Exposure to micro- and nanoplastics via food and feed

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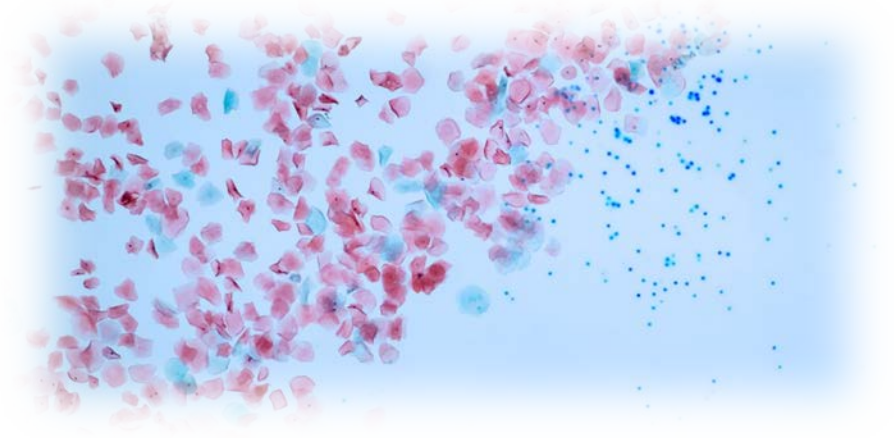


EFSA Scientific Colloquium N°25: a coordinated approach to assess human health risks of micro- and nanoplastics in food
6-7 May 2021

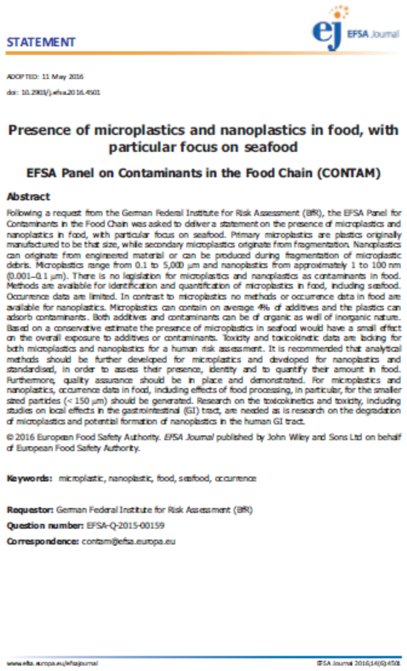
Outline

- **Impact of microplastic contamination on food chains and resulting human exposure**
  - Marine environment
  - Terrestrial environment
  - Food processing
  - Bottled and tap 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

Scientific opinions, reports and reviews addressing dietary exposure to MPI/NPI

Material considered herein:

- Scientific opinions and reports
- Reviews: including Cox *et al.* (2019), Toussaint *et al.* (2019), Paul *et al.* (2020), van Raamsdonk *et al.* (2020), Nor *et al.* (2021)
- Some dozens of individual peer-reviewed publications



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)

Abstract

Following a request from the German Federal Institute for Risk Assessment (BfR), the EFSA Panel for Contaminants in the Food Chain was asked to deliver a statement on the presence of microplastics and nanoplastics in food, with particular focus on seafood. Primary microplastics are plastics originally manufactured to be that size, while secondary microplastics originate from fragmentation. Nanoplastics can originate from engineered material or can be produced during fragmentation of microplastic debris. Microplastics range from 0.1 to 5,000 µm and nanoplastics from approximately 1 to 100 nm (0.001–0.1 µm). There is no legislation for microplastics and nanoplastics as contaminants in food. Methods are available for identification and quantification of microplastics in food, including seafood. Occurrence data are limited. In contrast to microplastics no methods or occurrence data in food are available for nanoplastics. Microplastics can contain on average 4% of additives and the plastics can adsorb contaminants. Both additives and contaminants can be of organic as well of inorganic nature. Based on a conservative estimate the presence of microplastics in seafood would have a small effect on the overall exposure to additives or contaminants. Toxicity and toxicokinetic data are lacking for both microplastics and nanoplastics for a human risk assessment. It is recommended that analytical methods should be further developed for microplastics and developed for nanoplastics and standardised, in order to assess their presence, identity and to quantify their amount in food. Furthermore, quality assurance should be in place and demonstrated. For microplastics and nanoplastics, occurrence data in food, including effects of food processing, in particular, for the smaller sized particles (< 150 µm) should be generated. Research on the toxicokinetics and toxicity, including studies on local effects in the gastrointestinal (GI) tract, are needed as is research on the degradation of microplastics and potential formation of nanoplastics in the human GI tract.

