Imperial College London

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Potential for microplastics in drinking water to impact health

SCCWRP

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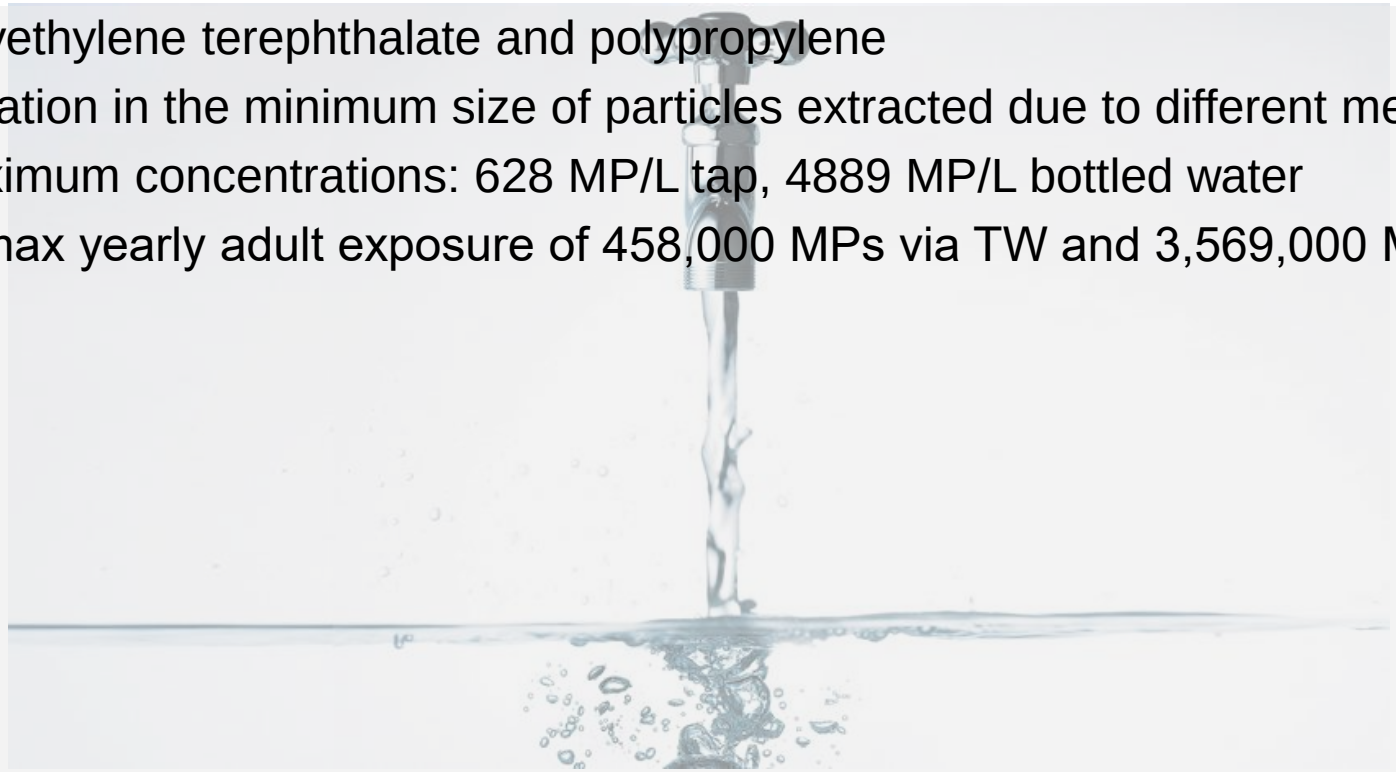
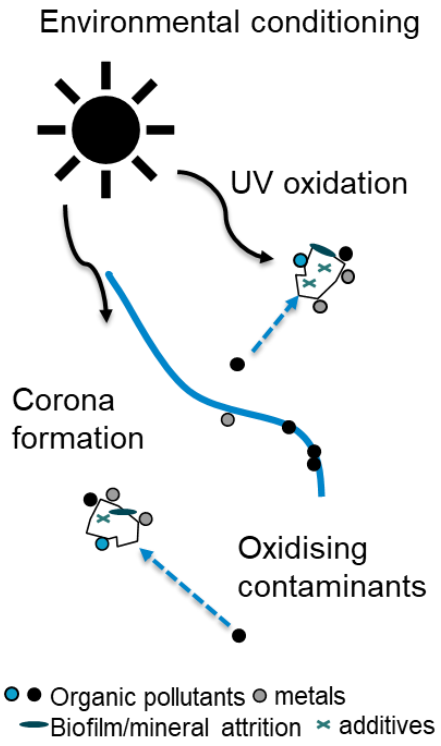
Microplastics in Drinking Water – the Headlines

