Microplastics in the Freshwater Environment

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Hi, I'm Nanna

- Toothpaste may contain 0.1 - 5 % microbeads (PE).
- Americans use 2,500,000 plastic bottles every hour/ Only 14% of are recycled.
- In one week we go through 10 billion plastic bags worldwide/ The average American family takes home almost 1,500 bags a year.
- In a lifetime the average American will personally throw away 600 times his/her bodyweight of plastic.
- Exfoliating washes may contain 0.4-10.5 % microbeads (PE).
- 93% of Americans test positive for the presence of BPA in their bodies.

Approx. 300 million tons of plastic is manufactured every year → approx. 7000 million tons since 1950 → 7 km^3 → 7 million km^2 (if 1 mm thick) → USA is 7.7 million km^2

Plastic fantastic

Material:	Degradation rate:
Plastic beverage holder	400 years
Plastic bag	Up to 1000 years
Plastic bottle	100-1000 years
Synthetic fabric	500 years
Foam cup	50 years
Fishing line	600 years
Polystyrene case	100 – 1000 years

Microplastics in the Freshwater Ecosystem:

What we know and what we need to know

What we know:

- Accumulation of plastics in the aquatic environment
- Microplastics (< 5 mm)
- Microplastics in the food web
- Many studies on marine plastics

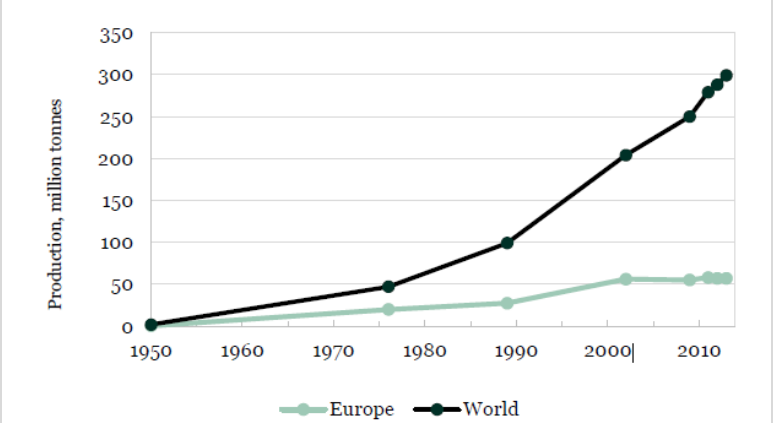


FIGURE 12
TREND IN PLASTICS PRODUCTION IN EUROPE AND THE WORLD (BASED ON DATA FROM PLASTICS

What we need to know:

- Very few studies of plastics in freshwater environment
- Very few studies on biological effect
- How to measure concentrations in the environment/animals
- Should we be concerned and regulate ?

What are Microplastics?

Classification:

- Size

Large : 1 – 5 mm, Small: 1 µm – 1 mm

- Origin

Primary (produced as such) vs. secondary (fragmented macroplastic)

- Shape and color

Irregular fragments (angular), pellets (cylinders, disks, spherules), filaments (fibers) or granules (rounded)

- Polymer type

Polyethylene (HD/LD-PE), polyethylene terephthalate (PET), polypropylene (PP), polystyrene (PS), polyvinyl chloride (PVC) and polyamide fibers (nylon) ……..

Where does Microplastics come from ?

Primary:

- Resin pellets
- Synthetic fibers
- Abrasion and exfoliating beads
- Paints
- Beads used in furniture, insulation….
- Medical products
- Tire recycling

"**Microbead-free Waters act**" of 2015 signed by Obama banning micro-beads in the US from 2017.

Secondary:

Fragments of larger plastic items

+

=

And where does it all end up ?

Plastic articles, material and coatings

Fragmentation, weathering, abrasion etc

Formation of secondary

Solid waste

Release

Soil

Urban run-off

Surface water

Bypassing STP

Sewage

Sedimentation

Solid waste

WWTP

Sludge

Agricultural soil

Incineration

Danish Environmental Protection Agency, Project 1793

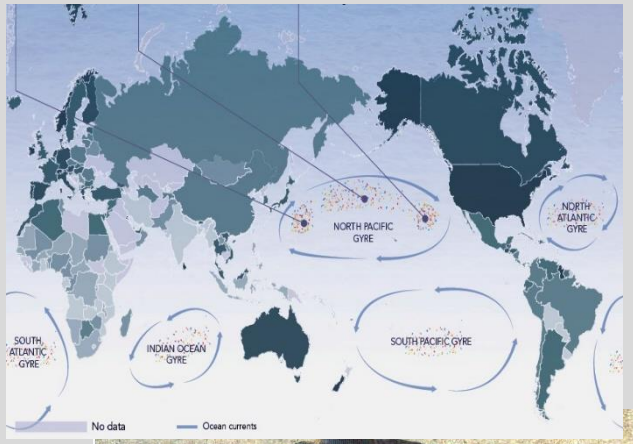
Plastic Recovery

Exhibit 2: Plastic Waste Generation and Recovery in the United States, 2012

(a) Type of Product	(b) Generation (Short Tons)	(c) % of Total Generation	(d) Recovery (Short Tons)	(e) % of Total Recovery	(f) Recovery Rate (%)
HDPE	5,530,000	17.4%	570,000	20.4%	10.3%
LDPE/LLDPE	7,350,000	23.1%	390,000	13.9%	5.3%
PET	4,520,000	14.2%	880,000	31.4%	19.5%
PP	7,190,000	22.6%	40,000	1.4%	0.6%
PS	2,240,000	7.1%	20,000	0.7%	0.9%
PVC	870,000	2.7%	0	0%	0%
All Plastics	**31,750,000**		**2,800,000**		**8.8%**

Source: EPA (2014).

