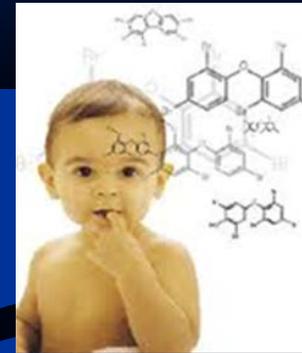


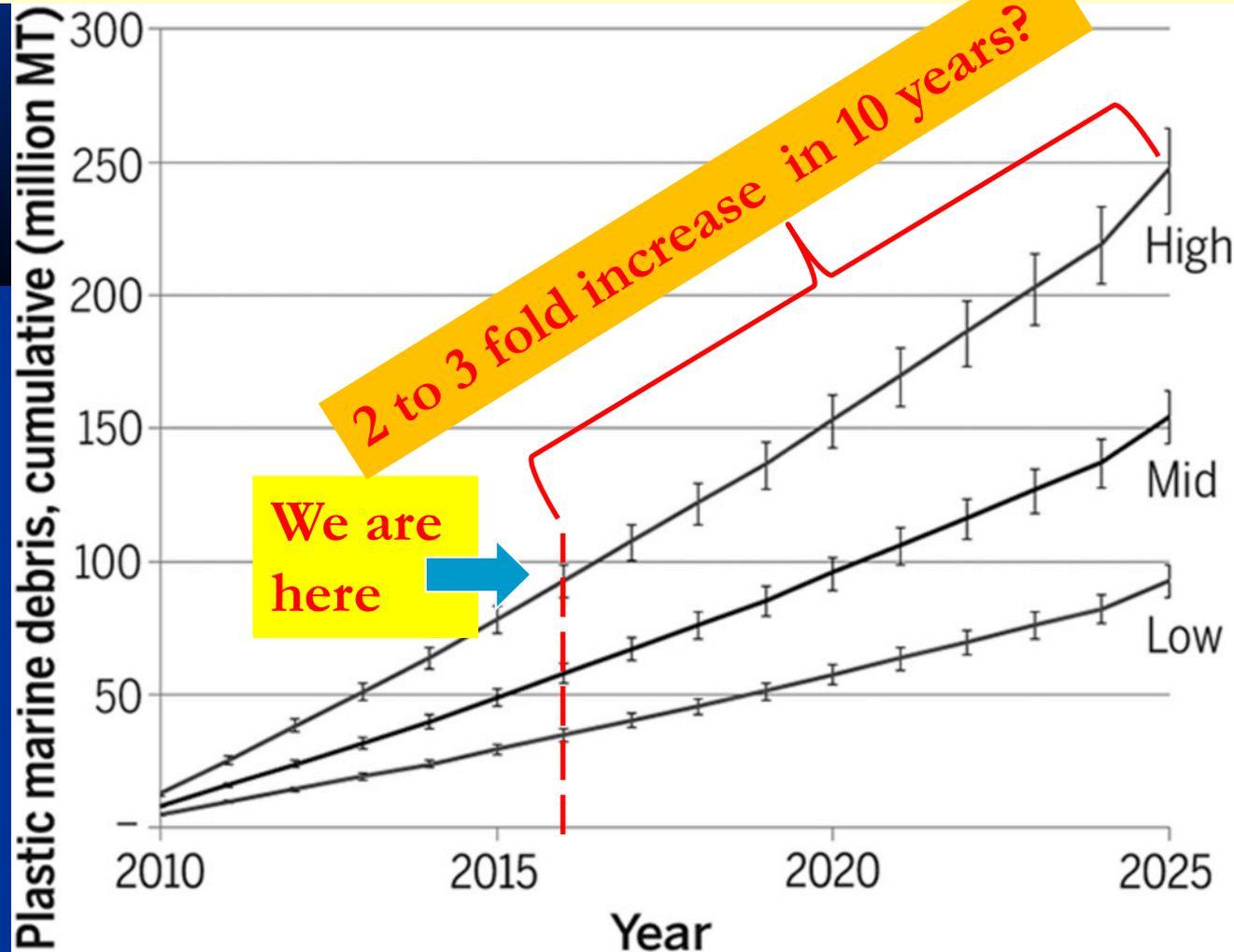
Microplastics & Human Health: Searching for Links



Rob Hale, Professor
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Ellen Harvey & Kelley Uhlig

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Fig. 2 Estimated mass of mismanaged plastic waste (millions of metric tons) input to the ocean by populations living within 50 km of a coast in 192 countries, plotted as a cumulative sum from 2010 to 2025. Estimates reflect assumed conversion rates of mismanaged plastic waste to marine debris (high, 40%; mid, 25%; low, 15%).



Plastic Marine Debris & Potential Human Health Risks

Workshop

April 23, 2014

THE NATIONAL ACADEMIES
Advisers to the Nation on Science, Engineering, and Medicine



Purpose: convene a meeting of experts to discuss available data & studies on the interaction of toxic chemicals & plastic marine debris & the potential for human health impacts from the ingestion of fish that have consumed plastic particles.

