TOX/2023/51

Committee on the Toxicity of Chemicals in Food, Consumer Products and the Environment.

Sub-statement on the potential risk(s) from exposure to microplastics: Inhalation route (Fourth draft)

1. In 2019, as part of horizon scanning, the Committee on Toxicity of Chemicals in Food, Consumer Products and the Environment (COT) identified the potential risks from microplastics as a topic it should consider to inform Food Standards Agency (FSA) discussions on this (TOX/2019/08). Since then, several discussion papers have been presented to the COT (see Annex A1 and in 2021, the COT published an overarching statement on the potential risks from exposure to microplastics (COT Statement 2021/02). This document was first presented to the COT in May 2022 (COT Minutes May 2022) and follow up drafts in December 2022 and July 2023 (COT Minutes December 2022; COT minutes July 2023). This provided a high-level overview of the current state of knowledge, data gaps and research requirements with regards to this topic.

2. The purpose of this sub-statement is to provide supplementary material to the overarching statement (COT Statement 2021/02) and to consider in detail the potential toxicological risks of exposure from microplastics via inhalation. It is based on currently available literature and on data from internal tools at the UK FSA (these internal tools include: a literature search application and signal prioritising dashboards). This would help inform overall exposure of microplastics and also any further toxicological information. As Members will recall, particles arising from tyre wear were considered outside

the scope of this assessment, but some information has been included to provide context.

3. When the Committee discussed this paper at the July 2023 meeting, it was advised that the definition of microplastics be clarified. The definition originally made by COT in the overarching statement has now been included at the beginning of the paper. The Committee suggested some restructuring of the statement and to clarify references to food as the inhalation statement has broader relevance. References to MPs in food have been removed. Some restructuring of the paper has been carried out at the request of the COT and additional text has been highlighted in yellow. Furthermore, the COT Secretariat has added a table of future priorities for risk assessment.

Questions for the Committee

4. The Committee are asked to consider the following questions:

- Are the Committee content with the updated version of the sub-statement considering all the suggestions by Members?
- As requested by the Members, the research priorities have been ranked. Do the Committee agree with the ranking provided?
- Does the Committee have any further comments?
- May the sub statement be cleared by Chairs action?

Secretariat
October 2023

Annex A to TOX/2023/51

Committee on the Toxicity of Chemicals in Food, Consumer Products and the Environment.

Sub-statement on the potential risk(s) from exposure to microplastics: Inhalation route (Fourth draft)

Background

1. In 2019, as part of horizon scanning, the Committee on Toxicity of Chemicals in Food, Consumer Products and the Environment (COT) identified the potential risks from microplastics as a topic it should consider to inform UK Food Standards Agency (FSA) discussions on this area (TOX/2019/08). Since then, several discussion papers have been presented to the COT (see Annex A1) and in 2021, the COT published an overarching statement on the potential risks from exposure to microplastics (COT Statement 2021/02), which contained their working definition of microplastics as synthetic particles or heavily modified natural particles with a high polymer content that are submicron-mm in size (0.1 to 5,000 µm or micrometres). Plastics that are below this size range are classed as nanoplastics (i.e. 1 nm to 0.1 µm) (COT, 2021).

2. This document provided a high-level overview of the current state of knowledge, data gaps and research requirements with regards to this topic. This was followed by a sub-statement considering oral exposure to microplastics in more detail.

3. The COT previously noted that there is little data on the effects of microplastics on mammals (including humans) whether taken in orally or via inhalation. The majority of microplastics (>90%) are excreted from the body but small amounts may remain in the gut (gastrointestinal tract; GIT) or move from the GIT into organs or tissues due to endocytosis by M cells or paracellular persorption. No epidemiological or controlled dose studies that evaluated the effects of orally ingested microplastics in humans were identified and there is a similar lack of information on inhaled microplastics.

4. Although exposure to airborne microplastics can arise from a wide range of environmental sources (see paragraph 77) there is still limited information regarding the concentrations of airborne microplastics.

5. In 2022, England's Chief Medical Officer Professor Chris Whitty published a report on indoor and outdoor air pollution which included comments on microplastics. In the report it is noted that microplastics are in the air unintentionally by stating:

> "The airborne transport and inhalation of microplastics is an example showing how unintended air quality consequences might possibly arise far downstream from the public use of an originally safe synthetic product. Too great a focus on only meeting existing air quality standards and regulations, without considering how atmospheric composition may change with society and technology more broadly, may lead to problems that could have been intercepted earlier with greater non-targeted surveillance and horizon-scanning. A clear evidence gap exists between the extensive regulatory efforts placed on monitoring existing regulated air pollutants and research studies of emerging atmospheric composition, the latter being rarely systematic or long-term in nature" (CMO, 2022).

6. The fate and dispersion of microplastics in outdoor environments is dependent on several factors (see paragraph 74).

7. Atmospheric deposition of microplastic particles (MPPs) onto food prior to consumption must also be considered as a potential source of exposure. For example, Catarino et al., (2018) compared the potential exposure of humans to household dust fibres during a meal with the amounts of MPPs present in edible mussels from Scottish waters, showing that exposure was considerably higher from the household source (see paragraph 83).

8. An American study (Cox et al., 2019) estimated daily consumption and inhalation to be 142 MPPs and 170 MPPs in adult males, respectively. For adult females, the estimated values are 126 MPPs and 132 MPPs, respectively. Based on these values, an annual estimated exposure of ~120,00 and ~98,000 MPPs annually was calculated in male and female adults, respectively (see paragraph 78 below).

9. The deposition of inhaled microplastics within the lung is dependent on the particle's physicochemical properties, as well as the subject's physiology and lung anatomy shown from paragraph 43.

10. Inhalation of microplastics could result in toxicity due either to the particles (i.e. physical effect) or their leachates (i.e. chemical effect). The mechanisms of inhaled particle injury are covered in paragraph 80. With regard to the available inhalation studies in laboratory animals, Environment and Climate Change Canada and Health Canada (ECCC and HC) in their review of the scientific literature noted that no dose-response relationship had been observed in mortality, survival time, behaviour, clinical observations, or tumour incidence from inhalation exposures (ECCC and HC 2020).

11. The COT previously reviewed risk assessments carried out by various groups such as the European Tyre and Road Wear Platform; Tyre Industry Project (Jekel, 2019), Joint Research Centre (Grigoratos & Martini, 2014),

Defra (AQEG, 2019), Health and Safety Executive (RUBIAC, 2007; HSE, 2011), Committee on Medical Effects of Air Pollutants (COMEAP, 2015; 2020), WHO (WHO, 2013), National Institute for Public Health and the Environment (Verschoor et al., 2016), and ECHA (ECHA, 2017).

12. The COT concluded that the literature data on exposure to particles from tyre wear would need separate consideration from microplastic exposure since the particles are chemically quite different in their polymeric nature. The COT considered that inhalation was likely to be the most significant route of exposure to TRWPs (tyre and road wear particles). Risk assessments of such materials were considered outside of the scope of the current exercise; however some information has been included to provide context. The COT was of the opinion that uptake by plants, with subsequent dietary exposure, was unlikely to be a major route of exposure but it would need further studies to review and confirm this.

Scope and purpose

13. As there is evidence for the presence of plastic particles in both indoor and outdoor air, inhalation is a possible route of exposure (Gasperi et al., 2018; Domenech & Marcos, 2021).

14. The purpose of this sub-statement is to provide supplementary material to the overarching statement (COT Statement 2021/02) and to consider in detail the potential toxicological risks of exposure from microplastics via the inhalation route. It is based on the currently available literature and data from internal tools at the FSA (these include: a literature search application and signal prioritising dashboards).

Microplastics

15. Currently there is no internationally agreed definition of a microplastic, however, publications by Verschoor (2015) and Hartmann et al., (2015) have proposed criteria that could be included in the definition of microplastics. In Europe, the European Chemicals Agency (ECHA) has proposed a regulatory definition for a microplastic under the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) Regulation (ECHA, 2019). In the US, the California Water Boards also recently published a proposed definition of microplastics in drinking water in March 2020.

16. Verschoor (2015) included 5 major properties that could be considered including chemical composition, physical state, particle size, solubility in water and degradability. Similarly, Hartmann et al., (2015) proposed seven criteria; chemical composition, solid state, solubility, size, shape and structure, colour and origin (i.e. primary or secondary particles; also known as pristine and aged), as discussed in the following paragraphs.

17. In Europe, the definition of a microplastic (including nano size) proposed by ECHA is a “material consisting of solid polymer-containing particles, to which additives or other substance(s) may have been added, and where ≥ 1% w/w have (i) all dimensions 1 nm ≤ x ≤ 5 mm or (ii) for fibres, a length of 3 nm ≤ x ≤ 15 mm and length to diameter ratio of >3. Polymers that occur in nature that have not been chemically modified (other than by hydrolysis) are excluded, as are polymers that are (bio)degradable.” (ECHA, 2019).

18. The current definition of microplastics (excluding nano size) in drinking water adopted by the California Water Boards is: “Microplastics in drinking water are defined as solid polymeric materials to which chemical additives or other substances may have been added, which are particles which have at least two dimensions that are greater than 1 and less than 5,000 µm. Polymers that are derived in nature that have not been chemically modified (other than by hydrolysis) are excluded.” (California Water Boards, 2020).

19. As noted above, the definitions of microplastics are broad. Therefore, for the purposes of this document, the COT has adopted a working definition that microplastics are defined as synthetic particles or heavily modified natural particles with a high polymer content that are submicron in size (0.1µm to 5 mm). Plastics that are below this size range are classed as nanoplastics (i.e. 1 nm to 0.1 µm) (COT, 2021;Bermúdez and Swarzenski, 2021; Frias and Nash, 2019). However, consensus on the size range is challenging.

20. The Committee also noted that microplastic particles that are present in the environment are not stable in size, meaning that as the duration of the degradation and agglomeration processes lengthens, the particle size continues to decrease due to fragmentation and erosion/weathering.

Nanoplastics

21. Nanoplastics have been defined as a material with any external dimension in the nanoscale or having internal structure or surface structure in the nanoscale (1 nm to 0.1 µm) (EFSA, 2016, European Commission, 2011). Nanoparticle is a general term based on the physical properties for a variety of chemical compositions. There is currently no further proposed definition.

22. A number of authoritative bodies have assessed the risks of nanomaterials and provided guidance on their assessment, which could also apply to nanoplastics. For example, the European Food Safety Authority (EFSA) Scientific Committee published an opinion on the potential risks arising from nanoscience and nanotechnologies on food and feed safety in 2009 (EFSA, 2009). This opinion did not provide any definitions; however, it was stated that the term nanoscale refers to a dimension of the order of 100 nm and below. Engineered nanomaterial was described as any material that is deliberately created such that it is composed of discrete functional and structural parts, either internally or at the surface, many of which will have one or more dimensions of the order of 100 nm or less.

23. The EFSA Scientific Committee recommended that the addition of other metrics (i.e. specific surface area which is independent of the agglomeration status of particles) should be included into the current definition of nanoscale materials (EFSA, 2009).

24. In 2011, EFSA published a guidance document on how EFSA's Panels should assess potential risks related to certain food-related uses of nanotechnology. New guidance on assessing the safety for humans and animals of nanoscience and nanotechnology applications in the food and feed chain was published in 2018 (EFSA, 2018).