The Plastic Ocean



Presence of Microplastics in the Freshwater Ecosystem

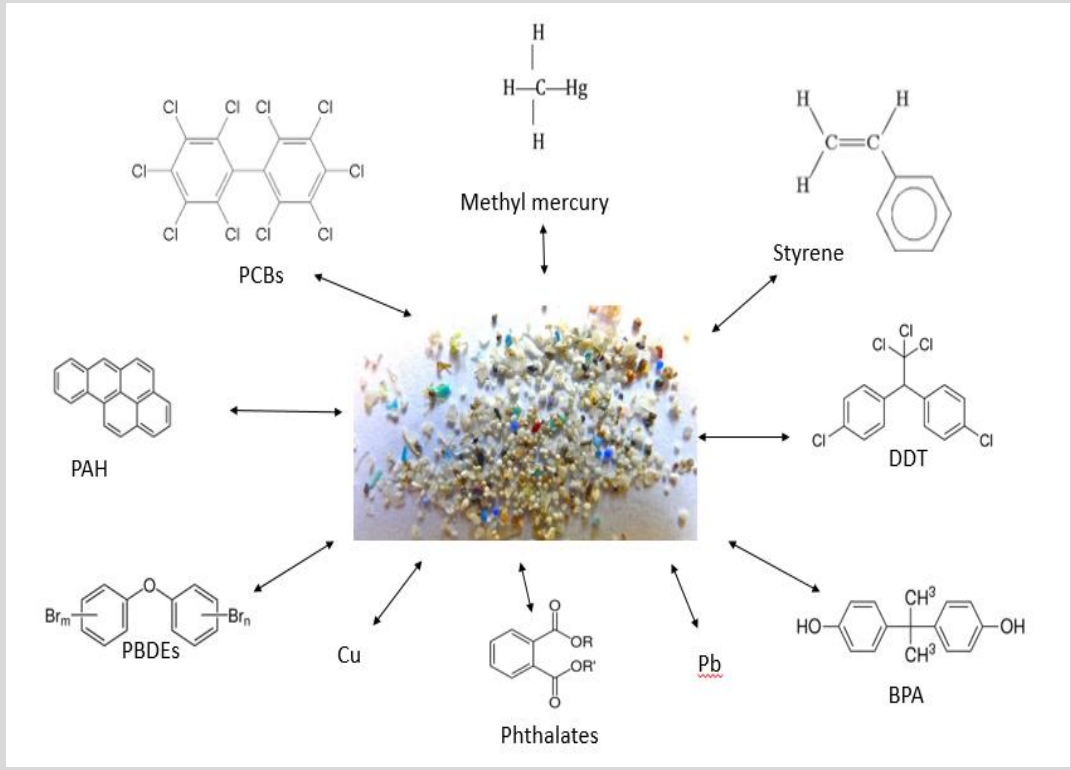
Continent	Water body	Authors	What was sampled	Size	Max. abundance/ mean abundance
North America	St. Lawrence river, Canada/USA	Castaneda et al., 2014	Sediment	> 500 µm	? 13,759 – 136,926 items/m^2
	Lake Superior, Huron and Erie, Canada/USA	Eriksen et al., 2013	Surface water	> 355 µm	463,423 items/km^2 43,157 items/km^2
	North Shore Channel of Chicago, USA	McCormick et al., 2014	Surface water	0.3-5 mm	17.93 items/m^3 Higher count downstream WWTP than upstream.
	Los Angeles River, San Gabriel River, Coyote Creek, USA	Moore et al., 2011	Water column	1-4.75 mm	Coyote: 4999 items/m^3 San Gabriel: 51,603 items/m^3 L A river: 1,146,418 items/m^3
	Chesapeake Bay 4 estuarine rivers, USA	Yonkos et al., 2014	Surface water	0.3 – 5 mm	297,927 items/km^2 (245.7 g/ km^2)
	Lake Huron, Canada/USA	Zbyszewski and Corcoran, 2011	Sediment	< 5 mm, > 5 mm, polys.	3209 items
	Lake Erie and St. Clair, Canada/USA	Zbyszewski et al., 2014	Sediment	< 2 cm	Erie: 1576 items St. Clair: 817 items
	Tennessee River, USA	 2016	Surface water	153 µm-5 mm	? Higher count downstream WWTP than pristine area.
Asia	Lake Hovsgol, Mongolia	Free et al., 2014	Surface water	355 µm -4.74 mm	44,435 items/km^2 20,264 items/km^2
Europe	River Seine, France	Dris et al., 2015	Surface water	?	108 items/m^3
	Lake Geneva, France/Switzerland	Faure et al., 2012	Sediment Surface water	< 2mm/< 5mm < , > 5 mm	9 items/sample 48,146 items/ km^2
	Lake Garda, Italy	Imhof et al., 2013	Sediment	9 µm-5 mm	1108 items/m^2 ?
	Rhine river, Germany	Klein et al., 2015	Sediment	< 5 mm	3763 items/kg
	Danube river, Austria	Lechner et al., 2014	Surface water	< 2–20 mm	141,647 items/1000 m^3 317 items/1000 m^3
	Tamar estuary, UK	Sadri and Thompson, 2014	Surface water	< 2– 5 mm, > 5mm	204 items 0.028 items/m^3
	Elbe, Mosel, Neckar and Rhine rivers, Germany	Wagner et al., 2014	Sediment	< 5 mm	64 items/kg

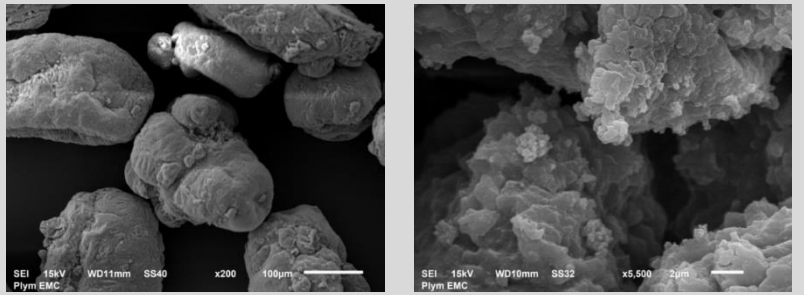
From Eerkes-Medrano et al., Water research 75: 63-82, 2015 and own survey

And that is not all……..

- Microplastics can potentially leach toxic chemicals, including endocrine disruption chemicals, such as bisphenol A and phthalates.

- Microplastics can adsorb persistent organic pollution compounds, metals and environmental endocrine disruptors.



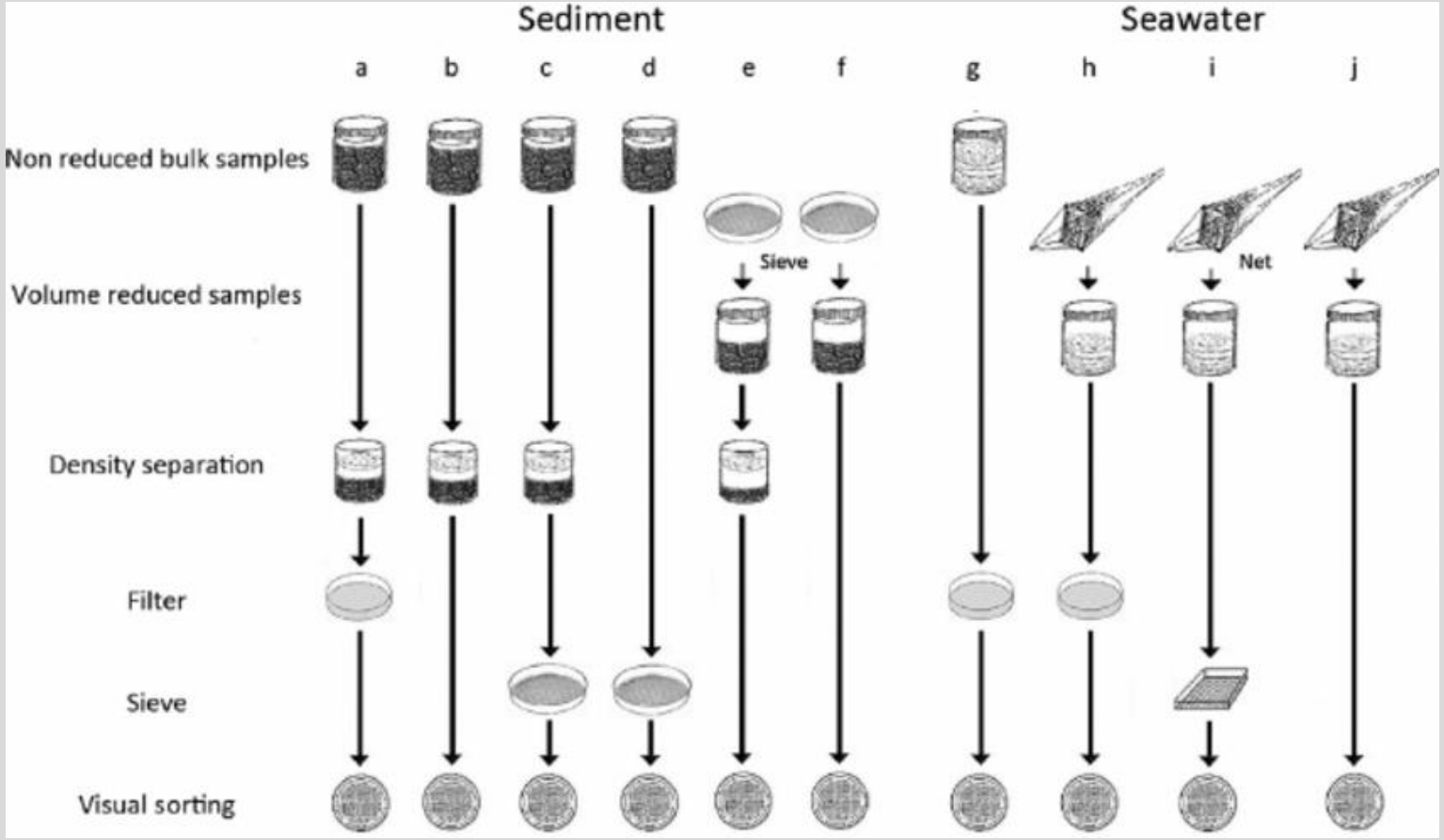


Sleight et al, 2016, in review

E.g.. Teuten et al., 2009, Phil. Trans. R. Soc. B 364:2027-2045

Extraction of Microplastics

Extraction of Microplastics



Hindalgo-Ruz et al., Env. Sci. Technol. 46:3060-3075, 2012

Tissue

- Acid
- Base
- **Enzyme**

ID by:

- Visual examination by microscope.
- Spectrometric methods like Fourier Transform Infrared Spectroscopy or Raman microspectroscopy.

Impact of Microplastics to Freshwater Species

MP's are transferred to animals through ingestion

- Sanchez et al, 2014: 12 % of Wild gudgeon (*Gobio gobio*) caught in French streams contain MP's (Environ. Res. 128:98-100)
- Peters et al, 2016: Approx. 45 % of Sunfish (*Lepomis macrochirus* and *Lepomis megalotis*) from the Brazos river basin, TX, contained microplastics (Environ. Pollut. 210: 380-387)

Ingestion of microplastics with/without associated co-contaminants

↓

- Behavioral effects
- Morphological effects
- Physiological effects
- Life cycle effects

Effects of Ingestion of Microplastics

Questions:

Do organisms ingest MPs?

Are ingested MPs absorbed across epithelia?

How long do MPs reside within GI tract before egestion?

Approach:

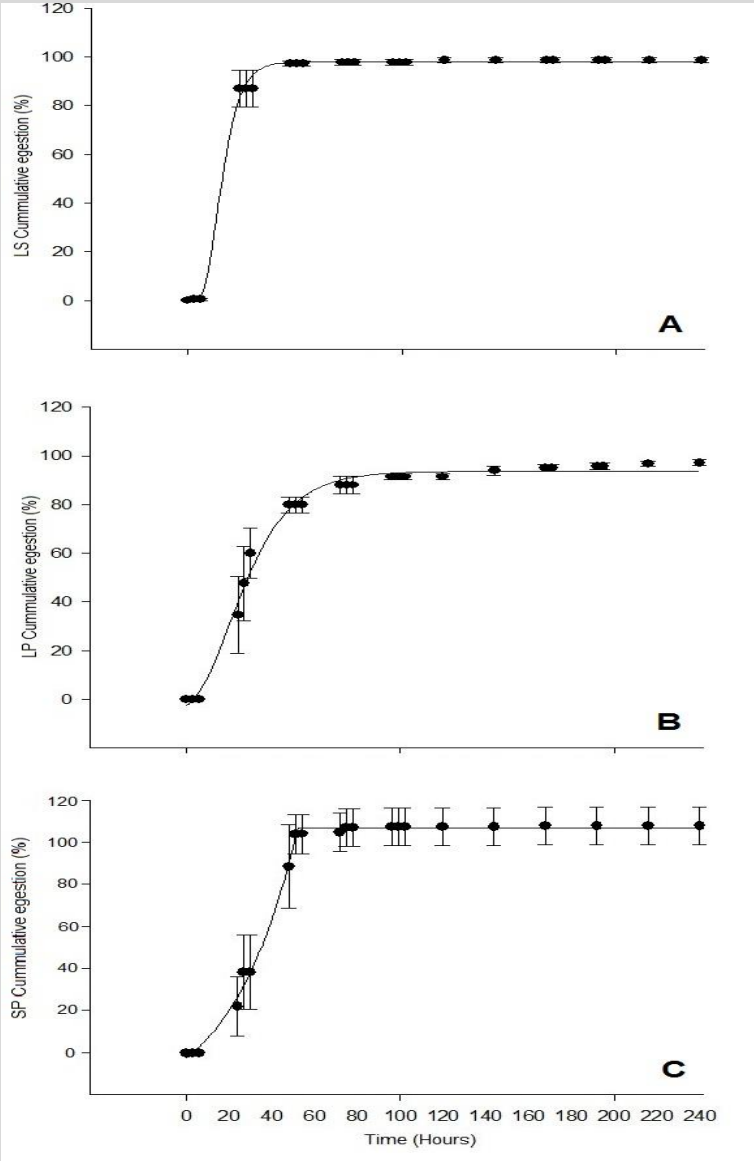
- Feed pellets: fish paste and gelatine (pellet weight 0.25 g)
  - Particles counted and specific amount added to each pellet
  - Sub-sample of pellets examined to verify numbers of particles/pellet
- Treatments:
  - Control without particles
  - Large sand (LS) 1000-1230 µm
  - Large plastic (LP) polyethylene microspheres 850-1000 µm
  - Small plastic (SP) polyethylene microspheres 47-53 µm
- Procedure
  - Crabs fed particle-free food for > 5 days
  - Crabs starved for 3 days before being fed a single treatment pellet
  - After feed pellet administered, control pellet given every 24 hours
  - Crab washed, faeces and water collected, filtered, particles counted/time

Shore crab *Carcinus maenas*

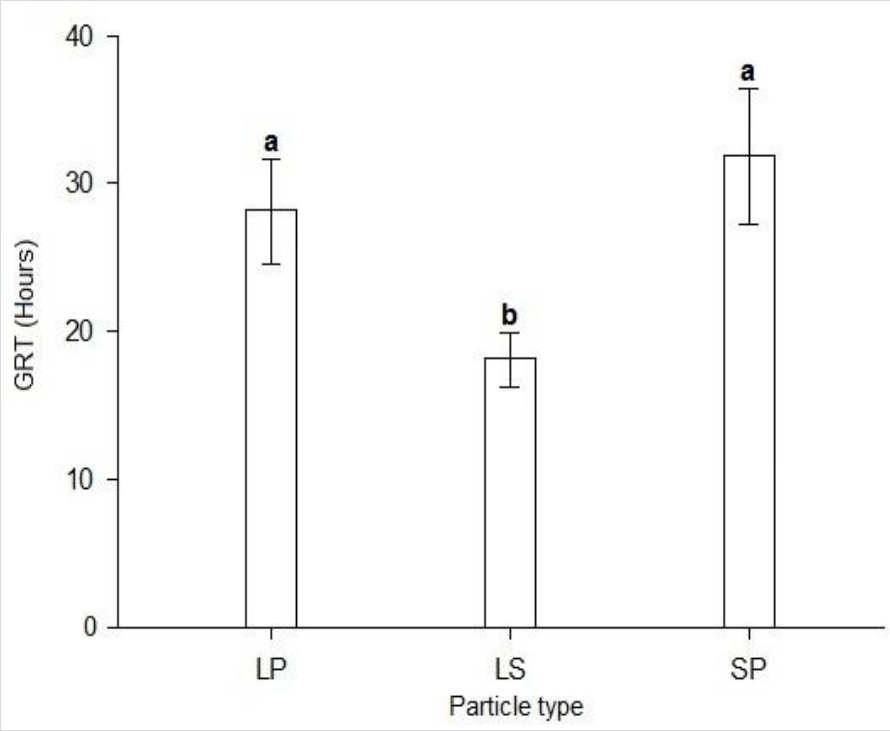
Joseph Hatfield

Heriot-Watt University, Edinburgh, Scotland, UK

Effects of Ingestion of Microplastics



- Crabs did ingest these MPs
- These MPs not appreciably absorbed
- Gut retention varied by particle type
- **Essentially all MPs recovered upon egestion**



