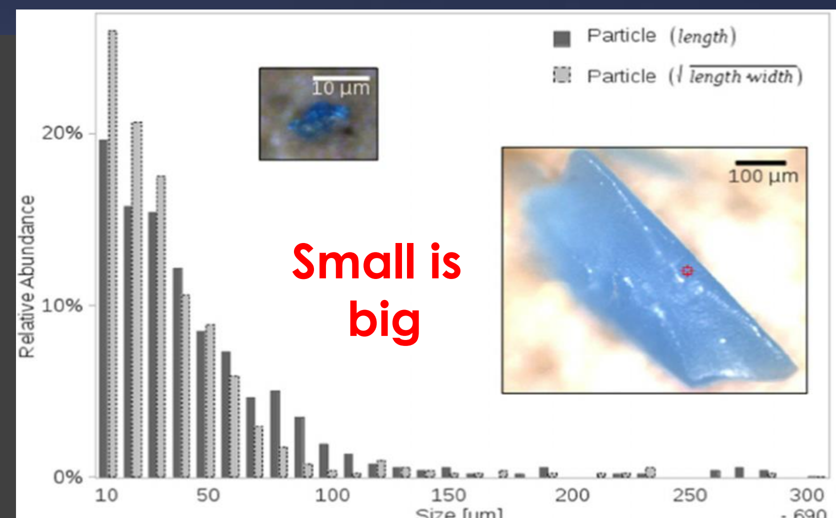
Adapted from Jambeck et al. 2015. *Science* 347:768-771



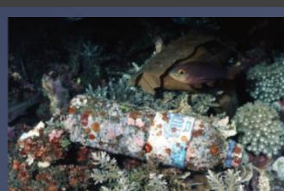
Plastics weather & fragment over time

Secondary Microplastics

- Weathering
  - F (polymer/environ. conditions)
    - Abrasion (beach)
    - UV light
    - Oxidation
    - Biodegradation
      - Biofouling



Enders et al. 2015. Abundance, size and polymer composition of marine microplastics ≥ 10 µm in the Atlantic Ocean and their modelled vertical distribution. Mar. Poll. Bull. 100: 70–81.



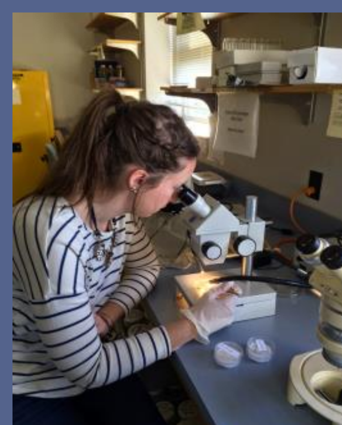
Impact of bio-fouling on density?

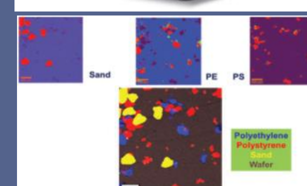
Neuston net
Mesh size

99% of ocean plastic missing

Cozar et al. 2014. Plastic debris in the open ocean. *PNAS* 111(28), 10239–10244 .

- **What we find depends on:**
  - **Where we look?**
    - Beaches & water surface
  - **What we look for & how we look?**
    - “big” pieces > 0.3 um





Microplastics in the Marine Environment: A Review of the Methods Used for Identification and Quantification. Environ. Sci. Technol. 2012, 46, 3060−3075.

Microplastics in Chesapeake Bay

Yonkos et al. 2014. Microplastics in Four Estuarine Rivers in the Chesapeake Bay, U.S.A. *Environ. Sci. Technol.*, 48: 14195–14202.