25. The EFSA 2018 guidance is applicable to:

- a material that meets the criteria for an engineered nanomaterial, as outlined in Novel Food Regulation (EU) No 2015/2283 and Regulation (EU) No 1169/2011 (i.e. have particle sizes in the defined nanoscale; 1-100 nm),
- a material that contains particles having a size above 100 nm which could retain properties that are characteristic of the nanoscale (not further elaborated),
- a material that is not engineered as nanomaterial but contains a fraction of particles (<50% in the number-size distribution) with one or more external dimensions in the size range 1-100 nm or less,
- a nanomaterial having the same elemental composition but that occurs in different morphological shapes, sizes, crystalline forms and/or surface properties, and;
- a nanoscale entity that is made of natural materials.

26. In July 2020, EFSA held a public consultation on its draft "Guidance on technical requirements for regulated food and feed product applications to establish the presence of small particles including nanoparticles". The draft guidance outlines appraisal criteria grouped in three sections, to confirm whether or not the conventional risk assessment should be complemented with nano-specific considerations.

27. The first group of criteria addresses solubility and dissolution rate as key physicochemical properties to assess whether consumers will be exposed to particles. The second group establishes the information requirements for assessing whether the conventional material consists of small particles or contains a fraction thereof, and its characterisation. The third group describes the information to be presented for existing safety studies to demonstrate that the fraction of small particles, including those at the nanoscale, has been properly evaluated. Post-finalisation, this guidance was to completement the EFSA 2018 guidance (as described above) (EFSA, 2020).

28. The definitions of nanomaterials above (paragraphs 25-28) are based on EFSA Guidance, but their guidance for the risk assessment of nanomaterials could also apply to nanoplastics.

Types of microplastics

29. Microplastics can be divided into two major types. Firstly, those that are deliberately manufactured to be in the size range of 0.1 to 5,000 µm which are known as primary microplastics and are intentionally used in personal care products (for example, microbeads) or for various industrial applications. Secondary microplastics can be formed in the environment due to fragmentation of larger pieces of plastic caused by a culmination of physical, biological and photochemical degradation. Secondary microplastics have been termed microplastic particles (MPPs). MPPs can be further degraded to form nanoplastics, as defined above.

30. Besides the types of microplastics mentioned above, there is some debate within the scientific field as to whether rubber tyre particles should be considered microplastics. Tyres were initially made of natural rubber from the Brazilian rubber tree (Hevea brasiliensis). Currently, tyres are produced from a mixture of natural and synthetic materials. Synthetic rubbers are made from petroleum products and are functionalised with the addition of sulfur (1-4%), zinc oxide (1%), carbon black/silica (22-40%) and oil (Kole et al., 2017).

31. Car tyres release wear particles through mechanical abrasion, resulting from contact between the road surface and the tyre. The amount and particle size are dependent on several factors such as climate (temperature), composition and structure of the tyre, tyre age, road surface, driving speed, vehicle characteristics and style, and nature of the contact. As such, tyre wear particles could be described as another environmental source of microplastics, depending on the presence of synthetic materials in their composition (Baensch-Baltruschat et al., 2020; Kole et al., 2017).

32. Tyre wear and microplastics were previously reviewed by the COT (Annex B1). The COT summarised that "tyres contain a wide range of chemicals, the bulk of tyre tread is composed of a variety of rubbers, including natural rubber co-polymers, poly-butadiene rubber, styrene-butadiene rubber, nitride rubber, neoprene rubber, isoprene rubber, and polysulphide rubber. The interaction of tyres and pavement alters both the chemical composition and characteristics of particles generated compared to the original tyre tread due to heat and friction, as well as incorporation of materials such as environmental "dust", brakes, fuels and the atmosphere, as well as roadway particles.

33. Human exposure to chemicals leached from tyres, shredded tyres, and tyre wear material can occur by dermal exposure from environmental sources and ingestion of contaminated materials, as well as inhalation of airborne particulate matter derived from tyre wear material.

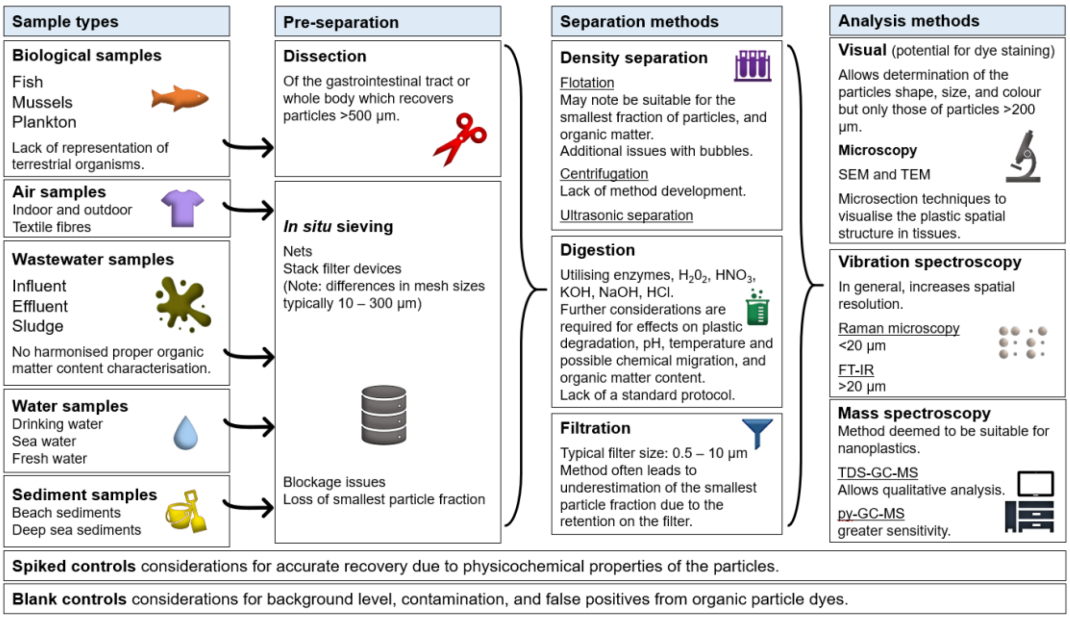
34. Challenges associated with evaluating risk from exposure becomes complex when considering other factors such as the effects of weathering and ageing of tyre materials, the effects of temperature, pavement types and driving style. All in all, this will result in the generation of various chemicals with significantly different biological and toxicological effects and potencies".

35. In the recent CMO report it stated “In the longer term, measuring tyre pollution accurately is also needed to assess the full impact of tyres on air and microplastic pollution, and reduce toxicity” (CMO, 2022).

Analytical detection methodologies

36. From the literature, the detection methods described for microplastics include one or more of the following steps: sample collection and removal of biogenic matter, detection and quantification/enumeration and, the characterisation of the plastic (i.e. its chemical composition or polymer type) (Nguyen et al., 2019; Kwon, et al., 2020). It is important to note that during all these steps, precautions to avoid contamination from particles in the air, or with fibres from clothing, equipment or the reagents used, should be optimised (see Figure 1).

37. As seen in Figure 1, the majority of biological samples have been taken from aquatic species. The pre-separation method is dissection which recovers MPPs >500 µm, followed by separation methods including density separation, digestion using enzymes and various chemical compounds and filtration techniques. The analytical method is split between three categories: visual microscopic analysis, vibration spectroscopy (e.g. FTIR and Raman spectroscopy) and mass spectroscopy, the last of which is also suitable for the characterisation, quantification and identification of nanoplastics.



Sample types

Biological samples
Fish
Mussels
Plankton
Lack of representation of terrestrial organisms.

Air samples
Indoor and outdoor
Textile fibres

Wastewater samples
Influent
Effluent
Sludge
No harmonised proper organic matter content characterisation.

Water samples
Drinking water
Sea water
Fresh water

Sediment samples
Beach sediments
Deep sea sediments

Pre-separation

Dissection
Of the gastrointestinal tract or whole body which recovers particles >500 µm.

***In situ* sieving**
Nets
Stack filter devices
(Note: differences in mesh sizes typically 10 – 300 µm)
Blockage issues
Loss of smallest particle fraction

Separation methods

Density separation
Flotation
May note be suitable for the smallest fraction of particles, and organic matter.
Additional issues with bubbles.
Centrifugation
Lack of method development.
Ultrasonic separation

Digestion
Utilising enzymes, H_20_2, HNO_3, KOH, NaOH, HCl.
Further considerations are required for effects on plastic degradation, pH, temperature and possible chemical migration, and organic matter content.
Lack of a standard protocol.

Filtration
Typical filter size: 0.5 – 10 µm
Method often leads to underestimation of the smallest particle fraction due to the retention on the filter.

Analysis methods

Visual (potential for dye staining)
Allows determination of the particles shape, size, and colour but only those of particles >200 µm.
Microscopy
SEM and TEM
Microsection techniques to visualise the plastic spatial structure in tissues.

Vibration spectroscopy
In general, increases spatial resolution.
Raman microscopy
<20 µm
FT-IR
>20 µm

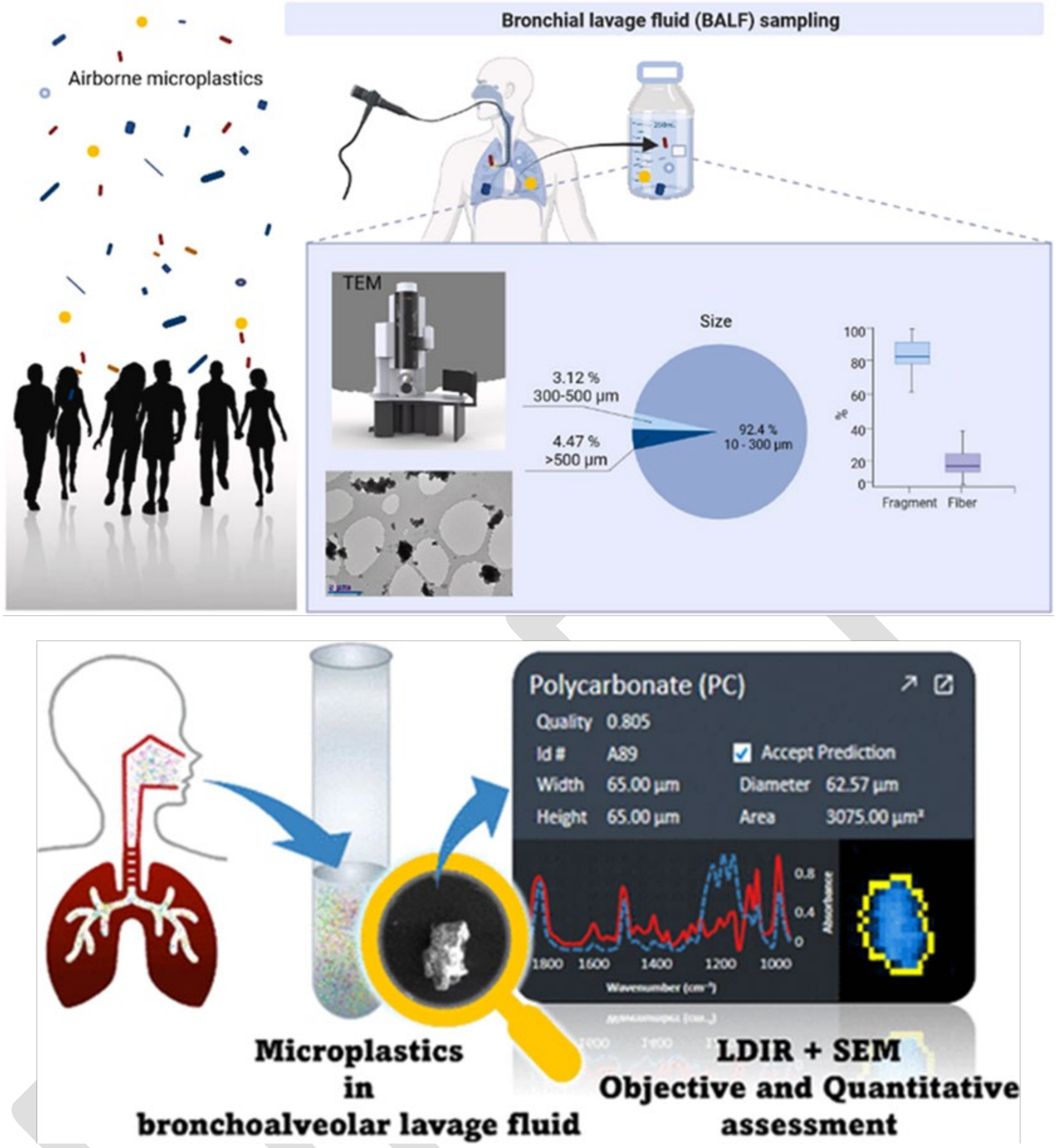
Mass spectroscopy
Method deemed to be suitable for nanoplastics.
TDS-GC-MS
Allows qualitative analysis.
py-GC-MS
greater sensitivity.

