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UNIVERSITY OF LISBON
INTERDISCIPLINARY STUDIES
ON SUSTAINABLE ENVIRONMENT AND SEAS

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UNITE! University Network for Innovation, Technology and Engineering

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Co-funded by the Erasmus+ Programme of the European Union

Nanoplastics and Health
Where do we stand in Toxicology research and Risk Assessment?

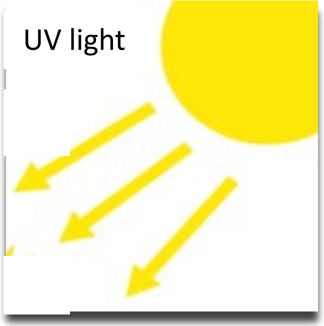
Vasco Branco, 2021
Research Institute for Medicines (iMed.ULisboa), Faculty of Pharmacy
University of Lisbon

Co-funded by the Erasmus+ Programme of the European Union

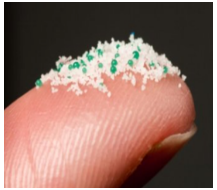
What are nanoplastics? Where do they come from?

Macroplastics (size>5 mm)

Organism level effects
e.g. Impaired feeding, motility and breathing;



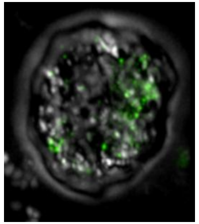
Microplastics (5 mm>size>100 nm)



Organism and tissue level effects
e.g. bruising, damage to epithelia;

Fragmentation and degradation

Nanoplastics (size< 100 nm)



Cellular and Molecular level effects
e.g. oxidative stress, inflammation;

Bioconcentration, bioaccumulation, biomagnification?

How much nanoplastic exists in the ocean?

We don’t know!

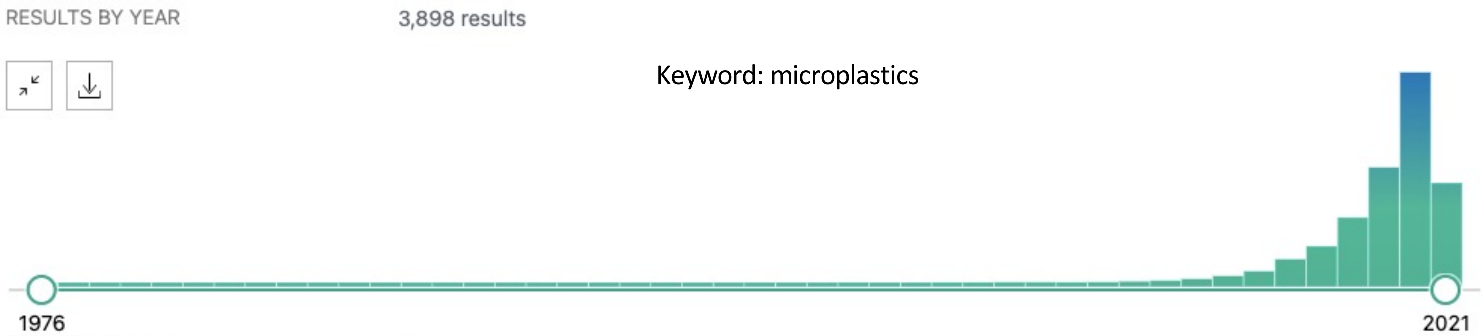
And in seafood?