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



Consider risks not just from microplastics in ocean, but plastics & additives during manufacture, use & disposal



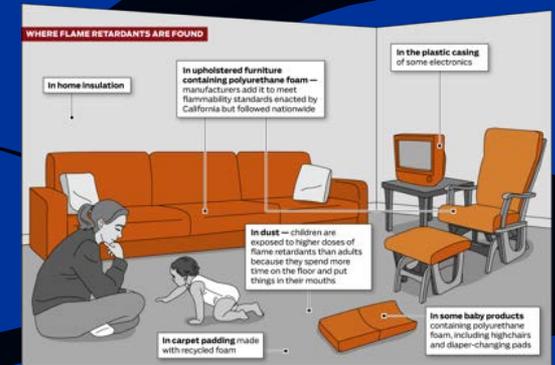
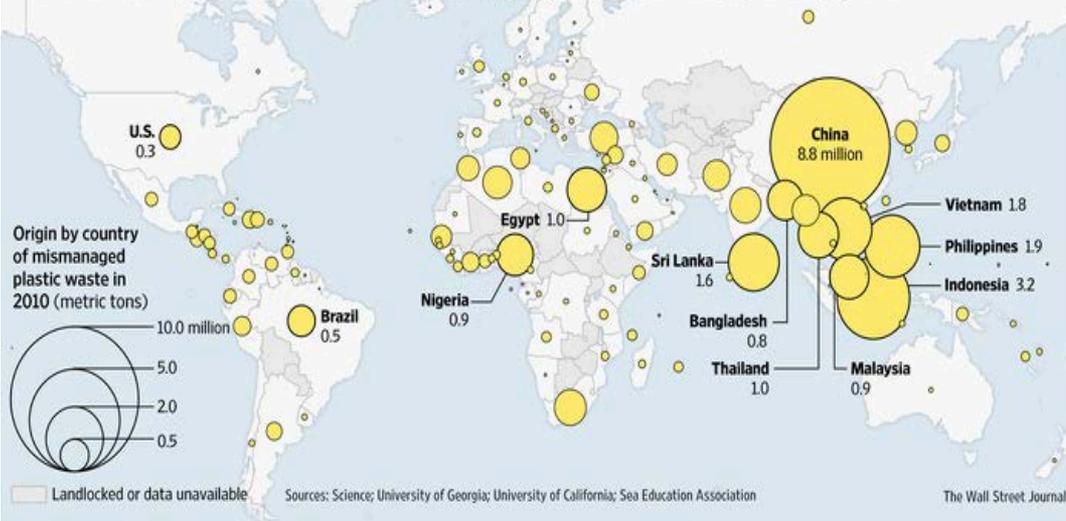
Human risk ~75% of waste is on land with us

Lebanon: 'River of trash' chokes Beirut suburb as city's garbage crisis continues

FEBRUARY 25, 2016

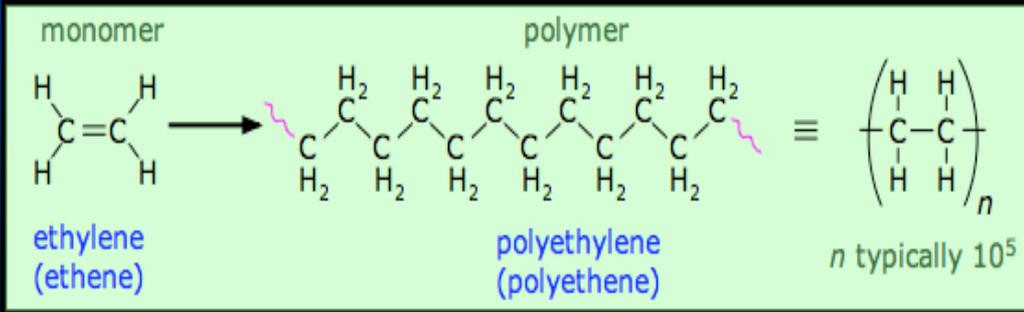


Ocean Detritus | Much of the world's mismanaged plastic waste ends up fouling global waters





Polymeric chemicals



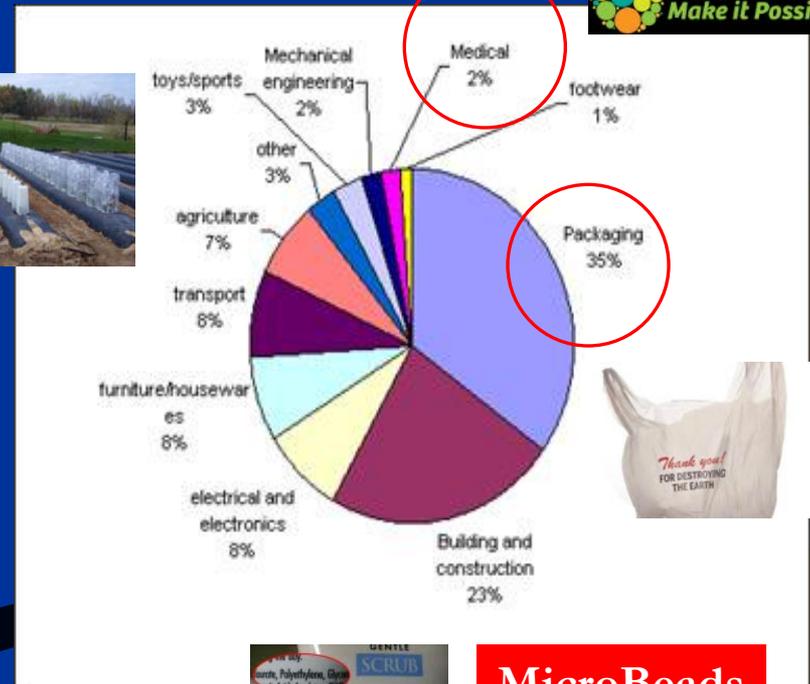
chitin



Monomer structures of different polymers

<p>Polyethylene (PE)</p> $ \begin{array}{c} \text{H} & \text{H} \\ & \\ -\text{C} & - \text{C}- \\ & \\ \text{H} & \text{H} \end{array} $	<p>Polyvinyl chloride (PVC)</p> $ \begin{array}{c} \text{H} & \text{H} \\ & \\ -\text{C} & - \text{C}- \\ & \\ \text{H} & \text{Cl} \end{array} $	<p>Polypropylene (PP)</p> $ \begin{array}{c} \text{H} & \text{H} \\ & \\ -\text{C} & - \text{C}- \\ & \\ \text{H} & \text{CH}_3 \end{array} $
<p>Polytetrafluoroethylene (PTFE)</p> $ \begin{array}{c} \text{F} & \text{F} \\ & \\ -\text{C} & - \text{C}- \\ & \\ \text{F} & \text{F} \end{array} $	<p>Polystyrene (PS)</p> $ \begin{array}{c} \text{H} & \text{H} \\ & \\ -\text{C} & - \text{C}- \\ & \\ \text{H} & \text{C}_6\text{H}_5 \end{array} $	<p>Polymethyl methacrylate (PMMA)</p> $ \begin{array}{c} & \text{O} \\ & \\ \text{H} & \text{C} \\ & \\ -\text{C} & - \text{C}- \text{O}-\text{CH}_3 \\ & \\ \text{H} & \text{CH}_3 \end{array} $