Spiked controls considerations for accurate recovery due to physicochemical properties of the particles.

Blank controls considerations for background level, contamination, and false positives from organic particle dyes.

Figure 1. Provides an overview of the methodologies utilised in the separation and analysis of microplastics and nanoplastics in complex environmental samples including: biological samples (fish, mussels and plankton), air samples (indoor and outdoor, synthetic textile fibres), wastewater samples (influent, effluent and sludge), water samples (drinking water, sea water and fresh water) and sediment samples (adapted from Nguyen et al., 2019). Abbreviations: H_2O_2 = hydrogen peroxide; HNO_3 = nitric acid; KOH = potassium hydroxide; HCl = hydrochloric acid; SEM = Scanning electron microscope; TEM = Transmission electron microscopy; FT-IR = Fourier-transform infrared; TDS-GC-MS = Thermodesorption gas chromatography-mass spectrometry; py-GC-MS = Pyrolysis gas chromatography-mass spectrometry (Image taken from COT Microplastics Overarching Statement 2021).

38. Studies have now reported human samples obtained during bronchoscopy procedures, whereby bronchoalveolar lavage fluid (BALF) was obtained. A measured fluid, such as saline solution was passed into the lung and then aspirated. These samples were then analysed using optical and TEM-EDX microscopy or SEM microscopy as shown in Figure 2 (Qiu et al, 2023; Uoginte et al. 2023). Other studies have detected microplastics in human lung samples using µFT-IR (Jenner et al. 2021).



Polycarbonate (PC)

Quality 0.805

Id # A89

☑ Accept Prediction

Width 65.00 µm

Diameter 62.57 µm

Height 65.00 µm

Area 3075.00 µm²

Figure 2. Diagrams taken from two studies observing microplastics in BALF samples (Qui et al, 2023; Uoginte et al. 2023).

39. Currently there are only limited analytical methods available to detect and quantify the presence microplastics in various matrices. These include FT-IR, Nile Red staining techniques, Micro-Raman spectroscopy, quantitative 1H nuclear magnetic resonance spectroscopy (qNMR) (Peez et al., 2019) and mass-spectroscopy; however, each of these methods has its own associated limitations (Nguyen et al., 2019).

40. Additionally, there are neither standardised testing protocols for different matrices (i.e. air, soil, food and water), nor standard refence materials for the analysis, characterization and quantification of micro and nanoplastics. No single technique is suitable for all plastic types or for all particle sizes or shapes. Therefore, the use of either a suite of methods or generation of new techniques will be necessary.

41. Comparison and replication of studies can be difficult due to differences in sampling, extraction, purification and analytical methods for enumerating and characterising microplastics. These methods are not yet standardized and have not been subject to interlaboratory validation. Contamination with airborne microplastics or cross contamination of samples can also occur, so suitable control samples may be difficult to obtain.

42. Most studies have performed tests on pristine particles; however, this may not be representative of what is present in the environment (i.e. the particles have not been subject to environmental degradation). Therefore, it is important to consider the variability among samples and batches of pristine particles when comparing studies of the same polymer type. However, these are not the only limitations and won’t necessarily solve the problem.

Physicochemical properties

43. There are four morphological and chemical characteristics of microplastics, i.e. physicochemical properties, which influence their potential hazards. These are:

i). Physical (e.g. bulk, fibres in the lung or those which could lead to gut blockage, as observed in aquatic and avian species);
ii). Chemical composition (unbound monomers, additives, sorbed chemicals from the environment e.g. persistent organic pollutants and metals);

iii). Metabolism or degradation to form monomers or other derivatives, some of which could be chemically reactive (e.g. isocyanates from polyurethane) and;
iv). The presence of biofilms (attachment and colonisation of microorganisms on the plastics).

44. Due to the small size of some nano-/microplastics (NMPs) (0.1 μm to 5 mm), uptake across the gastrointestinal tract (GIT) and uptake into internal tissues is possible and thus they may have both local and systemic effects. Particles <50 μm in size can be absorbed from the gut via inter-cellular gaps and by phagocytic and endocytic pathways but only those of <1-2 μm in size are able to cross the cell membranes of internal organs.

Physical properties

45. NMPs can differ in their physicochemical properties (shape, size, density, surface charge, etc). The consideration of physical properties during hazard and/or risk assessment of plastic particles is important because the interactions of NMPs with biological systems can vary with differences in their size and shape (Nel et al., 2009), even when they have the same chemical composition.

46. The physical properties and morphologies of tyre materials can also vary under different sampling conditions. Those collected from road runoff and shredded tyres have elongated shapes, whilst samples generated from road simulator systems in laboratories range between jagged, droplets, granules, warped, porous, irregular, and near spherical in shape (Wagner et al., 2018). A review by Kole et al., (2017) revealed that the size distribution range of tyre wear and tear particles, could be from 6-350,000 nm. This wide size distribution range was attributed to several factors including the use of difference size metrics (e.g. particle mass versus particle numbers), analytical difficulties in separating tyre from road particles, and the large variation in experimental conditions and analytical equipment.

Chemical Properties

47. A particle's chemical properties such as charge or zeta potential (when particles are immersed in a conducting liquid such as water) are dependent on its chemical composition.

48. A particle's properties can also be influenced and changed by its surface chemistry. Each particle could have its own unique corona consisting of proteins adsorbed from plasma and/or intra/extracellular fluid, adsorbed chemicals from the environment or microbiological organisms (see Figure 3).

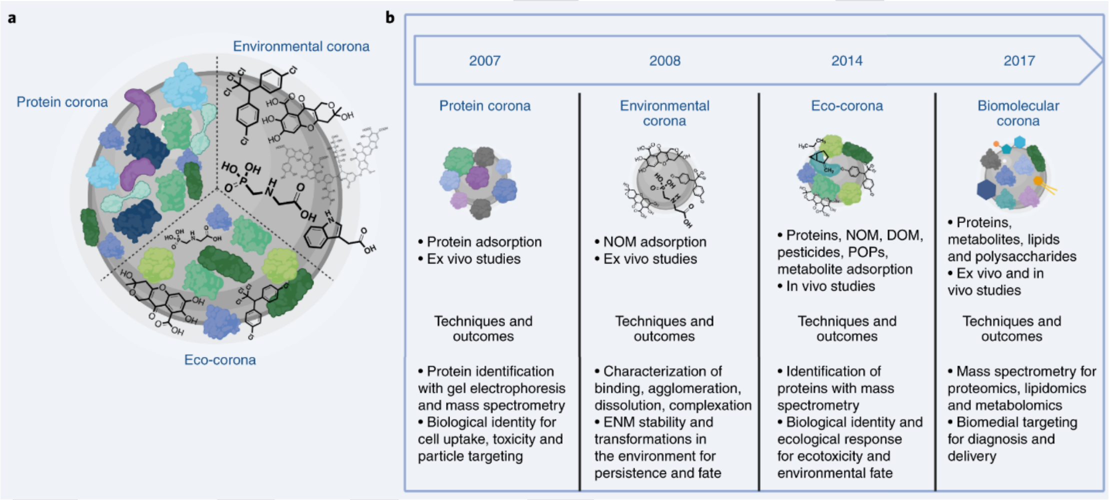


Figure 3. (a) Comparison of the protein, environmental, and eco-coronas.

Formed within organisms at locations of high protein content, the term protein corona has been used to describe the binding of proteins to ENM (engineered nanomaterials) surfaces, but also incorporates lipids, metabolites (typically <1000 Da which are either reactants, intermediaries or products of enzymatic processes), and other biomolecules. To date, the term environmental corona has described a corona formed in aquatic environments with high concentrations of NOM, including humic substances. By contrast, the eco-corona incorporates features of both the protein and environmental coronas, where the balance of proteins and other molecules varies. (b) The evolution of the protein corona concept, adapted from Hadjidemetriou and Kostarelos.

Studies of protein adsorption to surfaces and particles dates back to at least the 1960s. The term protein corona was first coined in 2007. Protein corona studies developed with mass spectroscopy-based proteomics to aid identification of the proteins bound at the surface of ENMs and explore the role of surface curvature in altering protein structure and function relative to macroscale surfaces. Protein corona studies evolved in parallel with those on the environmental corona, but the characterization techniques and goals for each area remained separate, with environmental corona focusing mainly on the dispersion stabilization provided by NOM (natural organic material). The environmental dimensions of the protein corona began to appear later, as the concept of the eco-corona and its role in (nano)ecotoxicity emerged. Both the eco-corona and biomolecular corona embrace the diversity of molecules in solution with the goal of understanding and controlling downstream biological responses to nano-enabled technologies. (Image obtained from Wheeler et al. 2021).

49. The physicochemical properties of micro and nanoplastics can change over their life cycle and can also affect each other. For example, physical degradation resulting in the formation of nano-sized plastic particles and/or plastic particles with different shapes can generate a higher number of particles and thus gives rise to a larger total surface area and higher particle number which in turn affects the concentration. The weathering process can change the surface chemistry and size of microplastics, and chemical migration from the MPPs into the surrounding medium results in altered stability which in turn changes the physical degradation processes (Wheeler et al. 2021).

Toxicity

50. The COT have previously reviewed the human data on the toxicity of microplastics via inhalation (TOX/2019/62). The available toxicity data in humans was based on studies of occupational exposure. In 1975, Pimental et al., found that seven patients who had been exposed to synthetic fibres

presented with different manifestations of bronchopulmonary disease. This was attributed in part to the dose and concentration of fibre exposure and also the length of service in the industry.

