

2025 MARII Summit on Microplastics

Beyond Microplastic Ingestion: A Multidimensional Analysis of Human Exposure to Plastic Additive Chemicals

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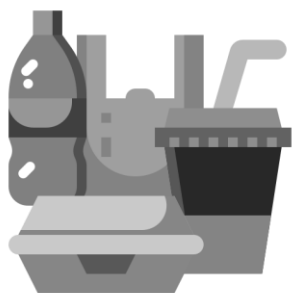


Micro vs. Macro Aspects of the Additives in Plastics Issue



14 million metric tons of plastic additive chemicals*

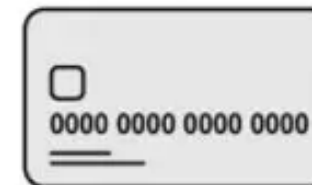
since 1950, identified as POPs and regulated by the Stockholm Convention
(Li et al. *Environ. Sci. Adv.* 2023, 2, 55-68)



7,000 million metric tons of plastics

since 1950 (Estimate according to Statista)

Total plastic ingested = 5g



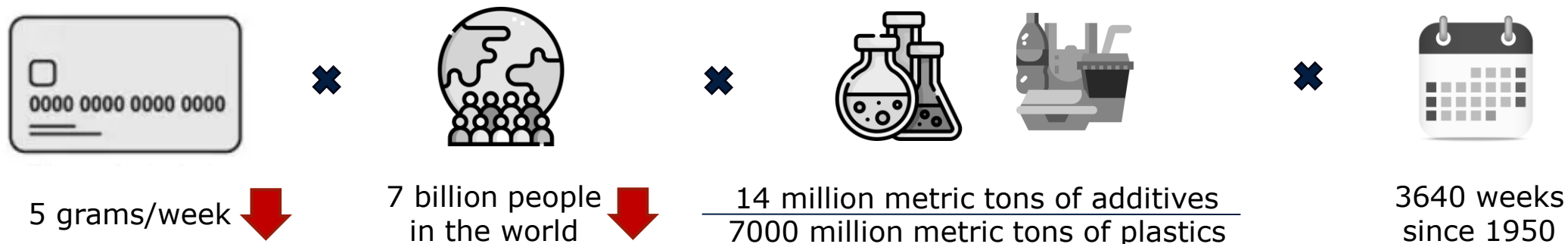
The equivalent of
one credit card

“One credit card per week”

(shown to be a 1,000x to 1,000,000x overestimate by later studies)
(Senathirajah et al. *J. Hazard. Mat.* 2021, 404, 124004)

* This estimate includes PBDEs, HBCDDs, PCBs, and SCCPs

Where is the Majority (98%) of These Plastic Additive Chemicals?



0.3 million tons of plastic additive chemicals
potentially taken by the world's population

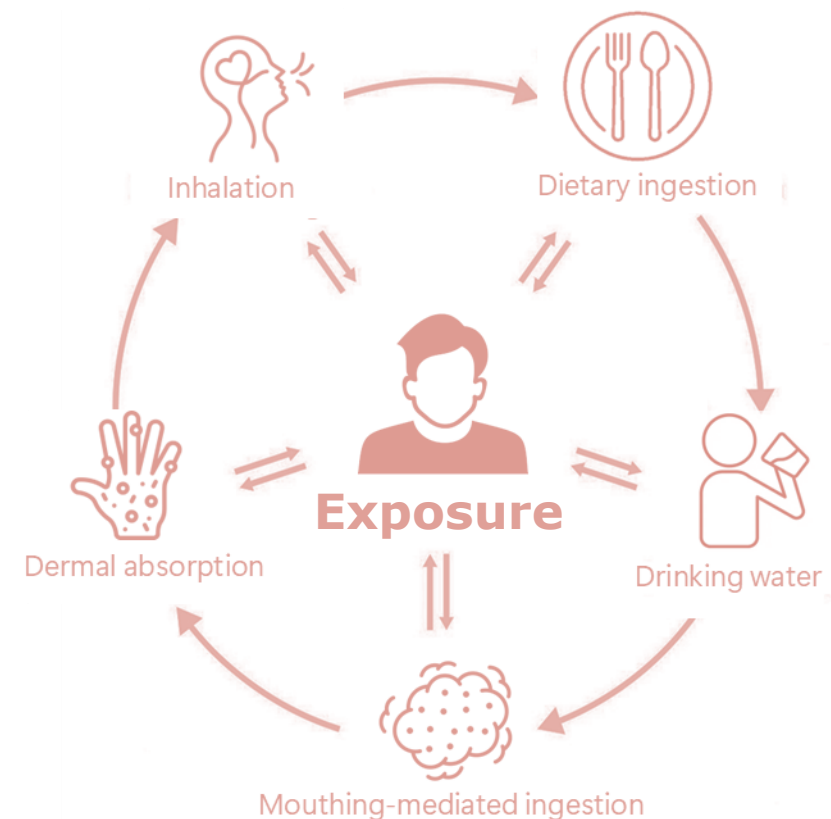
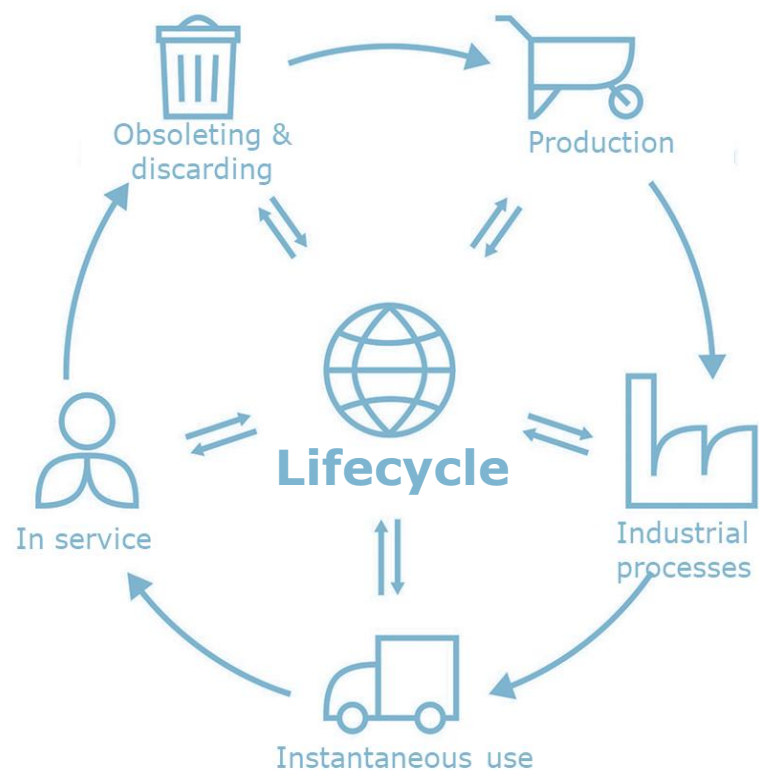
The actual number is expected to be much lower than this