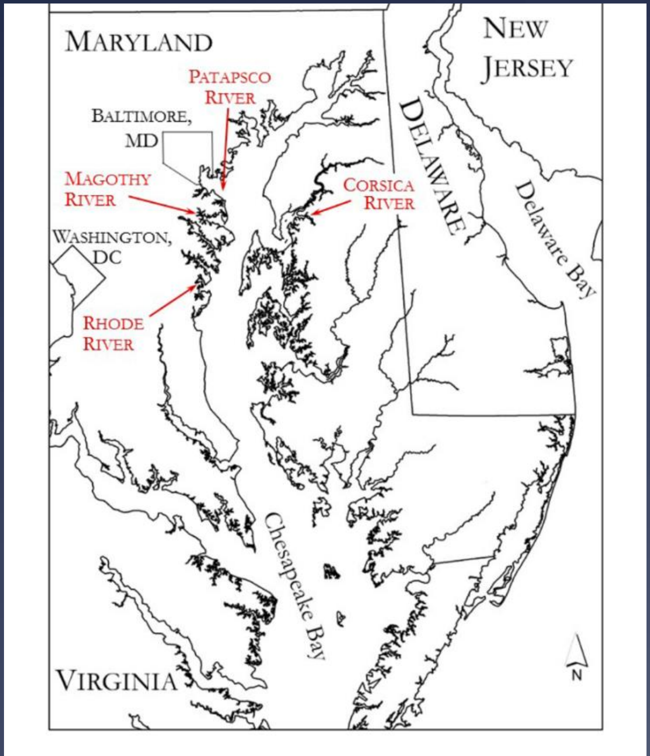
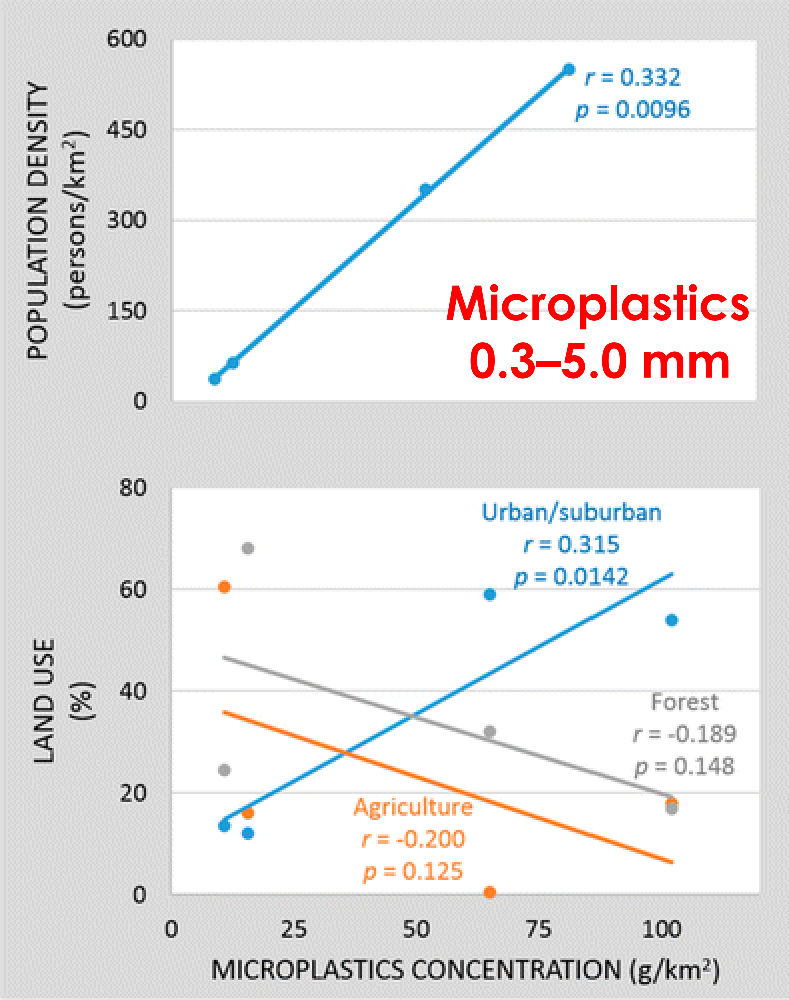
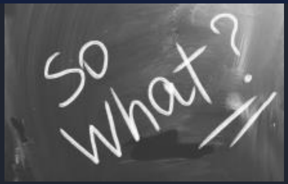
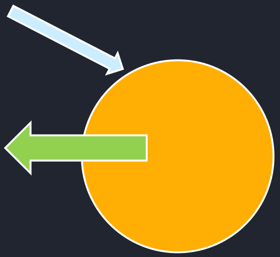