51. In Hillerdal et al., (1988), a case study of three female workers in the synthetic textiles industry reported fibrotic areas of the lung with multiple foreign bodies believed to be inhaled fibres which caused inflammation. Although the size of the fibres was unreported, from other literature it was known that the length, biopersistence and width of inhaled fibres was related to their potential pathogenicity (Davis et al. 1986).

52. Pauly et al., (1998) reported a comparison study of inhaled cellulosic and plastic (polyester) fibres which were found in human lung tissue with samples being taken from different pulmonary sites, indicating the inhaled fibres were distributed throughout the lung. The authors suggested a a possible correlation between the inhalation of these plastic fibres and lung cancer, whereas the cellulosic fibres were relatively inert. However, these were the authors conclusions and would need further investigation.

53. In their discussion of TOX/2019/62 the COT considered that the assessment of microplastics exposure via inhalation could be easier in comparison to the assessment of oral exposure given the availability of occupational data from the synthetic textile industry, however, the context should be considered. The Committee further noted that microplastic concentrations present in food and water were thought to be lower in comparison to airborne exposure.

54. According to Panko et al., (2019), particulate matter (PM) from tyre abrasion may represent between 0.8 and 8.5 % mass fraction of PM_{10} and 1 to 10% of $PM_{2.5}$ in the air. However, it is unknown what percentage of the PM2.5 burden consists of microplastics (Zhang et al., 2020).

55. The toxicological properties of microplastics may differ to that of $PM_{2.5}$ (or other pollutants) due to the additives present and their particular characteristics such as morphology and chemical composition (Zhang et al., 2020).

56. In 2020, the Committee on the Medical Effects of Air Pollutants (COMEAP) considered that the evidence on non-exhaust particles (road surface wear, re-suspended road dust, brake and tyre wear) from road transport and associated health effects should be re-evaluated. COMEAP concluded that, as a whole, the body of published work is small and did not provide a compelling narrative of adverse health effects of exposure to non-exhaust particles. However, as there was strong evidence that exposure to particulate pollutants in ambient air is harmful to health, some health risk associated with exposure to non-exhaust particles was likely.

57. COMEAP concluded that the available evidence is not very informative about which components or sources of particulate air pollution are particularly harmful to health and that evidence relating to non-exhaust emissions from traffic, is limited (COMEAP, 2020; 2022)

Inhalation studies (2020-March 2023)

In vitro

58. When the Overarching Statement by the COT was published, it included studies up to 2020 and therefore this statement concentrates on those studies published from 2020 to the March 2023.

59. Dong et al., (2020) assessed the pulmonary toxicity of polystyrene microplastics in vitro using BEAS-2B lung cells to determine the cytotoxic and inflammatory effects. The polystyrene MPs decreased 1 α-antitrypsin levels and transepithelial electrical resistance by depleted zonula occludens proteins: these are a type of scaffolding protein. The study results indicated that low levels of polystyrene MPs cause disruption to the protective

pulmonary barrier and high levels may have an adverse effect on human lung health. This is based on testing in a single cell line which is not representative of in vivo exposure, however there are now 3D models available which can provide a more suitable model for examining the effects of airborne microplastics (Winkler et al. 2022).

In vivo

60. There is limited research on in vivo exposure to airborne microplastics. Lim et al., 2021 used a modified version of the OECD guideline (TG 412) 28-day inhalation toxicity study using a whole-body system. Sprague-Dawley rats were exposed to three different concentrations (0.75, 1.50 and 3.00 x 10^5 particles/cm^3) of 0.1 μm polystyrene NMPs for 6 h each day, 5 days/week for 2 weeks. There was a lack of dose response and no definitive link between concentration at 14 days exposure, and observed alterations to the physiological, serum biochemical and haematological parameters or markers of respiratory function. However, there was a concentration-dependent response associated with increased expression of TGF-β and TNF-α inflammatory proteins. These authors suggest that sustained exposure to higher concentrations of NMPs may result in alterations at the molecular level, thus a risk to health from inhalation of polystyrene micro/nanoplastics. However, caution must be given to the weighting of this study as rat lungs differ greatly from human lungs and therefore may not give a realistic representation of exposure in the human lungs. In addition, it is important to distinguish between normal acute particle clearance mechanisms and more persistent, potentially pathophysiological, responses.

Toxicokinetics

61. As discussed in COT Statement Number 2021/02 , the toxicity of microplastics is dependent on a number of factors including size, morphology, chemical composition, additive leaching density and surface functionalization.

62. Surface functional groups may affect the adsorption of organic contaminants and heavy metals leading to different mobility and toxicity (Kim et al., 2017; Sun et al., 2020; Yao et al., 2022). However, the MP vector effect is usually framed as ‘complex’, ‘under debate’ or ‘controversial’ (Koelmans et al., 2022b).

63. Deposition of respirable fibres occurs in the lung as a function of their aerodynamic diameter of the particle, whereas non-respirable fibres are often inhaled through the nasal passage but are then caught in mucus and swallowed thus creating a secondary exposure via the gastrointestinal tract. There are four main mechanisms of deposition in the lung: impaction, sedimentation, diffusion and interception (Darquenne, 2006).

64. Inertial impaction occurs for particles with a diameter > 5 μm or for those with excessive momentum. As a particle travels through the airways, it remains on the same trajectory. If the air flow changes direction, the particle will remain on its existing pathway, deviating from the changed airflow and impacting on to the surface of the airways. Inertial impaction occurs in both the upper respiratory tract and the conducting zone only.

65. For particles with a diameter between 0.5 to 5 μm, the main deposition mechanism is sedimentation. This occurs mainly in the bronchi and bronchioles; when air resistance and gravity overcome the buoyancy of the particle causing it to settle on the surface of the lung.

66. Airborne particles are in constant random Brownian motion, due to collisions with the gas molecules. This results in random, omnidirectional particle movement, known as diffusion. This occurs only with smaller particles, typically < 0.5 μm. Occasionally particles will collide with the cell surface, causing them to settle there. Diffusion occurs mainly in the small airways and alveoli, although the particles can also deposit in the upper airways by this mechanism particularly when their diameter is < 0.01 μm (Tsuda et al., 2013).

67. Interception occurs when fibres with a large ratio between their length and diameter travel so close to the surface of the lung that they make contact. Deposition by interception increases with the length of the fibre. The area of deposition in the lung is dependent on the aspect ratio of the fibre but can also arise due to changes in airflow.

68. The deposition of inhaled microplastics in the lung is dependent on the particle’s physicochemical properties, as well as the subject’s physiology and lung anatomy. Deposition in the upper airways occurs by impaction, while in the small airways it occurs by sedimentation. Fibres have higher potential than spherical particles for penetration due to their high aspect ratio (Donaldson & Tran, 2002). Clearance relies on mechanical processes (e.g. mucociliary clearance where the mucous progresses towards the pharynx caused by the beating of cilia), alveolar macrophage phagocytosis and migration, and by lymphatic transport which can result in deposition in the GIT.

69. Clearance mechanisms for inhaled MPs > 5 µm, are likely to occur via the mucociliary escalator, where the particles are either expelled from the body via sneezing or coughing, or they are swallowed and taken into the gastrointestinal tract.

70. Some particles bypass the mucociliary clearance and travel deeper into the lung where phagocytosis occurs. Macrophage phagocytosis can break down particles < 20 µm by either dissolution or degradation but this is dependent on the particle biopersistence. If a particle is > 20 µm in length, macrophages will not be able to fully engulf the particle, resulting in frustrated phagocytosis (Donaldson et al., 2010). This state causes an increased recruitment of macrophages, which can result in the phenomenon known as an “oxidative burst” occurring where inflammatory mediators and oxidants are released in high concentration, potentially leading towards the onset of lung inflammation and fibrosis (Donaldson et al., 2010; Gasperi et al., 2018). Inflammation induces cell proliferation and secondary genotoxicity due to the

continuous formation of reactive oxygen species (ROS), resulting in oxidative stress, but this is not always the case.

71. It is believed that once particles reach the pleura then they may reach the pleural space, however it is currently unknown how this particle migration occurs. Once particles reach the pleura, they may then travel to the lymphatic system which also helps clear phagocytic cells (Donaldson, et al., 2010; Enyoh et al., 2019). Translocation to secondary tissues and organs may then occur (Fournier et al., 2020; Wright and Kelly, 2017).

Exposure

72. Microplastics are present in the indoor and outdoor environment. The MPs can result from textiles, furniture, toys, electric cables and cleaning agents, construction material and litter.

73. The data available on outdoor exposure is limited. However, studies have shown than when comparing inhalation and ingestion routes indoors, microplastic exposure via ingestion is minimal in comparison to inhalation.

Outdoor exposure from air

74. Microplastics found outdoors are more likely to fracture due to weathering in comparison to the microplastics present indoors. However, data on the levels and types of microplastics in the air compared to other media are limited (Ageel et al., 2021).

75. Environmental exposure to airborne microplastics occurs from a wide range of sources with synthetic textiles and the erosion of synthetic rubber tyres being the most frequently reported in the literature. Resuspended city dust which contains a fraction of settled synthetic fibres/rubber tyre wear is a secondary source of airborne microplastics. Wind transfer is estimated to be responsible for 7% of the ocean’s contamination (Boucher & Friot, 2017).

76. The fate and dispersion of microplastics in outdoor environments are dependent on several factors. These include the vertical pollution concentration gradient where there are higher concentrations near the ground due to deposition and settling, wind speed and direction, land topography, precipitation and temperature. Concentrations of airborne microplastics in outdoor air are expected to be low, due to dilution. O'Brien et al. (2023) noted in their review that the concentration of microplastics in outdoor ambient air ranges between <1 and >1000 microplastics/m^{3,} while the outdoor deposition concentrations ranged between 0.5 and 1357 microplastics/m^{2}/day.

77. There is limited information regarding the concentrations of airborne microplastics, however, the Dris et al., (2016, 2017) studies carried out in Greater Paris found average outdoor deposition rates of 53 and 110 particles/m^{2}/day. Data for Central London on outdoor deposition rates of microplastics have also been reported, and these range from 575-1,008 total MPPs/m^{2}/day; 510-925 fibres/m^{2}/day (Wright et al., 2020). These numbers are affected by climate conditions and seasonality and are also affected by the sampling and analytical methodologies used.

78. An American study (Cox et al., 2019) has proposed an estimated daily consumption and inhalation of 142 MPPs and 170 MPPs in adult male, respectively. For adult females, the estimated values are 126 MPPs and 132 MPPs, respectively for the same exposure routes. Based on these values, a total annual estimated exposure of ~120,00 and ~98,000 MPPs annually was calculated in male and female adults, respectively. These exposure estimates were based on reported microplastic concentrations in salt, alcohol (beer), seafood (fish, shellfish and crustaceans), added sugars (sugar and honey), water (bottled and tap), and in air. Note that the estimated annual exposure values did not take into account atmospheric deposition of microplastics during food preparation and consumption. The authors are of the view that "these estimates are subject to large amounts of variation; however, given methodological and data limitations, these values are likely underestimates."

79. As noted previously, inhalation of microplastics can result in toxicity due either to the physical effects of the particles or the chemical effects of their leachates. The author concluded the response in humans depends on differences in individual metabolism and susceptibility (AmatoLourenço et al., 2020). It is not yet known how the toxicity of synthetic fibres compares with that of organic/natural fibres (Donaldson & Tran, 2002). However, it is known that fibres from synthetic textiles are quite flexible (Bunsell (ed), 2018) and hence do not possess the characteristic long thin morphology of asbestos fibres, which is responsible for their toxicity and carcinogenicity.