This image is generated by DALL-E artificial intelligence

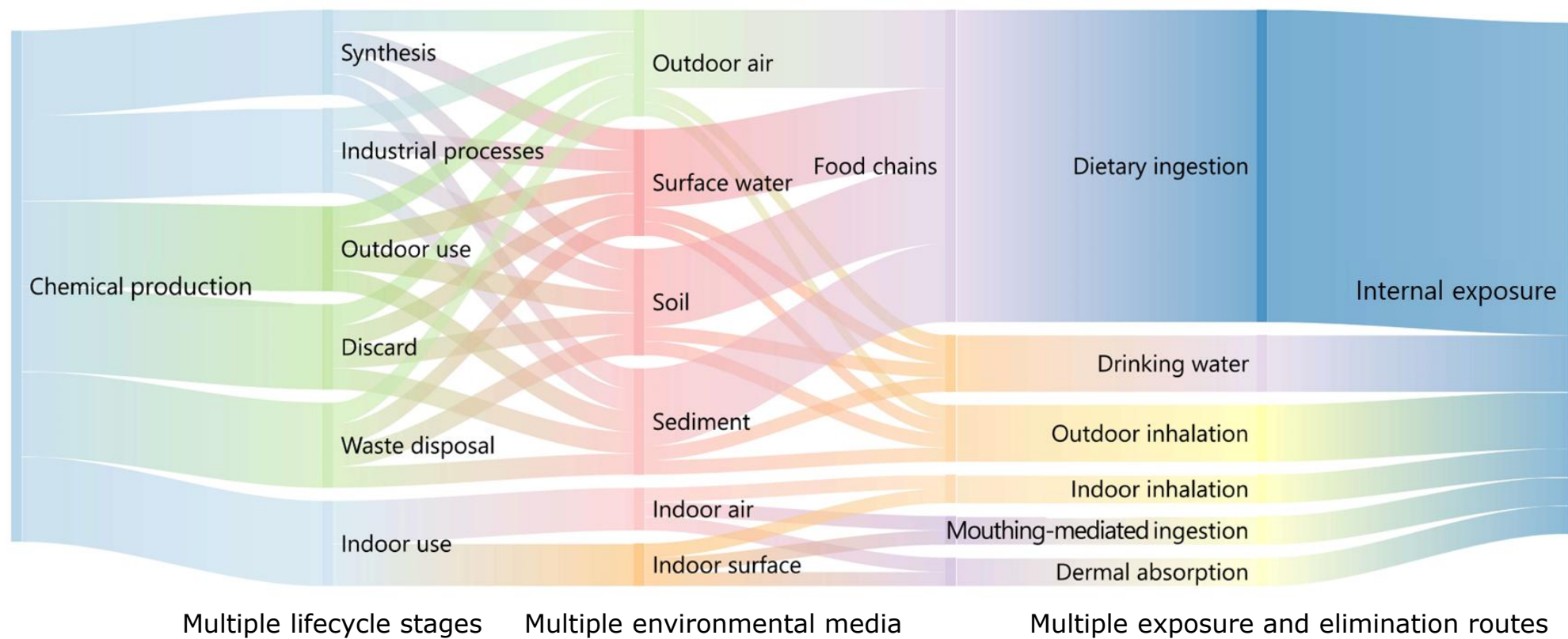
Multidimensionality of Exposure

- Humans are exposed to chemicals released from multiple lifecycle sources through multiple pathways of intake.