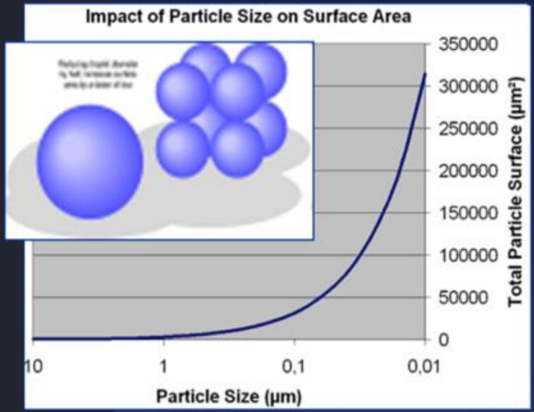
Figure 1. Locations of estuarine sites within the Chesapeake Bay sampled for microplastics between July and December 2011.





Microplastics:





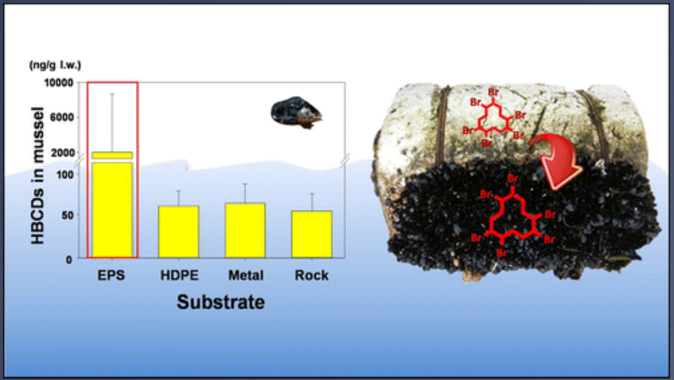
High surface area

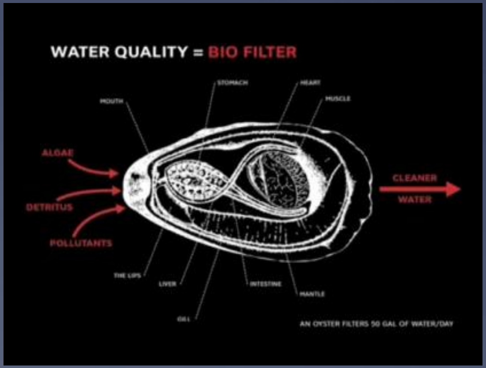
- Additive leaching
- Pollutant sorption

Small critters consume

- Zooplankton, filter feeders
  - Food chain transfer to Us?

Styrofoam Debris as a Source of Hazardous Additives for Marine Organisms
Environ. Sci. Technol., 2016, 50 (10), pp 4951–4960