80. In general, the mechanisms of inhaled particle injury include dust overload where high surface area particles induce high chemotactic gradients that prevent macrophage migration, oxidative stress (production of reactive oxygen species, which induces cell injury and release of inflammatory mediators), cytotoxicity (free intracellular particles may damage cellular structures), and translocation (injury of secondary sites and vascular occlusion by particles or increased coagulability). Depending on the nature of the particle and the extent of exposure, such mechanisms might lead to adverse endpoints such as fibrosis, which can develop as a result of chronic cytotoxicity and inflammation.

Indoor exposure

81. The indoor behaviour of airborne microplastics is dependent on factors including room partition, ventilation and airflow.

82. Atmospheric deposition of MPPs onto food prior to consumption should also be considered as a potential source of exposure.

83. As stated previously, Catarino et al., (2018) compared the potential exposure of humans to household dust fibres during a meal using information on the amounts of MPPs present in edible mussels from Scottish waters collected throughout 2015. Although this study mostly focussed on the

presence of microplastics ingested by mussels in different areas, the study also quantified the amount of microplastics/fibres that could contaminate food within a household environment and then compared the airborne number of microplastics in mussels with those consumed from airborne fibres landing on the food during cooking and consumption. The airborne fibres were collected using stationary passive samplers which consisted of 2 rectangular double-sided adhesive white pads in plastic petri dishes and the fallout was collected either by closed petri dish, open petri dish during cooking time of 20 minutes, open petri dish open for 20 mins during food consumption, open petri dish open for 40 minutes during both cooking and consumption of food and also a control. The mean number of MPPs in Modiolus modiolus was 0.086/gram wet weight (n=6). In Mytilus spp. the mean number of MPPs/gram wet weight was 3.0 (n=36). Fibres were the most common shape morphology of MPPs detected, utilising FT-IR and Nile Red staining techniques; PET was estimated to be the most common plastic type. The authors estimated that microplastic ingestion by humans via consumption of mussels was 123 MPPs/person/year in the UK, however, the risk of plastic ingestion via mussel consumption was minimal when compared to fibre exposure during an evening meal via dust fallout in a household at ~14,000-68,000 MPPs/person/year. These values were based on the following assumptions; deposition of 1 particle per 20 minutes for an area of 4.32 cm^2, this value was extrapolated to a 12.5 cm radius plate, resulting in 114 particles (assuming constant exposure rate), equating to approximately 42,000 MPPs consumption/person/year, for 20 minutes during consumption of an evening meal. During a cooking period of 20 minutes, a constant fibre fallout of 5 MPPs per 4.32 cm^2 was assumed, the potential human ingestion increases to ~207,000 MPPs/person/year. These values were then corrected by 33% which was reported to be the proportion of petrochemical based fibres found in dust by Dris et al., (2017).

84. Dris et al., (2017) investigated indoor (two apartments and one office) air samples in the city centre of Paris. Indoor concentrations of microplastics ranged between 1.0 and 60 fibres/m^3. The fibres that were measured indoors

consisted of 67% of natural materials, primarily made of cellulosic materials and the remaining 33% contained petrochemicals, predominantly polypropylene.

85. Zhang et al., (2020) collated data from 46 studies and calculated the annual intake of indoor and outdoor microplastics using an inhalation rate of 14.3 m^3 per day as 1.9 x 10^3-1.0 x 10^5 and 1 x 10-3.0 x 10^7 particles respectively, with approximate means of 3 x 10^4 for indoor exposure and 4 x 10^3 for outdoor exposure, confirming that there is increased exposure to microplastics in the indoor environment. Whereas Fang et al., (2022), calculated the annual atmospheric deposition of MPs as 3.5 x 10^5 – 2.2 x 10^7 items (Figure 4).

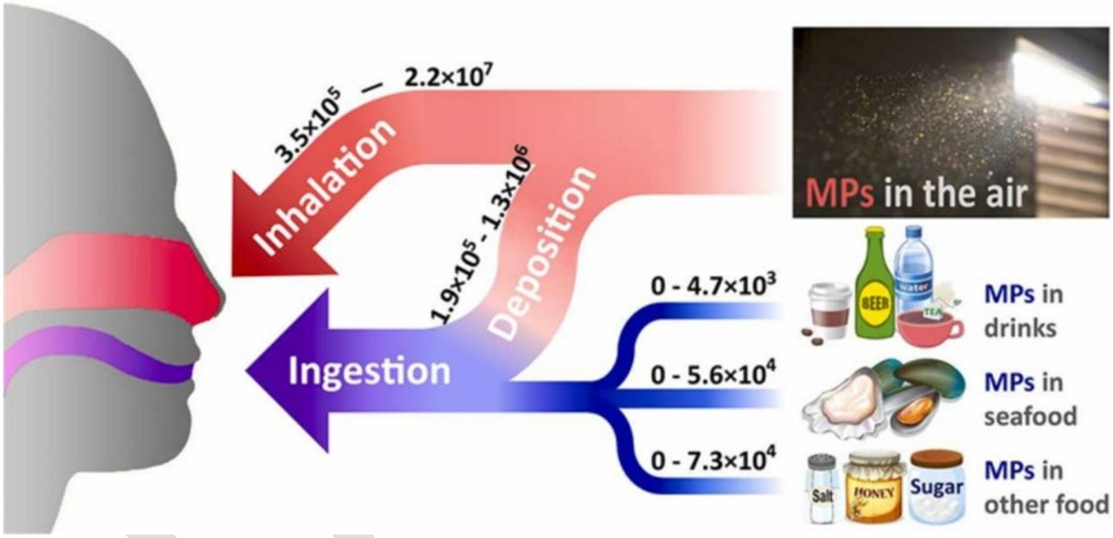


Figure 4. Diagram of microplastics (MPs) via the inhalation and ingestion routes of exposure showing that ingestion of microplastics (items/year) is minimal in comparison to the inhalation route, whereas microplastics that have deposited on food and then ingested was of a similar magnitude to the microplastics via the inhalation route(Taken from Fang et al., 2022).

86. A recent study conducted in Hull, UK sampled 20 households each month for a 6 month period for atmospheric fallout detecting an average of 1414 microplastics/m^2 per day with particles in the size range of 2-250 µm contributing 90% of the particles found. Polyethylene terephthalate (PET),

polyamide (PA) and polypropylene (PP) were the most abundant materials in the samples collected (Jenner et al., 2021).

87. Microplastics have been identified in all areas of the lung from tissue samples obtained following surgical resection for cancer or lung reduction surgery. Table 1 below contains the information obtained from the tissue samples, including the length and width of the particles found. Data was not normally distributed (p = 0.013) and a Kruskal-Wallis test showed that the number of NMPs in the lower region were significantly higher than the middle/lingular (p = 0.038) and the upper region (p = 0.026). Within the upper region (n = 6, total mass = 33.66 g), 11 NMPs were identified; PE (polyethylene) (18%), PP (18%), PES (polyester) (9%), PS (polystyrene) (9%), resin (9%), SEBS (styrene-ethylene-butylene co-polymer) (9%), TPE (thermoplastic elastomer) (9%). Within the middle/lingular region (n -3, total tissue mass = 12.19 g), 7 NMPs were identified; PET (29%), resin (29%), PE (14%), PMMA (polymethylmethacrylate) (14%), PUR (polyurethane) (14%). Within the lower region (n = 4, total tissue mass = 9.56 g), 21 NMPs were identified; PP (33%), PTFE (polytetrafluoroethylene) (19%), PET (14%), Resin (14%), PS (10%), PAN (polyacrylonitrile) (5%), PE (5%) (Jenner et al. 2022) (see Figure 5).

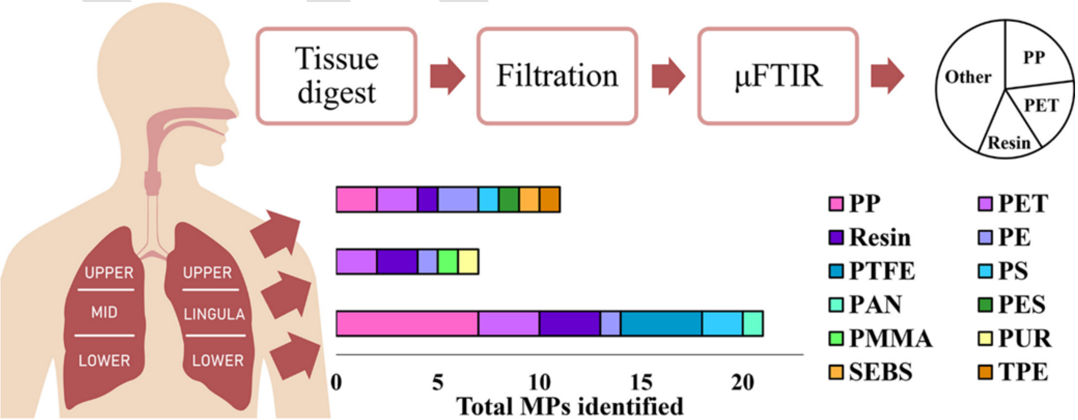
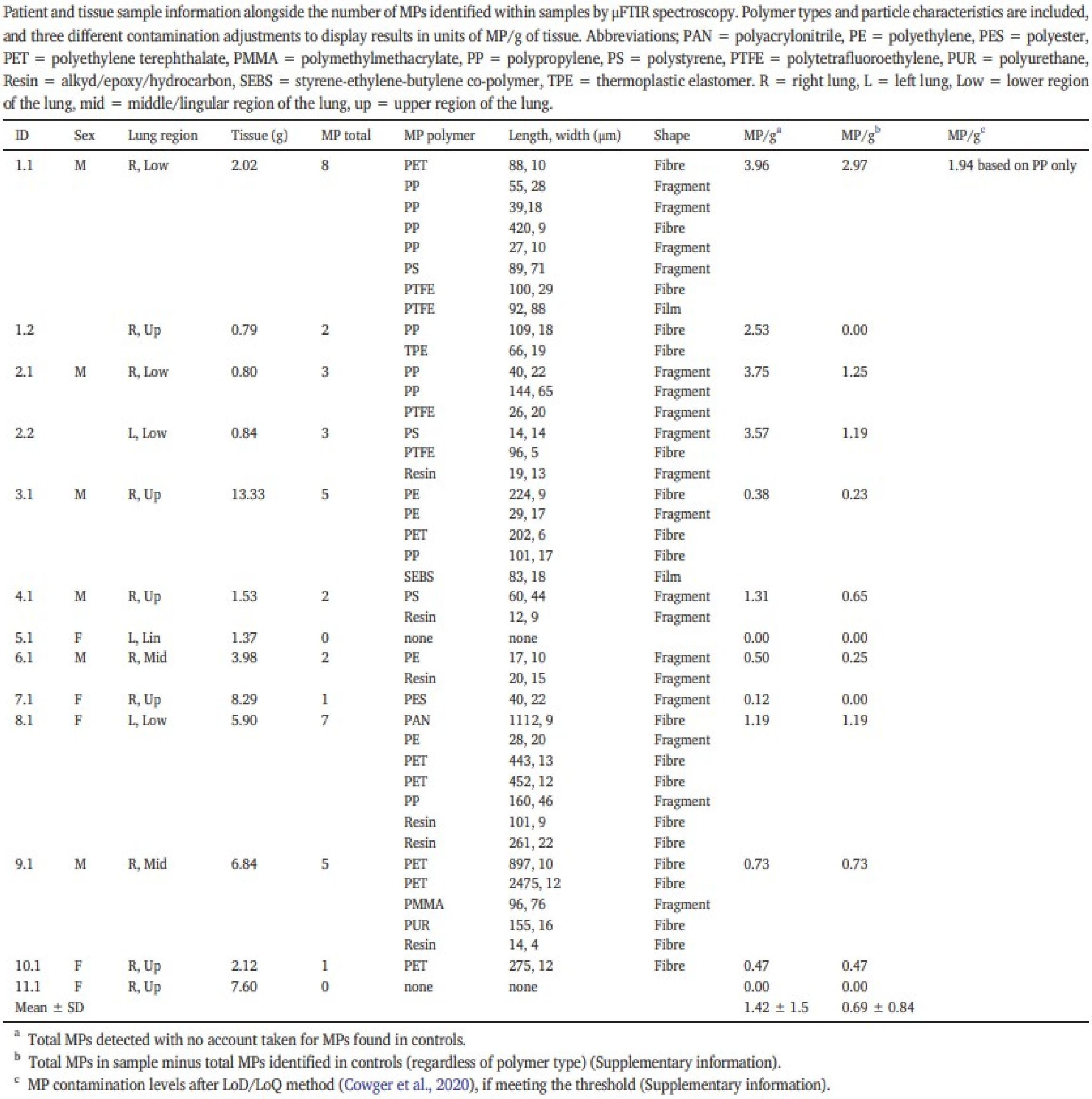