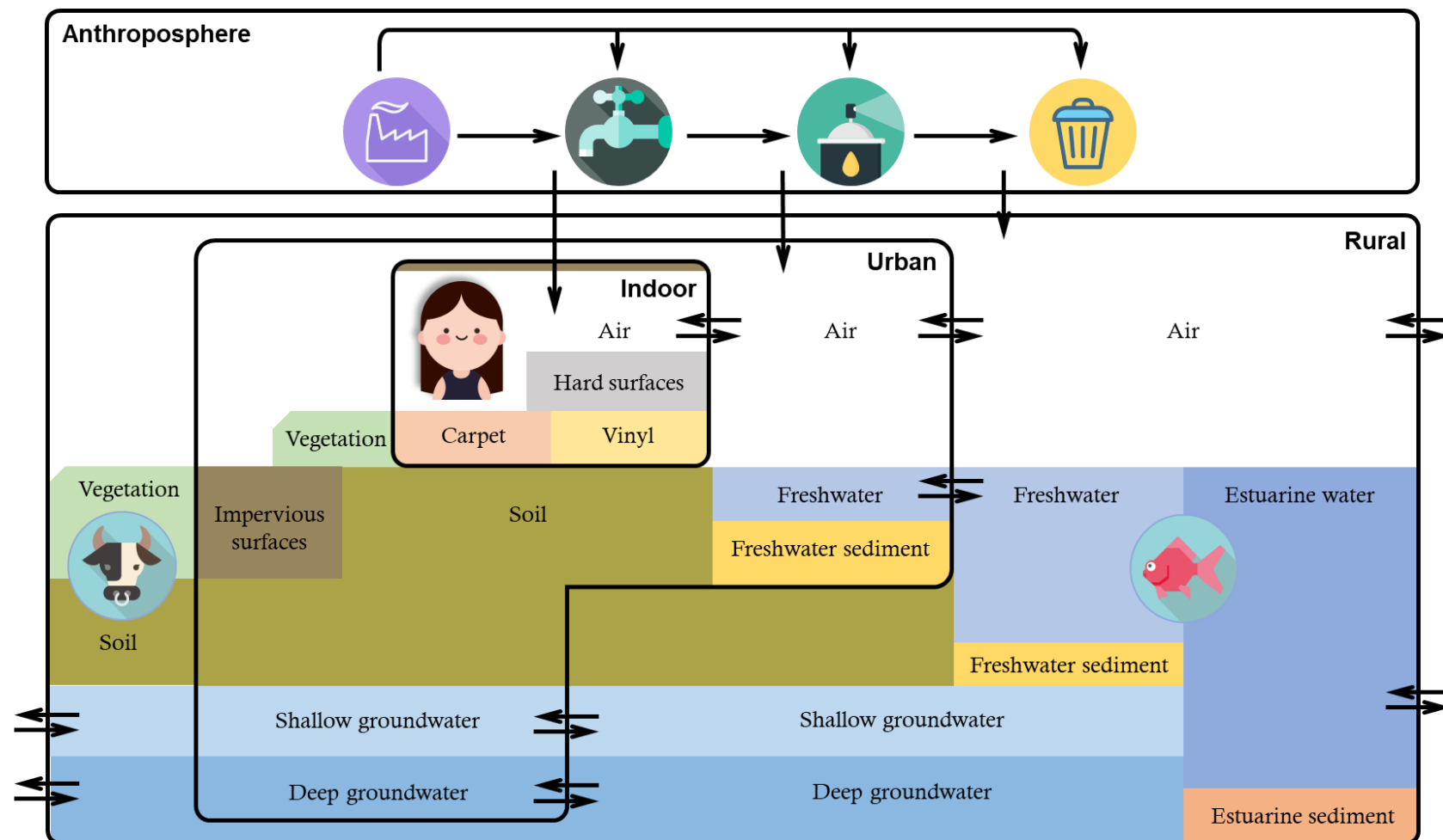
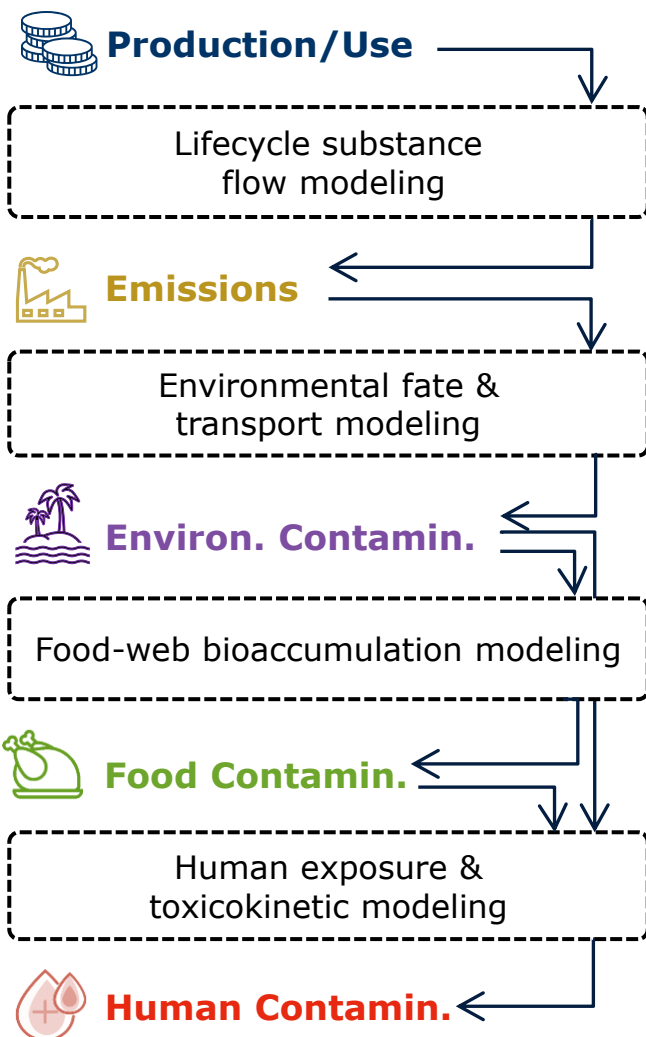
Multidimensionality of Exposure