www.substech.com



MicroBeads
0.001%

Plastics weather & fragment over time

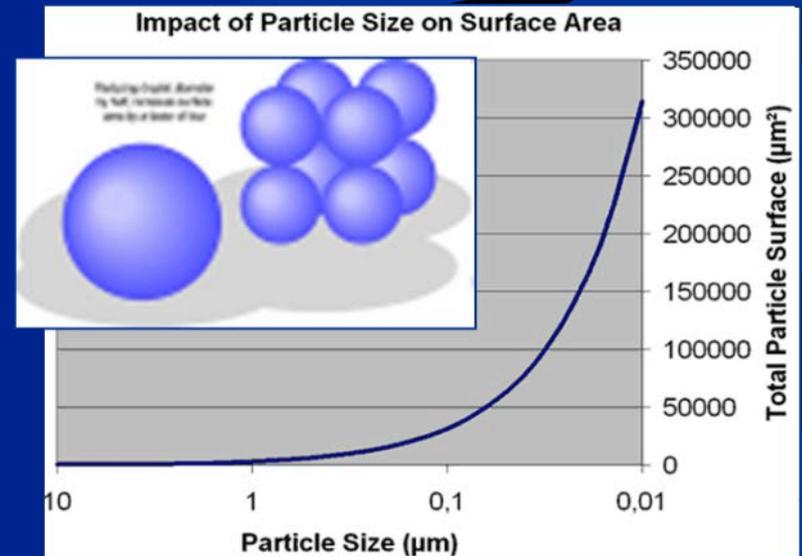


➔ Microplastics

• Weathering

Function (polymer/env conditions)

- Abrasion (beach)
- UV light
- Biodegradation
- Oxidation



Single piece of synthetic clothing can release ~ 2000 microfibers each time it's washed



Schreder & La Guardia. 2014. **Flame Retardant Transfers from U.S. Households (Dust and Laundry Wastewater) to the Aquatic Environment.** *Environ. Sci. Technol.*, 48: 11575.

FR Path: **Additive-contaminated dust** versus the **clothes fibers**

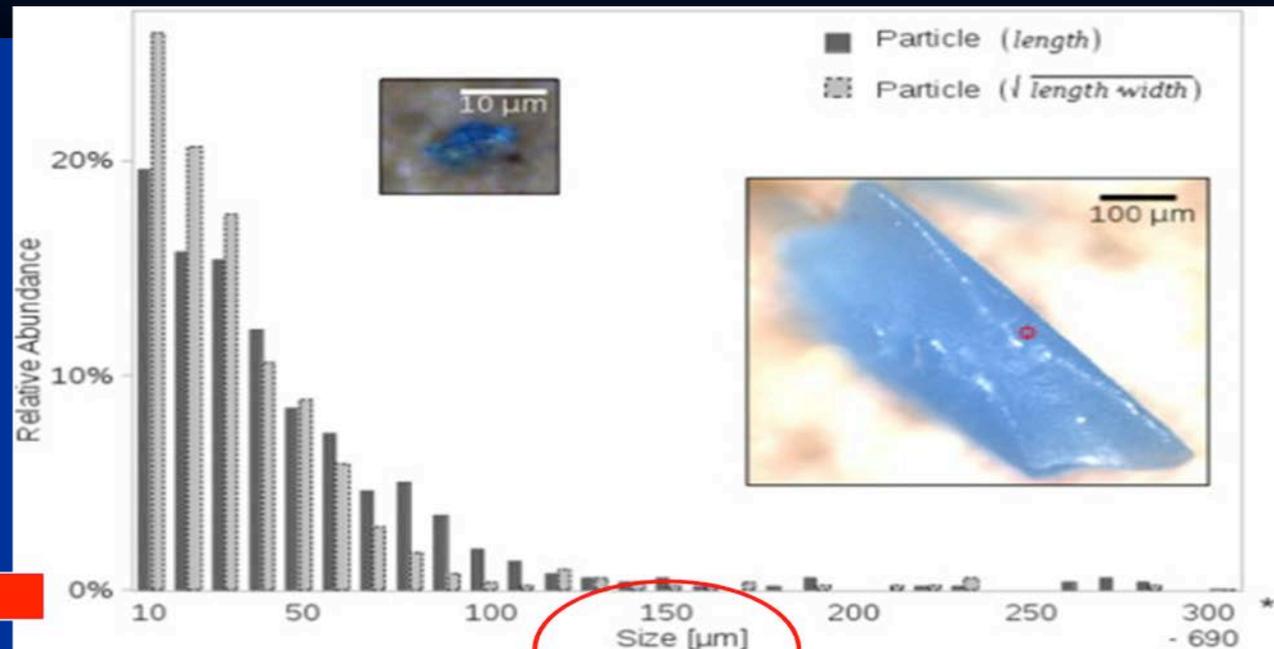
Microplastics

- *primary* – microbeads...
- *secondary* - fragments
 - abundant
 - transportable



Enders et al. 2015. Abundance, size and polymer composition of marine microplastics $\geq 10 \mu\text{m}$ in the Atlantic Ocean and their modelled vertical distribution. *Mar. Pollut. Bull.* 100(1), 70–81.