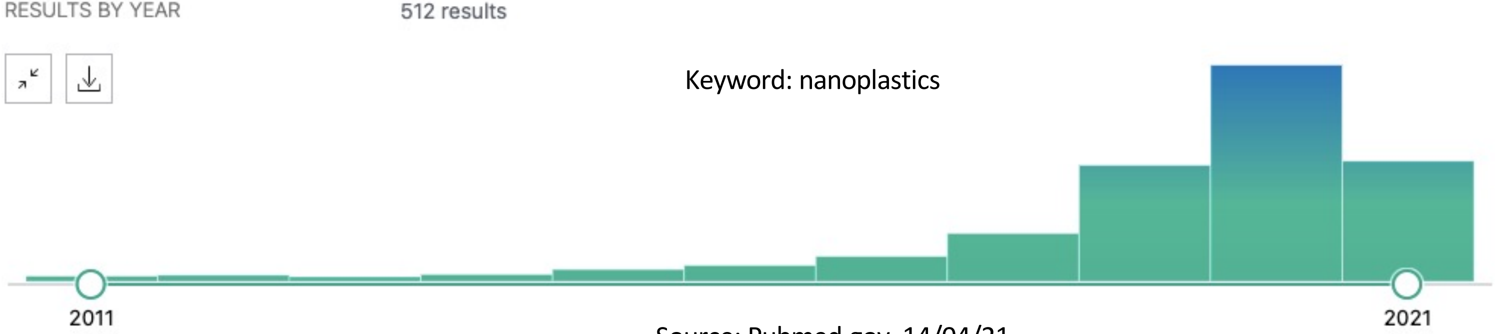
We don’t know!

What’s the impact over wildlife and humans?

We don’t know!

What is Science doing about it?





Source: Pubmed.gov 14/04/21.

What is Science doing about it?

STATEMENT

EFSA Journal

ADOPTED: 11 May 2016

doi: 10.2903/j.efsa.2016.4501

Presence of microplastics and nanoplastics in food, with particular focus on seafood

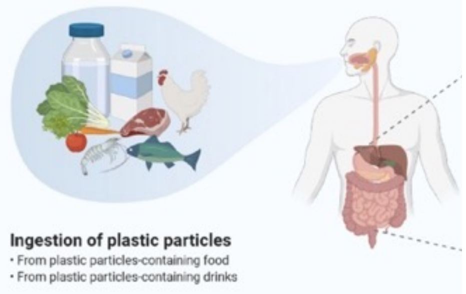
EFSA Panel on Contaminants in the Food Chain (CONTAM)

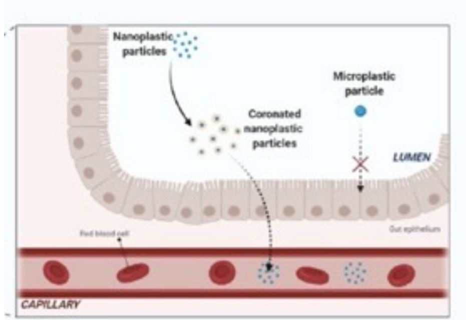
5.2. Nanoplastics

- Analytical methods should be developed and standardised, in order to assess their presence, identity (including shape) and to quantify their amount in food. Quality assurance should be in place and demonstrated.
- Occurrence data in food should be generated in order to assess dietary exposure.
- Research on the toxicokinetics and toxicity are needed.

Exposure routes

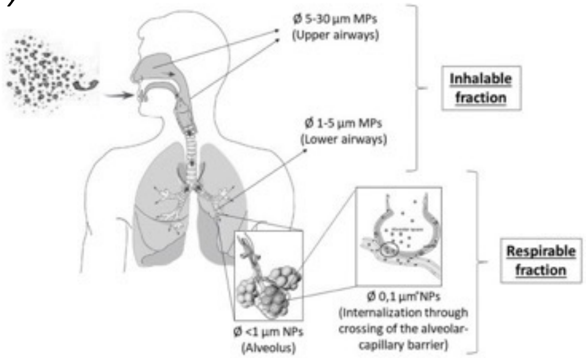
Oral





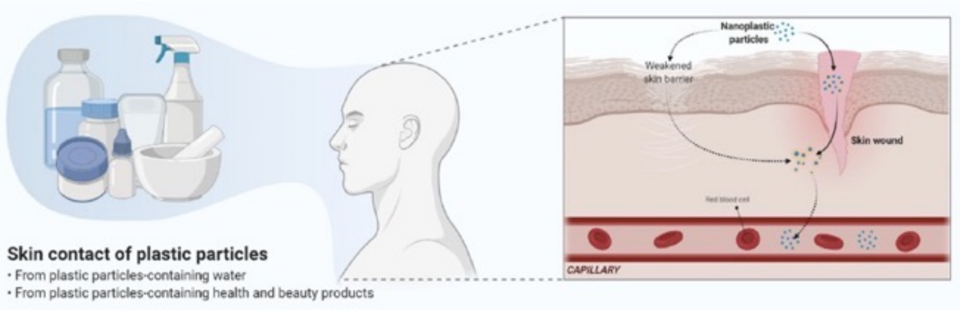
Source: Yee et al., 2021, Nanomaterials, DOI: 10.3390/nano11020496.