○ “Production-to-exposure” continuum

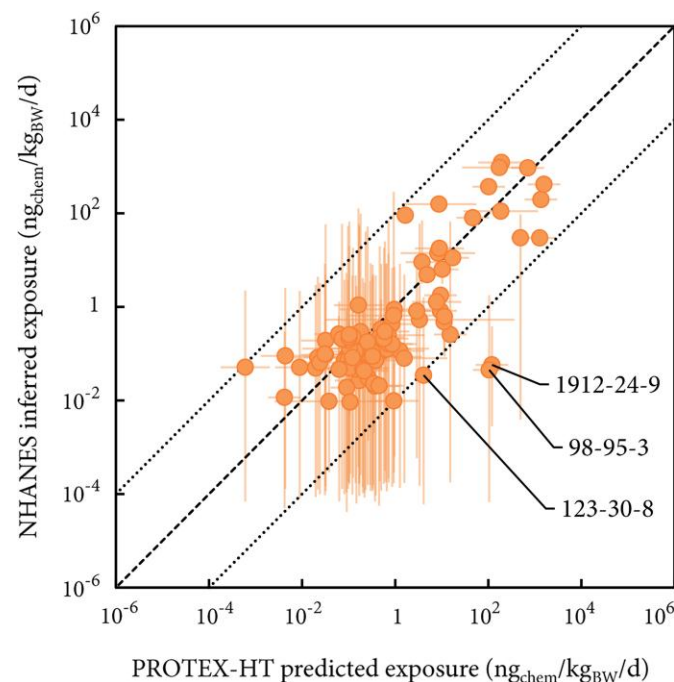


PROTEX: From the PROduction Line TO the EXposure Levels

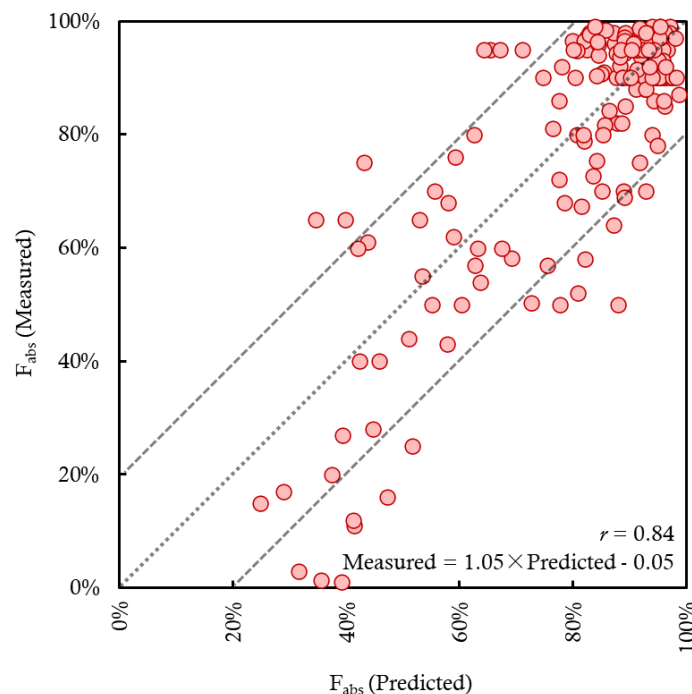
Scan this QR code for
more info about PROTEX



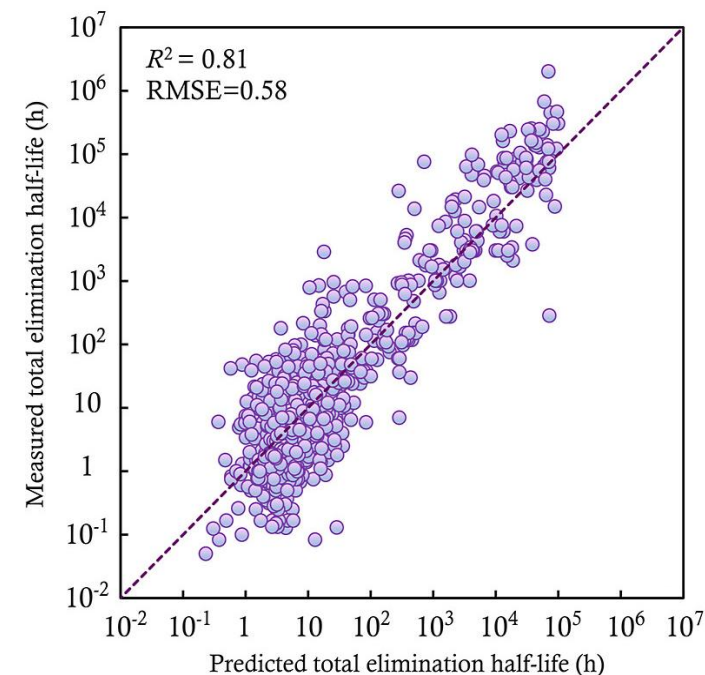
PROTEX's Reasonable Prediction Performance: Examples