(Estimated)
Sizes of
microplastics
in the
Atlantic
ocean



Relative microplastic particle size distribution of all analysed stations (np = 543). Dark grey bars represent particles by length. Light grey bars show the size as geometric mean of length and width.

Microplastics

High surface area

- Additive leaching
- Contaminant sorption
 - 1000x from water



All plastics
not alike!



TABLE 3. Isotherm Parameters for Sorption of Phenanthrene to Plastics and Sediments

solid phase	Freundlich model ^a		linear model ^a	
	log K_f ^b	n ^c	K_d ^d	K_{oc} ^e
Polymers				
polyethylene	4.60 ± 0.12	1.03 ± 0.11	38100 ± 5600	44500
polypropylene	3.33 ± 0.01	1.05 ± 0.06	2190 ± 170	2560
PVC ₂₀₀₋₂₅₀	3.00 ± 0.03	1.50 ± 0.09	1650 ± 200	4340
PVC ₁₃₀	3.24 ± 0.03	1.03 ± 0.20	1690 ± 310	4450
Sediments				
Plym	2.11 ± 0.03	0.97 ± 0.07	135 ± 16	20100
Mothecombe	1.17 ± 0.06	1.07 ± 0.14	19 ± 3	10400

^a ± SD. ^b Freundlich constant; log (L kg⁻¹). ^c Freundlich exponent. ^d Distribution coefficient (L kg⁻¹). ^e $K_{oc} = K_d$ /fraction organic carbon (L kg⁻¹).

Teuton et al. 2007. Potential for Plastics to Transport Hydrophobic Contaminants. *Environ. Sci. Technol.* 41: 7759-7764

Small critters consume & transfer pollutants up the chain



Increased exposure via ingestion of plastics with sorbed pollutants?

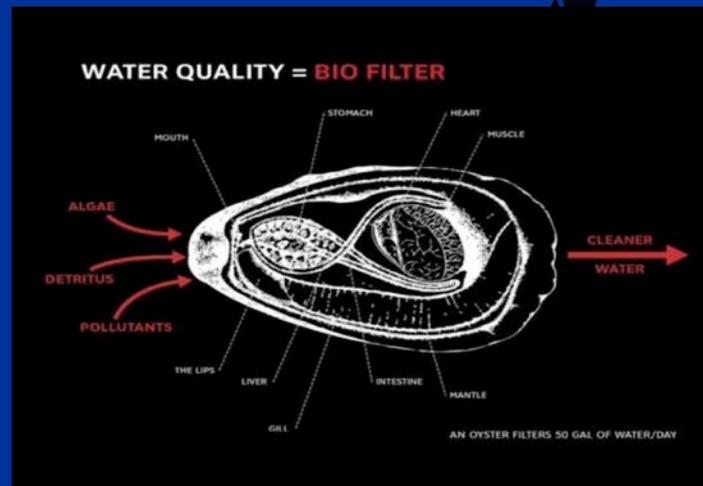
Most studies suggest modest bioaccumulation

But additives @ % levels!



Filter feeders? Shellfish, corals...

Composition & shape of MP

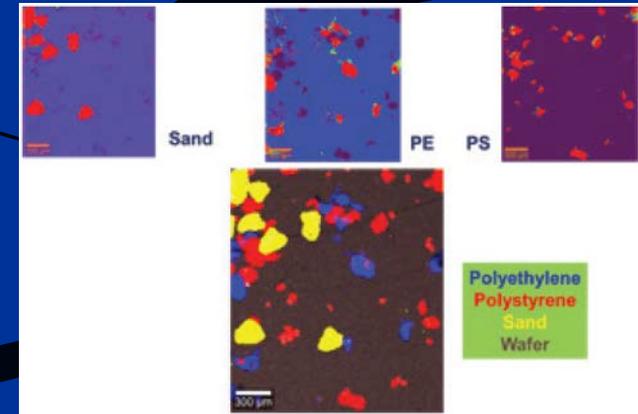
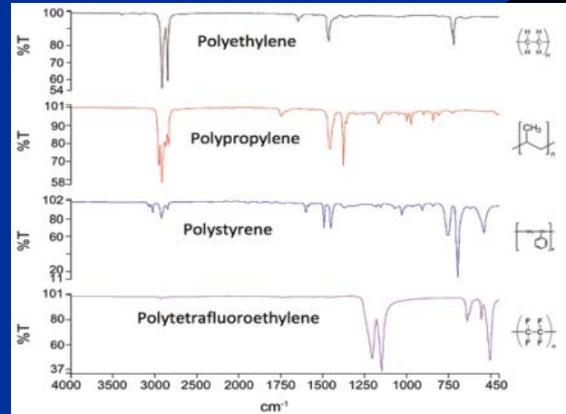
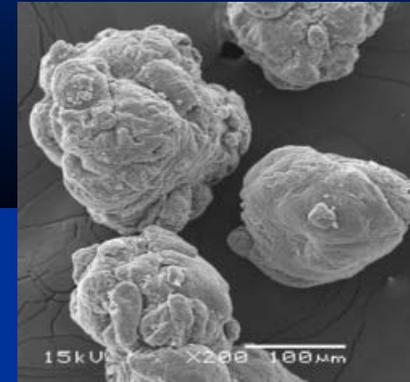




Identify microplastic particle composition: one by one?



Electron microscopy



Raman & FTIR microscopy – IR absorption spectra

Terrestrial exposure: plastic additives

Indoor dust: plastics fragments + sorbed – ingested & inhaled?