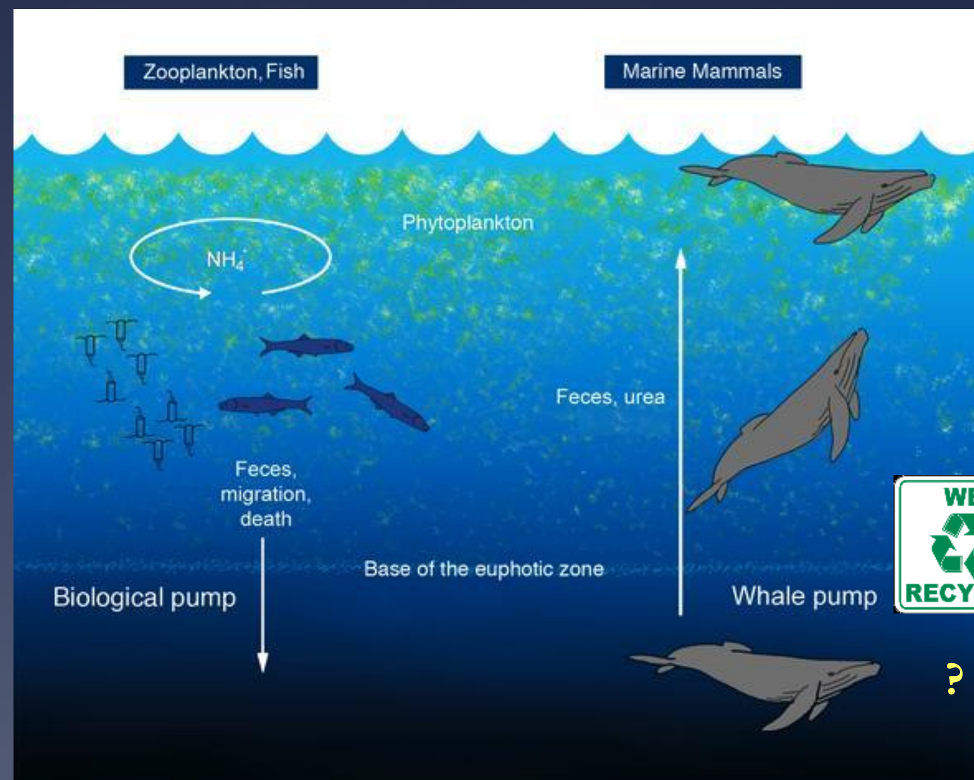
Effects on materials-processing?

Ingestion of buoyant microplastics alter density of zooplankton fecal pellets

- **derail deep ocean “fecal pellet express”?**

- **Oysters in Bay?**

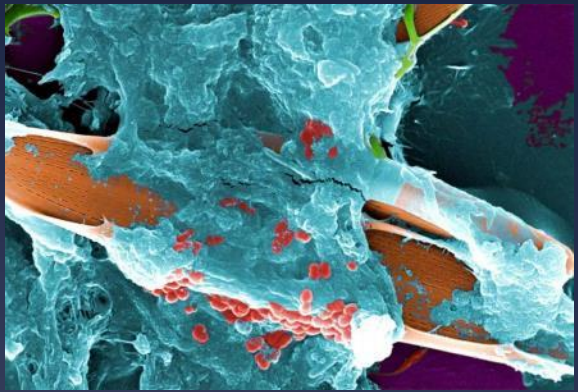
Cole et al. 2016. **Microplastics Alter the Properties and Sinking Rates of Zooplankton Faecal Pellets.** Environ Sci Technol 50, 3239-3246.



The Whale Pump: Marine Mammals Enhance Primary Productivity in a Coastal Basin. PLoS ONE, 2010;

Distinct microbes colonize plastics - biofilms

- **“Some …opportunistic pathogens such as Vibrio … *Plastisphere* communities are distinct from surrounding surface water …plastic serves as a novel ecological habitat.**



biofilm

Life in the “Plastisphere”: Microbial Communities on Plastic Marine Debris
Zettler et al. 2013. Environ Sci. Technol.

