Modelling human exposures to plastic additive chemicals and hydrophobic organic contaminants via microplastics

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TG Environmental Research

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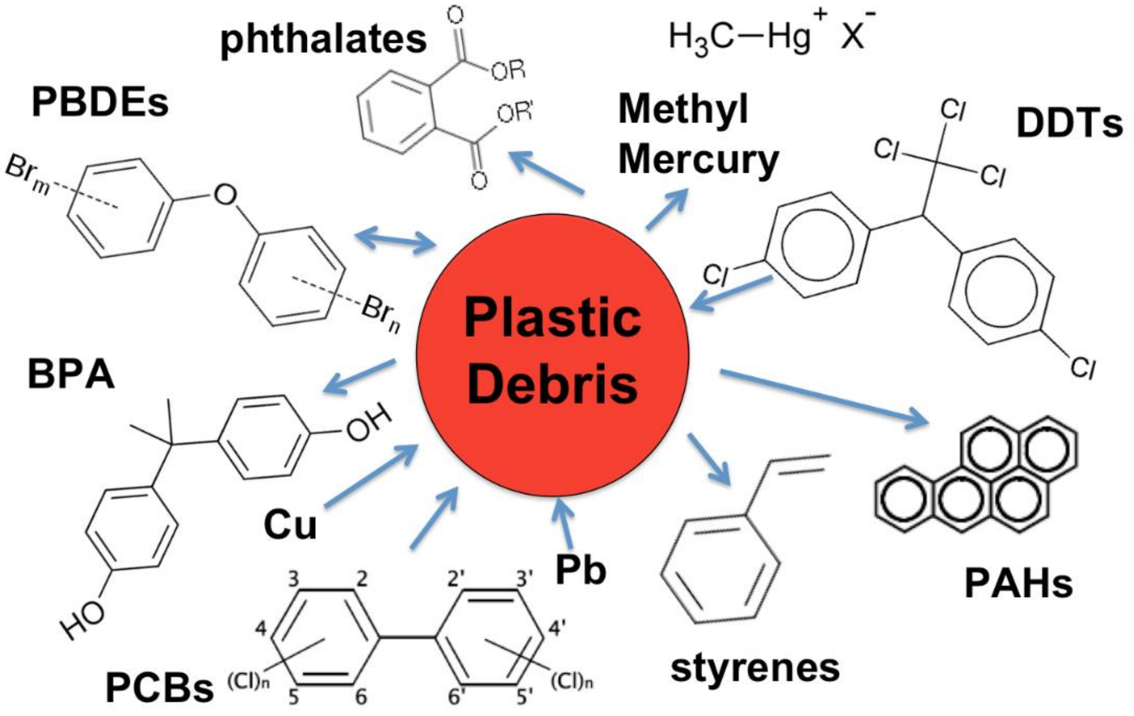
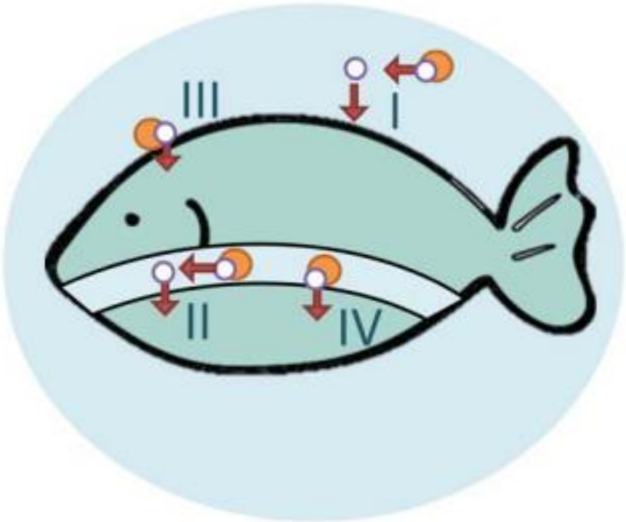
Microplastics as a vector for hydrophobic organic pollutants?

"Cocktail" of Chemical Contaminants




Daily Mail
TV'S FUNNIEST MOMENTS PULLOUT
Enough is enough. The peacocking saboteurs out to knife Mrs May are dragging their party – and their country – towards the abyss
Daily Mail COMMENT
THE PROOF WE ALL EAT PLASTIC
Landmark study found EVERY person tested contaminated
Drinking from plastic water bottles and eating fish blamed
Car crash at drive time as Simon Mayo walks out on Radio 2



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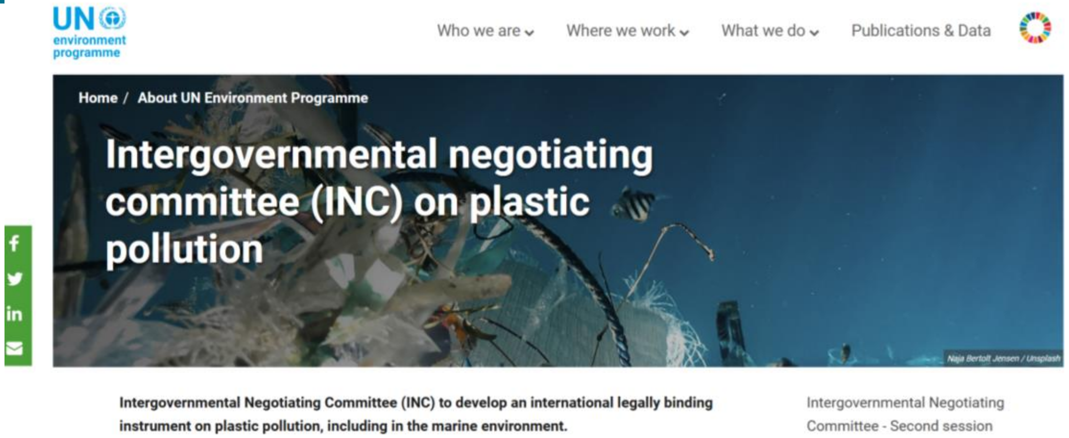
Hartmann, N. B., Rist, S., Bodin, J., Jensen, L. H. S., Nørgaard Schmidt, S., Mayer, P., ... Baun, A. (2017). Microplastics as Vectors for Environmental Contaminants : Exploring Sorption, Desorption, and Transfer to Biota. *Integrated Environmental Assessment and Management*, *13*(3), 488-493. https://doi.org/10.1002/ieam.1904

Plastic Additive Chemicals (PACs)

IPEN is calling for an international plastics treaty that:

- Protects health and the environment
- Ends the production and use of toxic chemicals in plastics
- Removes toxic impacts at all stages of the lifecycle of plastics
- Bans recycling of plastics containing hazardous chemicals
- Protects the public's right to know about chemicals in plastics and information on plastic production and waste exports
- Charges plastic producers to finance the treaty
- Promotes safer sustainable materials for a toxics-free circular economy
- Curbs toxic and climate pollutants

In the meantime, greater transparency on toxic chemical additives used in plastics is needed, along with data on the quantities of plastics made, traded, and disposed of. For more information see our **Plastics Treaty** page.



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What is the potential exposure (+ associated health risk) to humans associated with chemical ingestion (PACs & environmental) via MPs?

The "Trojan Horse" Effect

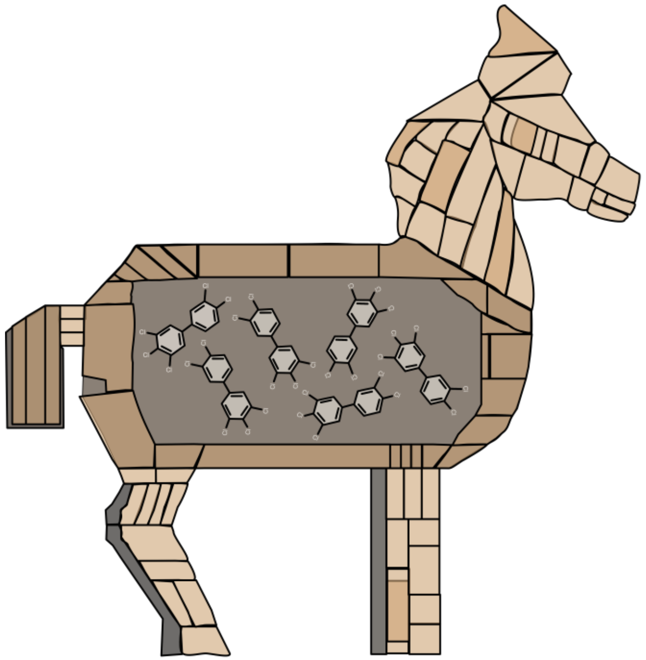

Image: Todd Gouin

MPs unlikely to enhance HOC exposures in marine wildlife …. BUT what about humans?

Environmental Science & Technology

ARTICLE

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A Thermodynamic Approach for Assessing the Environmental Exposure of Chemicals Absorbed to Microplastic

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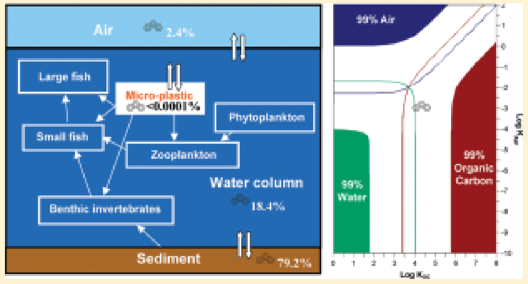
Supporting Information

ABSTRACT: The environmental distribution and fate of microplastic in the marine environment represents a potential cause of concern. One aspect is the influence that microplastic may have on enhancing the transport and bioavailability of persistent, bioaccumulative, and toxic substances (PBT). In this study we assess these potential risks using a thermodynamic approach, aiming to prioritize the physicochemical properties of chemicals that are most likely absorbed by microplastic and therefore ingested by biota. Using a multimedia modeling approach, we define a chemical space aimed at improving our understanding of how chemicals partition in the marine environment with varying volume ratios of air/water/organic carbon/polyethylene, where polyethylene represents a main group of microplastic. Results suggest that chemicals with log $K_{OW} > 5$ have the potential to partition >1% to polyethylene. Food-web model results suggest that reductions in body burden concentrations for nonpolar organic chemicals are likely to occur for chemicals with log K_{OW} between 5.5 and 6.5. Thus the relative importance of microplastic as a vector of PBT substances to biological organisms is likely of limited importance, relative to other exposure pathways. Nevertheless, a number of data-gaps are identified, largely associated with improving our understanding of the physical fate of microplastic in the environment.



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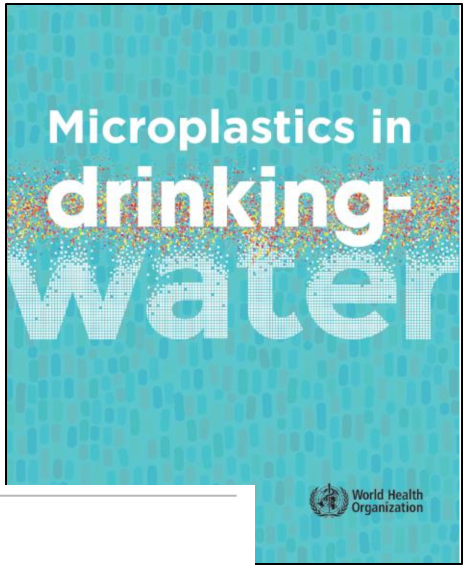
Chemical exposures & potential risks from ingesting microplastics in drinking water

Table 3.3 Upper-bound daily intake estimates of chemicals from microplastics, maximum levels of contaminants associated with microplastics, and corresponding MOE

Chemical[a]	Upper bound concentration in microplastic (µg/g)	Maximum daily intake (ng/kg bw/day)[b]	Point of departure (µg/kg bw/day)	Margin of exposure (MOE)	Adequacy of MOE	Conclusion
Bisphenol A	0.7297	0.001	609	5.9×10^{8}	MOE of at least 100	No safety concern
Cadmium	3390	5.0	0.8	1.7×10^{2}	MOE of at least 10[c]	No safety concern
Chlordane	0.0144	0.00002	50	2.5×10^{9}	MOE of at least 100	No safety concern
Di(2-ethylhexyl)phthalate	0.0699	0.0001	2500	2.5×10^{10}	MOE of at least 100	No safety concern
Dichlorodiphenyltrichloroethane	7.1	0.0001	1000	1.0×10^{8}	MOE of at least 100	No safety concern
Hexachlorobenzene	0.0587	0.00002	50	6.0×10^{8}	MOE of at least 100	No safety concern
Polyaromatic hydrocarbons	119	0.06	100	6.0×10^{5}	MOE of at least 10 000	No safety concern
PBDEs	9.9	0.01	100	7.2×10^{6}	MOE of at least 100	No safety concern
PCBs	18.7	0.03	5	1.9×10^{5}	MOE of at least 1000[d]	No safety concern



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Modified ACC-Human$_{STEADY}$ Food Web Model

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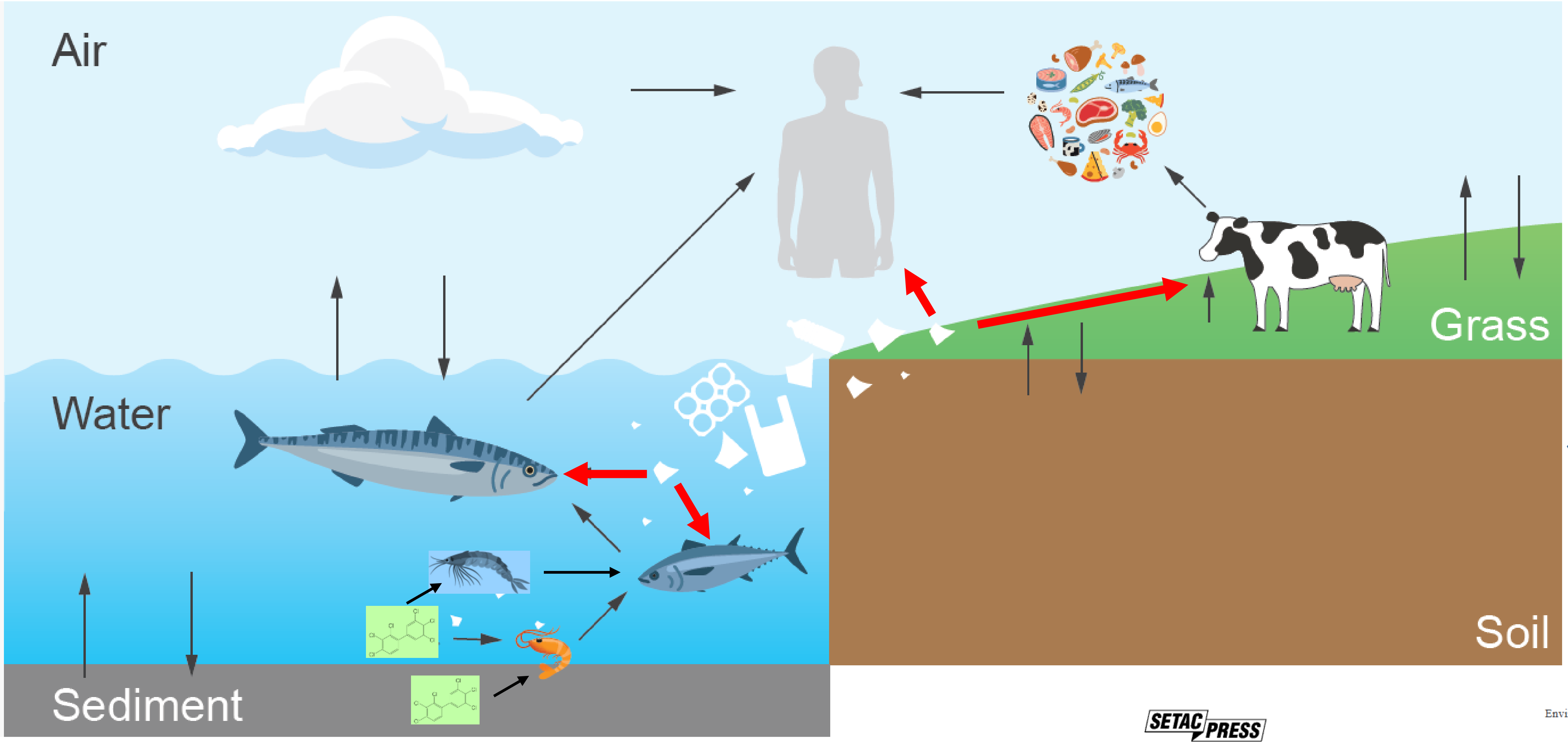

Steady-state, non-equilibrium (Level III) fugacity model for organisms.

Equilibrium assumed for chemicals in environmental media and plastic.

Plastic

Chemical

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Special Issue Honoring Don Mackay

A FOOD CHAIN MODEL TO PREDICT THE LEVELS OF LIPOPHILIC ORGANIC CONTAMINANTS IN HUMANS

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Chemical balance in the organism

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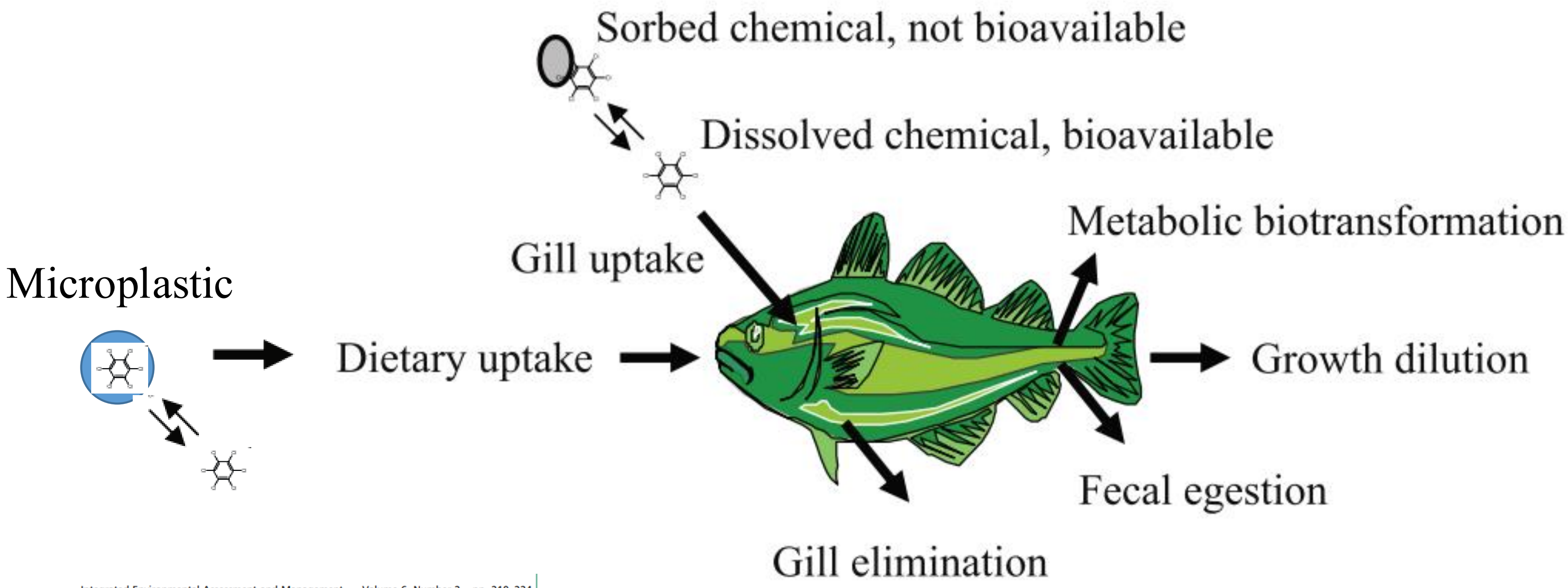

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Molecular Size Cutoff Criteria for Screening Bioaccumulation Potential: Fact or Fiction?

Jon A Arnot,*† Michelle I Arnot,‡ Don Mackay,† Yves Couillard,§ Drew MacDonald,§ Mark Bonnell,§ and Pat Doyle||

$$V_i . Z_i \frac{df_i}{dt} = \sum (D_{ji} . f_j) - f_i . \sum D_{ij}$$

RATE OF CHANGE IN MASS INPUTS OUTPUTS

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Assumptions about HOC behaviour with plastic

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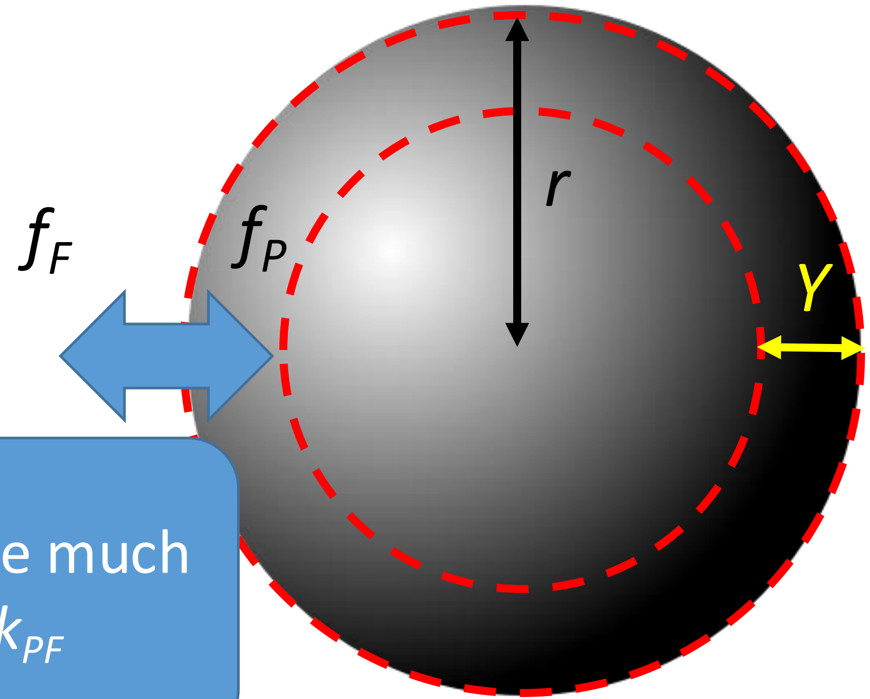
Plastic particles are PE spheres

In equilibrium with sea water ($K_{PE:W}$ from passive sampling)

Two film resistance model for PE-Gut mass transfer



$$\frac{1}{D_{PF}} = \frac{1}{D_P} + \frac{1}{D_F}$$

k_{FP} assumed to be much lower than k_{PF}

$Y = 1\ \mu\text{m}$

$B_P = 10^{-9} - 10^{-8}\ \text{m}^2\ \text{d}^{-1}$

$k_W >>> k_P = 0.1\ \text{m d}^{-1}$

So $k_{PF} \approx k_P$ *and* $D_{PF} \approx D_P$

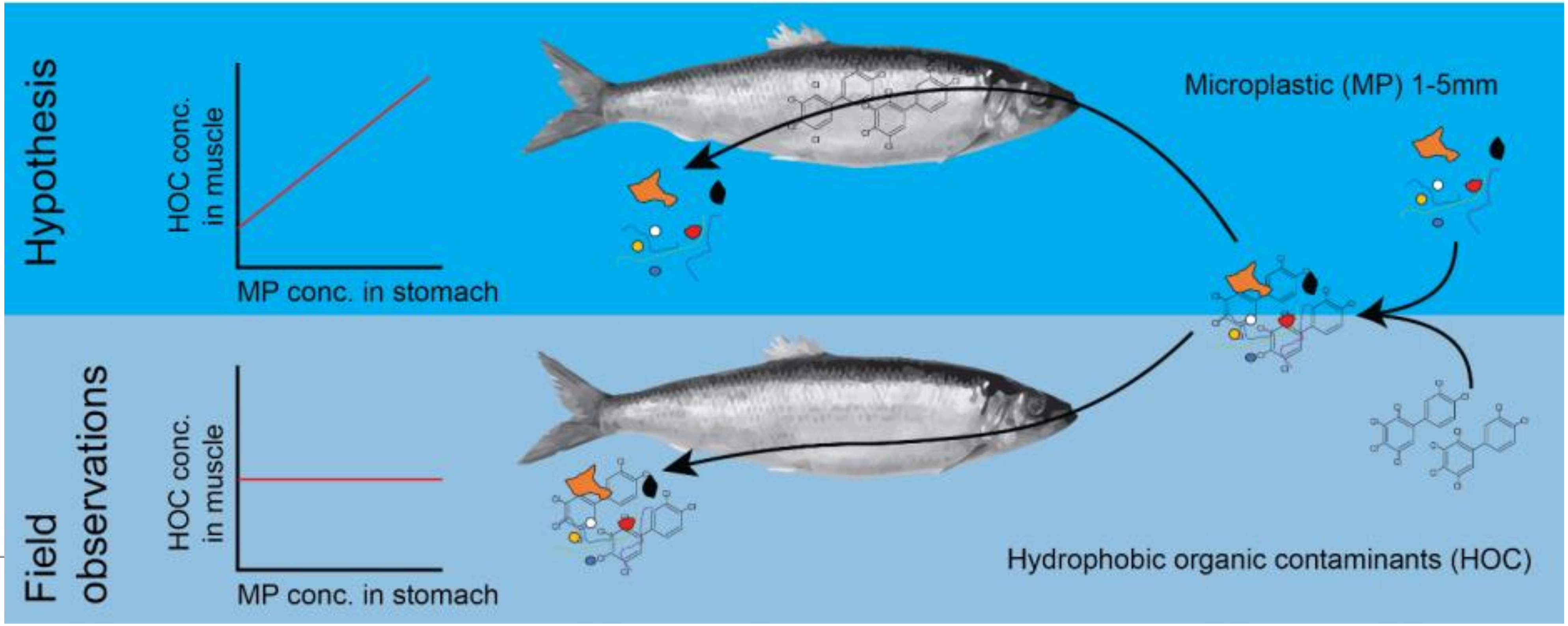
Su e area of MP

Mass of fish

$$D_{PF} = G_{PF}.Z_P = (k_{PF}.A_P.n_F.M_F).Z_W.K_{PW}$$

Number of MPs in fish

Some data suggest HOCs are *not* desorbed in fish



frontiers in Environmental Science

Microplastic Intake, Its Biotic Drivers, and Hydrophobic Organic Contaminant Levels in the Baltic Herring

Martin Ogonowski[1,2,3], Viktoria Wenman[1], Andreas Barth[4], Evelyne Hamacher-Barth[4], Sara Danielsson[5] and Elena Gorokhova[1*]*

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In Humans

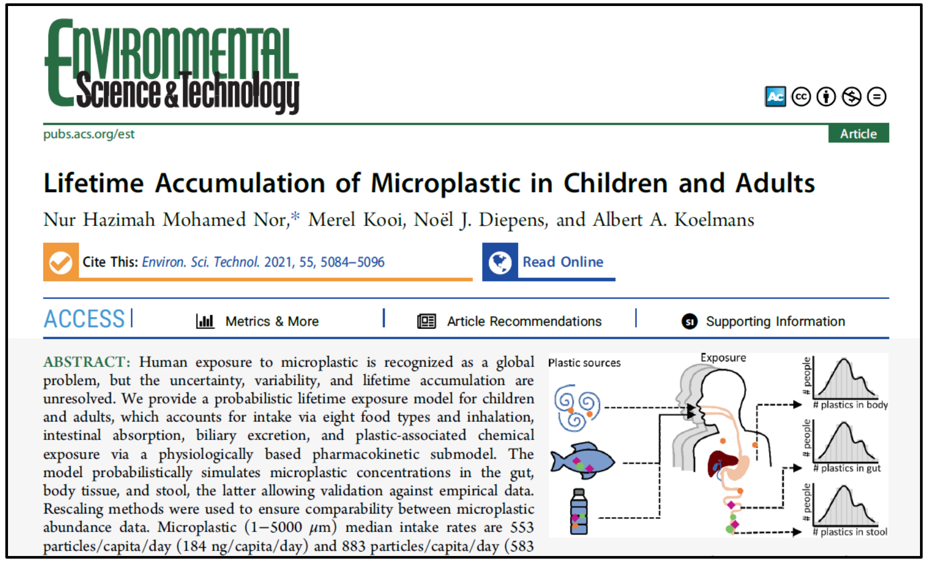
Ingestion = egestion (number of MPs per day)

$$I_P = E_P = mc_F . n_F \rightarrow n_H$$

Steady state number of MPs in the human

Mass of fish consumed by the human (kg d^{-1})

Number of MPs per kg fish


Environmental Science & Technology

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Article

Lifetime Accumulation of Microplastic in Children and Adults

Nur Hazimah Mohamed Nor,* Merel Kooi, Noël J. Diepens, and Albert A. Koelmans

Cite This: *Environ. Sci. Technol.* 2021, 55, 5084–5096

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ABSTRACT: Human exposure to microplastic is recognized as a global problem, but the uncertainty, variability, and lifetime accumulation are unresolved. We provide a probabilistic lifetime exposure model for children and adults, which accounts for intake via eight food types and inhalation, intestinal absorption, biliary excretion, and plastic-associated chemical exposure via a physiologically based pharmacokinetic submodel. The model probabilistically simulates microplastic concentrations in the gut, body tissue, and stool, the latter allowing validation against empirical data. Rescaling methods were used to ensure comparability between microplastic abundance data. Microplastic (1−5000 μm) median intake rates are 553 particles/capita/day (184 ng/capita/day) and 883 particles/capita/day (583

Assume fugacity in plastic (f_P) = fugacity in water (f_W)

Steady-state exposure + 1 day residence time in human

Model also enables relative comparison between exposure to hydrophobic organic chemicals via diet and air and what might occur via contaminated MPs

Scenarios

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1. PAC exposure *only* via ingestion of MPs containing 5% PAC MM^{-1} by
   (a) humans; (b) humans & fish; (c) humans, fish & cows

2. PAC exposure via the environment* and & MPs, which are ingested by
   (a) humans; (b) humans & fish; (c) humans, fish & cows

3. PAC exposure only via the environment* (no MPs present)

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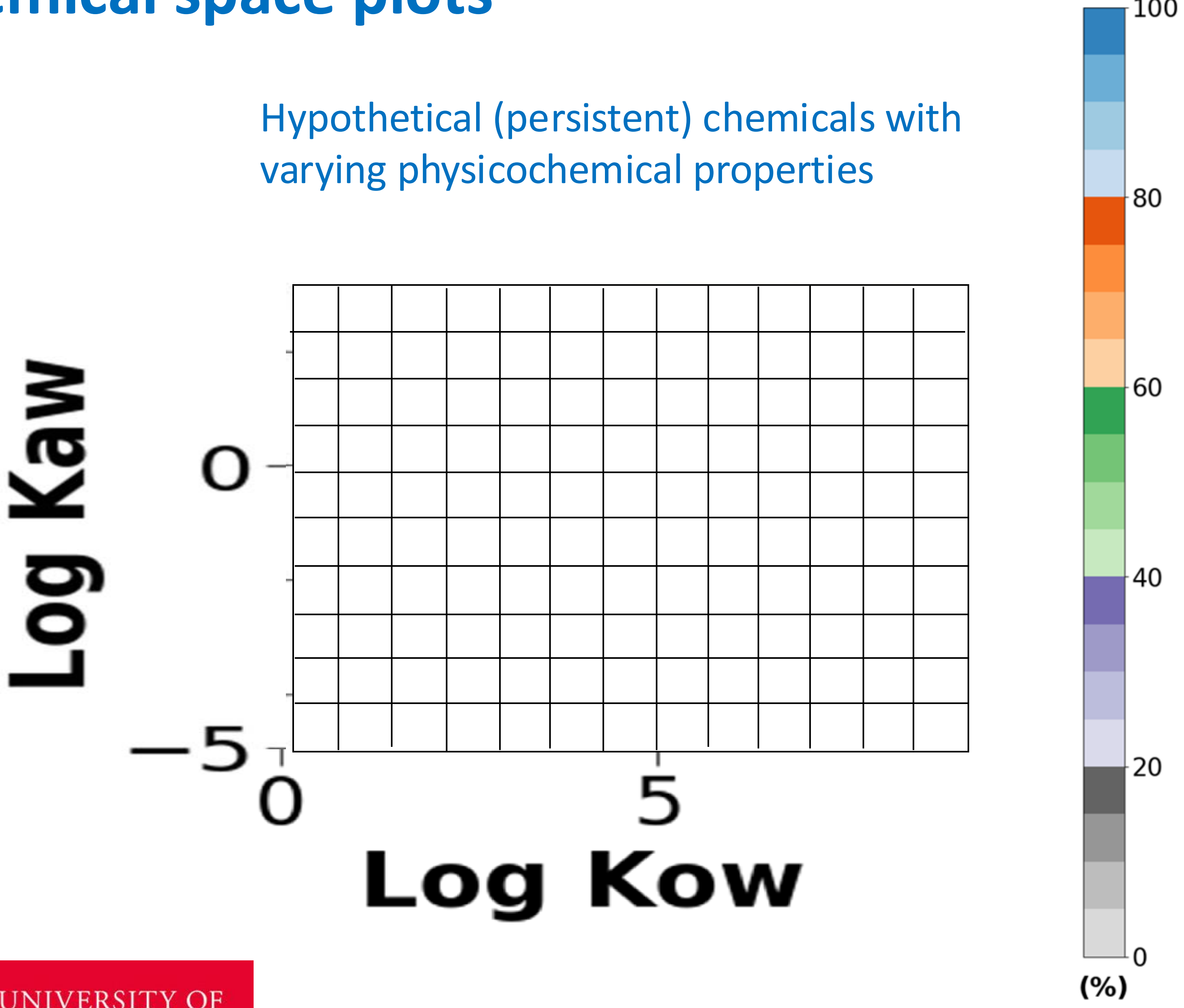
*Environmental exposures (Scenarios 2 & 3) assume all chemicals in all media & in MPs are at equilibrium with sea water (arbitrary conc = 1 ng L^{-1})

Chemical space plots

Hypothetical (persistent) chemicals with varying physicochemical properties



Relative contribution of MP ingestion to total chemical exposure for a given combination of chemical partitioning properties and for given assumptions about MP size and ingestion rate.

Illustrative examples mainly assume 1 μm MP size for 3 ingestion rates:

583 ng d^{-1}; 10 mg d^{-1}; 500 mg d^{-1}

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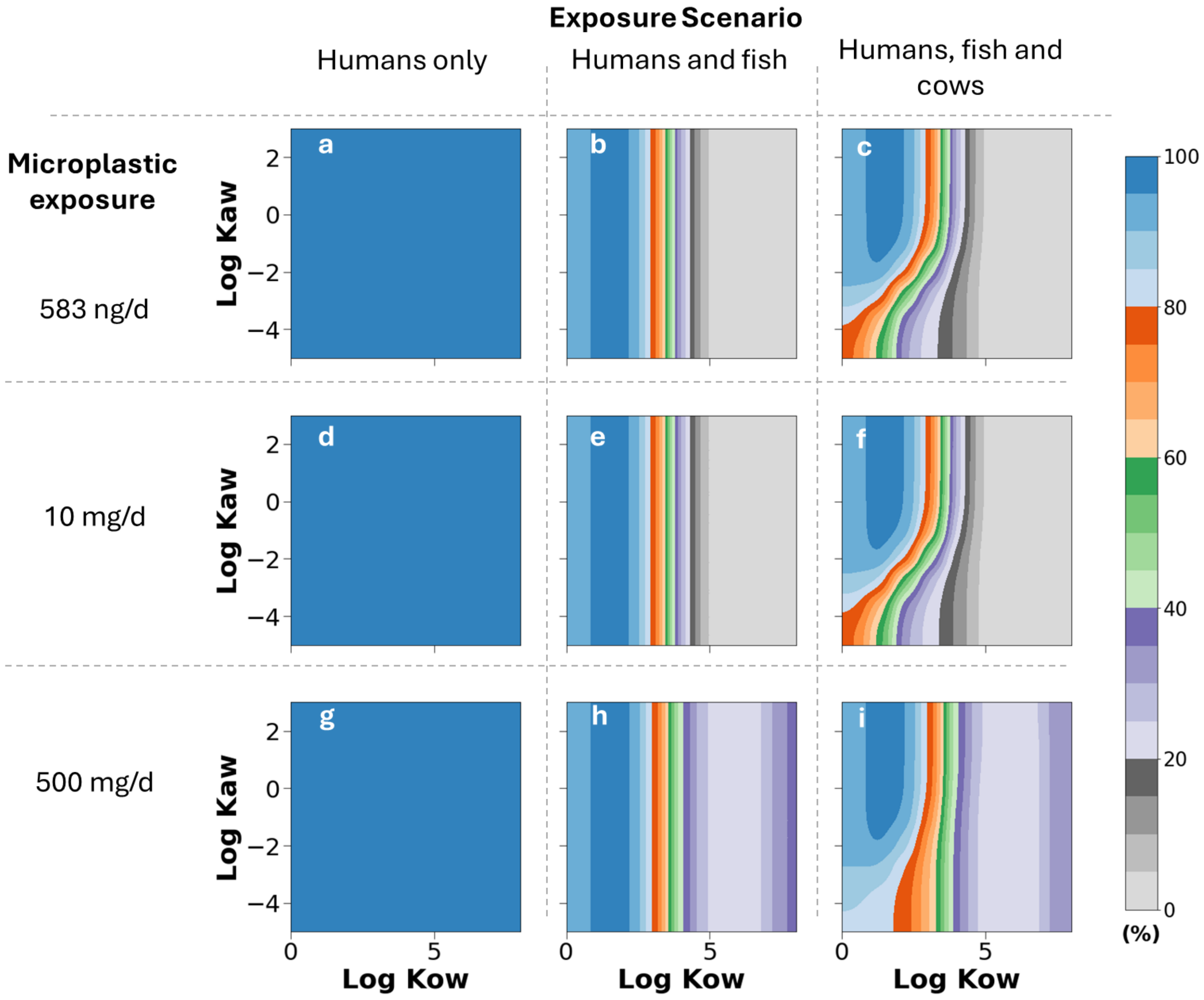
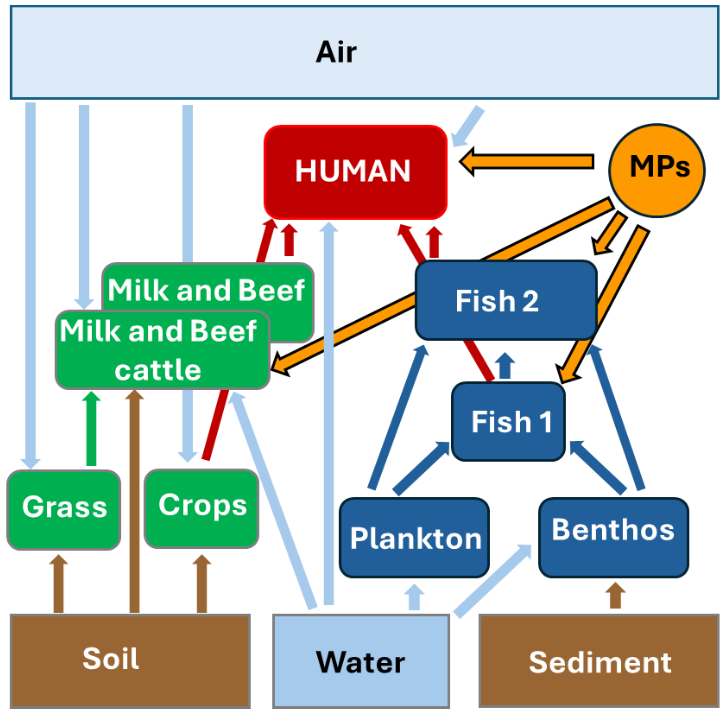
Scenario 1: Results





Relative MP contributions to exposure decrease as K_{OW} increases (biomagnification in food webs)

Scenario 2: Results

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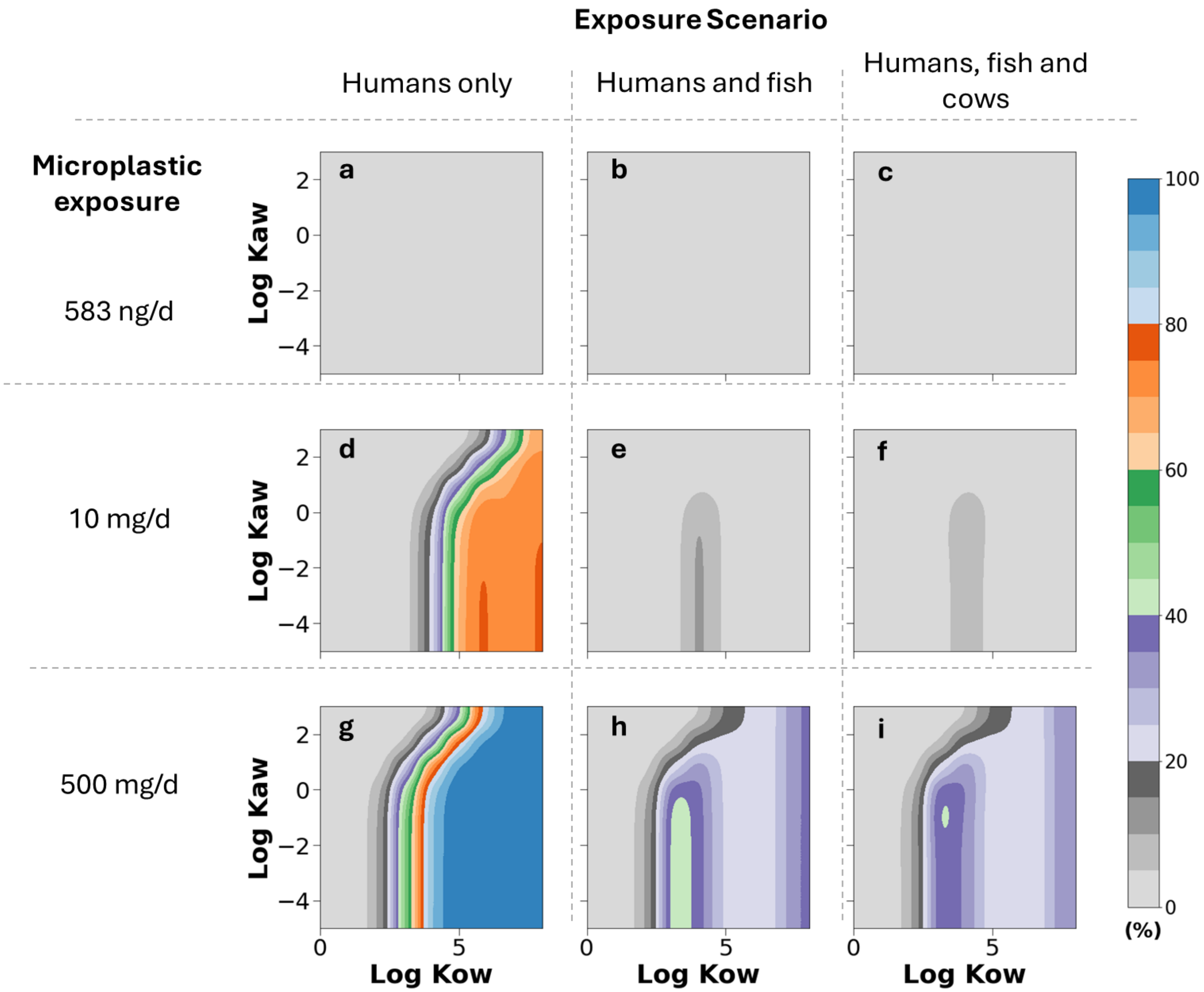

MP contribution to exposure increases with increased MP ingestion

Peak contribution around log K_{OW} 4

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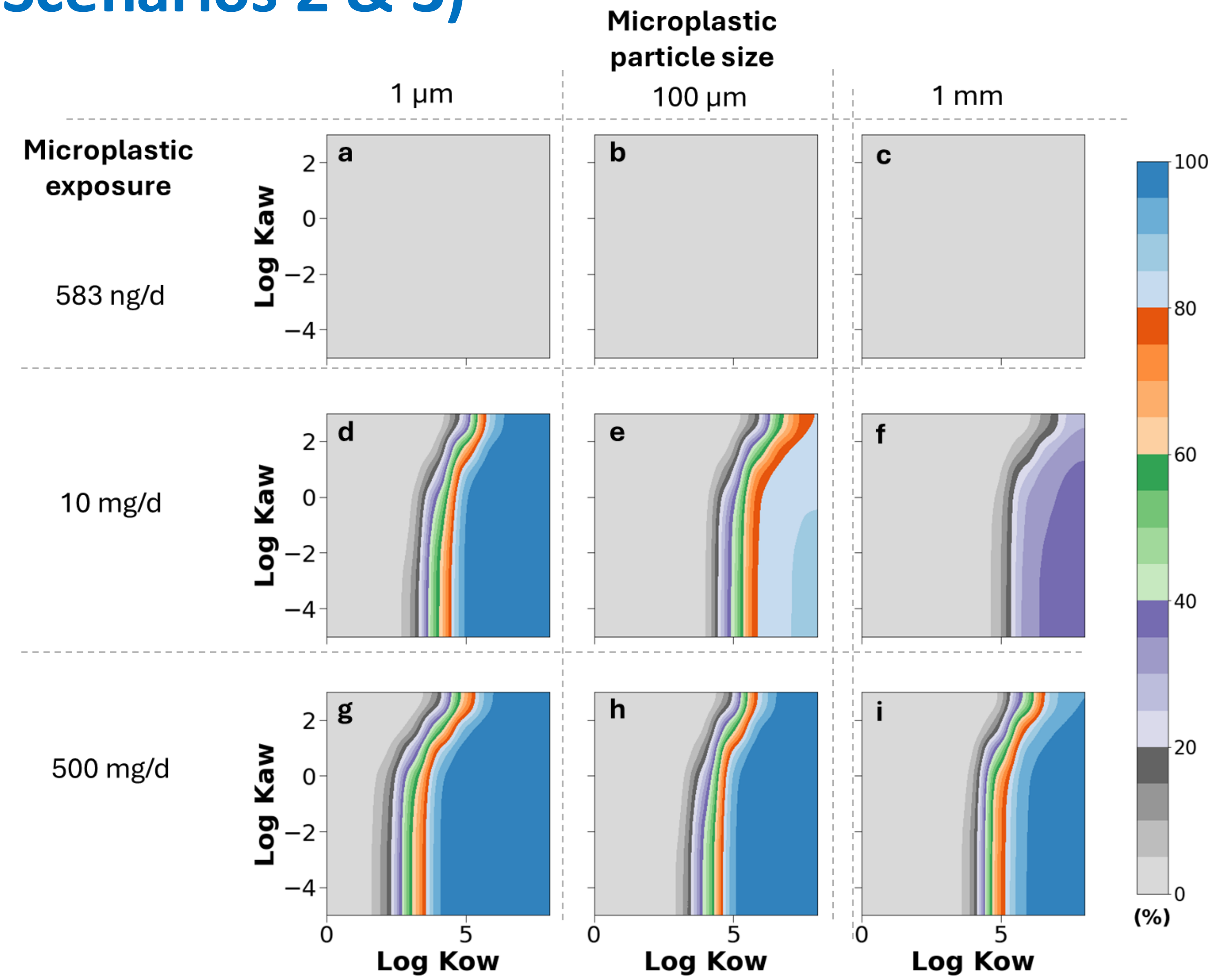
Relative contribution of MPs to PAC EDI (difference between Scenarios 2 & 3)



Absolute exposure and contribution of MPs to EDI decreases with increased particle size

MP contribution to relative PAC intake increases with increased K_{OW}

Application to Risk Assessment for specific PACs

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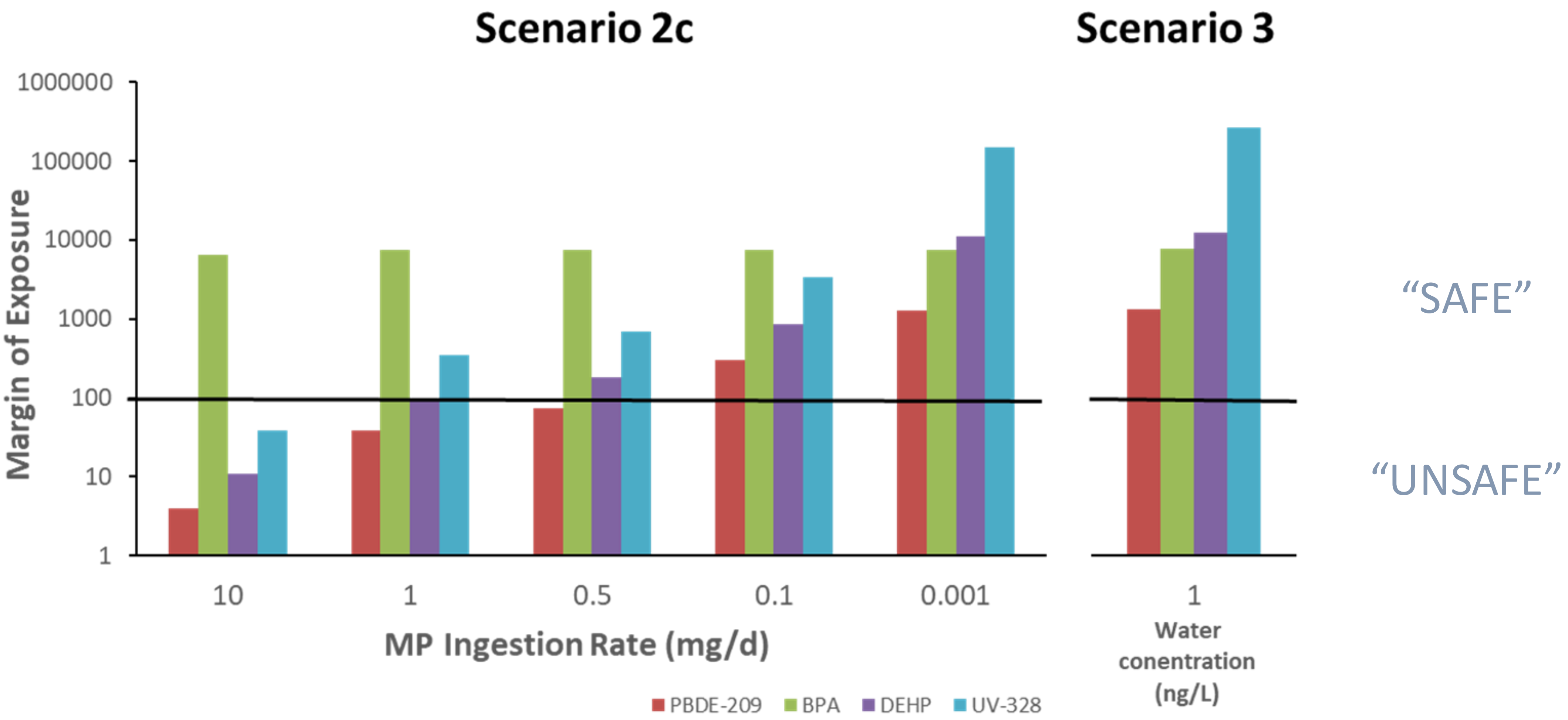

Relatively low K_{OW} so conc in MPs low

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Summary and next steps

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- Microplastics could act as vectors for PACs
- Modelling can provide an interpretive framework for
  - Comparing different exposure scenarios
  - Understanding the relative contribution of MPs to total exposure
  - Setting expectations about levels, sensitivity and uncertainty which can support field data collection and interpretation
  - Assessing risks
- Model outputs imply minor contribution of MPs to PAC exposure *cf* other exposure pathways
- Toxicological thresholds for PACs unlikely exceeded based solely on the ingestion of MP
- UNCERTAINTIES HIGH: Need to represent key inputs as probability distributions in Monte Carlo Simulations

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Thanks for Listening!

Acknowledgements

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We also thank Gertje Czub, Emma Undeman and Michael McLachlan from the University of Stockholm for making the *ACC-HUMAN*$_{STEADY}$ model available.

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