Keywords: microplastic, nanoplastic, food, seafood, occurrence

Requestor: German Federal Institute for Risk Assessment (BfR)

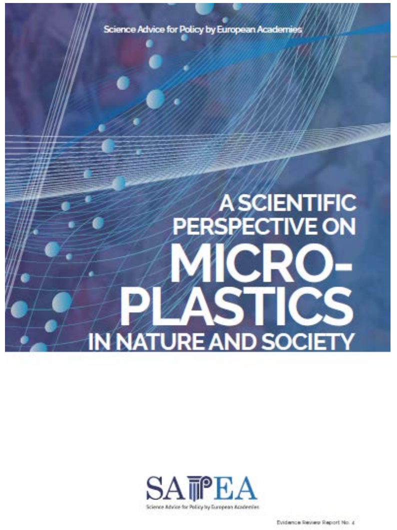
Question number: EFSA-Q-2015-00159

Correspondence: contam@efsa.europa.eu

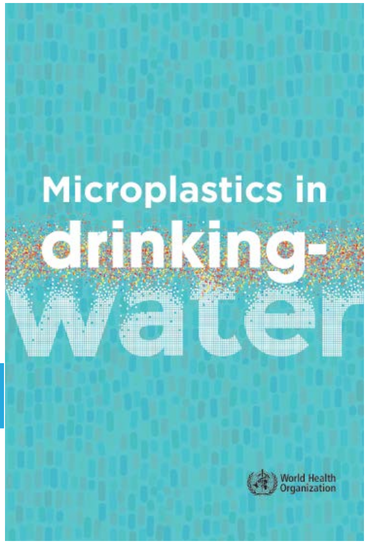
www.efsa.europa.eu/efsajournal   EFSA Journal 2016;14(6):4501

[EFSA 2016]

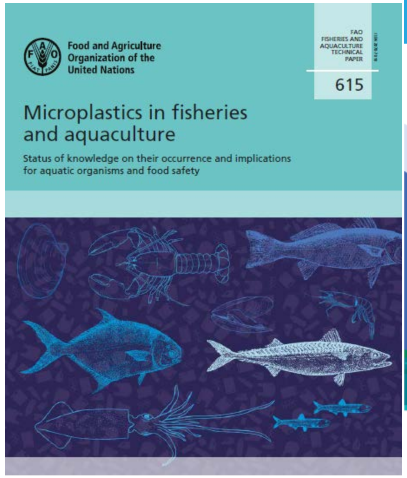
[SAPEA 2019]



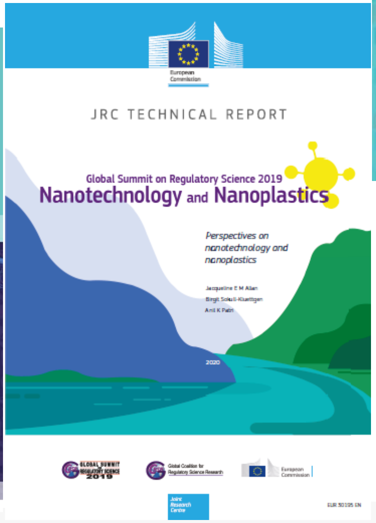
[VKM 2019]



[WHO 2019]



[FAO 2017]