- Polyethylene terephthalate and polypropylene
- Variation in the minimum size of particles extracted due to different methods
- Maximum concentrations: 628 MP/L tap, 4889 MP/L bottled water
- … max yearly adult exposure of 458,000 MPs via TW and 3,569,000 MPs via BW.

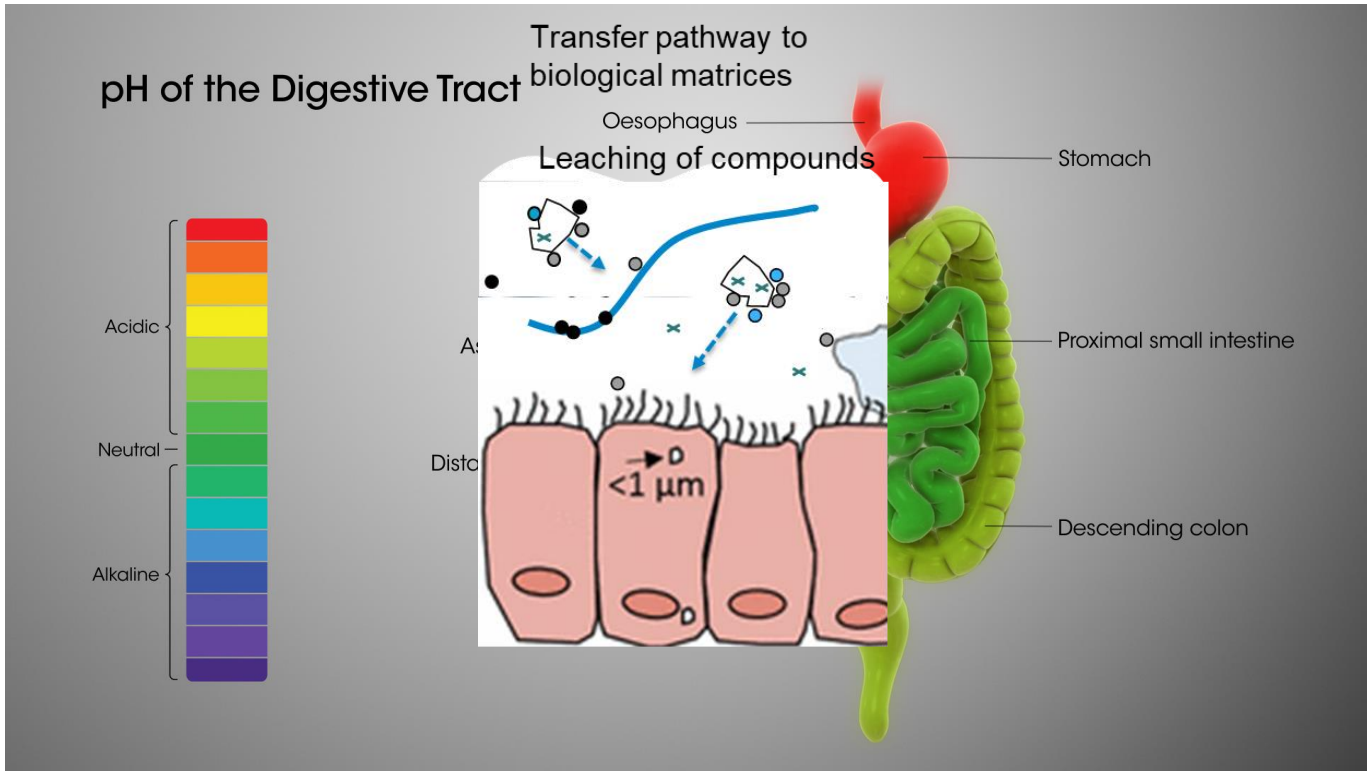


Danopoulos et al., 2020