Figure 5. Diagram showing the difference polymer types discovered in the lung and the area of the lung Particle number (total MPs detected with no account taken for MPs found in controls) and polymer type of MPs identified

within human lung tissue samples, assigned to their lung region. (Taken from Jenner et al., 2022).

Table 1. Data obtained in the Jenner et al. 2022 study including the length and width of particles and region of the lung particles are found (taken from Jenner et al. 2022).



Patient and tissue sample information alongside the number of MPs identified within samples by μFTIR spectroscopy. Polymer types and particle characteristics are included, and three different contamination adjustments to display results in units of MP/g of tissue. Abbreviations; PAN = polyacrylonitrile, PE = polyethylene, PES = polyester, PET = polyethylene terephthalate, PMMA = polymethylmethacrylate, PP = polypropylene, PS = polystyrene, PTFE = polytetrafluoroethylene, PUR = polyurethane, Resin = alkyd/epoxy/hydrocarbon, SEBS = styrene-ethylene-butylene co-polymer, TPE = thermoplastic elastomer. R = right lung, L = left lung, Low = lower region of the lung, mid = middle/lingular region of the lung, up = upper region of the lung.

ID	Sex	Lung region	Tissue (g)	MP total	MP polymer	Length, width (μm)	Shape	MP/g[a]	MP/g[b]	MP/g[c]
1.1	M	R, Low	2.02	8	PET	88, 10	Fibre	3.96	2.97	1.94 based on PP only
					PP	55, 28	Fragment			
					PP	39,18	Fragment			
					PP	420, 9	Fibre			
					PP	27, 10	Fragment			
					PS	89, 71	Fragment			
					PTFE	100, 29	Fibre			
					PTFE	92, 88	Film			
1.2		R, Up	0.79	2	PP	109, 18	Fibre	2.53	0.00	
					TPE	66, 19	Fibre			
2.1	M	R, Low	0.80	3	PP	40, 22	Fragment	3.75	1.25	
					PP	144, 65	Fragment			
					PTFE	26, 20	Fragment			
2.2		L, Low	0.84	3	PS	14, 14	Fragment	3.57	1.19	
					PTFE	96, 5	Fibre			
					Resin	19, 13	Fragment			
3.1	M	R, Up	13.33	5	PE	224, 9	Fibre	0.38	0.23	
					PE	29, 17	Fragment			
					PET	202, 6	Fibre			
					PP	101, 17	Fibre			
					SEBS	83, 18	Film			
4.1	M	R, Up	1.53	2	PS	60, 44	Fragment	1.31	0.65	
					Resin	12, 9	Fragment			
5.1	F	L, Lin	1.37	0	none	none		0.00	0.00	
6.1	M	R, Mid	3.98	2	PE	17, 10	Fragment	0.50	0.25	
					Resin	20, 15	Fragment			
7.1	F	R, Up	8.29	1	PES	40, 22	Fragment	0.12	0.00	
8.1	F	L, Low	5.90	7	PAN	1112, 9	Fibre	1.19	1.19	
					PE	28, 20	Fragment			
					PET	443, 13	Fibre			
					PET	452, 12	Fibre			
					PP	160, 46	Fragment			
					Resin	101, 9	Fibre			
					Resin	261, 22	Fibre			
9.1	M	R, Mid	6.84	5	PET	897, 10	Fibre	0.73	0.73	
					PET	2475, 12	Fibre			
					PMMA	96, 76	Fragment			
					PUR	155, 16	Fibre			
					Resin	14, 4	Fibre			
10.1	F	R, Up	2.12	1	PET	275, 12	Fibre	0.47	0.47	
11.1	F	R, Up	7.60	0	none	none		0.00	0.00	
Mean ± SD								1.42 ± 1.5	0.69 ± 0.84	

[a] Total MPs detected with no account taken for MPs found in controls.
[b] Total MPs in sample minus total MPs identified in controls (regardless of polymer type) (Supplementary information).
[c] MP contamination levels after LoD/LoQ method (Cowger et al., 2020), if meeting the threshold (Supplementary information).

88. The concentration of microplastics in indoor air is dependent on what occurs in the environment, for example, whether it is a home or occupational setting (discussed below in para. 95-96).

Occupational exposure

89. Certain occupations for example working in the synthetic and flock material industries can result in higher exposure to microplastics increasing the risk of developing occupational diseases. Burkhart et al., (1999) reported that in the nylon flocking area of a manufacturing plant, where the nylon particles are applied to a product, the highest concentration of airborne particles reached 7 mg/m^3.

90. Characterisation of MPs from nail salons found the predominant sizes to be <50 μm and the estimated average annual indoor exposure of MPs was 67,567 ± 81,782 MPs/year. The polymers were predominantly acrylic (27%), rubber (21%) and polyurethane (13%), however the characteristics and polymer composition differed between nail salons. Factors that influenced the concentrations of MPs included the type of nail treatment being conducted, the use of air conditioning units and number of people present (Chen et al., 2022). Therefore, concentrations of MPs are such that they are more likely to affect human health from occupational exposure than from indoor exposure at home and the concentration is dependent on the atmospheric conditions (Prata, 2018).

Potential new approaches

91. To date there are no standardised characterisation, collection and analytical methods for airborne microplastics or comprehensive risk assessment of NMPS. However, studies are beginning (Koelmans 2022a) to suggest ways in which this could be done.

92. It has also been suggested that an adverse outcome pathway (AOP) framework including the mechanisms of adverse effects, and new approach methodologies (NAMs) can be used in improving the decision making process with regard to microplastic hazard assessment. The use of read-across, microphysicochemical systems (such as organ on a chip), fluid dynamics,

computational models and “omics” cannot only reduce the number of animals used and the traditional testing methodologies, but might also provide a more robust scientific basis for decision-making (Halappanavar and Mallach 2021). However, at present, these methods have not had much success in relation to ambient air pollutants.

COT evaluation

93. NMPs are widespread, they are either intentionally added to products or occur as a result of plastics being fragmented down into smaller sizes by natural processes such as wear, weathering and corrosion. There is no internationally agreed definition of what a microplastic is, however, the most widely used size range is from 0.1-5,000 µm. Plastic particles that are smaller than the lower range are considered nanoplastics (i.e. 1 nm – 0.1 µm).

94. Microplastics can have a wide range of physicochemical properties, depending on the primary purpose of the plastic; however, these properties may not be the same in secondary microplastics, where fragmentation has occurred as a result of natural processes (and as such the MPPs are not considered pristine). Additionally, analytical methodology is limited to Fourier-transform infrared spectroscopy(FT-IR), Nile Red, quantitative nuclear magnetic resonance(qNMR), Micro-Raman spectroscopy and mass-spectroscopy.

95. There are no standardised testing methods for different matrices such as air, soil, food and water; the available methods have their own associated limitations, and suitable reference materials are not currently available. Furthermore, no single technique is suitable for all plastic types and/or for all particle sizes or shapes. Using a suite of methods or generation of new techniques may be necessary to fully assess microplastics.

96. In terms of the toxicity of NMPs, there are no studies suitable for identification of No Observed Adverse Effect Level (NOAEL) for any polymer

type (with the possible exception of PET powder at 2,500 mg/kg bw/day in rats for oral exposure as reported by Merski et al., 2008, however, this study has several limitations and was conducted using the oral exposure route). Available data from the European Chemical Agency registration, evaluation, authorisation and restriction of chemicals (ECHA REACH) database relates only to the starting materials i.e. the monomers. Furthermore, variability in exposure routes must also be considered.

97. Comparing studies using different methodology and analytical techniques can be challenging as there is currently no standardization for characterizing and testing microplastics.

98. Contamination with airborne microplastics or cross-contamination of samples may also affect the interpretation of studies, so suitable control samples may be difficult to obtain.

99. The COT also considered whether particles arising from tyre wear were considered to be microplastics (TOX/2020/15 Annex B1). It was concluded that human exposure can occur from airborne particulate matter derived from tyre wear material of which some could be considered as microplastics. However, challenges arise in evaluating the risk of this particulate matter due to other variables such as aging and weathering of tyres, temperature effects, the types of road surfaces they are used on and driving style. These variables result in the generation of a variety of chemicals which have significantly different biological and toxicological potencies and effects.

100. Most toxicity studies have been performed with pristine particles, mostly polystyrene; however, these may not be representative of what is present in the environment as the particles have not undergone degradative processes or contain any additional pollutants that attach to the microplastic. There are no specific reference materials that can be used and batch to batch variation can also occur.

101. Currently a full risk assessment on the potential toxic effect(s) of NMPs could not be carried out due to several data gaps including:

- The unavailability of harmonised methodologies to characterise, quantify and identify NMPs;
- The lack of toxicokinetic and toxicity data in general. There are no studies suitable for the identification of NOAELs for the different polymer types except possibly for PET powder by the oral route at 2,500 mg/kg bw/day in rats, (see paragraph 96), which had a number of limitations (e.g. particle size and count were not determined/reported);
- The paucity of currently available data for microplastics and airborne exposure and;
- The difficulty of performing an accurate exposure assessment.

102. For the reasons above, a case-by-case approach to risk assessments may need to be considered. This aligns with the conclusions reached by other authoritative bodies (WHO, 2022; Environment and Climate Change and Health Canada(ECC and HC), 2020; EU Science Advice for Policy by European Academies (SAPEA), 2019; EU Group of Chief Scientific Advisors; Scientific Advice Mechanism (SAM), 2019, as described in the COT overarching statement on the potential risks from exposure to microplastics; COT Statement 2021/02, paragraphs 101-129).