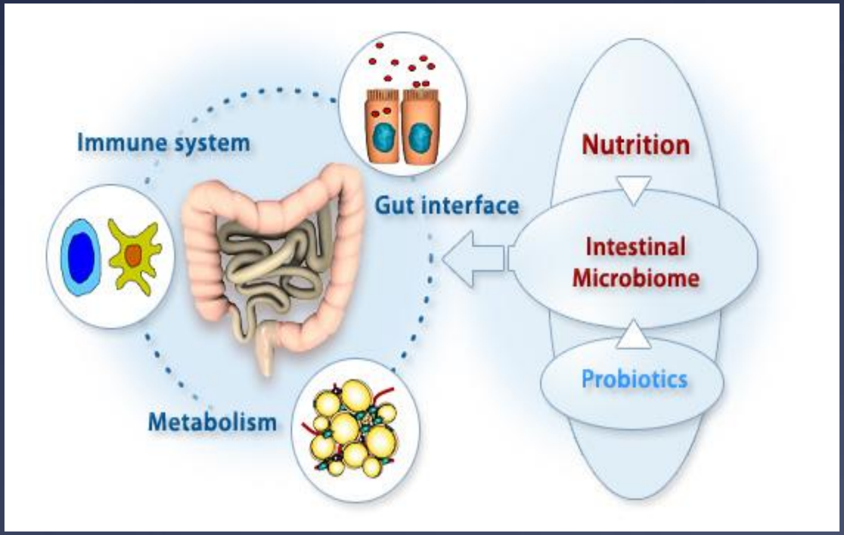
- **Could glowing microbes (e.g. Vibrio) be enticing ocean fish to snack on bits of plastic trash? … “It’s a whole new ocean habitat created by humans,” says microbiologist Tracy Mincer (WHOI)**

Zarubin et al. 2012. Bacterial bioluminescence as a lure for marine zooplankton and fish. PNAS 109. 853–857.

Gut Microbiome

Microbes in our gut play critical roles in our health - both detrimental & beneficial.

Velasquez-Manoff. 2015. Gut Microbiome: The Peacekeepers. *Nature.* 518:7540.



Study Says 90% of Seabirds Have Ingested Plastic

Wilcox et al. 2015. Threat of plastic pollution to seabirds is global, pervasive, and increasing. *PNAS* 112:11899–11904.

…incidence in coastal shellfish?

STAC Report findings: Fate & Transport

- Proper definition of "(bio)degradable"
  - Conversion to CO_2
  - Relative to naturally-occurring reference standards of same size (e.g., cellulose)
- Contaminant adherence
  - Nature of polymer & contaminant
  - Pathogens
- Geographic range of impact
  - Water & sediment
  - Surface microlayer
  - Shorelines

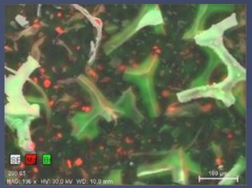
Potential Impacts

* Physical impacts?
  * Zooplankton, worms, mussels, fish
* Vector for associated chemicals?
  * Additives (not in microbeads?)
  * Adsorbed contaminants
* Bioaccumulation/biotransfer?
  * No trend across trophic levels
* Human health risks?
  * EPA/NRC Forum - April 2014

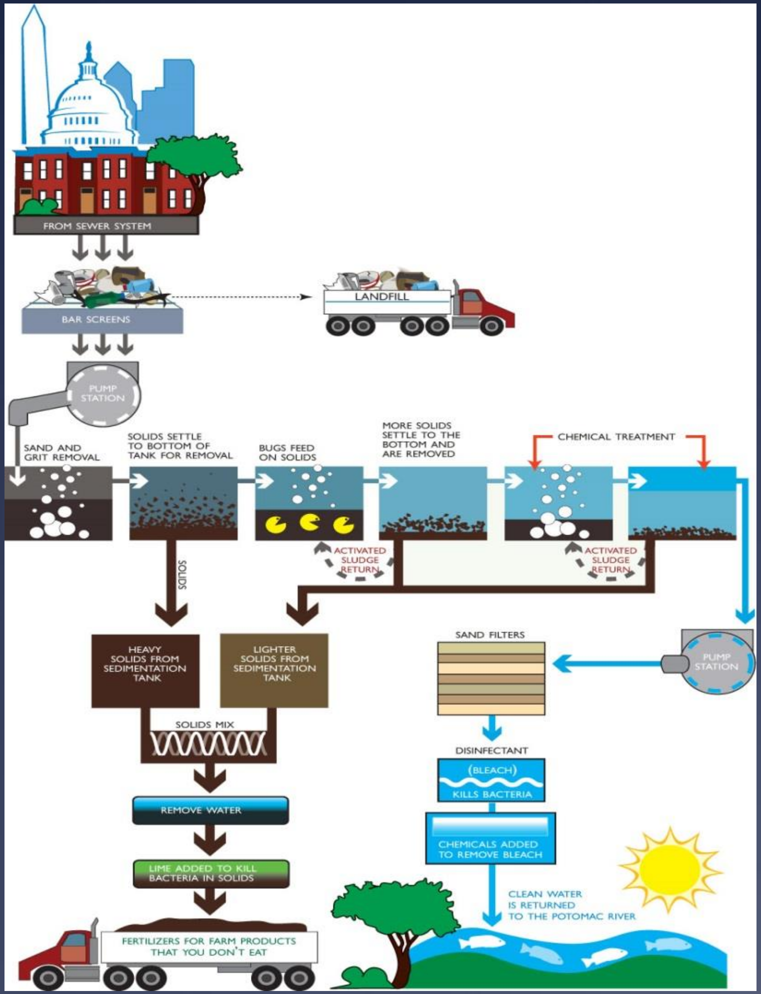
    Summary of Expert Discussion Forum on Possible Human Health Risks from Microplastics in the Marine Environment