Respiratory



Source: Facciolà et al., 2021, IJERPH, DOI: 10.3390/ijerph18062997

Dermal

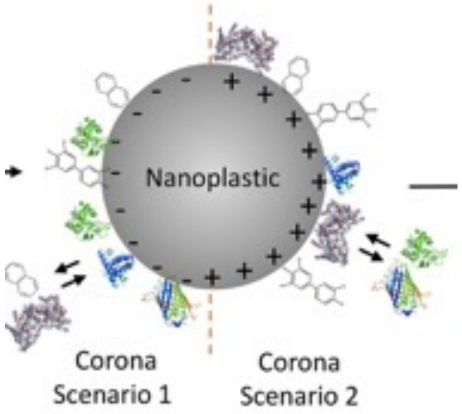


What are the implications of the nanoscale size?

The nanoscale size allows penetration of tissues and cells

Much higher bioavailability than microplastics

The relative surface area is larger increasing the number of potential interaction sites



Source: Kihara et al et al., 2021, Adv. Coll. Inter. Science, DOI: 10.1016/j.cis.2020.102337

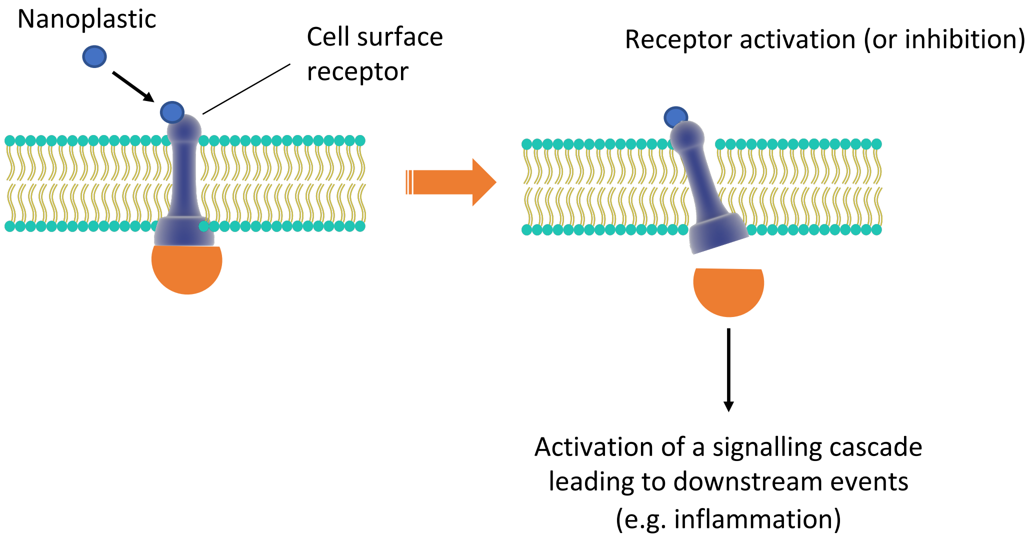
What are the major problems of nanoplastics?