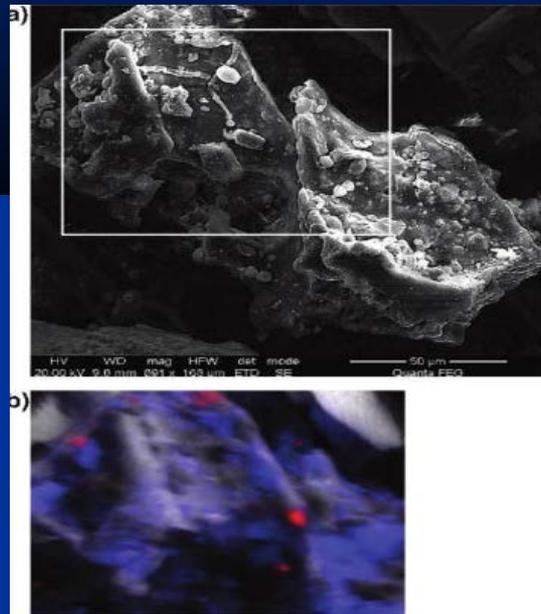


FIGURE 5. (a). Close-up secondary electron image of a bromine-containing dust particle. (b) Elemental map constructed using EDS of the boxed area in 5a (white = carbon, blue = calcium, red = bromine).

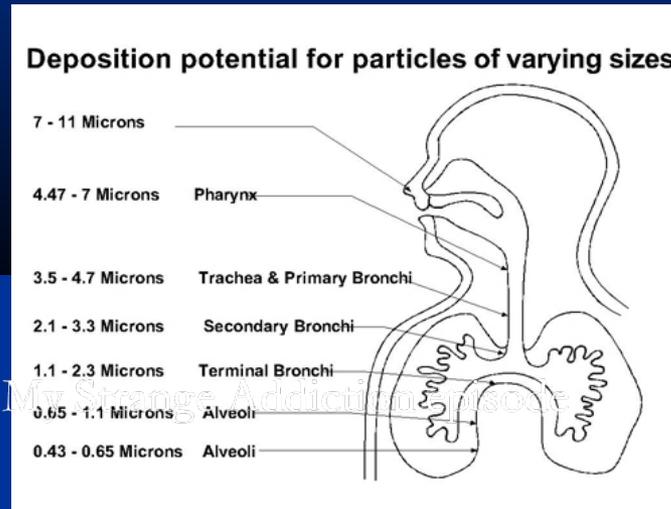
Webster et al. 2009.
Identifying Transfer Mechanisms and Sources of Decabromodiphenyl Ether (BDE 209) in Indoor Environments Using Environmental Forensic Microscopy. *Environ. Sci. Technol* 43:3067–3072

Wu et al. 2007. **Human exposure to PBDEs: Associations of PBDE body burdens with food consumption and house dust concentrations.** *Environ. Sci. Technol.* 41:1584-1589.



Indoor dust: microplastics – inhaled?

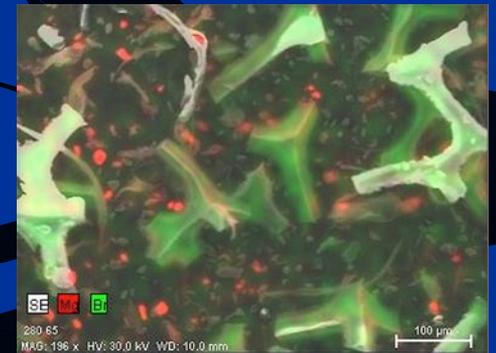
Small
is
“big”
again



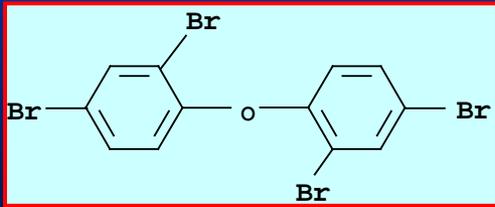
Dust from foam pit



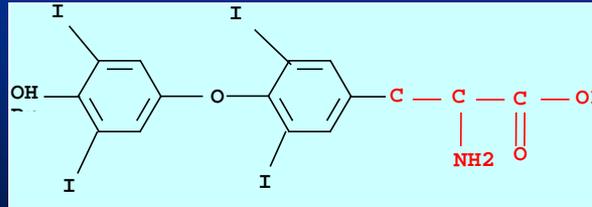
La Guardia MJ, Hale RC. 2015. **Halogenated flame-retardant concentrations in settled dust, respirable and inhalable particulates and polyurethane foam at gymnastic training facilities and residences.** *Environ Int.* 79:106-14.



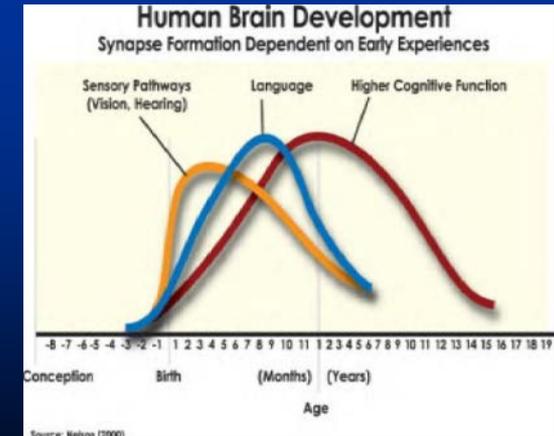
PBDE Mode of Toxicity



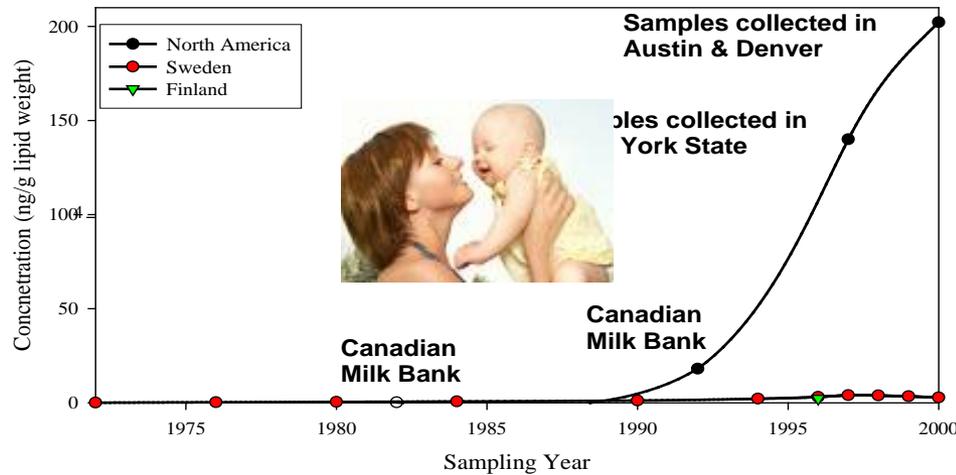
PBDE congener



thyroxine

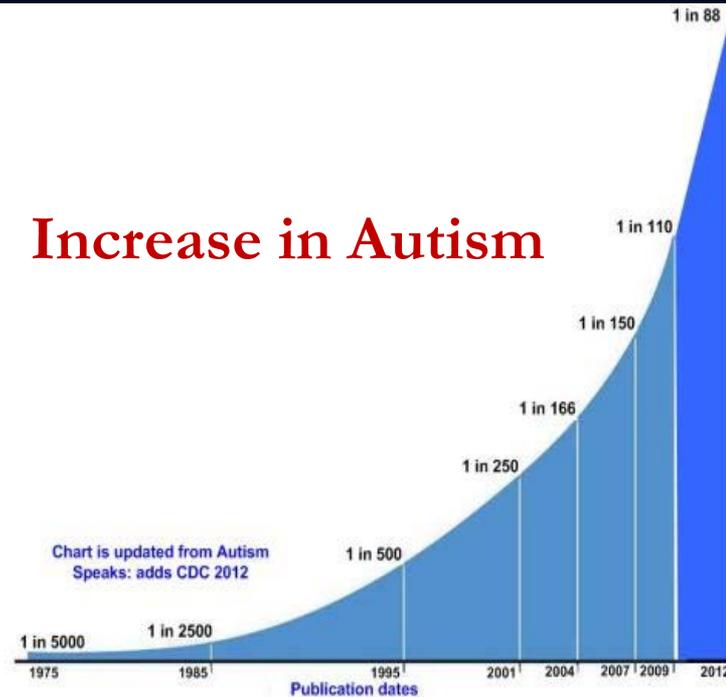


Comparison Between Concentrations of PBDEs in Breast Milk from North America and Europe



Canadian Milk Bank and New York State from Ryan and Patry 2000, Denver and Austin results from Papke et al 2001; Swedish data from Meironyte Guvernius and Noren 2001, Finnish data from Strandman et al. 2000

Increase in Autism

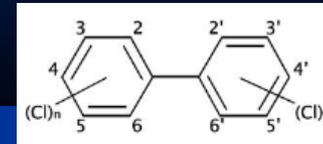


■ impact early neurodevelopment

Demonstrated uptake of plastic additives by fish VA Tributaries Monitoring Project

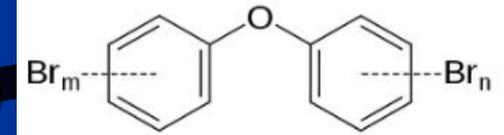


- Fish collected from different VA regions : DEQ
- Analyzed: VIMS
- Health Advisories issued: VDH



- PCBs detected in fish... + "unknowns"

Identified as Polybrominated diphenyl ethers (PBDEs)



- 9 of 50 VA sites had PBDE levels >1000 ppb (lipid wt)
 - Highest PBDE fish level reported in the world

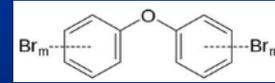
48 mg/kg (ppm): Carp - Mouth of Hyco Creek???



Hale, R.C., et al. 2001. Polybrominated diphenyl ether flame retardants in Virginia freshwater fishes (USA). *Environ. Sci. Technol.* 35:4585-4591.



The Source?



EPA Toxics Reduction Inventory & Passive samplers (PE) & shellfish monitoring



<http://www2.epa.gov/toxics-release-inventory-tri-program>



20 km upstream – NC WWTP

Car interiors



Wastewater sludge (biosolids) re-purposed as agricultural fertilizer

Treatment screens out big pieces, but...



Microplastics pass thru to “solids” & effluents



Zubris et al. 2005. **Synthetic fibers** as an indicator of land application of sludge
Environ Pollut. 138, 201–211

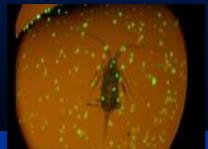
+ flame retardants.....Hale et al. 2001. **Flame retardants: Persistent pollutants in land-applied sludges.** *Nature* 412: 140.

Into the lab....

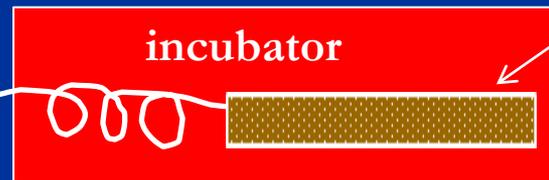


NOAA Marine Debris Program: Influence of suite of environmentally relevant conditions on PBT leaching from & sorption to marine microplastics

- Leaching of additives from polymers (PUF, PE, PS, PVC) by waters varying in temp, salinity, organic matter, gut fluid. Impact of particle size (10, 100, 1000 μm) & pre-weathering.
- Sorption from water of 2 PBT mixtures to polymers (PE & PVC). Influence of particle size & biofouling on sorption.



Water reservoir

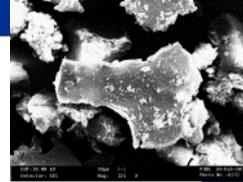


Microplastics + sand

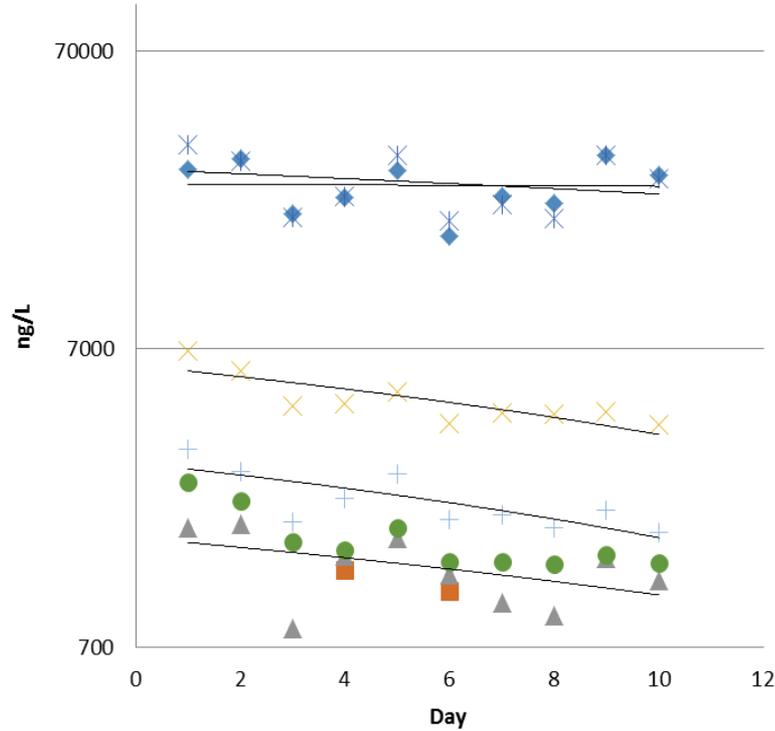
Effluent for analysis, toxicology experiments...



Polyurethane foam contains many FR additives

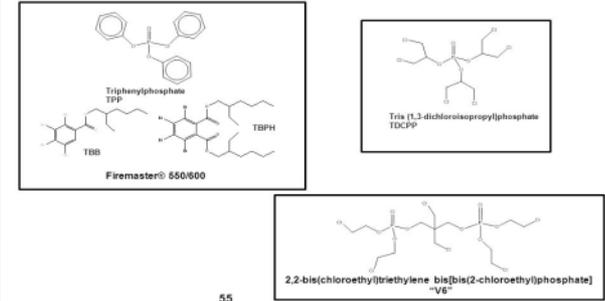


10 Day Column Extraction

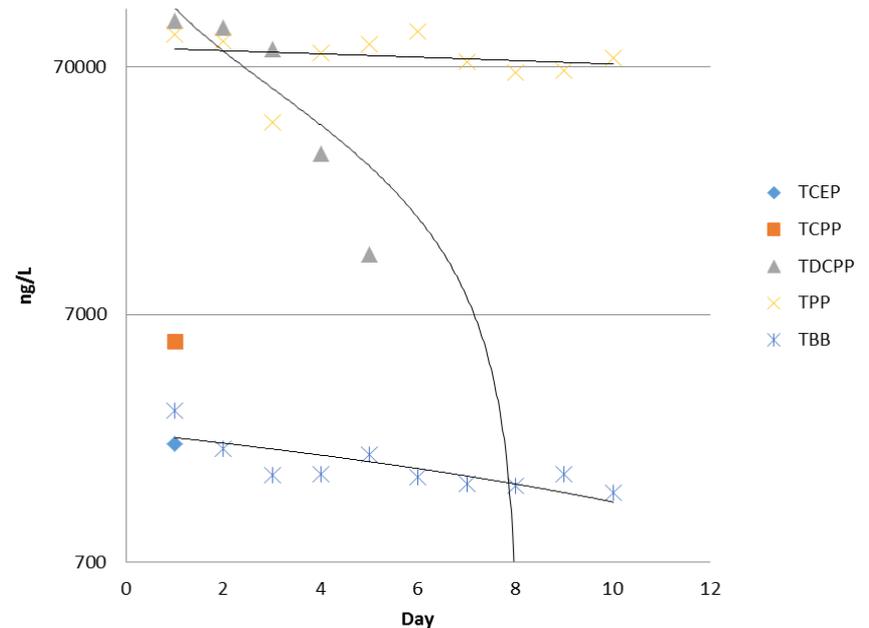


- ◆ BDE47
- bde66
- ▲ BDE85
- × BDE100
- × BDE99
- BDE154
- + BDE153

New Use Flame Retardants Detected in Furniture and in House Dust



10 Day Column Extraction

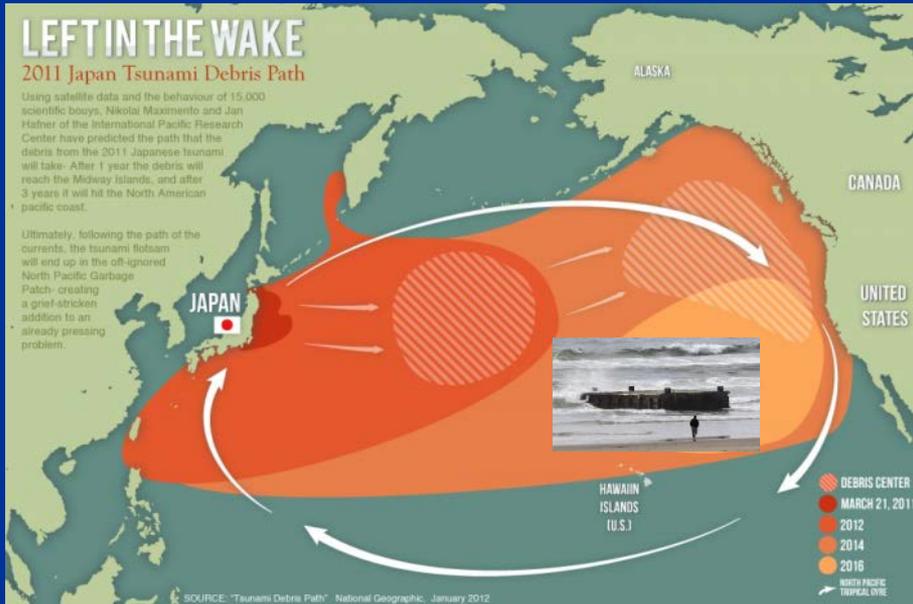


Continuous
fragmenting



Lost at sea

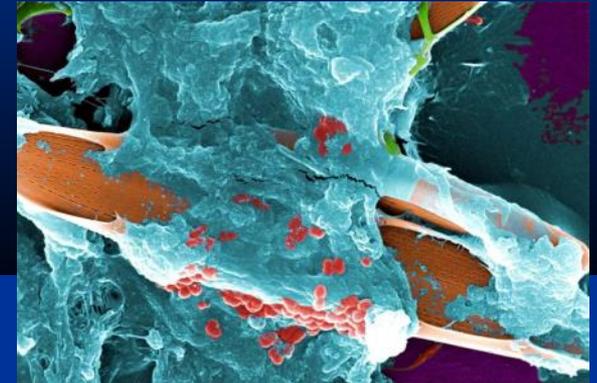
Plastics harbor & transport unusual biological communities?



Distinct microbes colonize plastics - biofilms

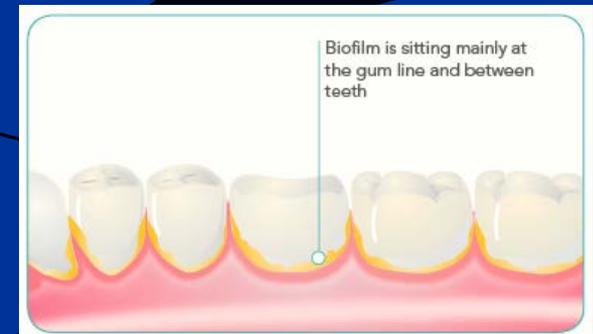
- “Some may be opportunistic pathogens such as *Vibrio* ... *Plastisphere* communities are distinct from surrounding surface water, implying that plastic serves as a novel ecological habitat in the open ocean.

Zettler et al. 2013. Life in the “Plastisphere”: Microbial Communities on Plastic Marine Debris. *Environ Sci. Technol.* 47:7137–7146



- Hunter, P. 2008. *Embo Reports* 9:314-317. The mob response. The importance of biofilm research for combating chronic diseases and tackling contamination

...biofilms are implicated in numerous debilitating—and often chronic—diseases, including cystic fibrosis, tuberculosis, orthodontal disease, sinusitis and some forms of heart disease. Biofilms also cause many problems elsewhere, such as contaminating food and its packaging, and fouling water supplies



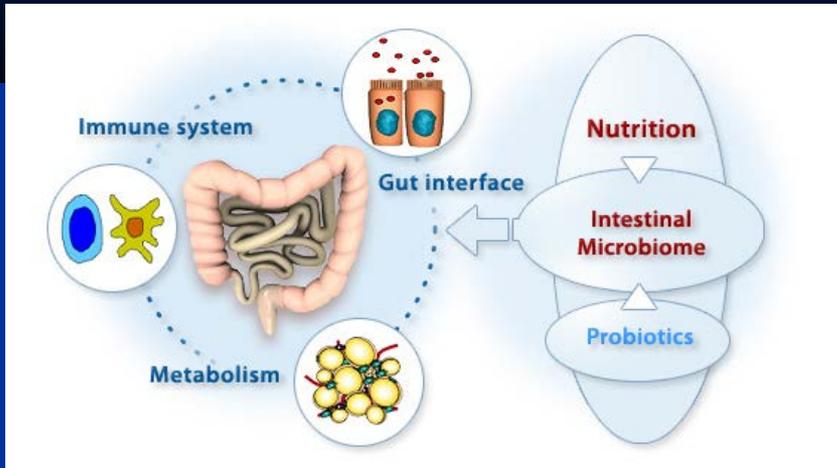
Gut Microbiome

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

HELPING Your
Gut BACTERIA
Can BOOST
Your HEALTH



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.



Sci Finder Search:

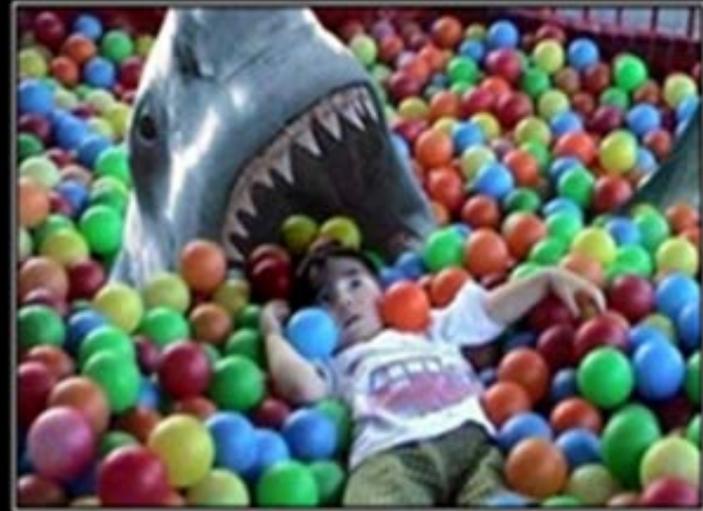
No references found containing the concepts "ingestion", "plastic" & "microbiome".

...incidence in coastal shellfish?



The End

- Questions?



BALL PIT

No one comes out alive.