 **Predicted vs. observed exposure rate data for 95 chemicals**
(Scan this QR code for more info)



 **Predicted vs. observed absorption data for 176 chemicals**
(Scan this QR code for more info)



 **Predicted vs. observed elimination data for 1100 chemicals**
(Scan this QR code for more info)

Multidimensionality of Exposure

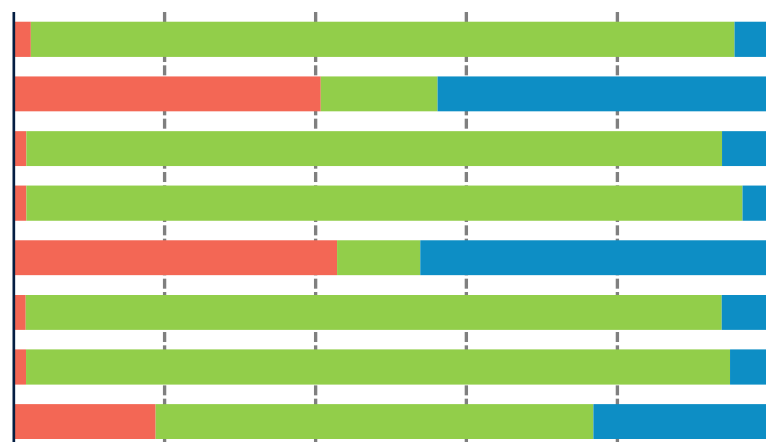
Scan this QR code to read the full text of the paper



- Humans are exposed to phthalates released from multiple lifecycle sources through multiple pathways of intake.

Release from lifecycle sources in the U.S.

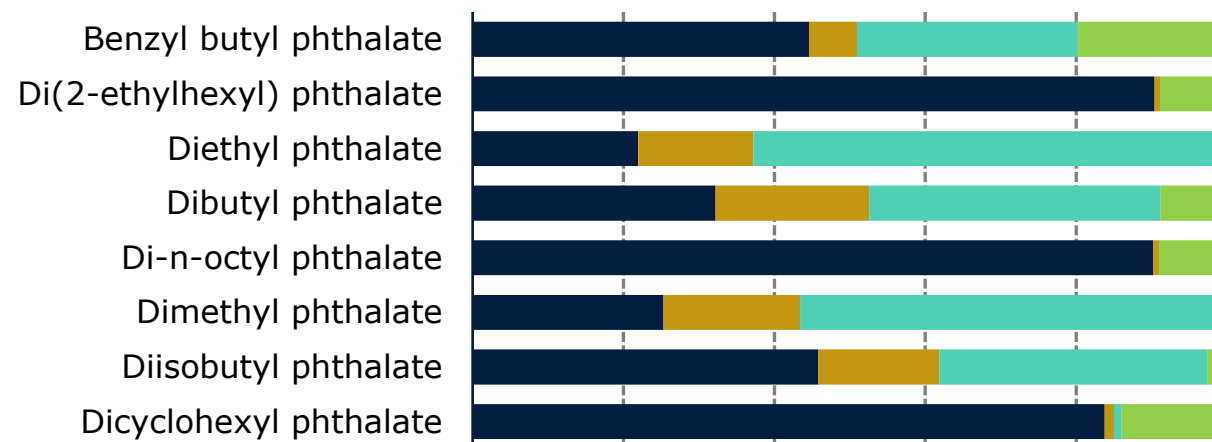
0% 20% 40% 60% 80% 100%



■ Production
■ Industrial processes
■ Instantaneous use
■ In service
■ Obsolete & discarding
■ Waste disposal

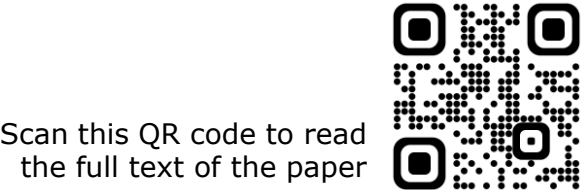
Pathways of the general Americans' exposure

0% 20% 40% 60% 80% 100%

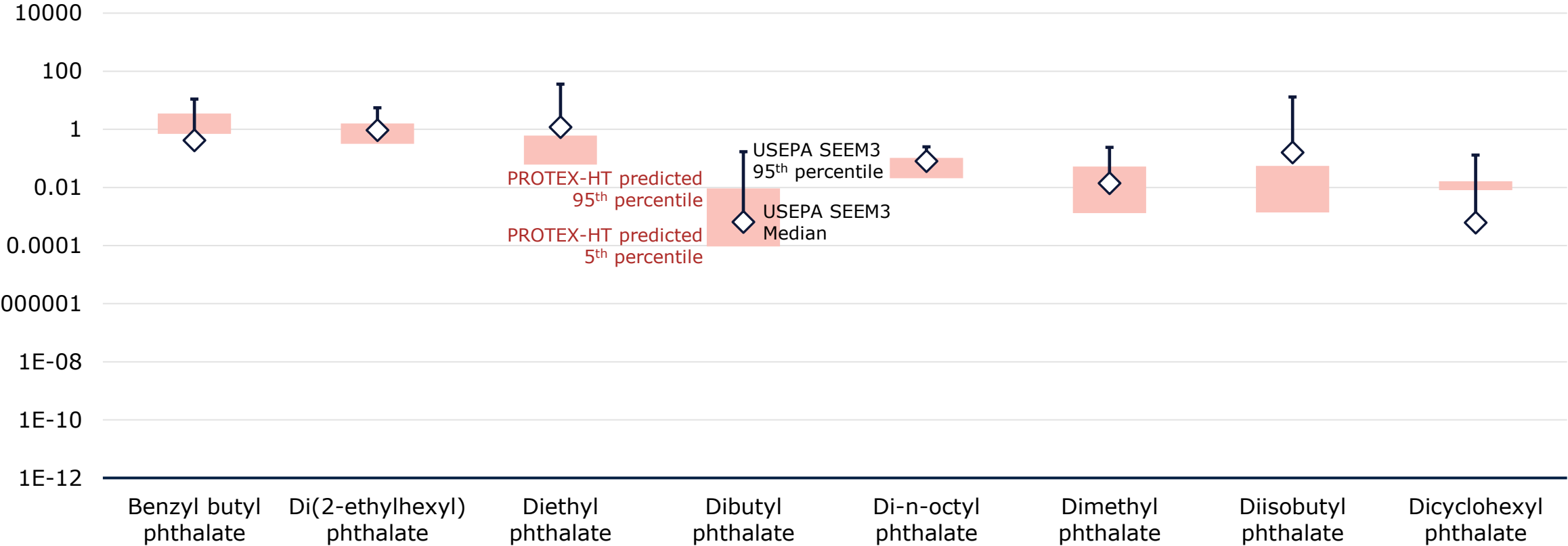


■ Dietary ingestion
■ Drinking water
■ Inhalation
■ Dermal absorption
■ Mouthing-mediated ingestion

Human Exposure to Phthalates



Average daily dose (All pathways other than consumption of microplastics)
($\mu\text{g}_{\text{chemical}}/\text{kg}_{\text{bodyweight}}/\text{d}$)



Estimating Human Exposure through Microplastic Ingestion

Chemical uptake through ingestion of microplastics

=

Ingestion rate of microplastics

x

Chemical mass fraction

x

Leaching fraction

Max estimate
(unrealistic worst case)

Mid estimate
(most plausible)

Min estimate
(unrealistic)

5 g/wk
(Order of magnitude proposed by Senathirajah et al. *J. Hazard. Mat.* 2021, 404, 124004)

5 mg/wk
(Order of magnitude proposed by Pletz *J. Hazard. Mat. Lett.* 2022, 3, 100071)

5 µg/wk
(Order of magnitude proposed by Mohamed Nor et al. *Environ. Sci. Technol.* 2021, 55, 5084-5096)

Maximum
(Collected measurements in in-use plastics by Aurisano et al. *Environ. Int.* 2021, 146, 106194)

Geometric mean
(Collected measurements in in-use plastics by Aurisano et al. *Environ. Int.* 2021, 146, 106194)

Minimum
(Collected measurements in in-use plastics by Aurisano et al. *Environ. Int.* 2021, 146, 106194)

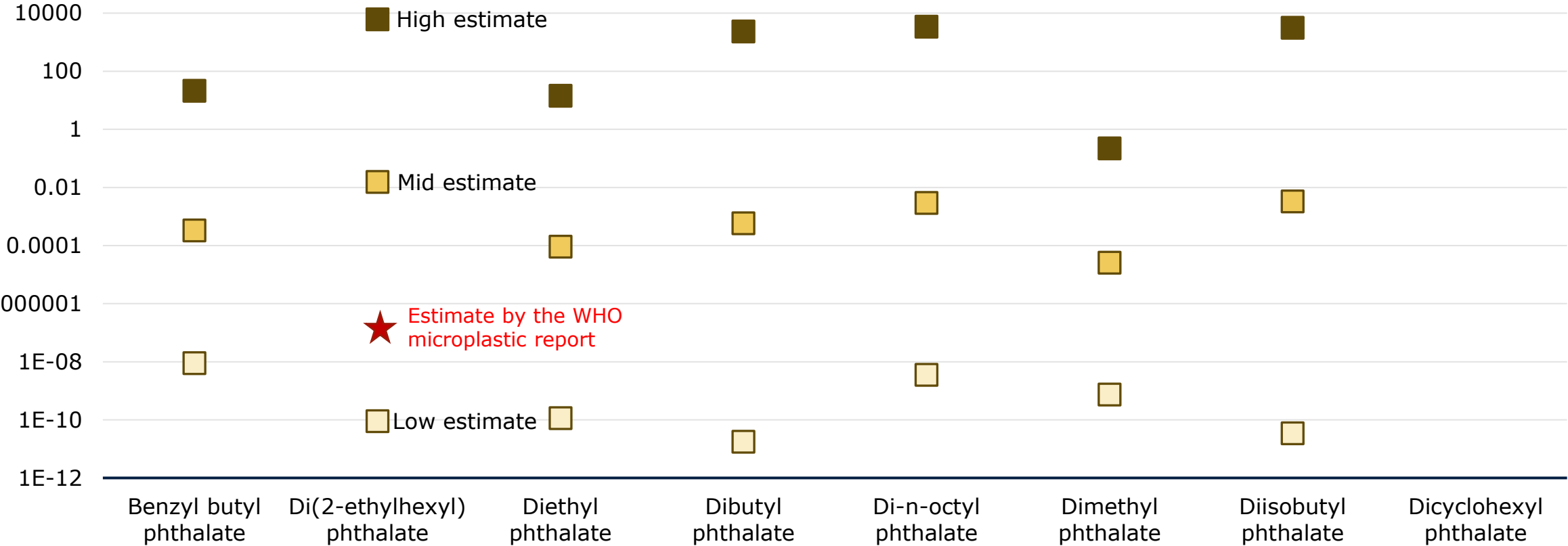
100%

50%

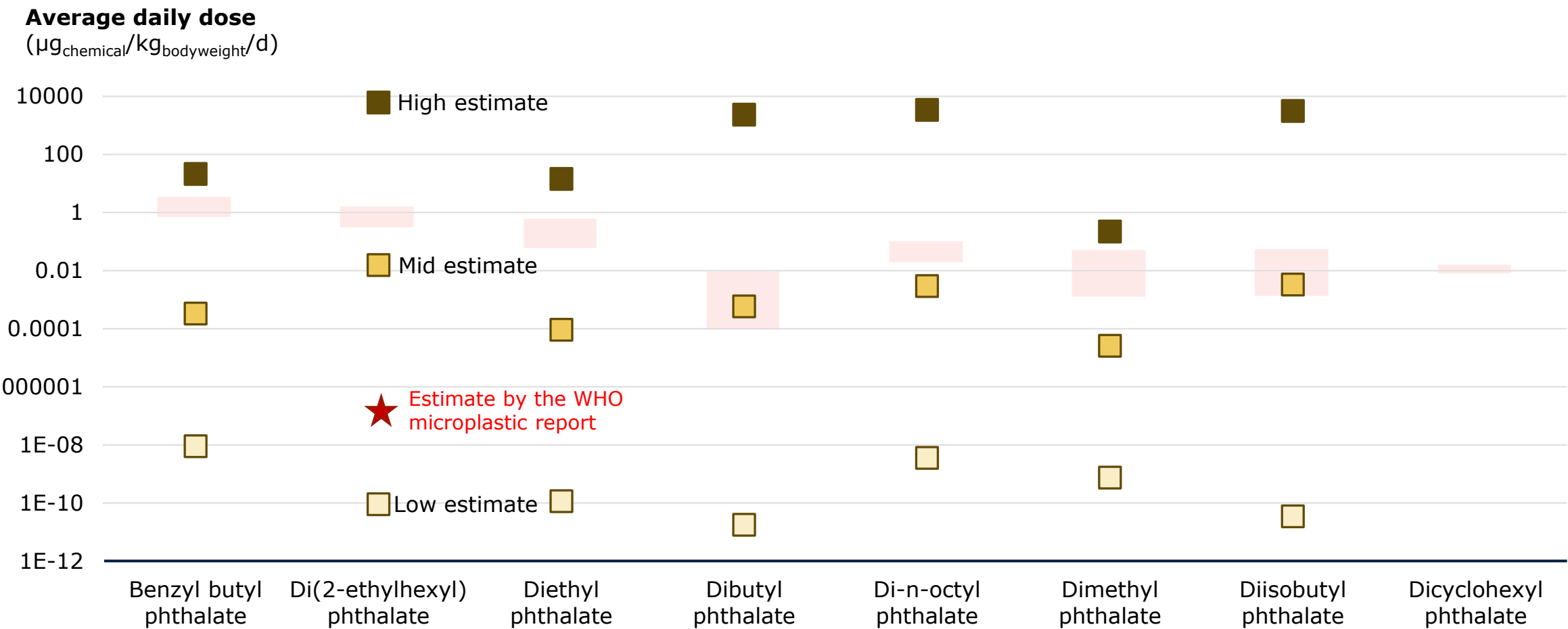
10%

Human Exposure to Phthalates

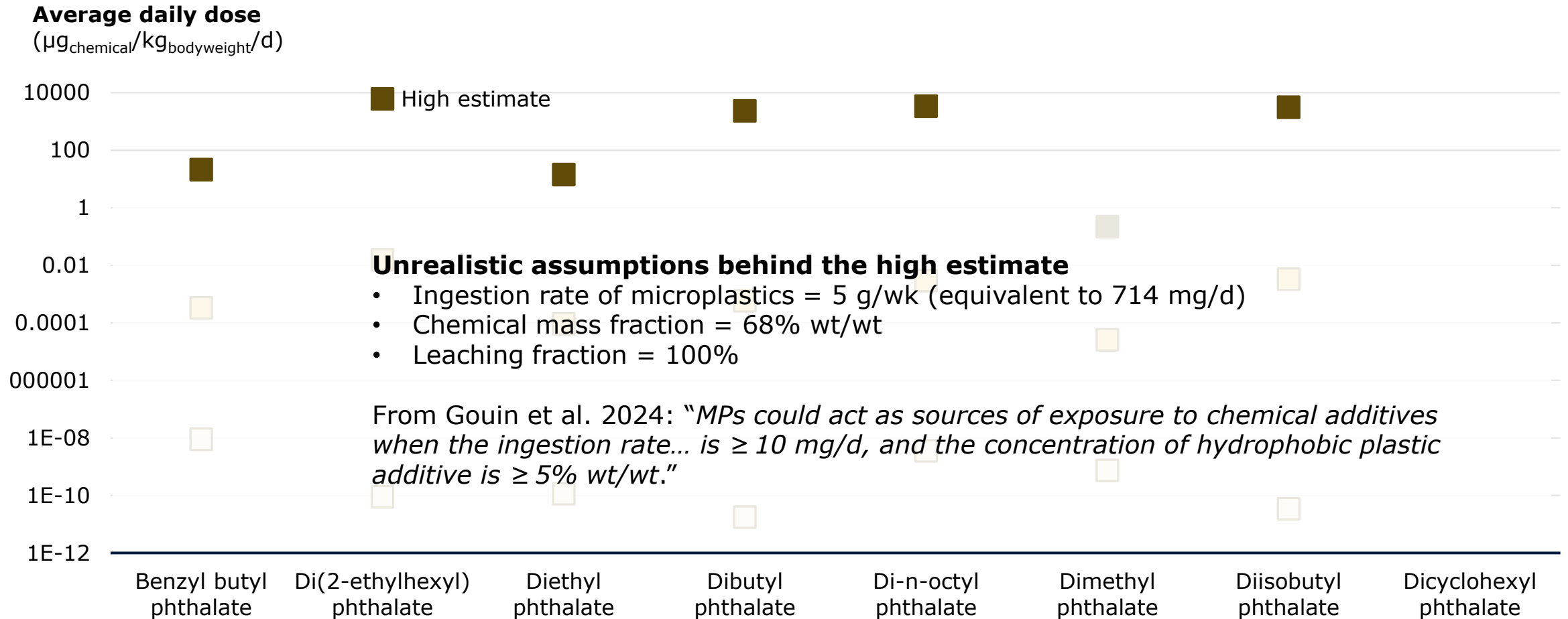
Average daily dose (Consumption of microplastics, with different levels of conservativeness)
($\mu\text{g}_{\text{chemical}}/\text{kg}_{\text{bodyweight}}/\text{d}$)



Human Exposure to Phthalates



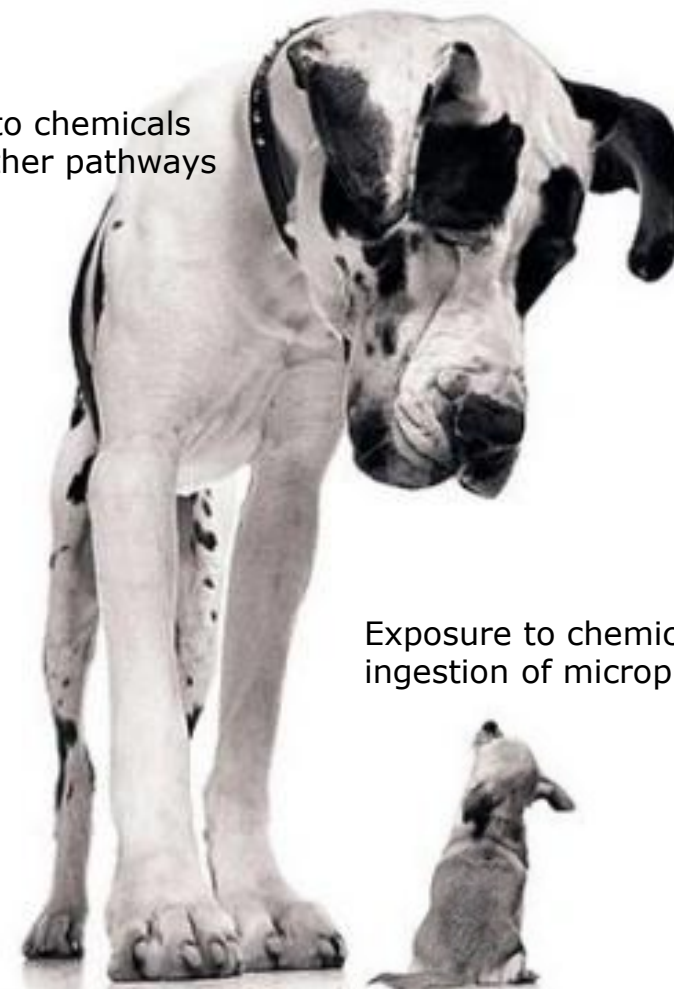
Human Exposure to Phthalates



Take-home messages

- The current understanding of human exposure to plastic additive chemicals via ingestion of microplastics is marked by significant uncertainty
- Environmental systems modeling help avoid a blurred impression of the relative magnitudes of releases from multiple lifecycle sources, the distribution of chemicals across multimedia environments at multiple scales, and the contributions of multiple exposure sources.

Exposure to chemicals through other pathways



Exposure to chemicals through ingestion of microplastics



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