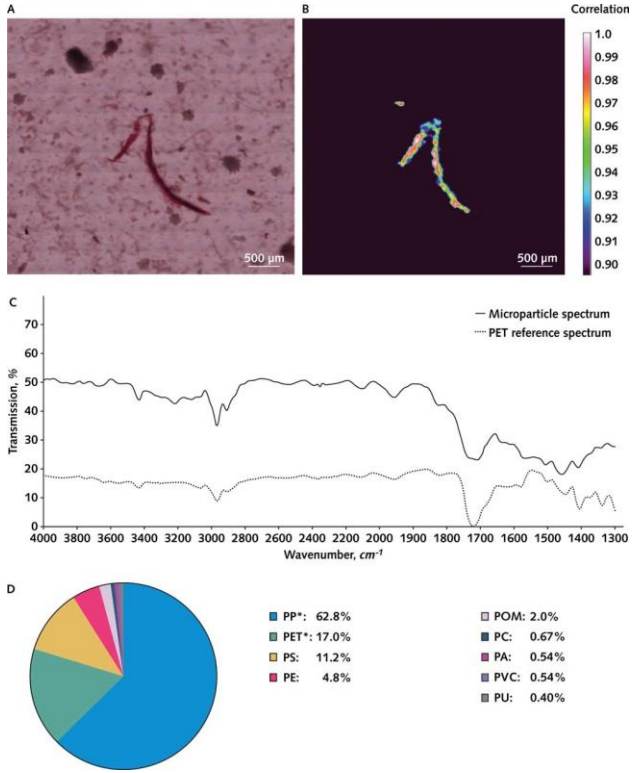
What's Going In?



The Digestive Environment

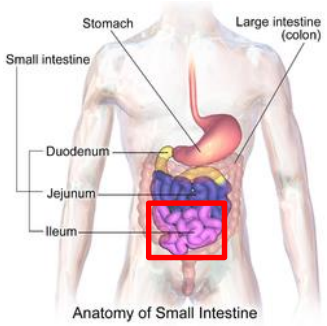


What Goes in Comes Out?



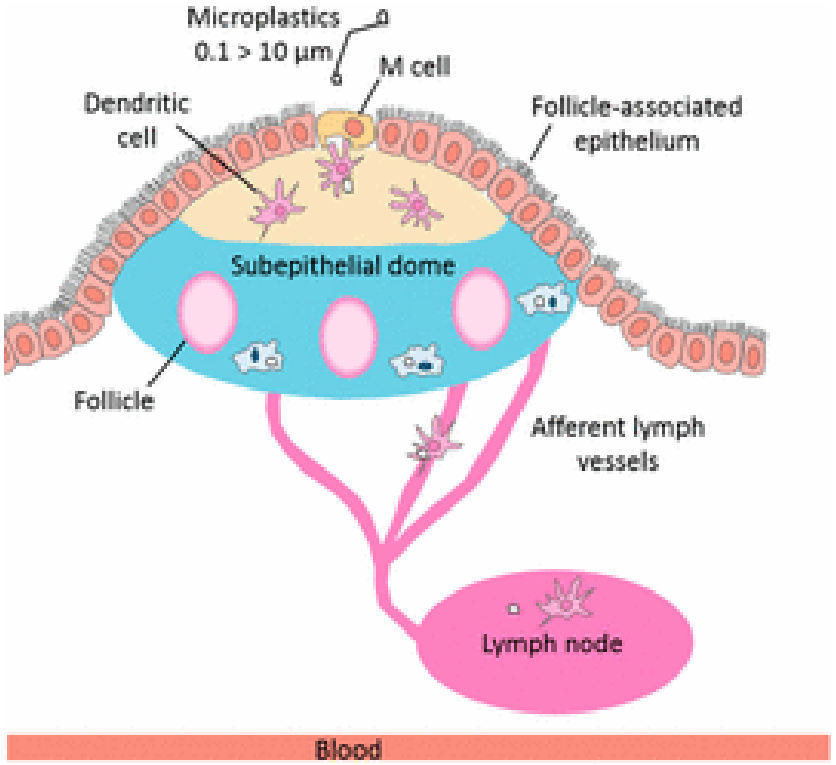
- Some particles may pass through.
- 8 to 416 (median 20) microplastic 50-500 µm per 10 g stool.
- Does the size distribution accurately reflect exposure?