Research priorities for risk assessment

Data gaps

103. For the inhalation route the significant data gaps include the lack of:

- Harmonised analytical methods for detection of different NMPs during sample collection;
- Methods of detection of NMPs in tissues and their systemic effects;

- Understanding the contribution and effects of different exposure scenarios (e.g. indoor and outdoor environments);

- Understanding how different pre-existing lung and other lung disease states may be involved in the observed effects from microplastic exposure and;

- How available occupational data and on other particle types should be extrapolated to the general population.

- Data on inhalation exposure to MPs that are resuspended in an indoor environment.

Priorities for risk assessment

104. The COT recommends the following research priorities in order of importance for addressing the data gaps in the potential toxicity of NMPs in humans and suggest a call should be put out to researchers. Information in these areas will assist in the future risk assessment of these particles by inhalation and other routes of exposure.

1. Studies (in silico, in vitro and/or in vivo) to explore the effect(s) of the same type of NMP on different tissues, and of different types of NMP (e.g. polymer type, size, shape) on the same target tissue. – Physicochemical properties

2. Development of reference standards and materials for use in wet lab/experimental settings. Also, development of appropriate fit-for-

purpose quantification and detection methodologies for micro and nanoplastics in different matrices.-Analytical methodologies

3. Investigation of the extent to which NMPs with a range of sizes and compositions are assimilated into human tissues and the development of techniques capable of identifying the presence of microplastics in the human body (e.g. in biopsies, samples from tissue banks, if possible, histopathology sections; presidual controls at point of sampling). – Biological effects.

4. From studies of particles at the nanoscale, it is known that nanoplastics can deposit lower down in the lung and have been shown to translocate across the pulmonary cellular barrier to secondary organs (Fournier et al., 2020). Therefore, more studies looking into the potential effects of nanoplastics are needed to understand size related effects. – Physicochemical properties

5. Studies on the persistence and potential accumulation of NMPs in the human body, and on the extent to which NMPs are digestible. – Kinetics

6. Assessment of the degradation of novel/emerging plastic-based materials on the market such as biobased plastics (for example bamboo ware, polylactic acid, chitin) and other advanced polymer matrix composite materials during their use and end-of-life for their possible contribution to NMPs. It is unclear whether, and by how much, they already contribute to the burden of NMPs or similar particles. – Migration and degradation.

7. Microplastic concentrations in the environment are expected to increase in the future. In addition, increased and widespread use of single-use plastic personal protective equipment due to the COVID-19 pandemic may also be a significant contributing source of plastic pollution (Silva et al., 2021; Ma et al., 2021; Devereux et al. 2023).

> However, the quantification methods for microplastic particulate matter is currently limited and can only be estimated, thus improved technology is required. Therefore, there will be a need to regularly assess the levels of NMPs in relevant food stuffs, water and the air, such as by establishing a monitoring programme. This data would ideally be shared by collaboration among academia, researchers and government bodies at a national and international level. – Migration/degradation and analytical methodology/detection.

COT conclusions

105. The COT noted that there are limited data regarding the toxicokinetic fate of inhaled microplastics in mammalian species. The extent to which retention in the lung is of concern is not yet clear. No epidemiological or controlled dose studies that evaluated the effects of inhaled microplastics in humans were identified.

106. As such, the COT concludes that based on the available data, it is not yet possible to perform a complete assessment for the potential risks from exposure to micro and nanoplastics via the inhalation routes; however, they concur with the conclusions reached by other authoritative bodies (EFSA (2016, 2020, 2021), WHO (2019, 2022), ECCC (2020) and HC, SAPEA (2019), SAM (2019), as described in the COT overarching statement on the potential risks from exposure to microplastics : COT Statement 2021/02, paragraphs 101-129).

107. The COT concluded that the literature data on exposure to particles from tyre wear from other plastics would need separate consideration from microplastic exposure from food, since the particles are chemically quite different in their polymeric nature. Risk assessment of such material was considered potentially outside the scope of the current exercise.

108. The most significant data gaps are the lack of appropriate and harmonised analytical methods for the detection of micro- and nanoplastics (together with suitable reference standards), as well as information on their toxicokinetic and toxicity profiles in/relevant for humans.

109. The COT highlighted that additional information will be needed from all exposure sources, which include indoor and outdoor air, dust and soil before a risk assessment can be completed. The presence of MPs in food and water needs to be put into perspective with other sources of MPs such as atmospheric fallout.

110. Current studies typically focus on only one type of particle/tissue interaction, as such, further research is necessary to explore the effects of the range of particle types in different tissues in vitro and/or in vivo. This range of particle types should also take account of emerging/novel plastic-based materials such as bioplastics. The future priorities for risk assessment are shown in Table 2.

Table 2. Table of future priorities for risk assessment divided into opportunities for improved study design and reporting and research needs.

Opportunities for improved study design and reporting	**Research needs**
Studies to explore the effect(s) of the same type of NMP on different tissues and of different types of NMP on the same target tissue.	Development of reference standards and an appropriate fit for purpose quantification and detection methodologies for micro and nanoplastics in different matrices.
More studies looking into the potential effects of nanoplastics to understand size related effects.	Investigations with NMPs of a range of sizes and compositions assimilated into human tissues and development of techniques capable of identifying the presence of microplastics in the human body.
Studies on the persistence and potential accumulation of NMPs in the human body and on the extent to which NMPs are digestible.	Improved technology and quantification methods for microplastic particulate matter.

Assessment of the degradation of novel/emerging plastic-based materials on the market such as biobased plastics and other advanced polymer matrix composite materials during their use and end of life for their contribution to NMPs.	No data.
Regular assessment of NMPs in water, air and relevant food stuff and establish a monitoring programme. This can then be shared between academia, researchers and government bodies both nationally and internationally.	No data.

Statement 2023

Abbreviations

1 α-antitrypsin	Alpha-1 antitrypsin
ABS	Acrylonitrile butadiene styrene
COT	Committee on Toxicity of Chemicals in Food, Consumer Products and the Environment
COMEAP	Committee on Medical Effects of Air Pollution
CONTAM	Contaminants in the Food Chain
Defra	Department for Environment, Food and Rural Affairs
EC	European Commission
ECC	Environment and Climate Change
ECHA	European Chemicals Agency
EFSA	European Food Safety Authority
FT-IR	Fourier-transform infrared spectroscopy
FSA	Food Standards Agency
GIT	Gastrointestinal tract
HC	Health Canada
ILSI	International Life Sciences Institute
MILC	Mothers' information on lactation and collection
MOE	Margin of exposure
MPPs	Microplastic particles
NEE	Non-exhaust emission
NMPs	Nano- and microplastics
NOAEL	No observed adverse effect level
OECD	Organisation for Economic Co-operation and Development
PAHs	Polyaromatic hydrocarbons
PCBs	Polychlorinated biphenyls
PE	Polyethylene
PET	Polyethylene terephthalate
PM_{10}	Particulate matter (10 µm)
PP	Polypropylene

py-GC-MS	Pyrolysis coupled with gas chromatography and mass spectroscopy
qNMR	Quantitative Nuclear Magnetic Resonance
RAC	Committee for Risk Assessment
REACH	Registration Evaluation Authorisation and Restriction of Chemicals
ROS	Reactive oxygen species
RUBIAC	Rubber Industry Advisory Committee
SAM	EU Group of Chief Scientific Advisors; Scientific Advice Mechanism
SAPEA	EU Science Advice for Policy by European Academies
SEAC	Committee for Socio-economic Analysis
TDS-GC-MS	Thermodesorption gas chromatography with mass spectrometric detection
TWPs	Tyre wear particles
TRWPs	Tyre and road wear particles
UK	United Kingdom
UKWIR	United Kingdom Water Industry Research
US	United States
VOCs	Volatile organic compounds
WHO	World Health Organisation
Zonula Occludens	Scaffolding proteins

References

Ageel, H., Harrad, S., Abou-Elwafa Abdallah, M. (2021). Occurrence, human exposure, and risk of microplastics in the indoor environment. Environ. Sci. Processes Impacts: Occurrence, human exposure, and risk of microplastics in the indoor environment – Environmental Science: Processes & Impacts (RSC Publishing)

Allen, S., Allen, D., Phoenix, V.R., Le Roux, G., Jiménez, P.D., Simonneau, A., Binet, S., Galop, D. (2019). Atmospheric transport and deposition of microplastics in a remote mountain catchment. Nature Geoscience, 12, 339-344: Atmospheric transport and deposition of microplastics in a remote mountain catchment | Nature Geoscience

Amato- Lourenço, L., dos Santos Galvão, L., de Weger, L. A., Hiemstra, P., S., Vijver, M. G. and Mauad, T. (2020) An emerging class of air pollutants: Potential effects of microplastics to respiratory human health? Science of the Total Environment 749, 141676.

AQEG. (2019) Non-exhaust emissions from road traffic: 1907101151_20190709_Non_Exhaust_Emissions_typeset_Final.pdf (defra.gov.uk)

Baensch-Baltruschat, B., Kocher, B., Stock, F., Reifferschied. G. (2020) Tyre and road wear particles (TRWP) – A review of generation, properties, emissions, human health risks, ecotoxicity, and fate in the environment. Science of the Total Environment 733, 137823.

Barrero-Moreno, J., Senaldi, C., Bianchi, I., Geiss, O., Tirendi, S., Folgado de Lucena, A., Barahona, F., Mainardi, G., Leva, P. and Aguar-Fernandez, P. (2018) Migration of Polycyclic Aromatic Hydrocarbons (PAHs) from plastic and rubber articles - Final report on the development of a migration measurement method. JRC Technical Reports JRC111476. kjna29282enn (1).pdf Accessed: 17/08/2020.

Bermúdez, J.R., and Swarzenski, P.W. (2021). A microplastic size classification scheme aligned with universal plankton survey methods. MethodsX, Vol 8, 101516. A microplastic size classification scheme aligned with universal plankton survey methods - ScienceDirect

Boucher, J. and Friot, D. (2017) Primary microplastics in the Oceans: A global evaluation of sources. Gland, Switzerland: IUCN: Primary microplastics in the oceans | IUCN Library System Accessed: 15/12/2020.

Bunsell, A.R. (ed.) (2018) Handbook of Properties of Textile and Technical Fibres, 2nd Edition. Woodhead Publishing/Elsevier Ltd, Duxford.

Burkhart, J., Piacitelli, C., Schwegler-Berry, D., Jones, W. (1999). Environmental study of nylon flocking process. J. Toxicol. Environ. Health, Part A, 57, 1-23: Environmental study of nylon flocking process - PubMed (nih.gov)

California Water Boards. (2020) State Water Resources Control Board Resolution No. 2020-0021. Adoption of definition of ‘Microplastics in Drinking Water’: rs2020-0021 (ca.gov). Accessed: 01/09/2020.