1) Direct effects caused by the plastic nanoparticle

2) Leaching of plastic additives

3) Adsorption and release of other xenobiotics

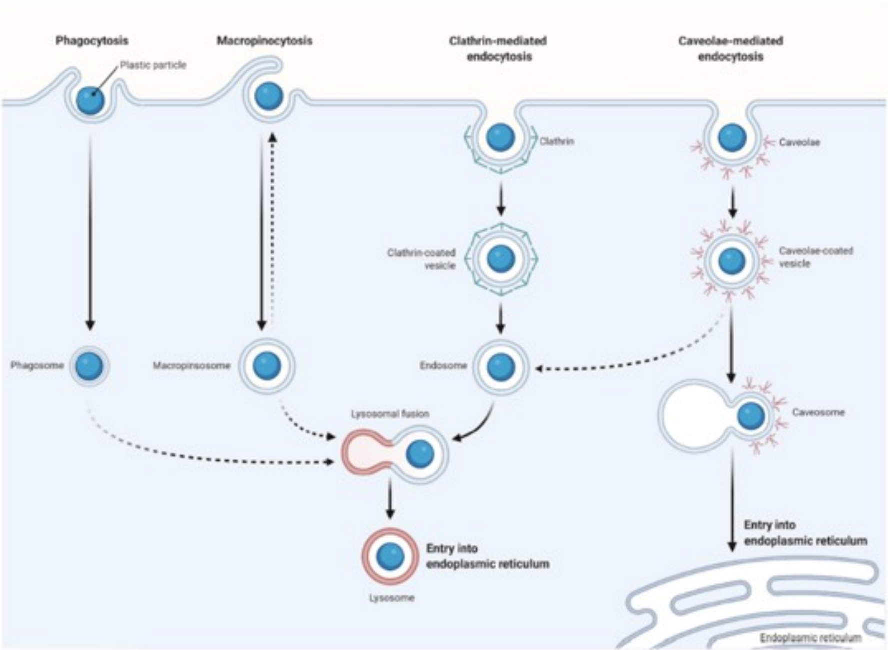
- Interaction with cell surface receptors



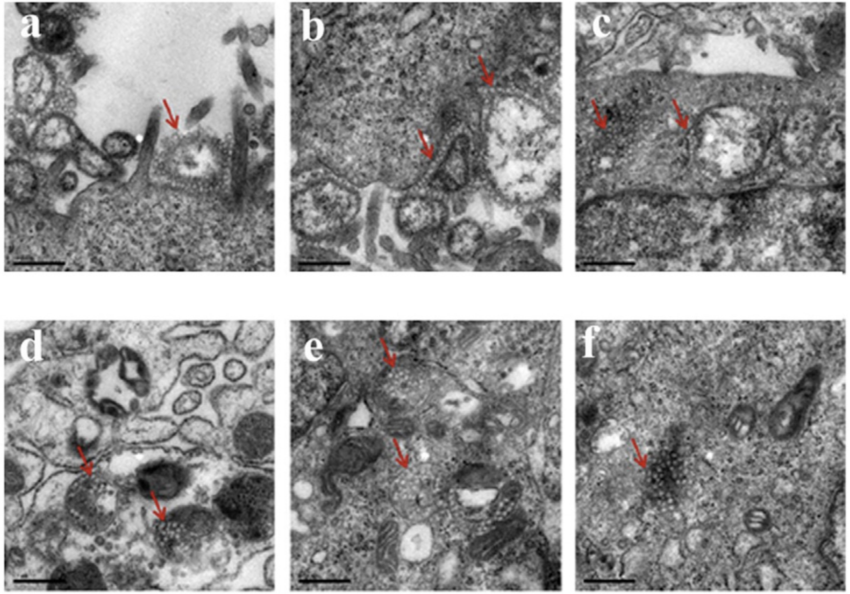
Still lacking evidence…

1) Direct effects

- Internalization



Source: Yee et al., 2021, Nanomaterials, DOI: 10.3390/nano11020496.

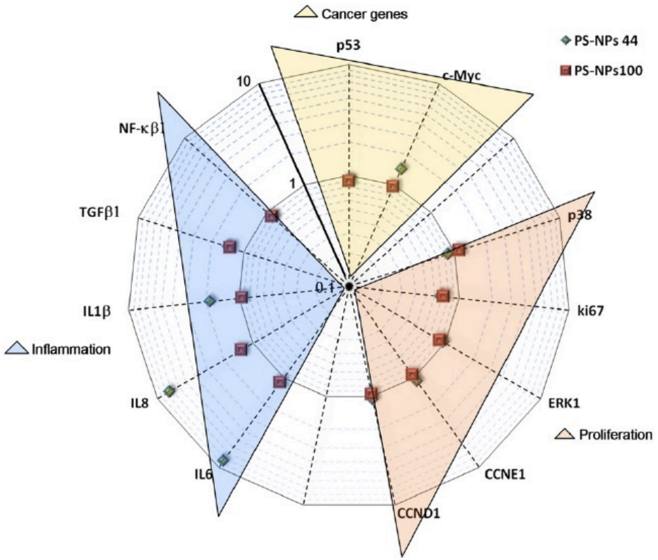


Source: Ding et al., 2021, Env. Poll., DOI: 10.1016/j.envpol.2021.116974.

1) Direct effects

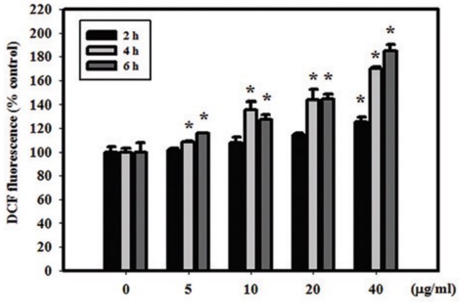
- Effects over cellular metabolism

Changes in gene expression

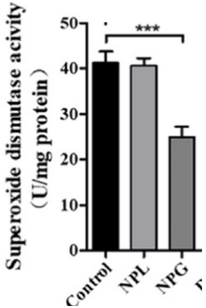


Source: Forte et al., 2016, Toxicol. In Vitro , DOI: 10.1016/j.tiv.2015.11.006.

Reactive Oxygen Species

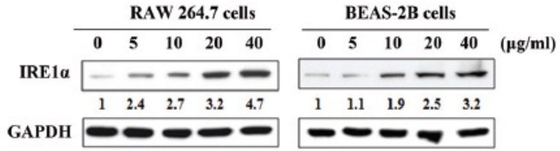


Source: Chiu et al., 2015, Nanoscale, DOI: 10.1039/c4nr05509h.



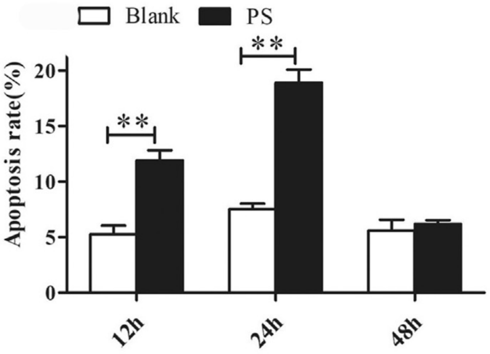
Source: Shi et al., 2021, Ecotox. Env. Saf., DOI: 10.1016/j.ecoenv.2021.112041.

ER Stress



Source: Chiu et al., 2015, Nanoscale, DOI: 10.1039/c4nr05509h.

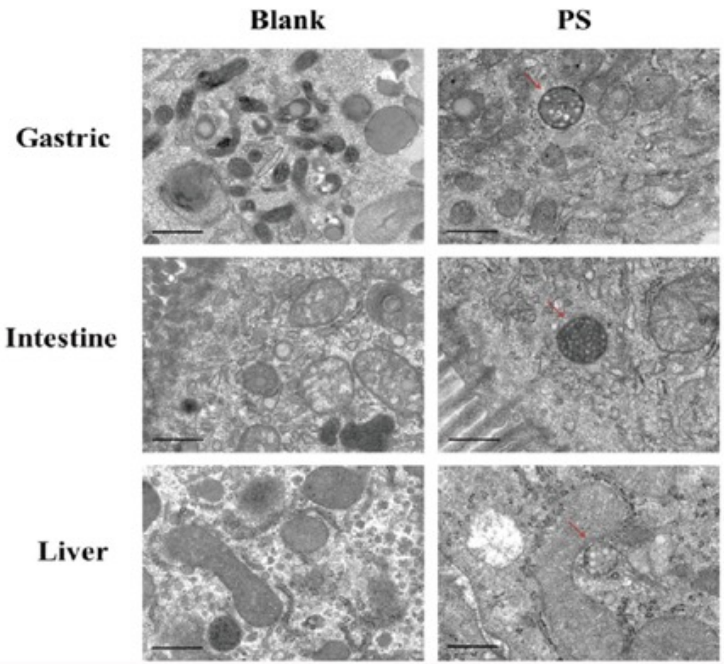
Cell Death



Source: Ding et al., 2021, Env. Poll., DOI: 10.1016/j.envpol.2021.116974.

1) Direct effects

- Systemic distribution



Source: Ding et al., 2021, Env. Poll., DOI: 10.1016/j.envpol.2021.116974.

Table 2. Distribution of 39.4-nm fluorescent latex particles (10 mg/L ERM) in organs of ST II medaka after 7 days' exposure, and comparison with rats.

Organs (no.)	Control[a] (mean ± SE)	Exposure[a] (mean ± SE)	*p*-Values[b]	Distribution of water-miscible C_{60} fullerene in rats[c] (% total dosed radioactivity)
Brain (16)	28.2 ± 5.6	57.1 ± 8.7	0.080	0.57 ± 0.19
Gills (16)	28.3 ± 4.2	113 ± 10	0.000029	NA
Liver (16)	48.7 ± 6.2	93.9 ± 19	0.067	91.7 ± 8.0
Kidney (16)	62.6 ± 14	103 ± 16	0.068	1.0 ± 0.3
Gallbladder (16)	183 ± 30	246 ± 3.1	0.028	NM
Intestine (16)	25.8 ± 3.7	147 ± 20	0.00046	NM
Spleen	NM	NM	NA	1.6 ± 0.2
Lungs	NA	NA	NA	1.0 ± 0.3
Testis (8)	47.1 ± 18	112 ± 15	0.052	0.09 ± 0.01
Ovary (8)	118 ± 67	129 ± 36	0.44	NM

Source: Kashiwada, 2006, Env. Health Perspect., DOI: 10.1289/ehp.9209

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2) Leaching of additives

Plastic particles are **more than the plastic polymer**.

Hazardous substance group	Product examples
Consumer products	
Antimicrobial substances such as organic tin compounds	Shower curtains and rain wear
Heavy metal based colorants, stabilisers and catalysts such as cadmium and lead and their compounds	Plastic shoes and bathroom products
Monomers, cross linkers, hardeners, chain modifiers and catalysts such as Bisphenol A	Mattresses and sports shoes, thermo paper (receipts)
Organic based colorants such as azo dyes	Clothes and bedding
Plasticisers such as different phthalates and short-chained chlorinated paraffins (SCCP)	Bags and cases, garden goods, plastic shoes and articles intended for pets
Solvents –neutral and reactive, such as N, N-dimethylformamide (DMF)	Office supplies
Others, such as nonylphenol and perfluorinated alkylated substances (e.g. PFOS and PFOA).	Sports shoes and mattresses (nonylphenol), textiles and non-stick products like pans (perfluorinated compounds)

Hazardous substance group	Product examples
Products for children	
Antimicrobial substances such as organic tin compounds	Diapers and car seats
Heavy metal based colorants, stabilisers and catalysts such as cadmium and lead and their compounds	Plastic toys and car seats, electronic toys
Flame retardants such as BFRs and organo-phosphates	Baby products and toys
Monomers, cross linkers, hardeners, chain modifiers and catalysts such as bisphenol A and formaldehyde	Drinking bottles for children and stuffing in car seats, pacifier holders, CD-disc, stickers
Organic based colorants such as azo dyes	Toys from textile and car seats
Plasticizers such as different phtalates and short-chained chlorinated paraffins (SCCP)	Bath toys and masquerade toys
Others, such as perfluorinated alkylated substances (e.g. PFOS and PFOA)	Children's clothes

Hazardous substance group	Product examples
Electronics (WEEE)	
Heavy metal based colorants, stabilisers and catalysts such as cadmium and lead and their compounds	Casing for TVs and PCs and consumer electronics, shredder residue
Flame retardants such as BFRs (e.g. c-OBDE, TBBPA ja c-DBDE)	Scanners and casings for TVs and video devices
Plasticisers such as short-chained chlorinated paraffins (SCCP)	Kitchen appliances and game controllers
Others, such as perfluorinated alkylated substances (e.g. PFOS and PFOA)	Photographic and electronic equipment and components
Furniture	
Flame retardants such as BFRs, hexabromocyclododecane (HBCDD) and organo phosphates	Upholstery and filling in bean bags
Organic based colorants such as azo dyes	Textiles and upholstery for furniture

Source: Nordic Council of Ministers, 2017. Hazardous substances in plastics – ways to increase recycling.

Important questions:

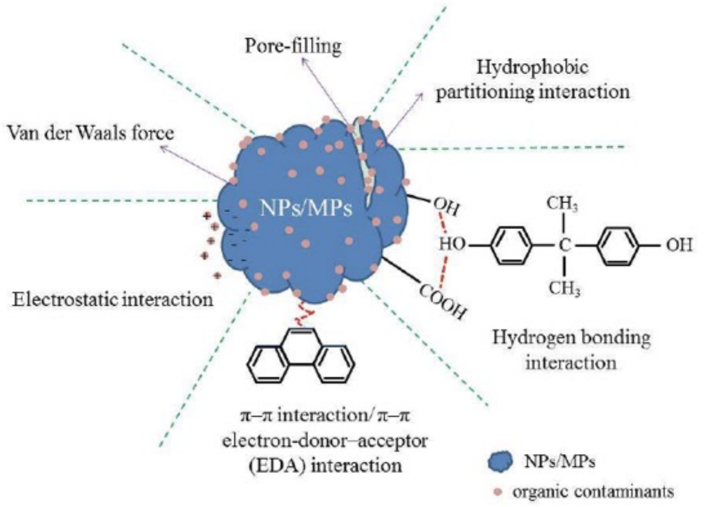
- How is leaching of these substances affected by digestive juices as the nanoplastic particle passes trough the gut?

- What implications does this have for toxicity associated to nanoplastic exposure?

3) Adsorption and Release of Pollutants

Nanoplastics have comparatively stronger sorption of organic and metallic pollutants than microplastics

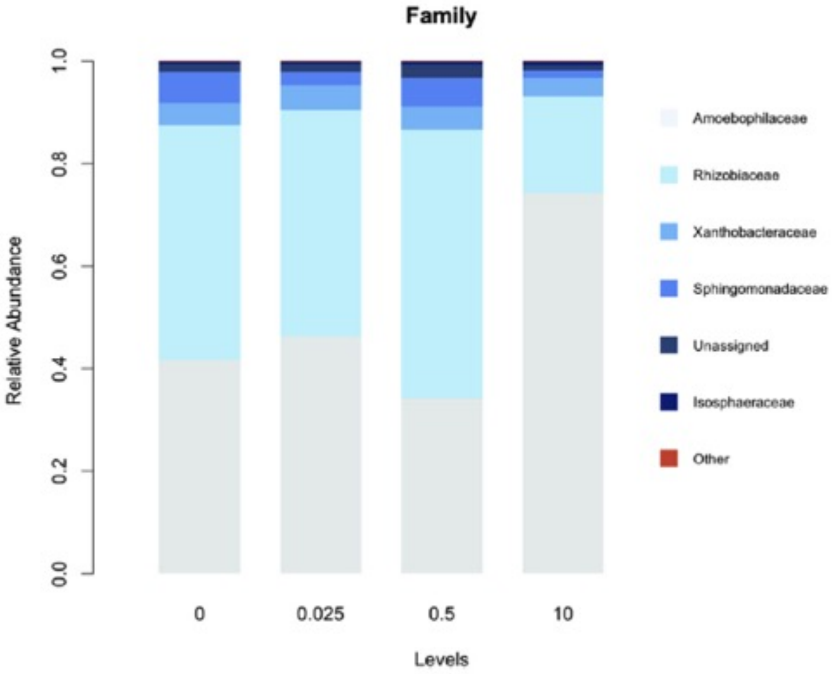
- *Metals (e.g. Pb, Hg);*
- *Polycyclic Aromatic Hydrocarbons*
- *Pesticides;*
- *Endocrine Disruptors;*
- *Pharmacologically active compounds;*