Schwabl et al., 2019; Wright & Mudway, 2019

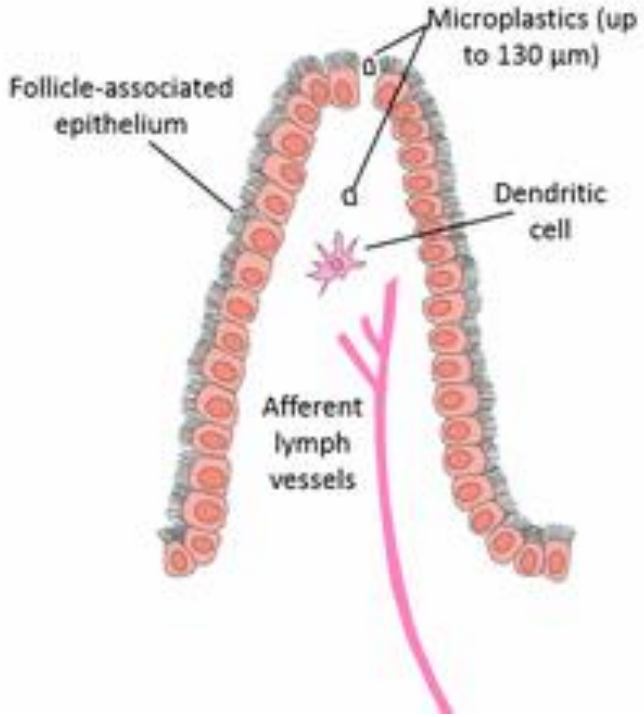


Active Uptake

- Peyer's Patches: up to ~5-10 µm (Hussain et al., 2001).
- Rate of uptake increases with decreasing size.
- <0.3 % 2 µm latex MPs (Carr et al., 2012).
- 1,374 MPs via TW (458,000 MPs).
- Surface chemistry.