https://www.epa.gov/sites/production/files/2015-02/documents/trash_free_waters_microplastics_expert_forum_meeting_summary_2-6-15.pdf

* Insights from indoor dust studies of BFRs



Wastewater Treatment
Microplastics



- Trash Screening – solid waste dump
- Clarifiers
  - 20-500 µm; settled; scum
- Tertiary treatment
  - Micro-screening for <100 µm
  - 90% removal of 10 µm particles, declining to roughly 10% removal of particles approaching 1 µm
- Activated sludge
  - Incineration
  - Landfilled
  - >50% Land application

Conclusions

1. "Rinse-off" microbeads < all microbeads. <<<< microplastics.
2. Immediate benefits of the *Microbeads-Free Waters Act* will not match its title.
3. Plastic use & entry into the environment increasing rapidly. Many polymers are persistent, so environmental levels exacerbated.
4. Microplastics may cause harm at many levels of biological organization, but research limited. Particle size, shape & composition are factors. Smaller particles, more easily consumed. Filter-feeders most impacted?
5. Plastics can be substrates for *unusual* microbial communities. Consequences on microbiome & health after ingestion?
6. Current trajectory of use & release of plastics may lead to major environmental problems. Recycling will help, but not an end-all.
7. Microplastics enter waters thru WWTPs, littering, surface runoff, wind & produced *in-situ* from fragmentation of larger debris & products.

8. Degradability (bio-, photo-, chemical, abrasive…) of plastics under realistic conditions, especially in aquatic compartments, is variable, often slow & poorly defined.

9. Polymers & additives are diverse, so treatment of microplastics as "compositionally homogenous" is problematic.

10. Polymer additives present at % levels! Thus are a source of contamination. Sorption of hydrophobic pollutants is widespread, but at lower levels. Fugacity of sorbed contaminants into tissues may limit uptake.

11. Analytical techniques to detect microplastics in complex media are inadequate. FTIR & Raman micro-imaging is the sharpest tool. This capability is lacking in the Bay watershed.

12. Accordingly, we are ignorant of the true extent of the microplastics problem in the Bay. Regardless, the smallest (most abundant) particles are presently undetectable.

13. Microplastic sources/transport include WWTPs, surface runoff, littering, wind… In-place clean up is impractical. Prevention & degradable plastic substitution are needed.

Consider Microplastics as POPs or Litter?

Acknowledgements

STAC/CBC

Microbeads Technical Review Panel members

Natalie Gardner, Chesapeake Research Consortium (CRC), STAC Coordinator

Dr. Denice Wardrop, Pennsylvania State University. STAC liaison and panel facilitator

(also from whose previous presentation I borrowed several slides)

Questions?