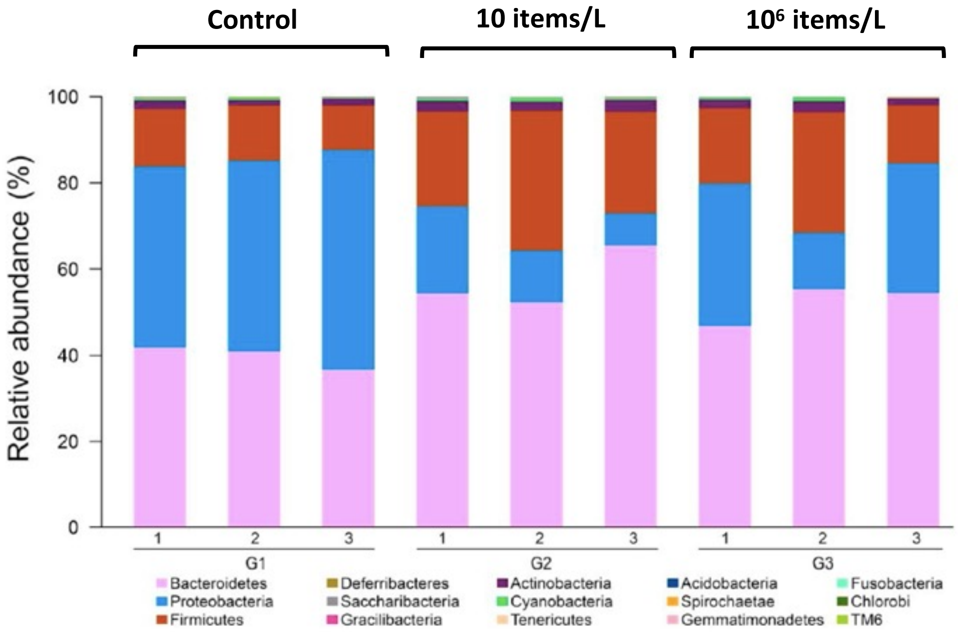
Source: Wang et al, 2020, Molecules, DOI: 10.3390/molecules25081827

The toxicological profile of both nanoplastics and pollutants may be affected → *Trojan Horse* Effect

Interaction with the microbiome



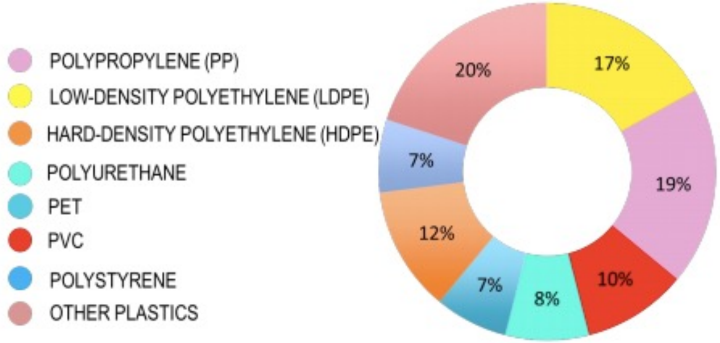
Source: Zhu et al., 2018, Env. Poll, DOI: 10.1016/j.envpol.2018.04.017



Source: Gu et al., 2020, J. Haz. Mat, DOI: 10.1016/j.jhazmat.2020.122773

Additional Research Challenges

Plastic polymers are diverse (e.g., PS; PE, PC, PVC; PP), varying densities, etc…



Source: Nordic Council of Ministers, 2017. Hazardous substances in plastics – ways to increase recycling

Nanoplastic particles interact with many molecules in the environment

Environmental relevance of toxicity studies

Thank you!

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