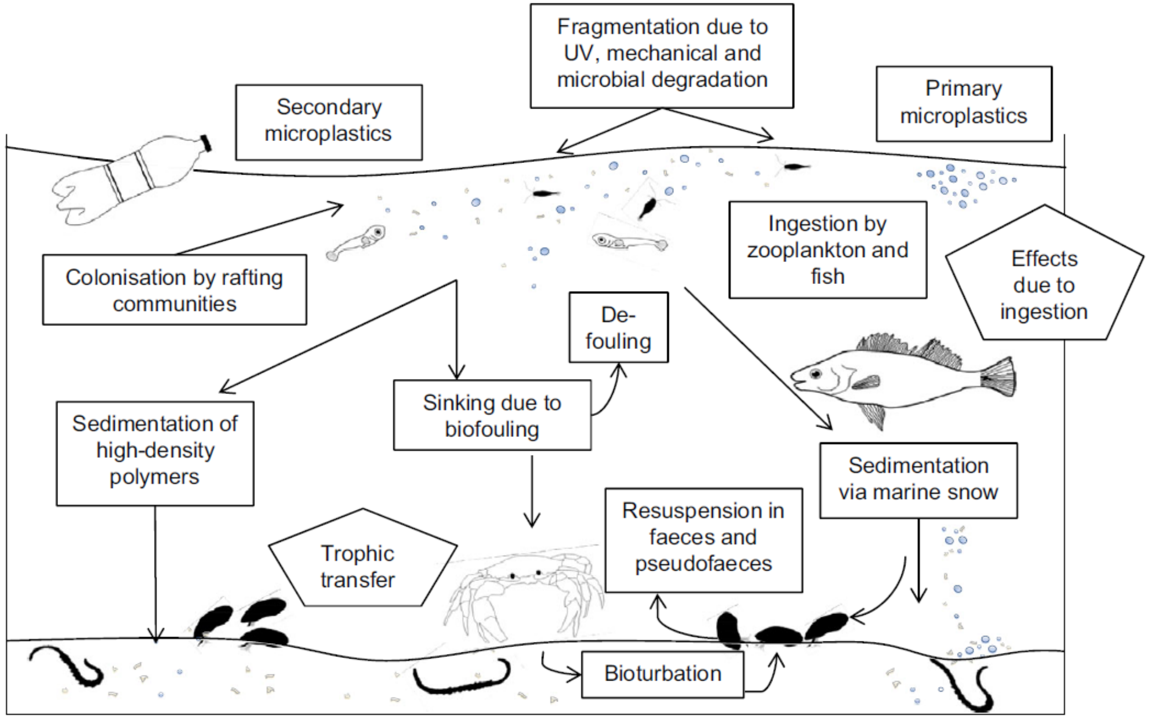


[JRC 2020]

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 MPl (‘secondary’ MPl)
- Primary MPl likely a minor contribution
- Further degradation can lead to NPl
- MPl 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 MPl 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

- MPl may enter agricultural soils through processed sewage sludge used as fertilizer
- MPl 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, MPl from marine sources might end up in non-marine foods

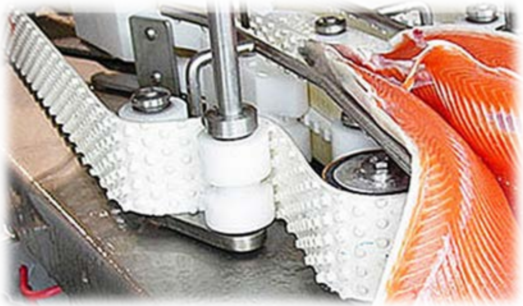
❑ **There is a knowledge gap about the potential uptake and deposition of plastic particles in vegetable and animal food and any associated human exposure**

- Existing data have limitations. Occurrence of MPl 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 MPl 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 MPl

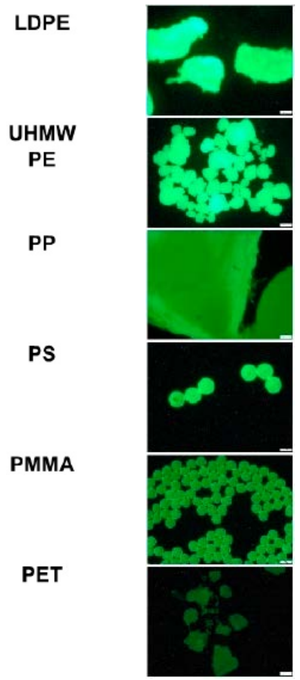
- Occurrence levels seem to be higher in bottled water
- Lower contamination in water sold in glass bottles
- Lower levels appear to be present in tap water
- Freshwater ecosystems less studied compared to marine ecosystems, but surface waters (used for water supply to some extent) might be heavily impacted
- 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

