Gut Passage of Microplastics and Bioavailability of Co-contaminants Associated with Microplastics in Organisms Exposed via Diet or Aqueous Phase

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Microplastics

Manufactured microplastics

- Industrial abrasives, exfoliants,
- Precursors (resin pellets etc.)

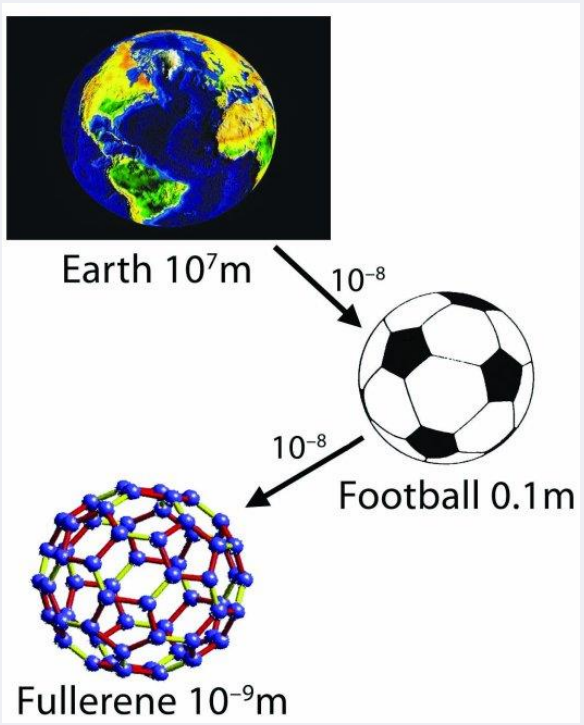
Microplastic (Wikipedia)

Breakdown of plastics

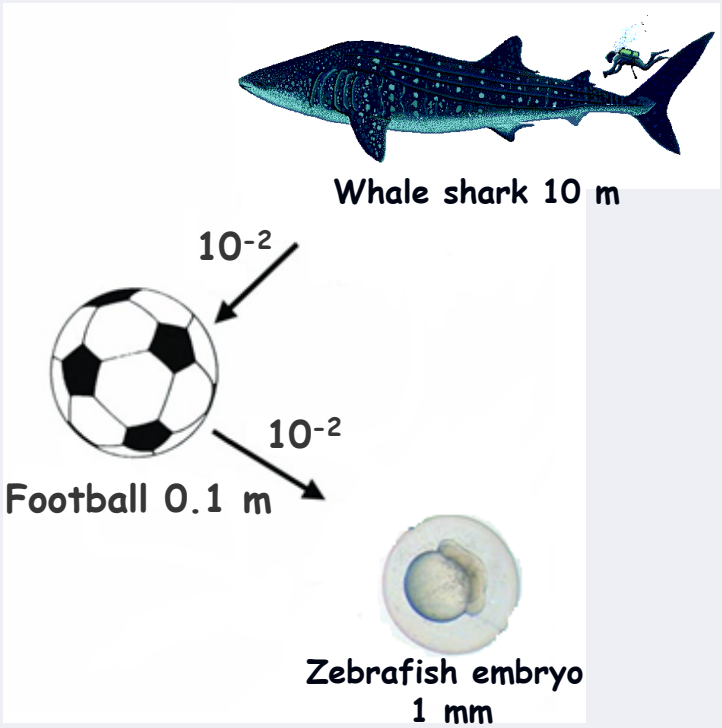
- Fibers (e.g., clothing)
- Weathering of larger pieces in environment

Project Kaisei (www.project kaisei.org)

Size Comparison: Particle of Diameter 1 nm versus 1 mm



1 nanometer



1 millimeter

Neutrophil ~10 μm

Comparison

Nanoparticles

- Definition debatable
- One dimension < 100 nm
- Source:
  - Deliberate manufacture
- Presence in surface waters
  - TiO_2-NPs, Ag-NPs: sub ppb
  - Carbon NPs??
  - **Anticipated** to become an environmental issue

Microplastics

- Definition debatable
- Plastic particles < 1-5 mm
- Source:
  - Deliberate manufacture
  - Breakdown of larger plastics
- Presence in surface waters
  - Marine environments in suspension and associated with sediments
  - Recognized as significant environmental debris

Comparison: Aquatic Toxicity

Nanoparticles

- Toxicity concerns:
  - Ingestion
  - Occlusion of gut/gills
  - Absorption across epithelia?
  - Trophic transfer?
  - Transfer of co-contaminants
    - Associated during manufacture
    - From environment

Microplastics

- Toxicity concerns:
  - Ingestion
  - Occlusion of gut
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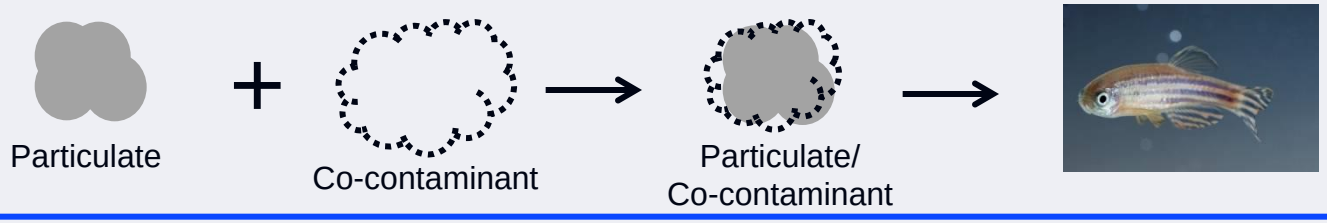
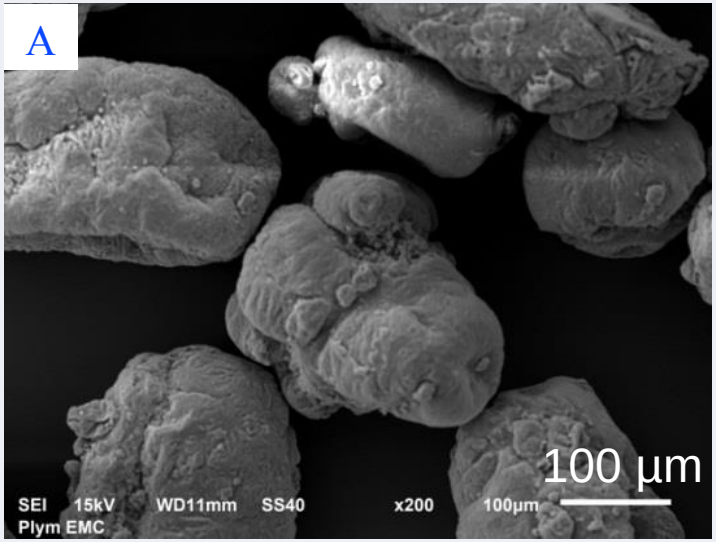
    - Substances from plastics
    - From environment