Catarino, A.I., Macchia, V., Sanderson, W.G., Thompson, R.C., Henry, T.B. (2018). Low levels of microplastics (MP) in wild mussels indicate that MP ingestion by humans is minimal compared to exposure via household fibres fallout during a meal. Environ Pollut. 237: 675-684: Low Levels of Microplastics (MP) in Wild Mussels Indicate that MP Ingestion by Humans is Minimal.pdf;jsessionid=1BC42A04D9E177F3C810388C7FEE987C (plymouth.ac.uk)

Chen, E-Y., Lin, K-T., Jung, C-C., Chang, C-L., Chen, C-Y. (2022). Characteristics and influencing factors of airborne microplastics in nail salons. Science of the Total Environment. Vol. 806 (4): 151472: Characteristics and influencing factors of airborne microplastics in nail salons - ScienceDirect

Chief Medical Officer (CMO) (2022). Chief Medical Officer's annual report 2022: air pollution. Available at: Chief Medical Officer's Annual Report 2022 (publishing.service.gov.uk)

COMEAP. (2015) Statement on the evident for differential health effects of particulate matter according to source or components: COMEAP_The_evidence_for_differential_health_effects_of_particulate_matter_according_to_source_or_components.pdf (publishing.service.gov.uk) Accessed: 03/01/2020.

COMEAP. (2020) Statement on the evidence for health effects associated with exposure to non-exhaust particulate matter from road transport: COMEAP Statement on the evidence for health effects associated with exposure to non-exhaust particulate matter from road transport (COMEAP Statement non-exhaust PM health effects (publishing.service.gov.uk) Accessed: 19/11/2020.

COMEAP. (2022) Statement on the differential toxicity of particulate matter according to source or constituent: Statement on the differential toxicity of particulate matter according to source or constituents: 2022 - GOV.UK (www.gov.uk)

Cox, K. D., Covernton, G. A., Davies, H. L., Dower, J. F., Juanes, F., Dudas, S. E. (2019) Human consumption of microplastics. Environmental Science & Technology 53, pp. 7068-7074.

Culp, S. J., Gaylor, D. W., Sheldon, W. G., Golstein, L. S. and Beland, F. A. (1998) A comparison of the tumors induced by coal tar and benzo[a]pyrene in a 2-year bioassay. Carcinogenesis 19, pp 117–124.

Darquenne, C. (2006). Particle deposition in the lung. Encyclopedia of Respiratory Medicine. Elsevier. PII: B0123708796002891 (sciencedirectassets.com)

Deng, Y., Zhang, Y. Lemos, B. and Ren, H. (2017) Tissue accumulation of microplastics in mice and biomarker responses suggest widespread health risks of exposure. Scientific Reports 7, 46687.

Devereux, R., Ayati, B., Kebede Westhead, E., Jayaratne, R., Newport, D. (2023). Impact of the Covid-19 pandemic on microplastic abundance along the River Thames. Marine Pollution Bulletin (189) 114763: Impact of the Covid-19 pandemic on microplastic abundance along the River Thames - ScienceDirect

Domenech, J. and Marcos, R. (2021) Pathways of human exposure to microplastics, and estimation of the total burden. Current Opinion in Food Science 39, pp. 144-151.

Donaldson, K., and Lang Tran, C. (2002) Inflammation caused by particles and fibres. Inhalation Toxicology 14, pp. 5-27.

Donaldson, K., Murphy, F.A., Duffin, K., Poland, C.A. (2010) Asbestos, carbon nanotubes and the pelural mesothelium: a review of the hypothesis regarding the role of long fibre retention in the parietal pleura, inflammation and mesothelioma. Part Fibre Toxicol. 22;7:5: Asbestos, carbon nanotubes and the pleural mesothelium: a review of the hypothesis regarding the role of long fibre retention in the parietal pleura, inflammation and mesothelioma | Particle and Fibre Toxicology | Full Text (biomedcentral.com)

Dong, C., Chen, C., Chen, Y., Chen, H., Lee, J., Lin, C. (2020). Polystyrene microplastic particles: In vitro pulmonary toxicity assessment. Journal of Hazardous materials, 385 121575: Polystyrene microplastic particles: In vitro pulmonary toxicity assessment – ScienceDirect

Dris, R., Gasperi, J., Saad, M., Mirande, C. and Tassin, B. (2016) Synthetic fibres in atmospheric fallout: A source of microplastics in the environment? Marine Pollution Bulletin 104, pp. 290-293.

Dris, R., Gasperi, J., Mirande, C., Mandin, C., Guerrouache, M., Langlois, V. and Tassin, B. (2017) A first overview of textile fibres, including microplastics, in indoor and outdoor environments. Environmental Pollution 221, pp. 453-458.

ECCC & HC. (2020) Science assessment of plastic pollution: Science assessment of plastic pollution - Canada.ca. Accessed: 23/12/2020.

ECHA. (2017) Annex XV Report. An evaluation of the possible health risks of recycled rubber granules used as infill in synthetic turf sports fields: Final (europa.eu) Accessed: 14/01/2020.

ECHA. (2019) Annex XV Restriction Report Proposal for a Restriction for intentionally added microplastics: Microsoft Word - rest_microplastics_axvreport_en.docx (europa.eu). Accessed: 10/11/2020/

EFSA. (2009) The potential risks arising from nanoscience and nanotechnologies on food and feed safety. The EFSA Journal 958, pp. 1-39: The Potential Risks Arising from Nanoscience and Nanotechnologies on Food and Feed Safety (wiley.com) Accessed: 01/09/2020.

EFSA. (2016) Presence of microplastics and nanoplastics in food, with particular focus on seafood. The EFSA Journal 14, 4501: Presence of microplastics and nanoplastics in food, with particular focus on seafood (wiley.com) Accessed: 04/08/2020.

EFSA. (2021) Guidance on risk assessment of nanomaterials to be applied in the food and feed chain: human and animal health. The EFSA Journal 19(8), 6768: Guidance on risk assessment of nanomaterials to be applied in the food and feed chain: human and animal health (wiley.com).

EFSA. (2020) EFSA Guidance on technical requirements for regulated food and feed product applications to establish the presence of small particles including nanoparticles: Draft-Nano-Technical-Guidance-For-Public-Consultation.pdf (europa.eu) Accessed: 10/11/2020.

Enyoh, C.E., Verla, A.W., Verla, E.N., Ibe, F.C., Amaobi, C.E. (2019) Airborne microplastics: a review study on method analysis, occurrence, movement and risks. Environ Monit Assess. 24: 191(11):668: Airborne microplastics: a review study on method for analysis, occurrence, movement and risks - PubMed (nih.gov).

European Commission, (2011). Commission recommendation of 18 October 2011 on the definition of nanomaterial. Official Journal of European Union, L275, 38–40.

Fadare, O. O., Wan, B., Guo, L-H. and Zhao, L. (2020) Microplastics from consumer plastic food containers: Are we consuming it? Chemosphere 253, 126787.

Fang, M., Liao, Z., Ji, X., Zhu, X., Wang, Z., Lu, C., Shi, C., Chen, Z., Ge, L., Zhang, M., Dahlgren, R.A., Shang, X. (2022). Microplastic ingestion from atmospheric deposition during dining/drinking activities. Journal of Hazardous Materials, 432: 128674.

Fournier, S.B., D'Errico, J.N., Adler, D.S., Kollontzi, S., Goedken, M.J., Fabris, L., Yurkow, E.J., Stapleton, P.A. (2020) Nanopolystyrene translocation and fetal deposition after acute lung exposure during late-stage pregnancy. Part Fibre Toxicol. 24:17(1):55: Nanopolystyrene translocation and fetal deposition after acute lung exposure during late-stage pregnancy | Particle and Fibre Toxicology | Full Text (biomedcentral.com)

Frias, J.P.G.L and Nash, R. (2019). Microplastics: Finding a consensus on the definition. Marine Pollution Bulletin, Vol 138, 145-147. Available at: Microplastics: Finding a consensus on the definition - ScienceDirect

FSA. (2020) A critical review of microbiological colonisation of nano-and microplastics (NMPs) and their significance to the food chain: A critical review of microbiological colonisation of nano- and microplastics (NMPs) and their significance to the food chain | Food Standards Agency Accessed: 24/08/2020.

Gasperi, J., Wright, S., L., Dris, R., Collard, F., Mandin, C., Guerrouache, M., Langlois, V., Kelly, F. J. and Tassin, B. (2018) Microplastics in air: Are we breathing it in? Current Opinion in Environmental Science & Health 1, pp. 1-5.

Grigoratos, T., Martini, G. (2014) Non-exhaust traffic related emissions. Brake and tyre wear PM; Literature review: Non-exhaust traffic related emissions - Brake and tyre wear PM - Publications Office of the EU (europa.eu). Accessed: 17/08/2020.

Halappanavar, S., and Mallach, G. (2021) Adverse outcome pathways and in vitro toxicology strategies for microplastics hazard testing. Current Opinion in Toxicology, 28: 52-61: Adverse outcome pathways and in vitro toxicology strategies for microplastics hazard testing - ScienceDirect

Hartmann, N. B., Hüffer, T., Thompson, R. C., Hassellöv, M., Verschoor, A., Daugaard, A. E., Rist, S., Karlsson, T., Brennholt, N., Cole, M., Herrling, M.

P., Hess, M. C., Ivleva, N. P., Lusher, A. L. and Wagner, M. (2019) Are we speaking the same language? Recommendations for a definition and categorization framework for plastic debris. Environmental Science and Technology 53, pp. 1039-1047.

Hillerdal, G., Steinholtz, Rosenhall, L. and Lindgren, A. (1988) Pulmonary fibrosis caused by synthetic textile fibres? VIIth International Pneumoconioses Conference, pp. 1405-1407: 90-108-2.pdf (cdc.gov). Accessed: 15/08/2019.

HSE. (2011) Safe to Breathe: Dust and fume control in the rubber industry: Safe to Breathe: Dust and fume control in the rubber industry (hse.gov.uk). Accessed: 02/01/2019.

Huerta Lwanga, E., Gertsen, H., Gooren, H., Peters, P., Salánki, T., van der Ploeg, M., Besselingm E., Koelmans, A. A. and Geissen, V. (2016) Microplastics in the terrestrial ecosystem: Implications for Lumbricus terrestris (Oligochaeta, Lumbricidae). Environmental Science & Technology 50, pp. 2685-2691.

Hurley, R. R., Nizzetto, L. (2018) Fate and occurrence of micro(nano) plastics in soils: Knowledge gaps and possible risks. Current Opinion in Environmental Science and Health 1, pp. 6-11.

Jekel, M. (2019) Scientific report on tyre and road wear particles, TRWP, in the aquatic environment a European TRWP Platform publication: FINAL-Scientific-Report-on-Tyre-and-Road-Wear-Particles.pdf (tyreandroadwear.com). Accessed: 19/12/2019.

Jenner, L.C., Sadofsky, L.R., Danopoulos, E., Rotchell, J.M. (2021). Household indoor microplastics within the Humber region (United Kingdom): Quantification and chemical characterisation of particles present. Atmospheric Environment 259 118512: Household indoor microplastics within the Humber region (United Kingdom): Quantification and chemical characterisation of particles present | Elsevier Enhanced Reader

Jenner, L.C., Rotchell, J.M., Bennett, R.T., Cowen, M., Tentzeris, V., Sadofsky, L.R. (2022). Detection of microplastics in human lung tissue using μFTIR spectroscopy. Scientce of the Total Environment 831, 154907. Available at: Detection of microplastics in human lung tissue using μFTIR spectroscopy - ScienceDirect

Kim, D., Chae, Y., An, Y-J. (2017) