

Microplastics and nanoplastics environmental contamination and human dietary exposure

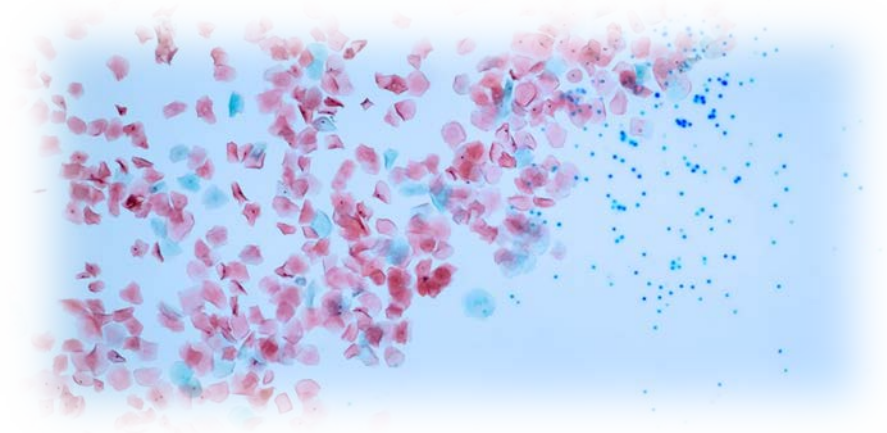
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Outline

- ❑ **Impact of microplastic contamination on food chains and resulting human exposure**
 - Aquatic environment
 - Terrestrial environment
 - Food processing
 - Drinking water

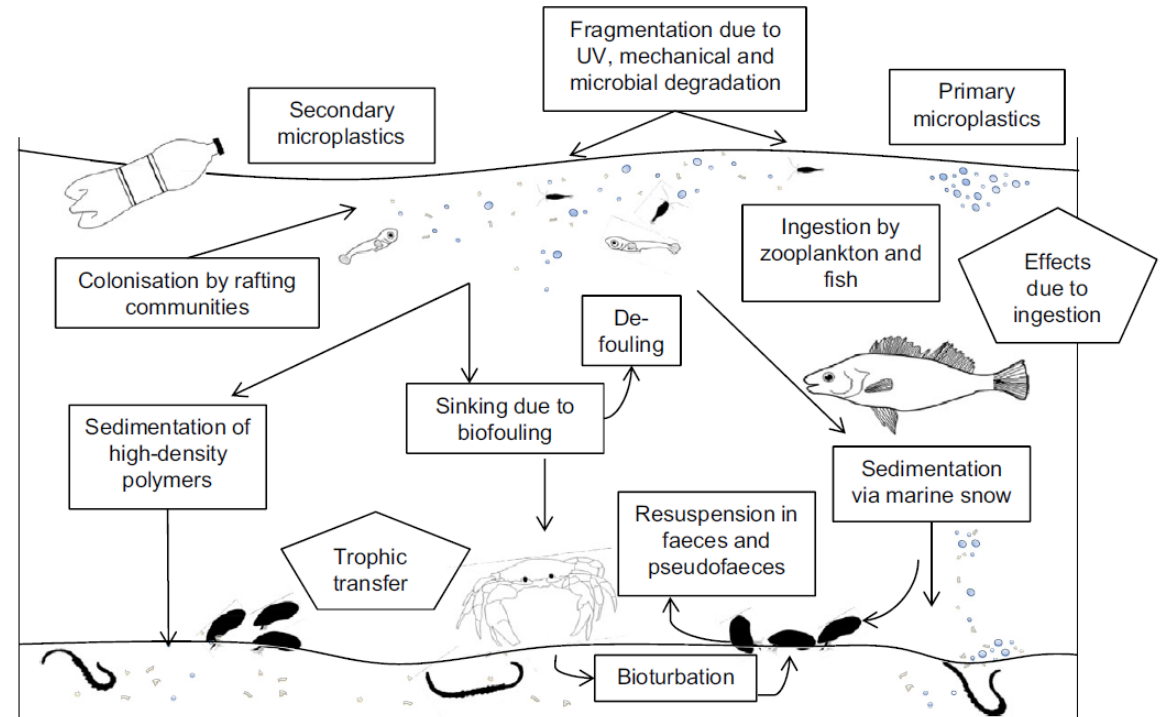
- ❑ **Gaps preventing dietary exposure assessment and way forward**
 - Focus on particle physicochemical properties
 - The issue of the size range: a risk assessment perspective
 - Other limitations of existing data
 - What we need for exposure assessment of micro- and nanoplastics via food and feed



Contamination of the marine environment and impact on seafood

A significant proportion of the plastic produced is not disposed of properly and persists in the environment, especially the marine environment

- Top 3 polymers: polyethylene (PE), polypropylene (PP) and polystyrene (PS)
- Degradation to MPI ('secondary' MPI)
- Primary MPI likely a minor contribution
- Further degradation can lead to NPI
- MPI can be ingested by both marine invertebrates and vertebrates, which are exposed either directly or via lower trophic levels



Potential pathways for the transport of microplastics and their biological interactions [EFSA Journal 2016;14(6):4501]

Seafood as a source of human dietary exposure to plastic particles

As most of the larger-sized MPI will remain confined within the GI tract, gutting is expected to decrease human dietary exposure compared to eating whole fish

- This does not apply to shellfish and certain species of small fish
- Might be less applicable to smaller-sized particles

❑ **Mussels are a worst case for plastic particle bioaccumulation**

- Mussels feed on phytoplankton and detritus filtered from the surrounding water and readily accumulate plastic particles
- Their consumption may lead to high exposure levels



Contamination of terrestrial food chains

Very little is known about terrestrial food chains

- MPI may enter agricultural soils through processed sewage sludge used as fertilizer
 - MPI in farming systems may result from the degradation of plastic materials used by farmers, such as plastic mulch
 - Fish meal is used in poultry production and pig rearing: hence, MPI from marine sources might end up in non-marine foods
- There is a knowledge gap about the potential uptake and deposition of plastic particles in vegetable and animal food and any associated human exposure**
- Existing data have limitations. Occurrence of MPI in sugar, salt and honey might indicate aerial deposition plays a role. Significant uncertainties regarding data for other matrices



Food processing as a potential source of contamination by plastic particles

Food processing might contribute to the occurrence of plastic particles in food items and resulting human exposure

- It is plausible that certain processes release MPI in food products
- Aerial deposition (e.g. of fibers) might also contribute
- Plastic is extensively used in food and beverage packaging too
- Release of plastic particles from food contact materials depends on the processing conditions and might increase upon recycling or reuse



Plastic particles in drinking water

Drinking water might represent a substantial source of exposure to MPI

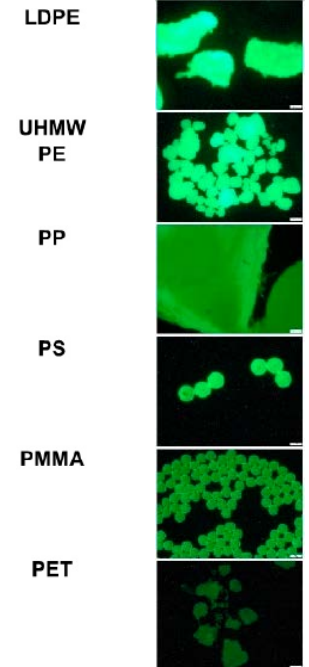
- Occurrence levels seem to be higher in bottled water
- Lower contamination in water sold in glass bottles
- Lower levels appear to be present in tap water
- Freshwater ecosystems less studied compared to marine ecosystems, but surface waters (used for water supply to some extent) might be heavily impacted
- Groundwater less impacted
- By the end of 2024 analytical methodology to measure MP will be identified allowing to place MP in the watch list of the EU Drinking Water Directive: targeting relevant size ranges will be essential (see following)



Focus on particle physicochemical properties

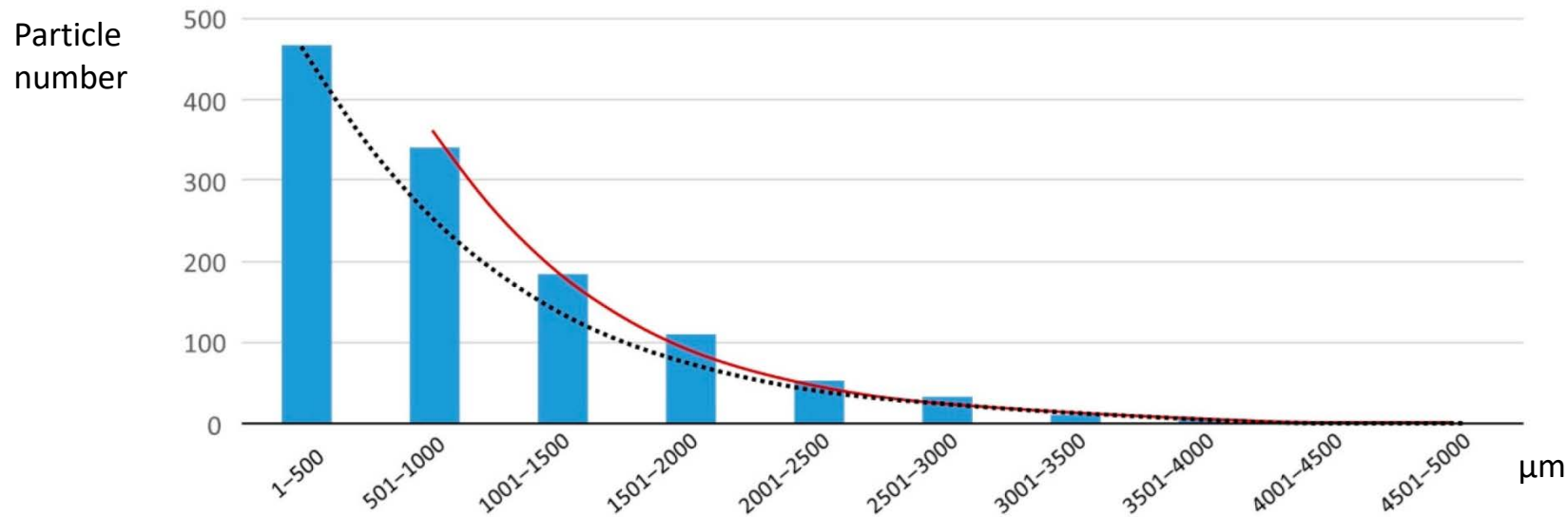
Experience with particle and fibre toxicology indicates that any potential adverse effect of micro and nanoplastics on human health will be dictated by their physicochemical properties

- ❑ After oral exposure, the ability of plastic particles to be taken up in the gut and cause any systemic toxicity will be dictated by:
 - Size
 - Morphology
 - Surface properties
 - Chemical composition (constituting polymers)
- ❑ Chemicals contained in or adsorbed onto the particles might be other determinants of toxicity



Environmental plastic particles occur along an extensive size continuum

Smaller plastic particles are likely to originate, to a large extent, from fragmentation of larger particles: differently from other types of particulate contaminants, environmental micro and nanoplastics appear to cover a broad size range extending over several (i.e. 6) orders of magnitude



Distribution over size classes of the total set of examined MPI in oysters collected from the East Coast of China [van Raamsdonk et al. 2020]

Relevance of existing data for dietary exposure assessment?

The broad definition of MPI encompasses a wide particle size range unrelated to potential human health effects

Overview of estimated exposure to MPI from diet, drinking water, and human stool, all expressed in particle counts

Material	Particle Size (μm)	Concentration (per L or Cup)	Estimated Daily Consumption	Exposure (Day^{-1})	Estimated Exposure ($\text{kg}^{-1} \text{bw Day}^{-1}$)
Diet, food, maximum [33]	Depending on source				142
Diet, food and bottled water, maximum [33]	Depending on source				389
Stool, median [6]	50–500				256
Tap water, average [39]	1 and larger	470	2 L	940	13
Bottled water, average [38]	1 and larger	3.8×10^3	2 L	7.5×10^3	108
Bottled water, average [40]	5 and larger	66	2 L	132	2
Bottled water, average [34]	6.5–100	325	2 L	650	9
Bottled water, maximum [38]	1 and larger	1.7×10^4	2 L	3.3×10^4	475
Bottled water, maximum [34]	6.5–100	1.0×10^4	2 L	2.1×10^4	297
Tea per cup [43]	2.5 and larger	2.3×10^6	2 cups	4.6×10^6	6.5×10^4

[van Raamsdonk et al. 2020]

Particle size distributions of different studies can not be compared

Studies focusing on food matrices investigate different and not comparable portions of the size continuum over which MPI occurs

Diameter 1 μm



Diameter 50 μm



Example of spherical particles with the same composition: the larger particle has a mass equal to 125,000 of the smaller particles

- ‘Exposures’ in terms of number of ingested particles of different size are not comparable (intrinsically different entities are dealt with)
 - Translation of such ‘exposures’ on a mass basis (e.g. $\mu\text{g kg}^{-1} \text{bw day}^{-1}$) would be even more misleading
 - Environmental plastic particles are irregular in shape, with fibres predominating in certain size ranges: this calls for additional caution when particle ‘size’ is dealt with
- Most importantly, none of the investigated particle size ranges is related to established human health effects**



Other limitations of existing data

Existing analytical methods are only capable to detect relatively large MPI and the chemical characterization is often lacking

- The plastic particles of relevance for human health following oral exposure are likely to be limited to the smaller-sized MPI and the NPI, which have the greatest likelihood of being absorbed in the gastrointestinal tract
- However, existing methods do not target this size range

❑ Other shortcomings of available data:

- Lack of harmonisation in analytical techniques
- Limited availability of chemically-specific data (particle composition)
- Poor (or absent) analytical quality control, indeed an essential requirement for analytes that are in most cases ubiquitous



The issue of the size range: a risk assessment perspective

Whereas definitions are essential in a regulatory perspective, for risk assessment relevant size ranges to focus on in hazard and exposure assessment should be based on toxicokinetics considerations

- A univocal regulatory definition is often invoked as the necessary prerequisite for harmonisation of methodological approaches and comparability of data
- However, whereas such a definition is essential in a regulatory perspective, in terms of human health risk, ADME considerations should be the starting point for prioritization of size ranges to focus on in hazard and exposure assessment
- **For the NPI**, a reference is the size range – **up to 250 nm** – considered for nano-specific risk assessment by the ‘EFSA Guidance on risk assessment of nanomaterials to be applied in the food and feed chain’: there is evidence of intestinal cell uptake of particles via endocytosis and other pathways within this size range
- **For the MPI**, there is some evidence that translocation across the mammalian gut (e.g. via M-cells in Peyer’s patches, phagocytosis by macrophages) may happen for particles **up to few μm** : EFSA 2016 states that only the smallest fraction (size < 1.5 μm) may penetrate deeply into organs