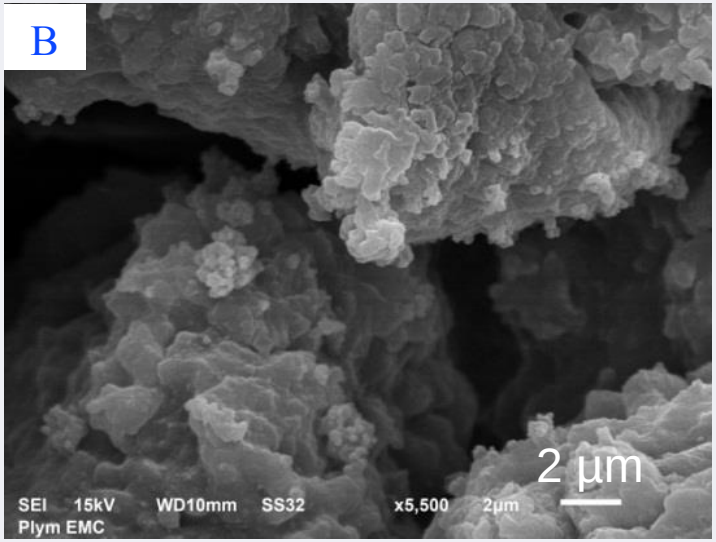
Study Objectives

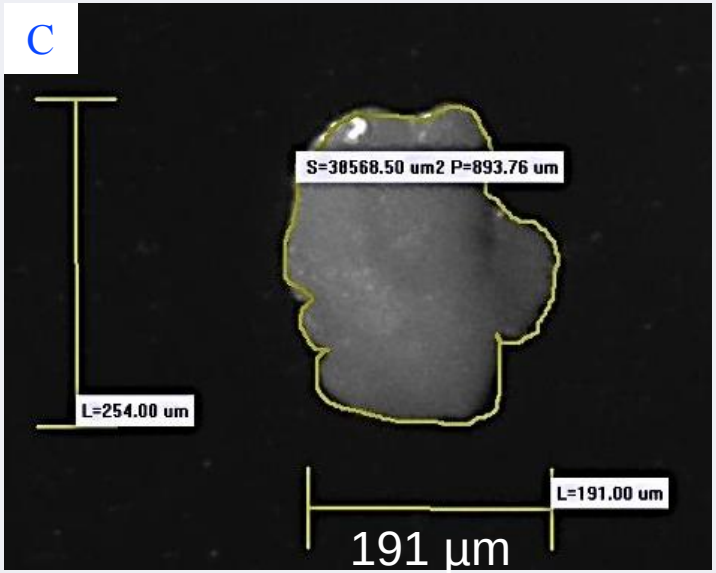
	Nanoparticles	Microplastics
	• Toxicity concerns:	• Toxicity concerns:
1.	• Ingestion	• **Ingestion?**
	• Occlusion of gut/gills	• Occlusion of gut
2.	• Absorption across epithelia?	• **Absorption across epithelia?**
	• Trophic transfer?	• Trophic transfer?
3.	• Transfer of co-contaminants	• **Transfer of co-contaminants?**
	• Associated during manufacture	• Substances from plastics
	• From environment	• **From environment?**



SEM Images of Microplastic Particles







- Amorphous
- Complex/porous surface
- Metals not detected by X-ray spect.
- Same particles used in sorption stuides (Bakir et al.)

Do Co-Contaminants Associate (sorption) with MPs?

Analytical chemistry: Yes (Bakir et al., 2014; others)

- Amount depends on plastic type (PVC < PE)
- Specific co-contaminant
- Salinity [not significant effect on sorption (phenanthrene)]

Effect on co-contaminant bioavailability?

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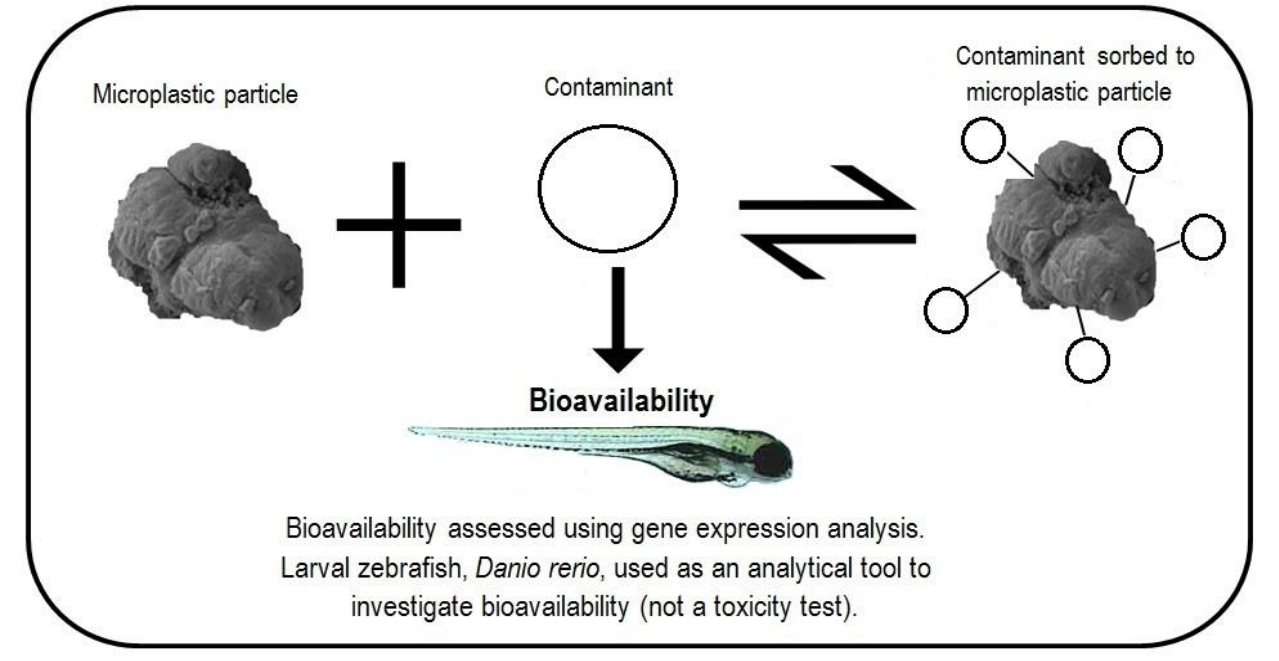

Bioavailability assessed using gene expression analysis. Larval zebrafish, *Danio rerio*, used as an analytical tool to investigate bioavailability (not a toxicity test).

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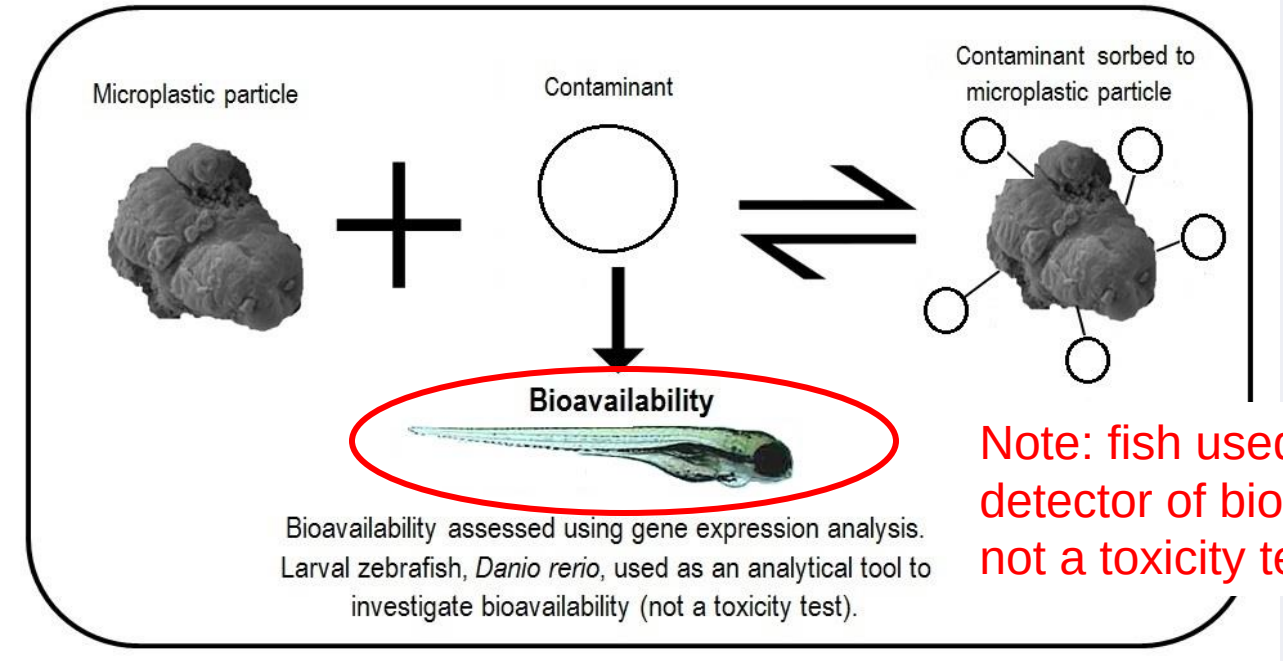
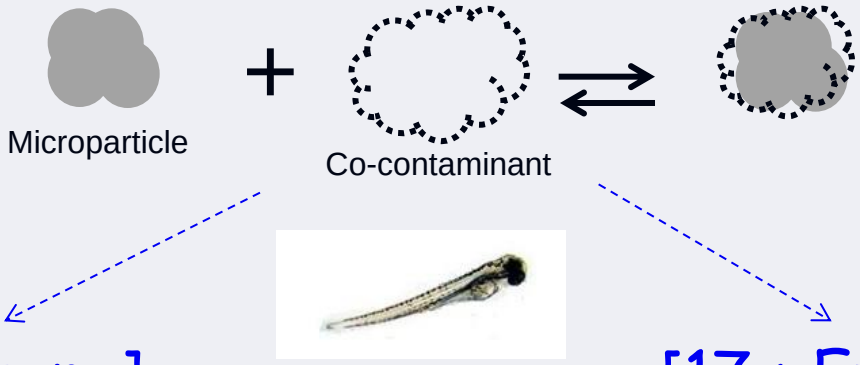


Bioavailability assessed using gene expression analysis. Larval zebrafish, *Danio rerio*, used as an analytical tool to investigate bioavailability (not a toxicity test).

Note: fish used as detector of bioavailability, not a toxicity test

ZF Gene Expression: Bioavailability



[Phenanthrene]

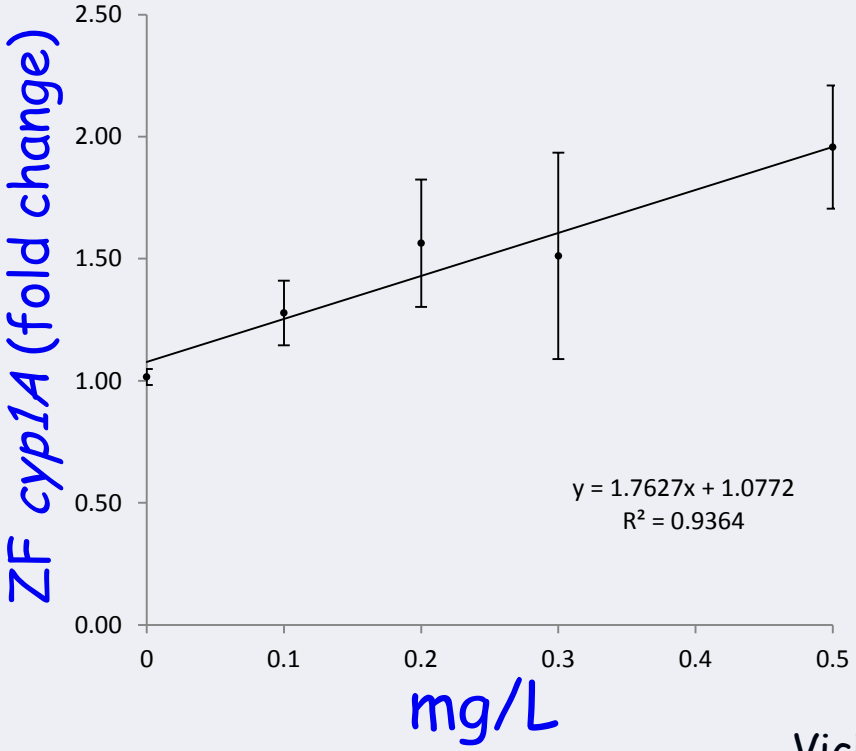
[17a-Ethinylestradiol]

ZF Gene Expression: Bioavailability

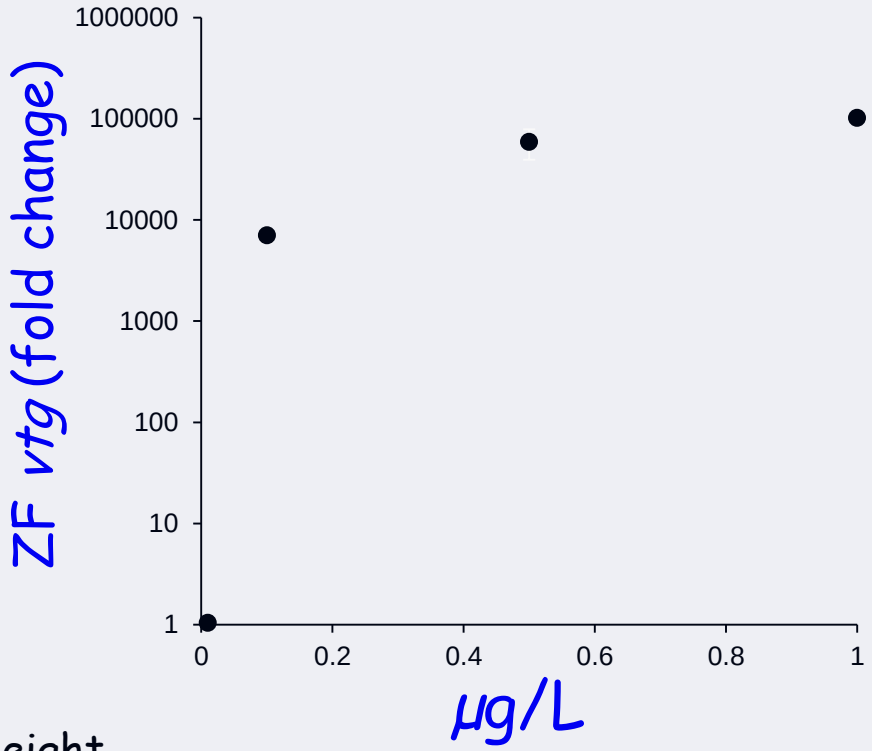
Is expression related to concentration?

First need to characterize response

[Phenanthrene]

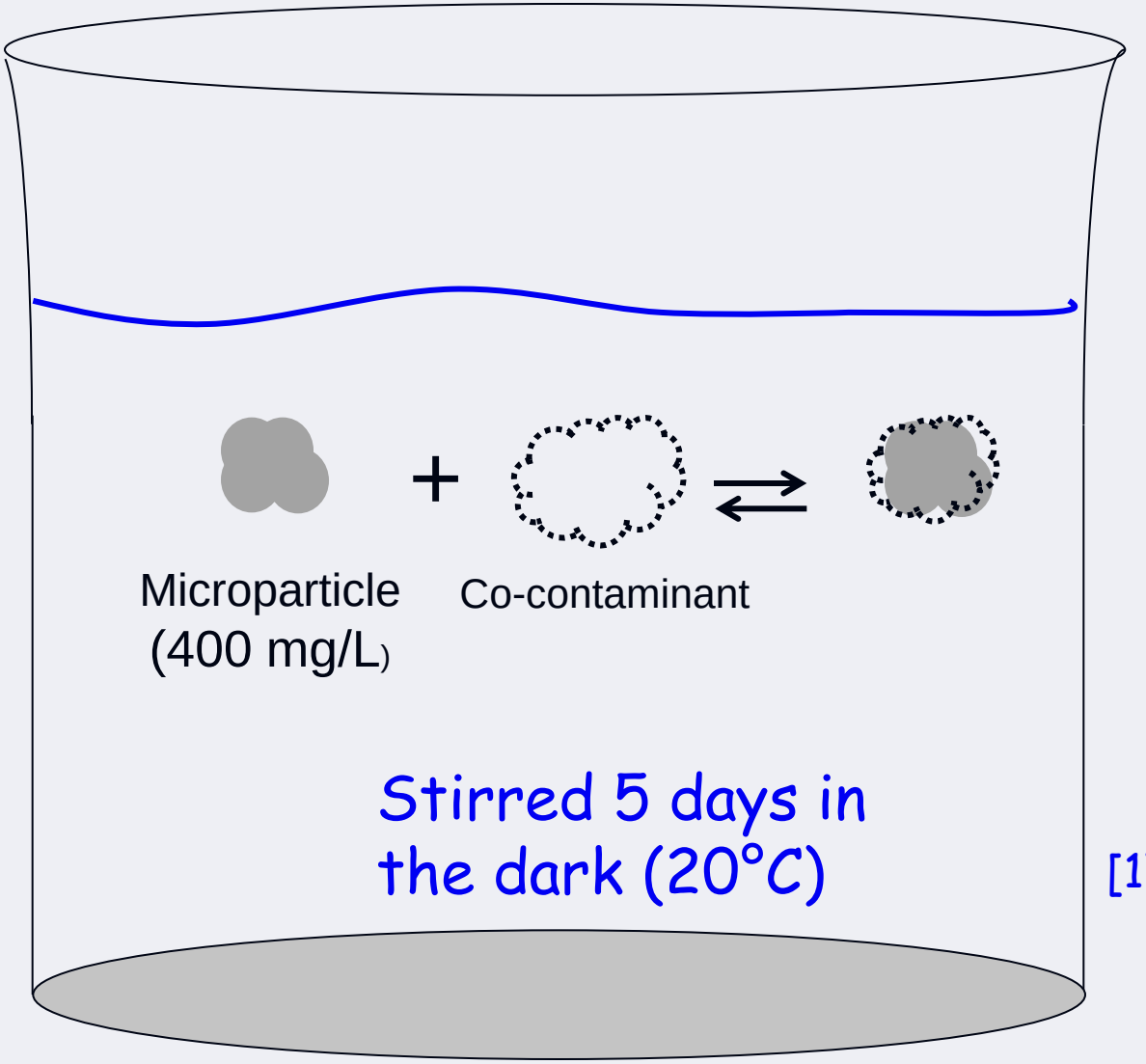


[17a-Ethinylestradiol]



Vicky Sleight

ZF Exposure: Bioavailability



[Phenanthrene] = 500 ppb

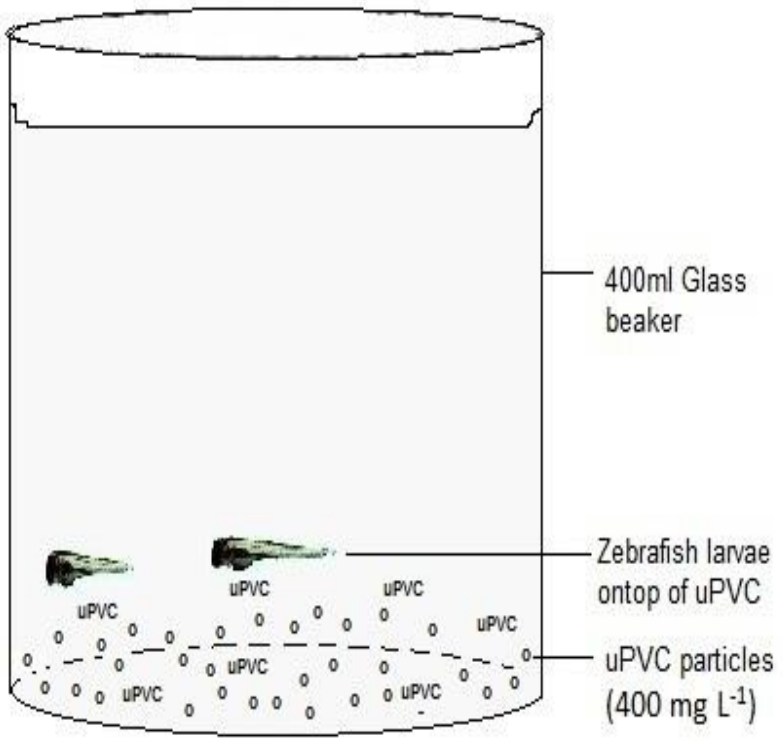
or

[17α-Ethinylestradiol] = 1 ppb

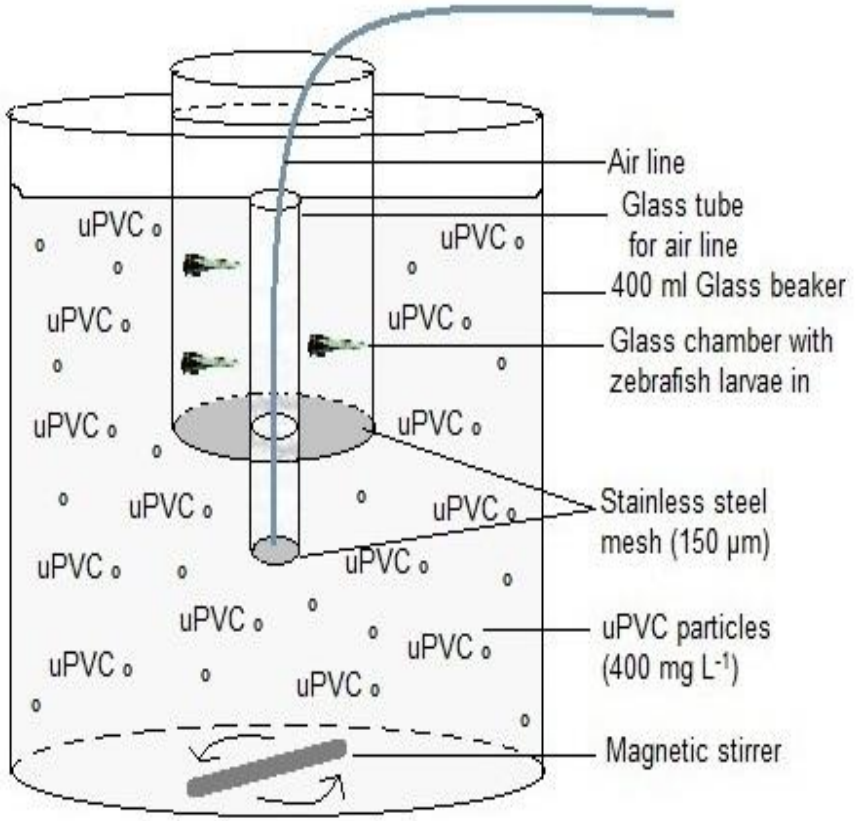
Vicky Sleight

ZF Exposure: Bioavailability

Sedimentation



Aqueous



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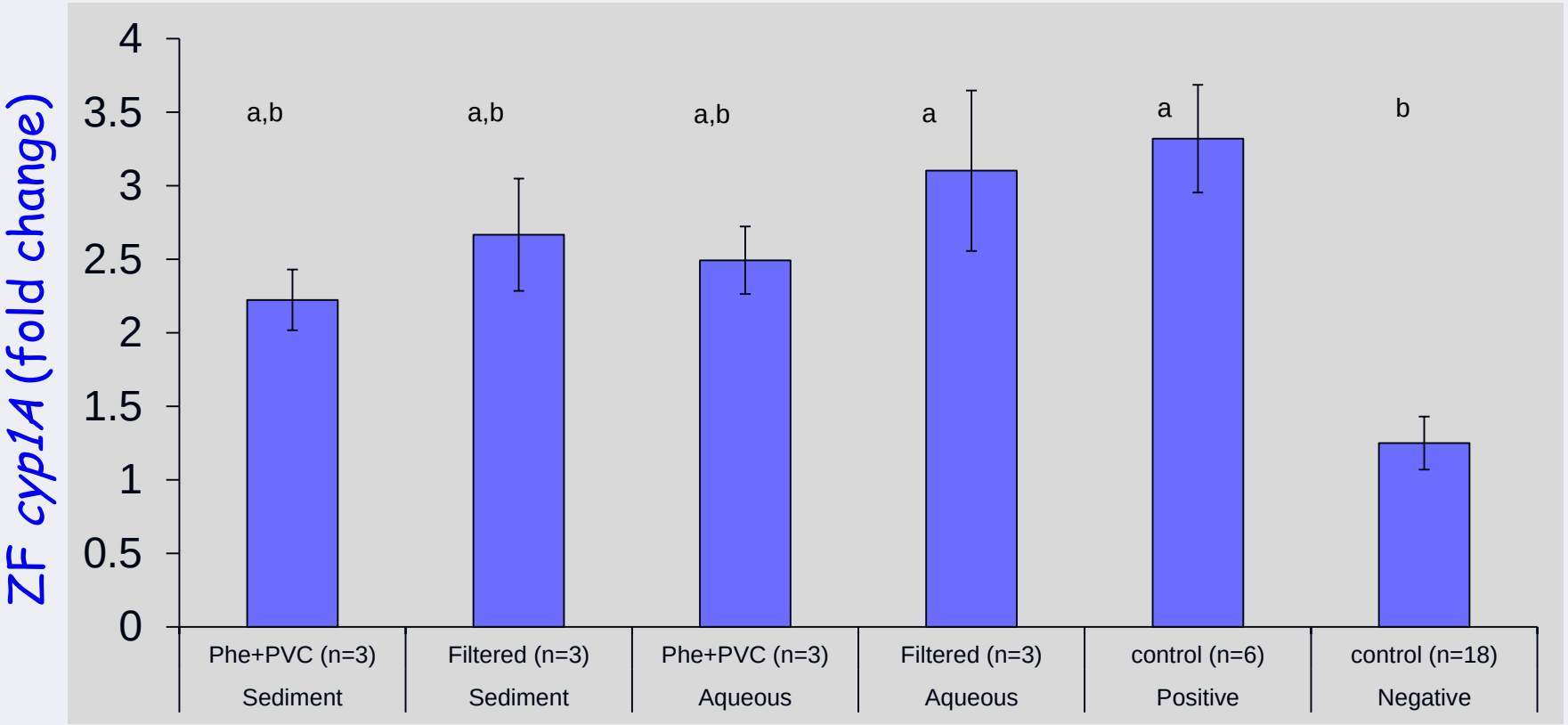
Phenanthrene Bioavailability

Sedimentation Aqueous 500 ppb 0 ppb



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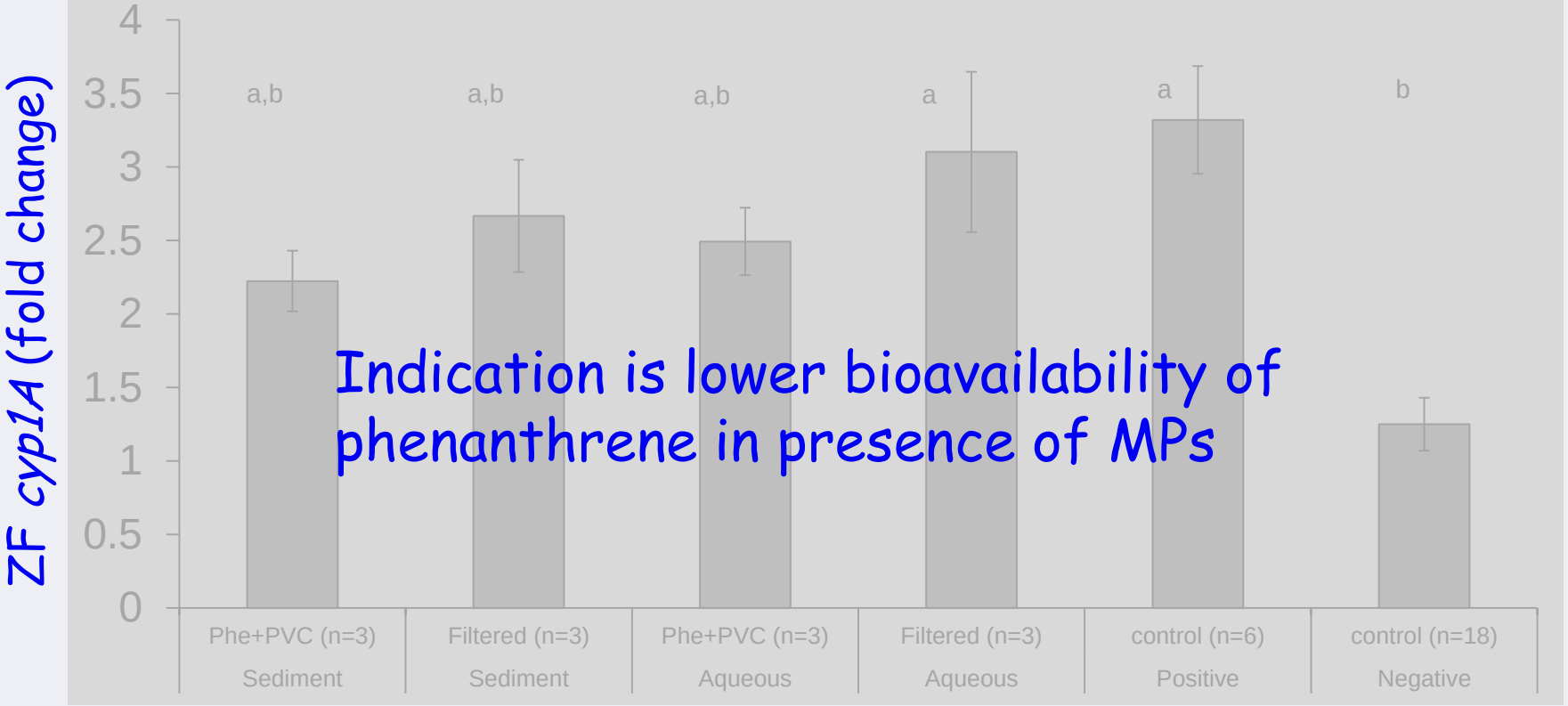
Phenanthrene Bioavailability

Sedimentation Aqueous 500 ppb 0 ppb



Indication is lower bioavailability of phenanthrene in presence of MPs

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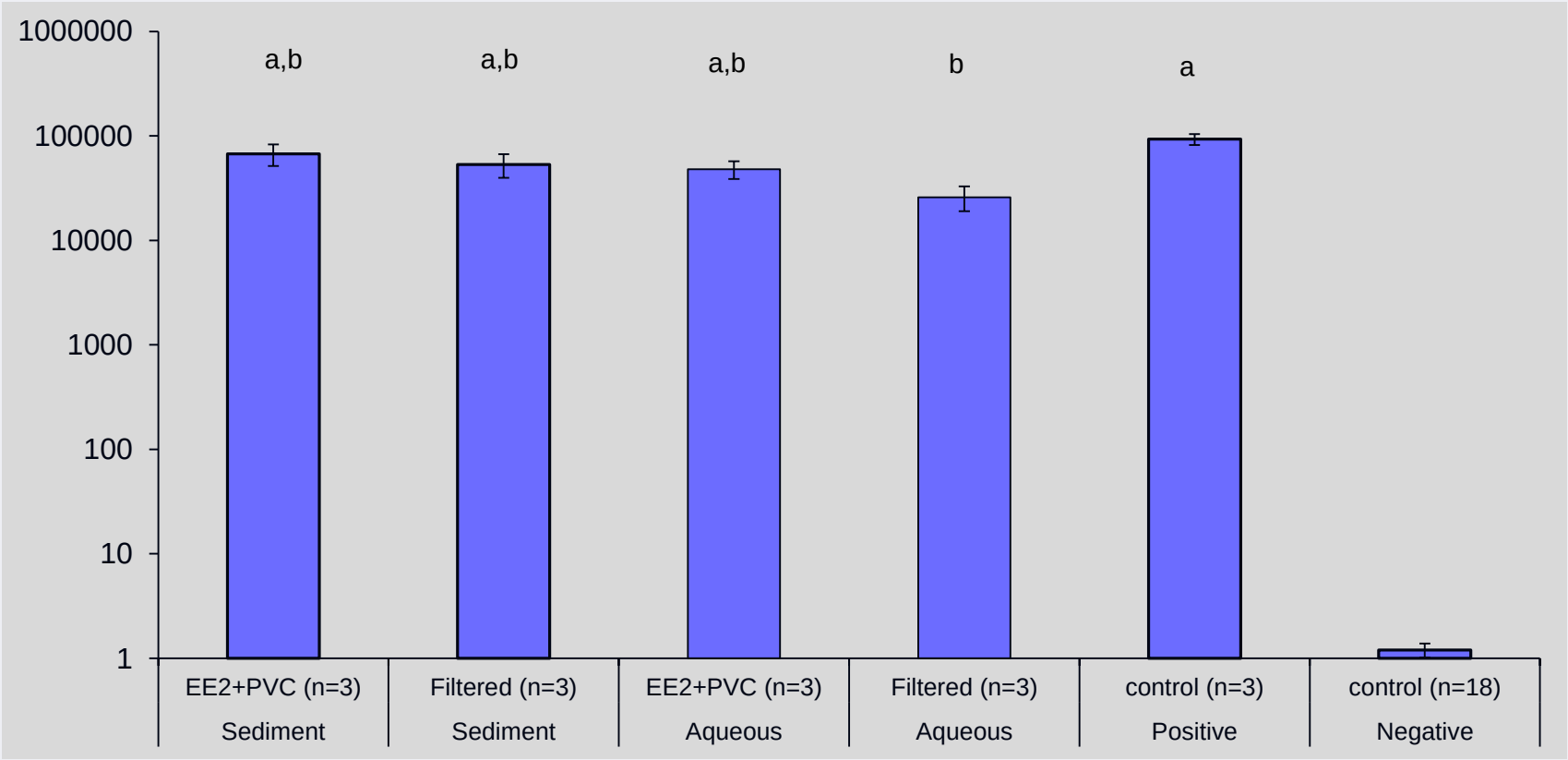
17α-Ethinylestradiol Bioavailability

Sedimentation Aqueous 1 ppb 0 ppb



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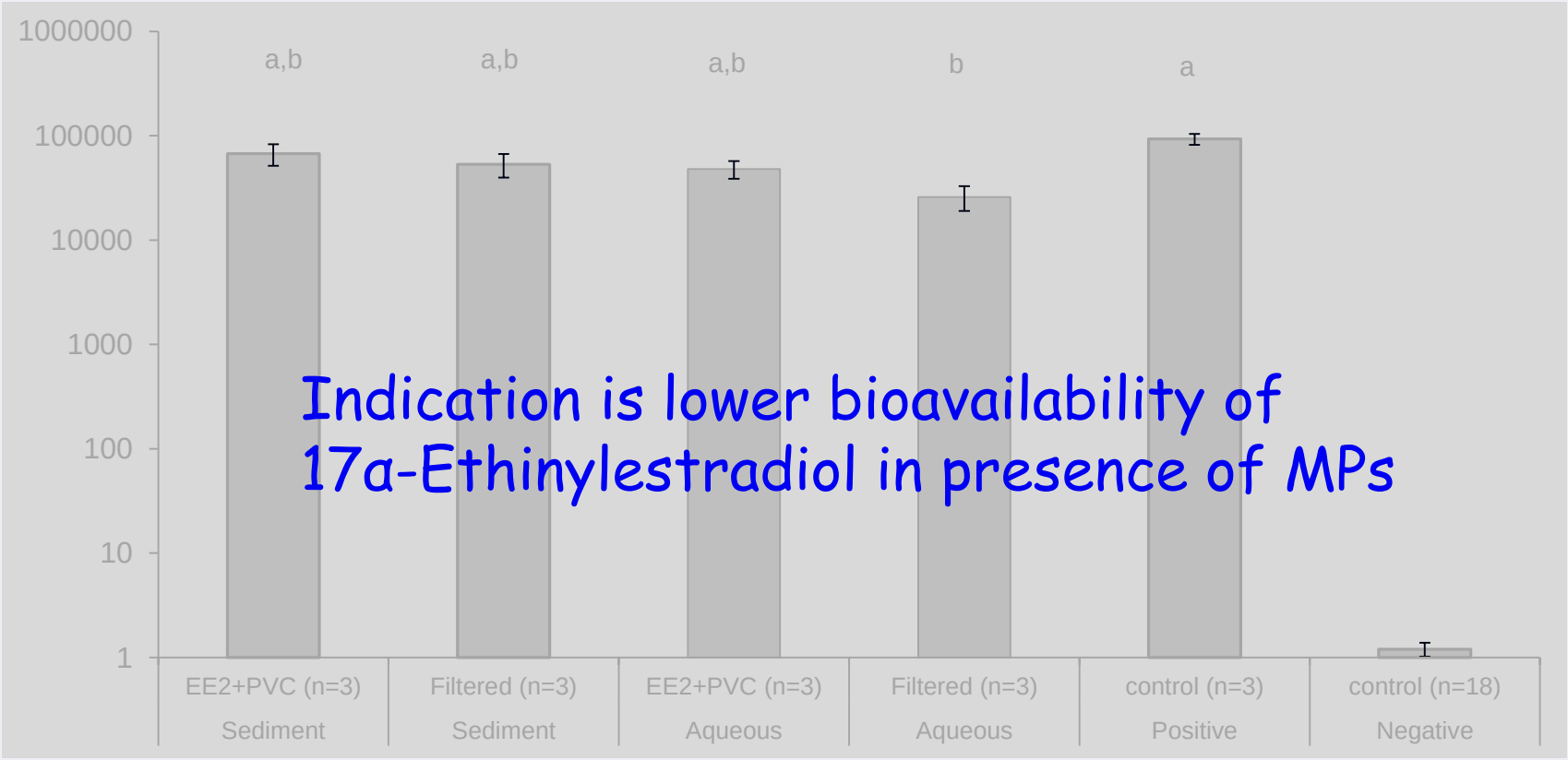
17α-Ethinylestradiol Bioavailability

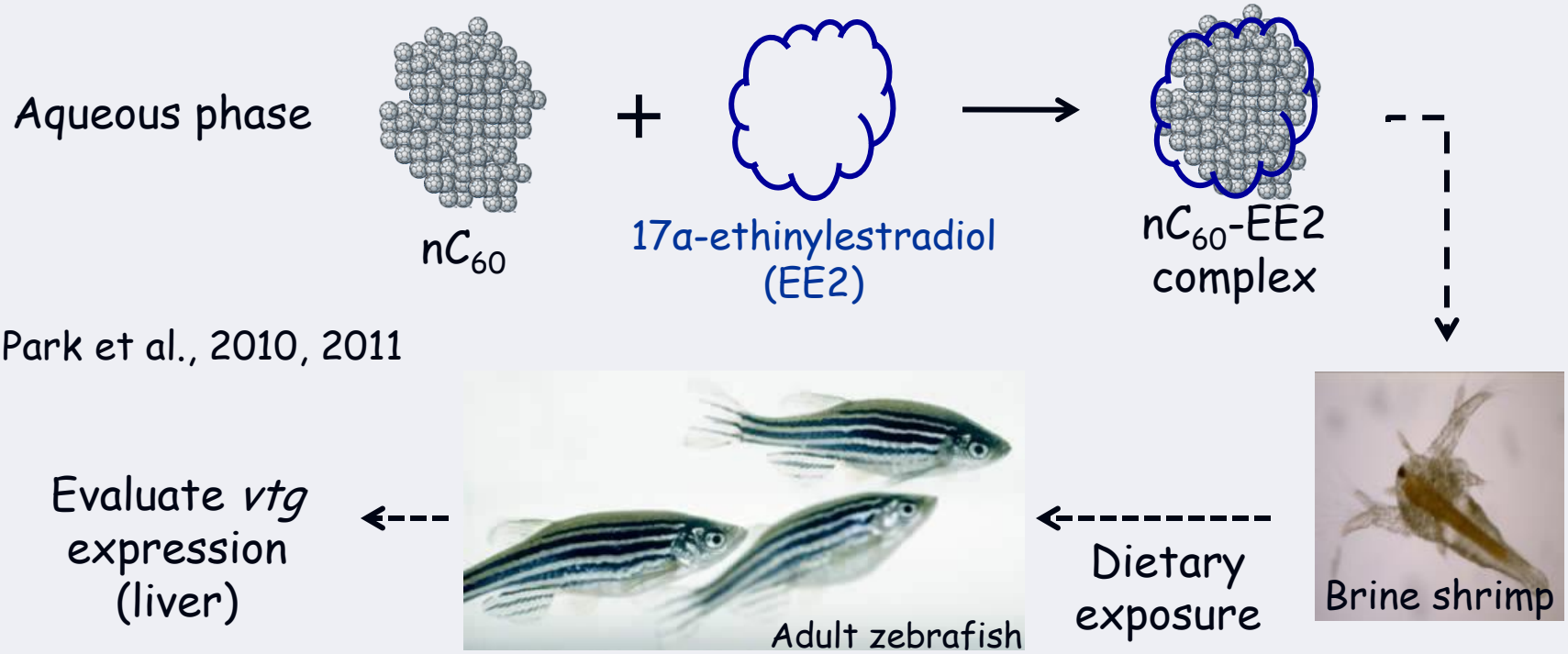
Sedimentation Aqueous 1 ppb 0 ppb



Indication is lower bioavailability of 17α-Ethinylestradiol in presence of MPs

Vicky Sleight

So, if substances sorb to MPs (indicated by analytical chemistry and reduced bioavailability tests) can they be transferred to organisms?



Questions for MPs:

- Do organisms ingest MPs?
- Are ingested MPs absorbed across epithelial membranes?
- How long do MPs reside within digestive tract before egestion?
- Can sorbed co-contaminants become bioavailable?

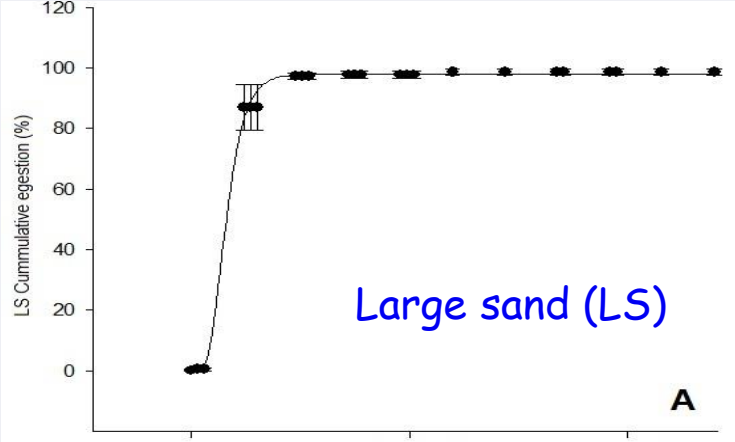
Do organisms ingest MPs?
Are ingested MPs absorbed across epithelia?
How long do MPs reside within GI tract before egestion?

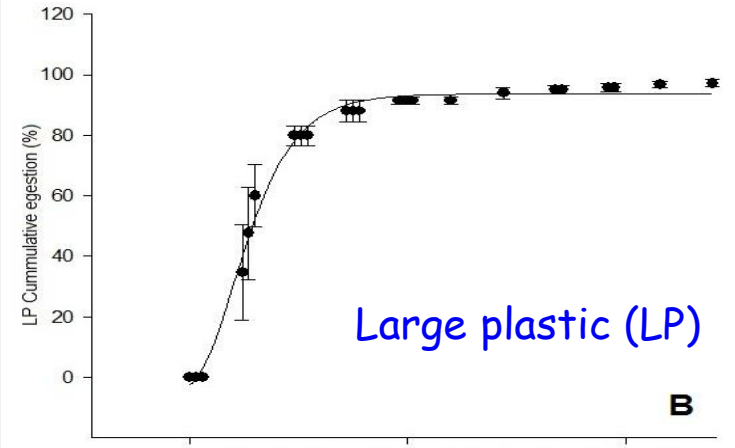
Test organism:

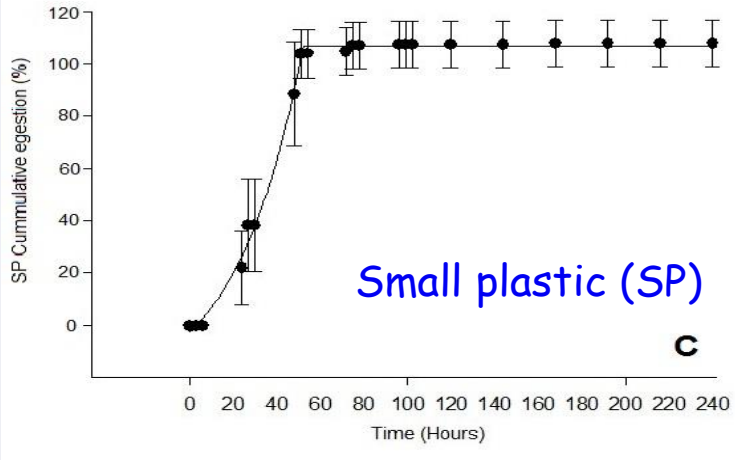
Shore crab *Carcinus maenas*

Approach:

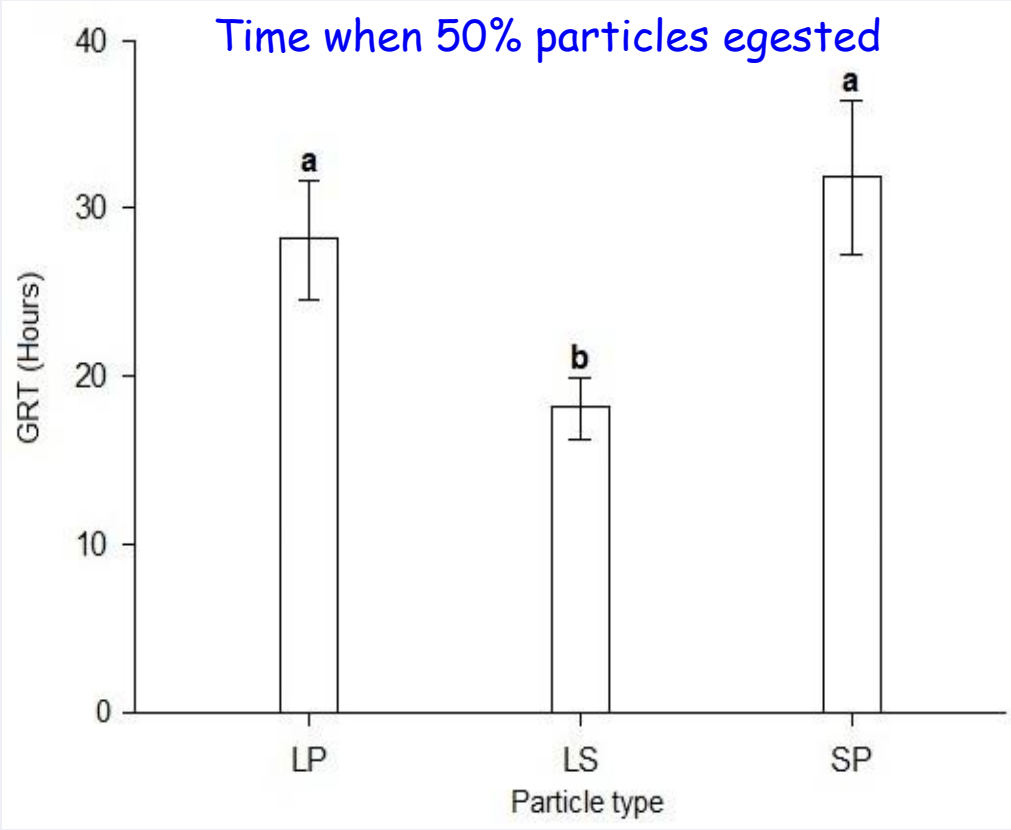
- Feed pellets: fish paste and gelatine (pellet weight 0.25 g)
  - Particles counted and specific amount added to each pellet
  - Sub-sample of pellets examined to verify numbers of particles/pellet
- Treatments:
  - Control without particles
  - Large sand (LS) 1000-1230 μm
  - Large plastic (LP) polyethylene 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







- Crabs did ingest these MPs
- These MPs not appreciably absorbed
- Gut retention varied by particle type



- What about sorbed co-contaminants?

Joseph Hatfield

Summary/Conclusions

Nanoparticles

- Toxicity concerns:
  - 1. Ingestion
  - Occlusion of gut/gills
  - 2. Absorption across epithelia?
  - Trophic transfer?
  - Transfer of co-contaminants
    - Associated during manufacture
    - 3. From environment

Microplastics

- Toxicity concerns:
  - **Ingestion: YES**
  - Occlusion of gut
  - **Absorption across epithelia? NO**
  - Trophic transfer?
  - **Transfer of co-contaminants**
    - Substances from plastics
    - **From water: associated with MPs, transfer to organisms?**

Acknowledgments:

- Stan McMahon; Helena Reinardy; Gabriela Aguirre; Robyn Wright; Andy Atfield (University of Plymouth)

Future Research:

- Dr. Ana Catarino: Marie Curie Research Fellow (June 2014-2016)
- "Marine microplastics toxicity: investigating microplastics and their co-contaminants in marine organisms (MARMICROTOX)"

SETAC North America (November 2014):

- Microplastics Session: "Environmental Impacts of Microplastics: an Issue of Local, Regional, and Global Concern"
- Session Chairs: Drs. Chelsea Rochman and Ted Henry
- Submit abstracts by 28 May 2014 (Platform and Poster session)