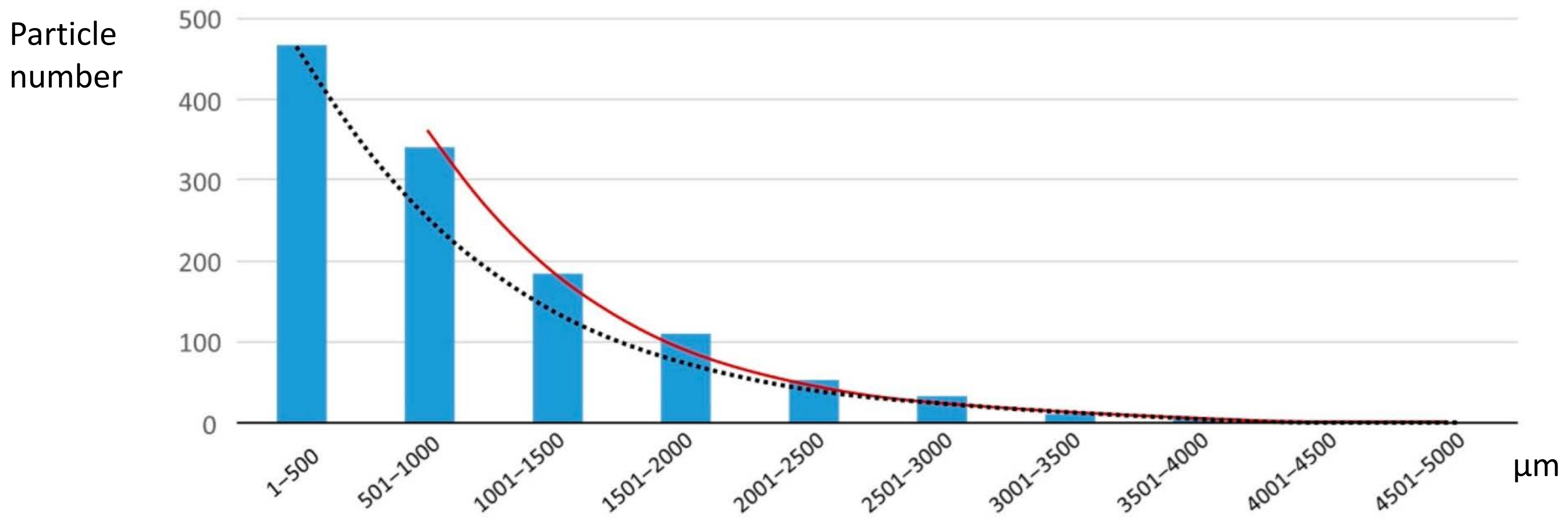
- **After oral exposure, the ability of plastic particles to be taken up in the gut and cause any systemic toxicity will be dictated by:**
  - Size
  - Morphology
  - Surface properties
  - Chemical composition (constituting polymers)

- **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 MPl 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 MPl encompasses a wide particle size range unrelated to potential human health effects

Overview of estimated exposure to MPl 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 (kg^{-1} 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 MPl occurs

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. µg kg^{-1} 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 MPl 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 MPl and the NPl, 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

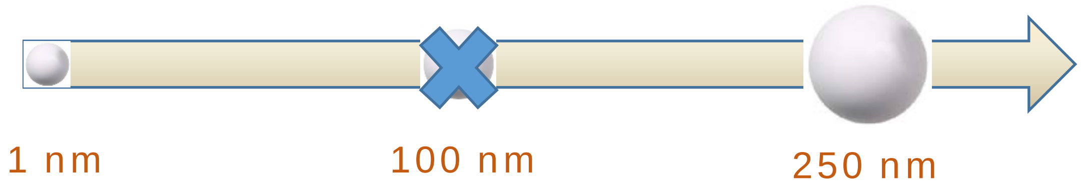
- A univocal regulatory definition is often invoked as the necessary prerequisite for harmonisation of methodological approaches and comparability of data
- However, whereas such a definition is essential in a regulatory perspective, in terms of human health risk, ADME considerations should be the starting point for prioritization of size ranges to focus on in hazard and exposure assessment
- **For the NPl**, 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 MPl**, 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

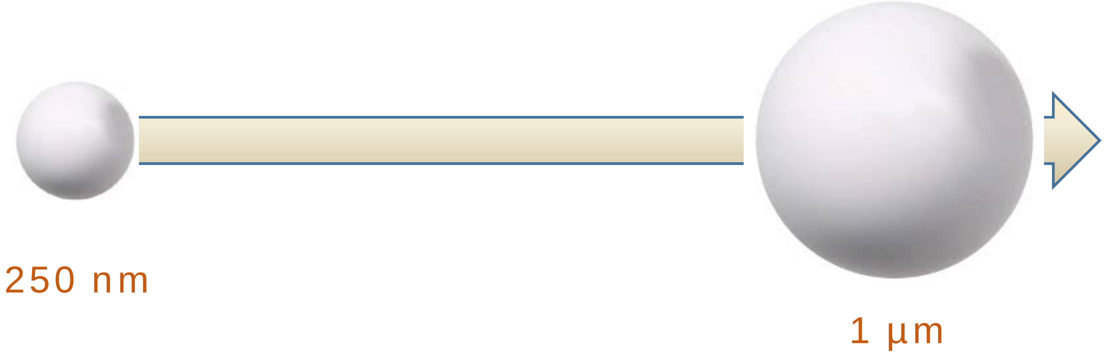
Nanoplastics (diameter of the equivalent sphere)

- 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 MPl/NPl 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 MPl/potential formation of NPl 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 **MPl** 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 **NPl** 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