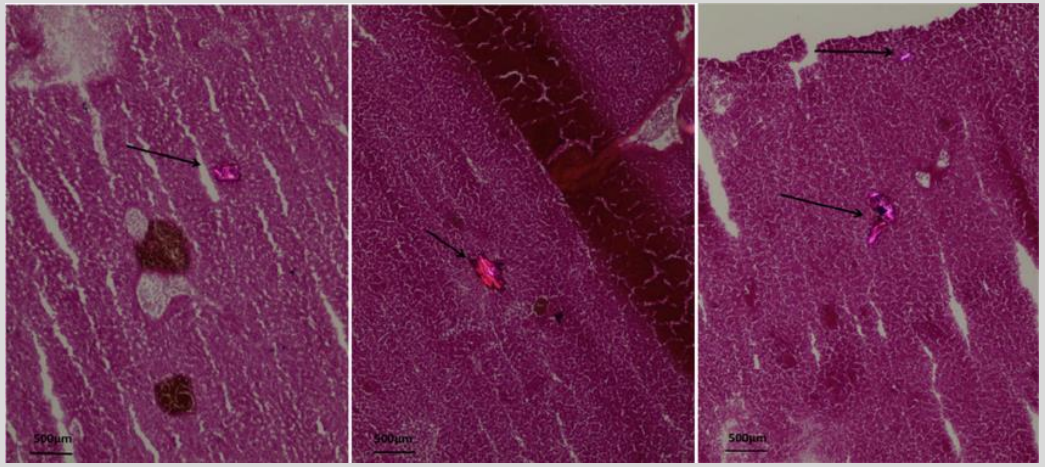
Effects of Ingestion of Microplastics in Fish

Are ingested MPs absorbed across epithelia?

- Lu et al., 2016: Small MP's accumulate in Zebrafish gills, liver and gut and cause inflammation and lipid accumulation in fish liver (Environ. Sci. Tech. 50: 4054-4060)

- Avio et al., 2015: MP's accumulate in stomach and liver in Mullet (Mar. Environ. Reserch 111:18-26)

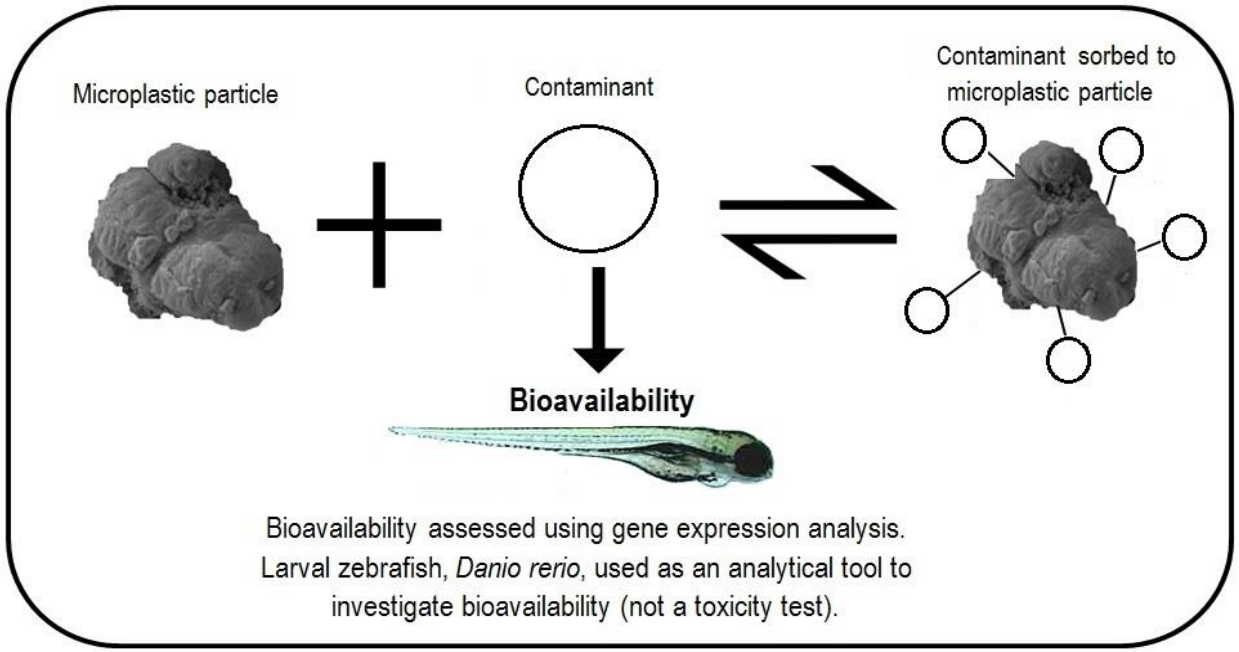
?



Avio et al., 2015

Effects of ingestion of Microplastics in Fish

Microplastic absorb environmental chemicals and may therefore act as vectors transferring environmental contaminants from water to biota.



Ted Henry

Rochman et al, 2013:
Ingested MP's transfers hazardous chemicals to fish and induces hepatic stress or endocrine disruption
(Sci. Rep 3:3263, Sci. Tot. Environ. 493: 656-661).

Sleight et al, 2016:
Assessed the bioavailability of absorbed Phenanthrene and 17α-Ethinylestradiol to zebrafish using gene expression analysis.

The toxicant sorption to the MPs was not consistent with toxicant physicochemistry

Transport of the MPs/co-contaminants to bottom did not increase toxicant bioavailability.
(not yet published)

Effects of Ingestion of Microplastics/Co-contaminants

Sleight et al, 2016 (not yet published)

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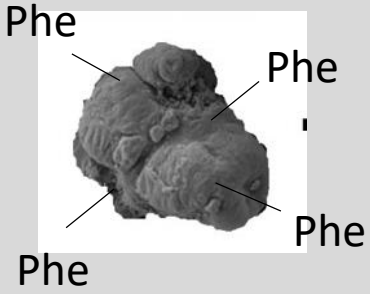
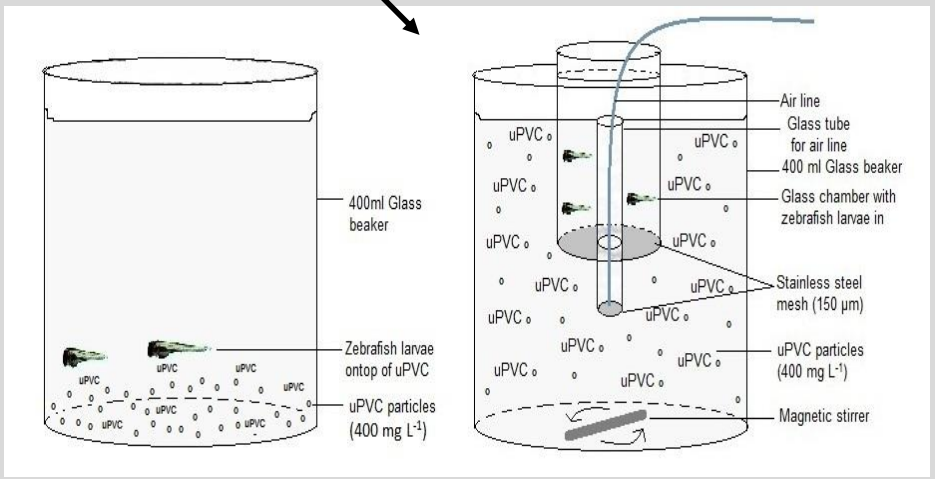


Phenanthrene

or

17α-Ethinylestradiol

Expose for 96 hours
(from 72 hpf – 168 hpf)



0.5 mg/L Phe and 1 µg/L EE2

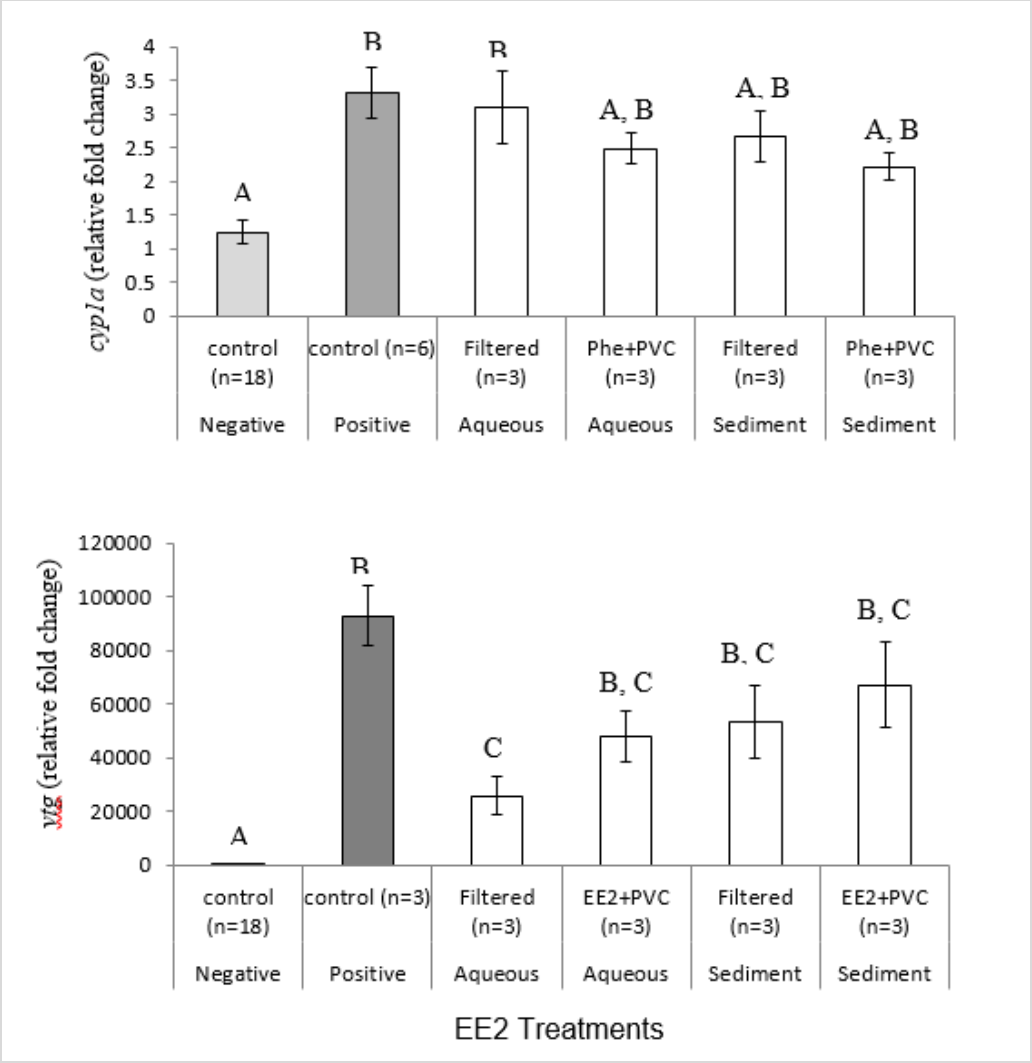
Gene expression of **Cyp 1A** (cytochrome P450-dependent monooxygenase enzymes) and **Vtg** (Vitellogenin)

Effects of Ingestion of Microplastics/Co-contaminants

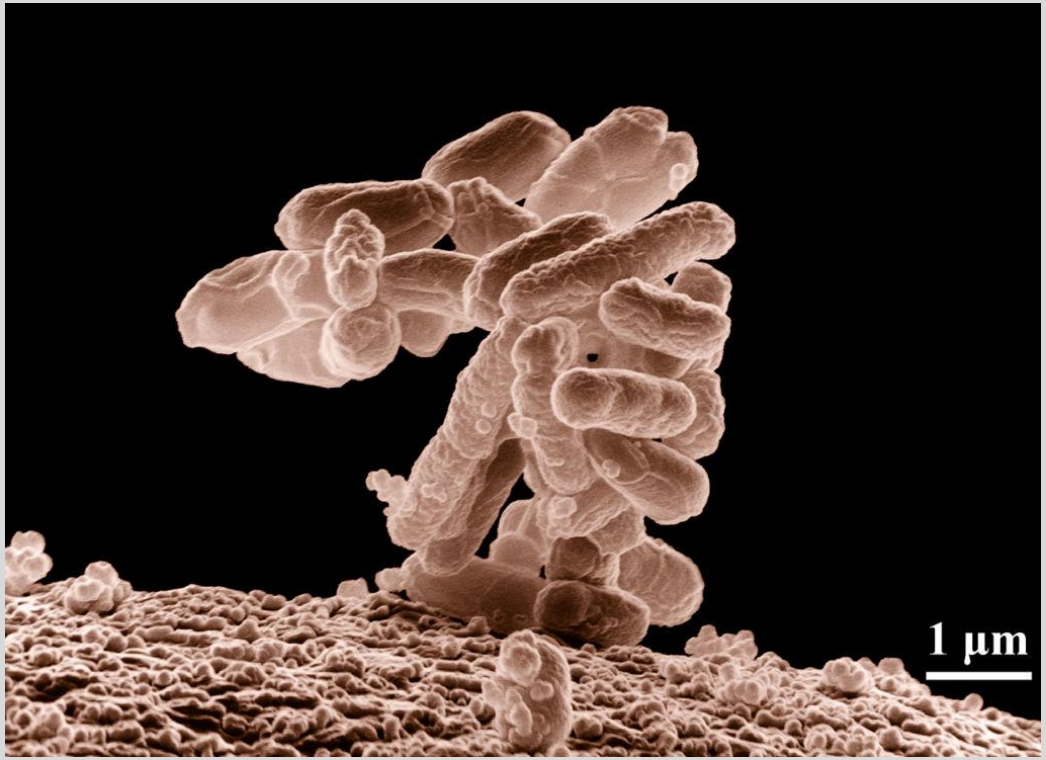
Sleight et al, 2016 (not yet published)

- Compared to positive controls (i.e., co-contaminant exposures without MPs) expression of *cyp1A* and *vtg* were reduced when MPs were present in the water column indicating reduced co-contaminant bioavailability consistent with co-contaminant sorption to MPs;

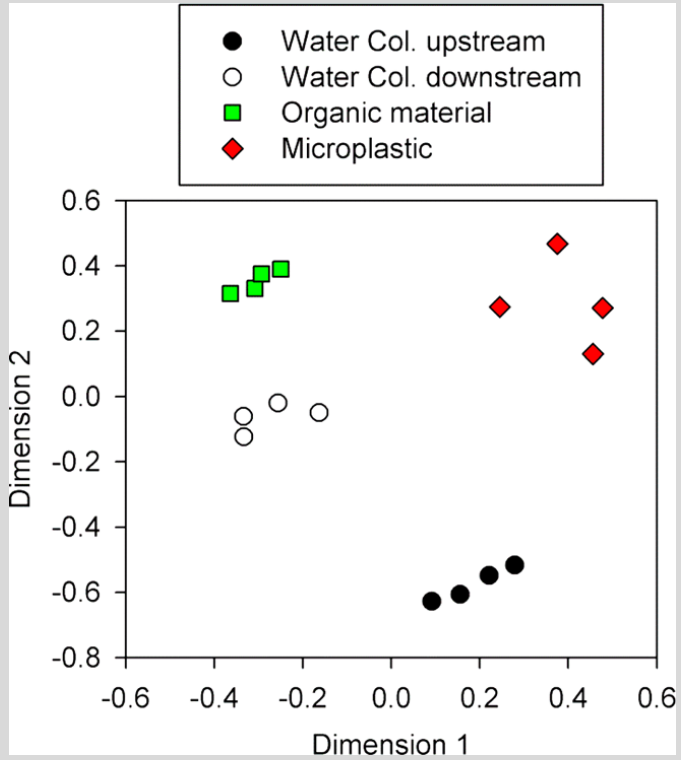
- The **presence of MPs reduced bioavailability** of Phe by 33% whereas with EE2 bioavailability was reduced by up to 48% .



Impact of Microplastics to Freshwater species



MP may serve as a vector for pathogens or may change the gut microbiome of fish when ingested ?



Nonmetric multidimensional scaling (nMDS) ordination of 16S sequencing data (Bray–Curtis dissimilarity) comparing assemblages of bacteria collected in the North Shore Channel.

McCormick et al, 2014, Environ. Sci. Technol. 48: 11863-11871

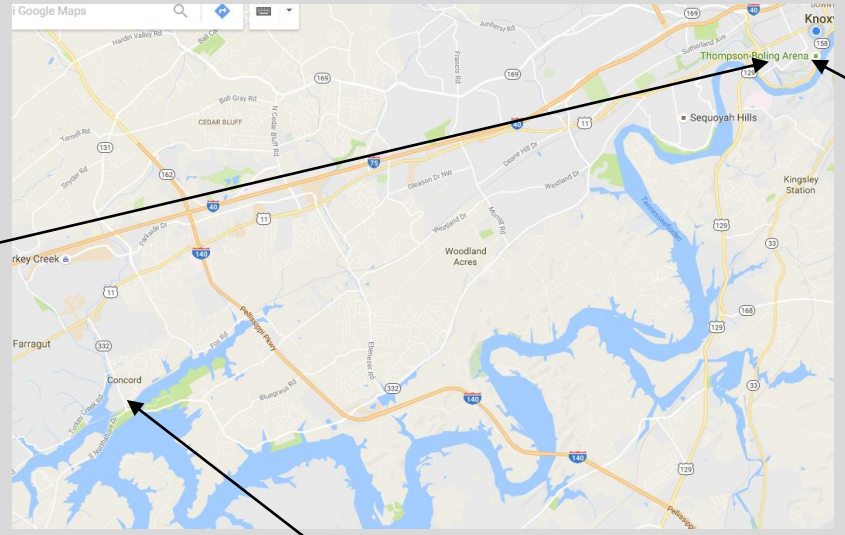
Just down the road……

Just down the road……

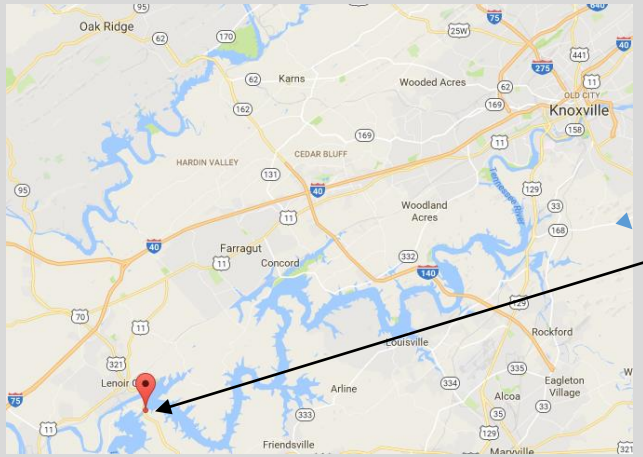
Just down the road……

Microplastics in Shad

Along my bike route…



University of Tennessee



Tellico (control site)

Threadfin shad (*Dorosoma petenense*)

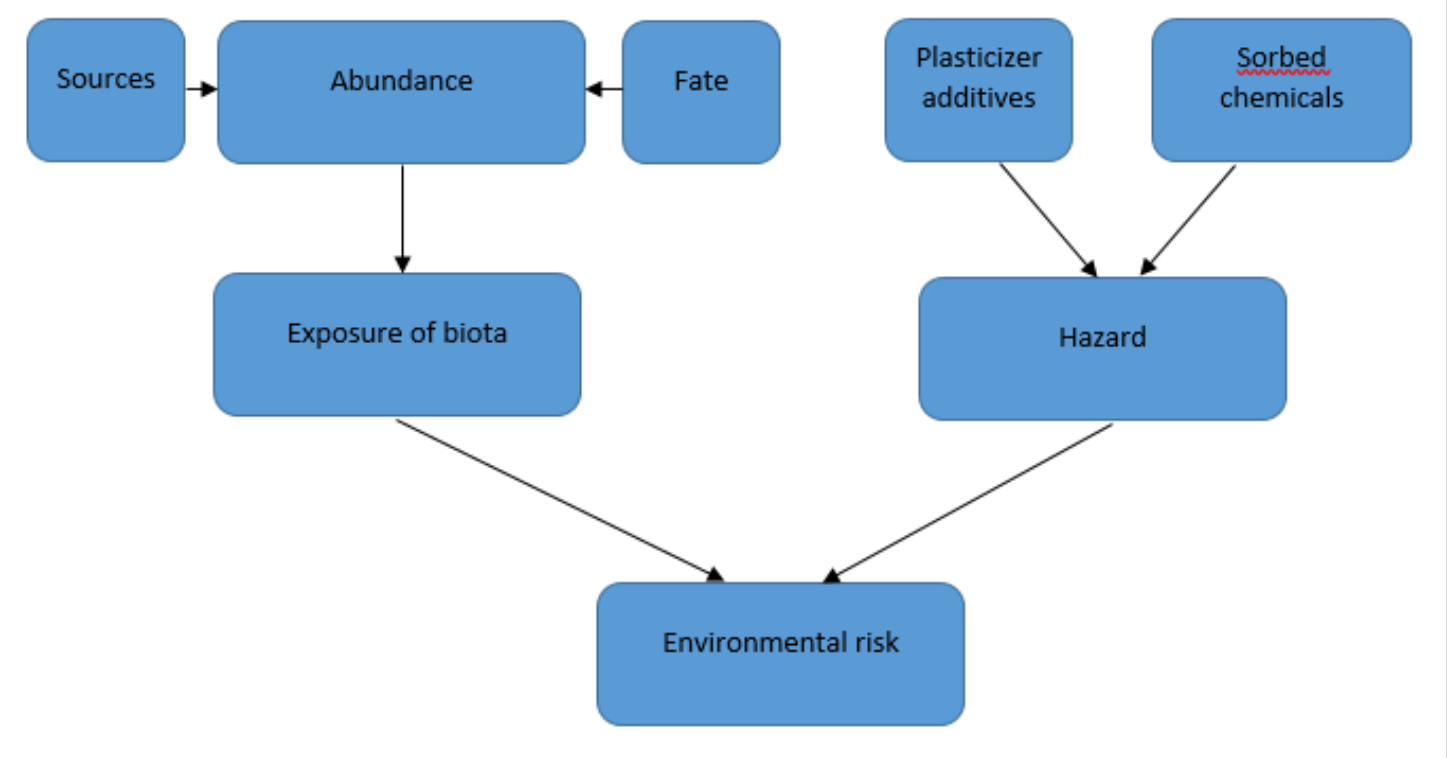
Concord wastewater treatment plant

Conclusions……
Should we be concerned?

Data on microplastics in freshwater ecosystems is at best fragmentary if not absent and that hampers a science based environmental risk assessment.

What we need to know:

- Sources, fate and abundance of plastics in freshwater environment
- Biological fate and effects of ingested microplastics in freshwater biota



EPA

- Has shown interest in issues relevant to plastic debris as it relates to existing legislation that regulates hazardous chemicals and substances in the environment, using the Comprehensive environmental response, compensation, and liability act (CERCLA), the pollution prevention act and the Clean water act.

- Have a guideline “ Organic chemicals, Plastics and synthetic fibers” Effluent guideline and standards (40 CFR Part 414)

- Waste Reduction Model (WARM)

- Several projects running

To perform accurate risk assessments more research is needed

Thank you.....

Granville island, Vancouver, Canada