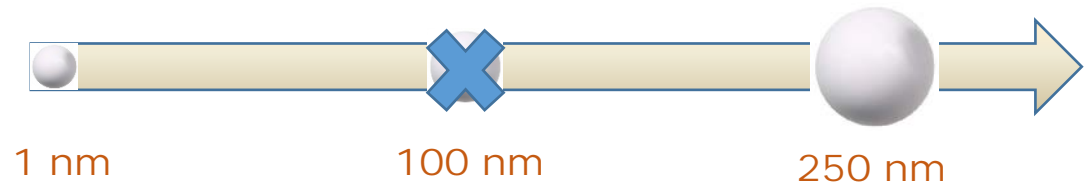


Size ranges of plastic particles: crossing of intestinal barrier and fate in the body

Based on the different routes for potential crossing of the intestinal epithelium and the likely different fate in the human body, relevant size ranges to be prioritized in hazard and exposure assessment should be established

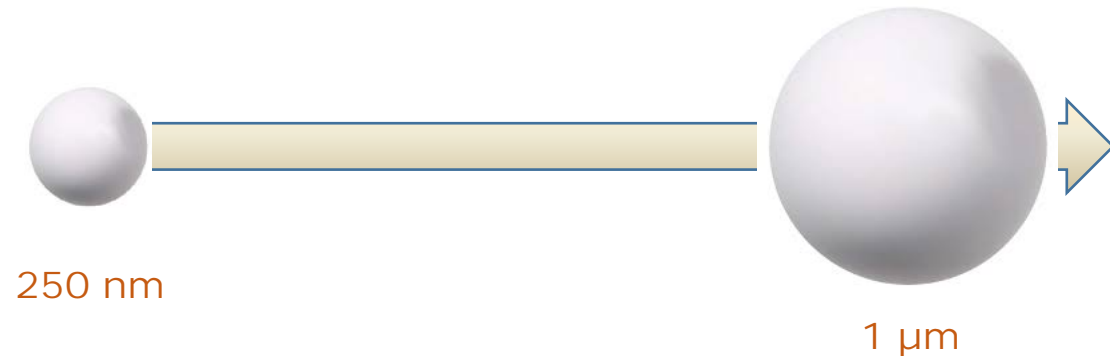
Nanoplastics (diameter of the equivalent sphere)

- Up to 250 nm



Microplastics (diameter of the equivalent sphere)

- 250 nm - ca. 1 μm



Gaps in dietary exposure assessment and way forward

Any development in exposure assessment of MPI/NPI via food and feed critically relies on progresses in (i) toxicokinetics and toxicology and (ii) analytical methods

❑ Toxicokinetics and toxicology

- Research on the degradation of MPI/potential formation of NPI in the human GI tract and on ADME of plastic particles
- Toxicology of plastic particles as related to their physicochemical properties, focusing on effects of long-term exposure
- Effect of aging (to what extent pristine particles can be representative of environmental plastic particles)?
- Can plastic particles change the ADME of contaminants (e.g. be carriers for absorption or trojan-horse effects)?

❑ Analytical methods

- Development of advanced analytical methods capable to measure relevant particles (based on hazard assessment) at the expected low background levels in food



Conclusions

- ❑ Many different approaches are used to study **MPI** and they are often matrix-specific. While this is inherent to an evolving field of research, it poses a challenge to exposure and risk assessment as **data comparability is limited**
- ❑ **Occurrence data of acceptable quality are limited:** there is paucity of chemically-specific data (particle composition) and analytical quality assurance/control is generally poor/absent
- ❑ After oral exposure the **size, morphology, surface properties, chemical composition (i.e. constituting polymers)** of plastic particles will determine their ability to be taken up in the gut and cause any systemic toxicity
- ❑ Hazard assessment is key to identify **relevant size ranges** and the **best metrics for exposure assessment** (number-based concentrations and/or mass-based concentrations, and appropriate conversion approaches when feasible)
- ❑ Occurrence and exposure data on **NPI** are absent: the need for analytical method development and exposure assessment **should rely on solid evidence from hazard assessment**
- ❑ The development of **analytical methods capable to measure the particles of relevance (in terms of health risks) at the expected low background levels in food** is prerequisite for reliable dietary exposure assessment





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**Thank you for your attention!
Questions?**



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