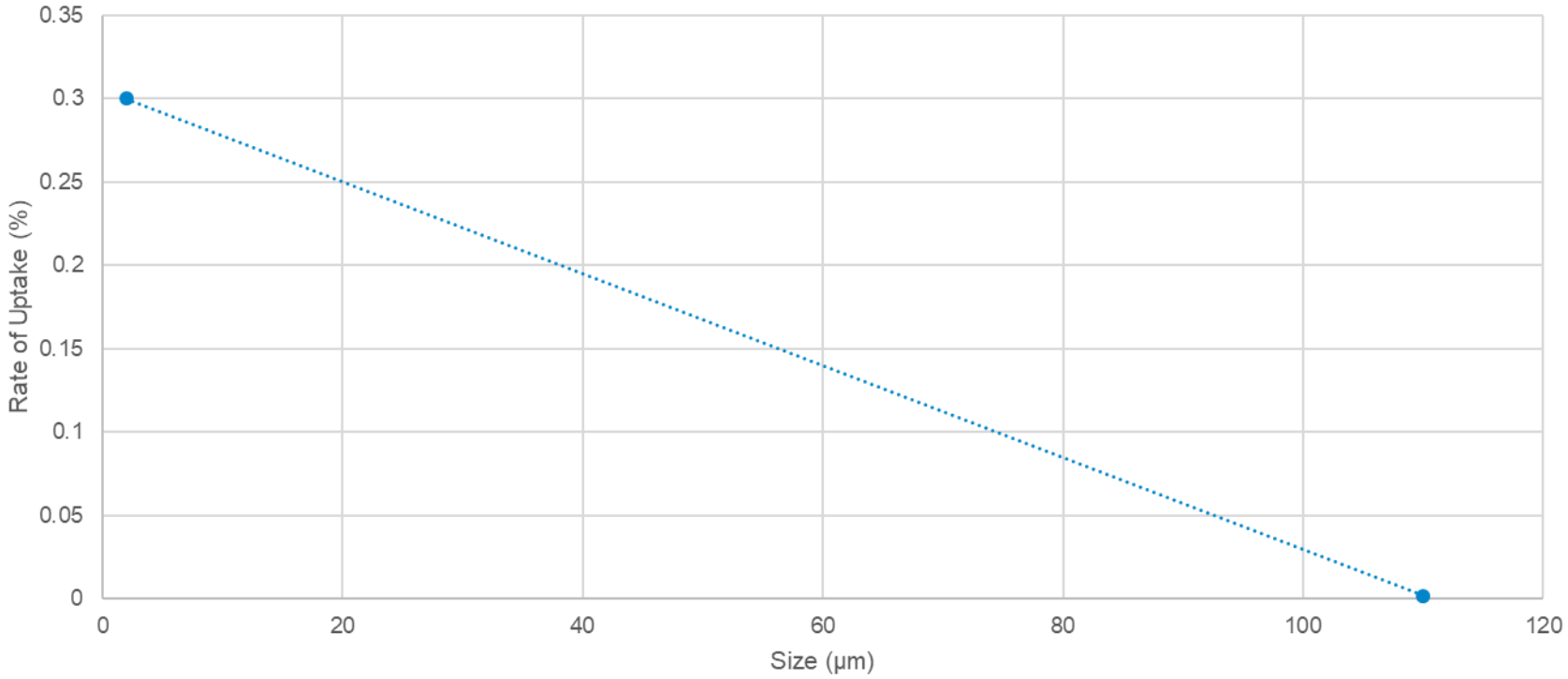


Passive Uptake



- Persorption
- Up to 150 µm PVC particles [dogs] Up to 110 µm starch [humans] (Volkheimer 1975).
- <0.002% particles absorbed (Steffens et al., 1992).
- 9.16 MPs via TW (458,000 MPs).

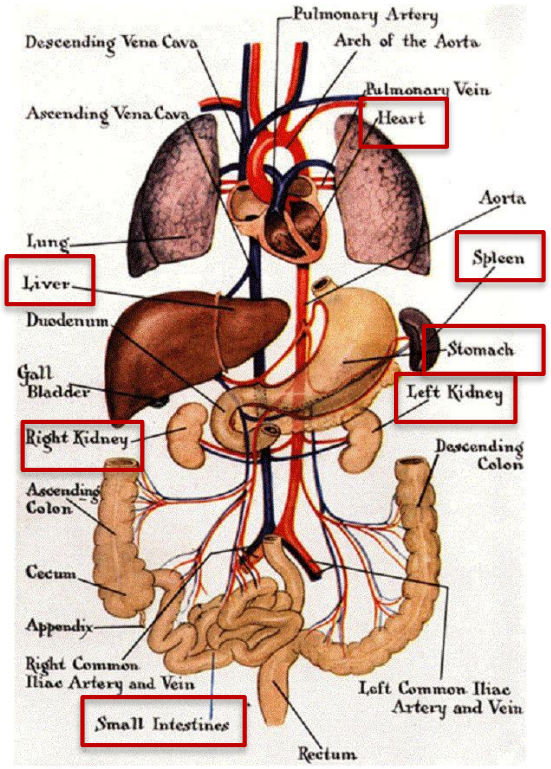
As particle size increases the rate of uptake decreases



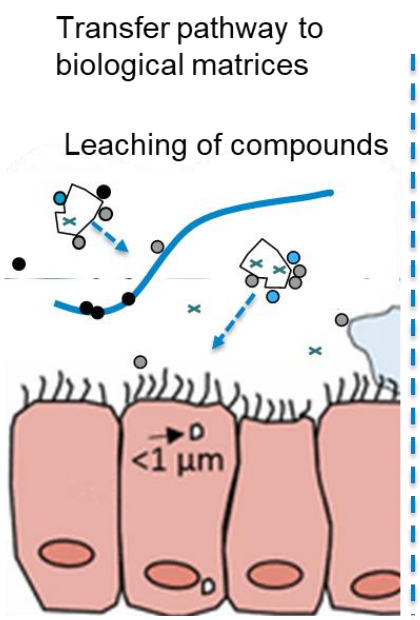
Steffens et al., 1992; Carr et al., 2012

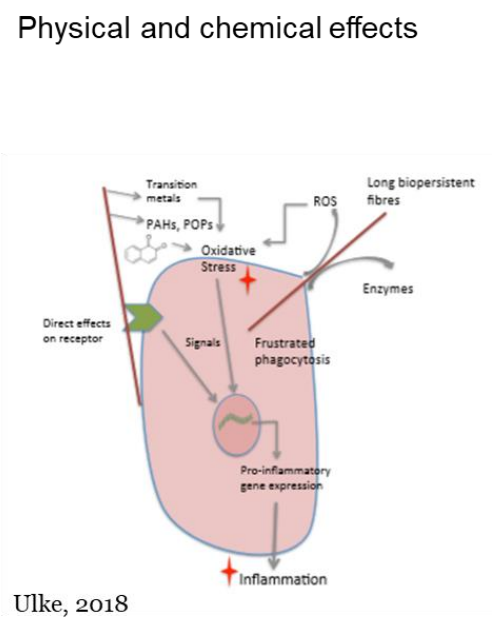
Where Do Particles Go?

- <1.5 µm = systemically available
- Kidney, spleen, heart, stomach wall, small intestine (PS^- (50 nm)) (Walczak et al., 2015).
  - Up to **1.7%** of ingested bioavailable
- Mesentary lymph nodes (1000 nm), spleen and liver (50, 500 nm) (Jani et al., 1992).
- Fate, rate = size and surface charge dependent.



What Type of Harm?





Ulke, 2018 (unpublished)

- No studies on population-level effects (epidemiology).
- No studies on human subjects (health).
- Animal (in vivo) and cell (in vitro) toxicity studies.

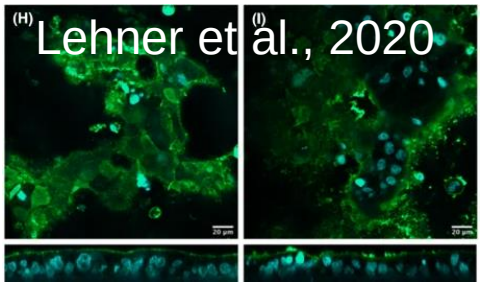
Toxicity in Animals

- Effects in the gut:
  - Inflammation (Li et al., 2020)
  - Reduced mucus secretion (Lu et al., 2018)
  - Altered gut microbiota (dysbiosis) (Lu et al., 2018; Jin et al., 2019; Luo et al., 2019; Li et al., 2020)
- Effects in the liver:
  - Changes in fat composition (Lu et al., 2018; Luo et al., 2019)
  - Metabolic disorder (Lu et al., 2018; Luo et al., 2019; Jin et al., 2019)
- No effects:
  - Oxidative stress, inflammation, lesions (Stock et al., 2019)

Experimental Parameters

Reference	Particle size (um)	Polymer	Dose	Duration	Administration
Lu et al., 2018	0.5 and 50	PS	100 and 1000 ug/L	5 wk	Water
Jin et al., 2019	5	PS	100 and 1000	6 wk	Water
Luo et al., 2019a	5	PS	100 and 1000	Gestation and lactation	Water
Luo et al., 2019b	0.5 and 5	PS	100 and 1000	Gestation	Water
Stock et al., 2019	1, 4, 10	PS	4.55 × 10^7, 4.55 × 10^7 and 1.49 × 10^6 particles	4 wk	Gavage, 3x/wk
Li et al., 2020	10–150 µm	PE	6, 60, and 600 µg/d	5 wk	Feed

Toxicity in Human Gut Cells



- No (cyto)toxicity:
  - PET (100 nm) 1-30 µg/mL (Magri et al., 2019)
  - PS beads (50 & 500 nm) up to 100 µg/mL (Heseler et al., 2019)
  - Mix including PP, tire rubber, PA & PU (50–500 µm) 823.5–1380.0 µg/cm^2 (Lehner et al., 2020)

- Variable effects on membrane integrity
  - Weak effect: 48 h 5 µm PS beads 50 µg/mL - genes related to tight junction pathways differentially expressed (Wu, S et al., 2019)
  - No effect: 24 h 0.046 to 5 µm PS beads up to 200 µg/mL (Wu, B et al., 2019; Hesler et al., 2019)

Toxicity in Human Gut Cells

- Variable ROS generation:
  - Weak effect: 24 h 0.1 and 5 μm PS beads 200 μg/mL (Wu, B et al., 2019)
  - No effect: 48 h 5 μm PS beads 12.5 - 50 μg/mL (Wu, S et al., 2019)

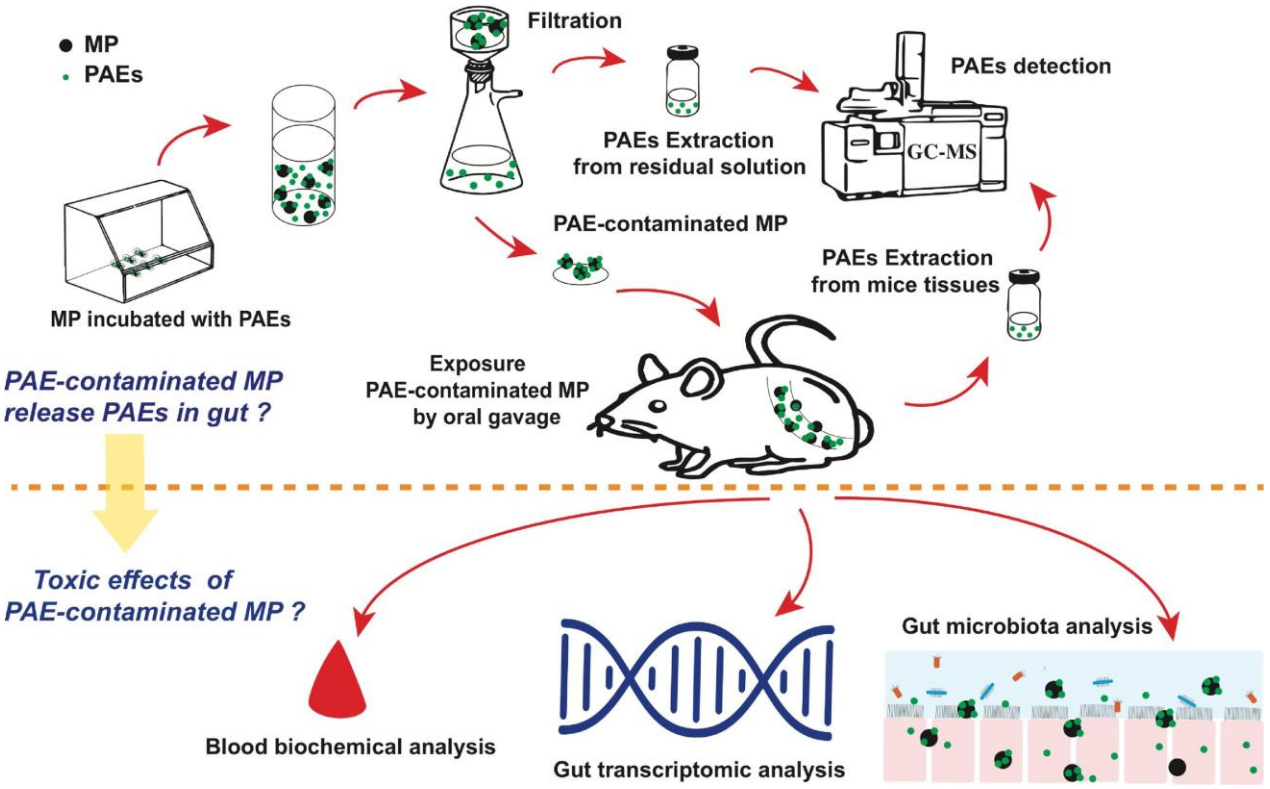
- Inflammation and immune responses
  - 48 h 5 μm PS beads (Wu, S et al., 2019)
  - No effect: Lehner et al., 2020

Chemical Toxicity?

- 1) Leaching during gut transit
- 2) Leaching in a cell
- 3) Release of new chemical products – does oxidation in stomach acid generate compounds?

- Rate of leaching relative to time in gut or cell
- Relative concentration in relation to body's equilibrium

Chemical Toxicity?



Deng et al., 2020

Chemical Toxicity?

- Accumulation of phthalate esters in the gut followed the order of sorption: DEHP > DBP > DEP > DMP.
- 30 d increased intestinal permeability and enhanced intestinal inflammation.
- Differentially expressed genes involved in oxidative stress, immune response, lipid metabolism, and hormone metabolism.
- Effects induced by DEHP-contaminated MPs were higher than individual DEHP and MPs.
- BUT – when we ingest MP with food, their PhE burden will be in balance with the environmental medium.

Deng et al., 2020

Summary

- Humans are likely exposed to microplastics via water consumption
- Still a lot of gaps concerning microplastic uptake, distribution and elimination in the human body
- The observed size distributions thus far indicate low rate of uptake, with little potential to redistribute to secondary organs
- Animal studies indicate mucus secretion and microbiota alteration, in addition to metabolic disorders, but there are question marks over interpretation
- Few cell studies indicate strong toxic effects, but these are mostly preformed using pristine polystyrene
- Need more dose-response studies
- The potential mixture effects need to be investigated.
- Need long term, chronic exposure studies.

Thank you!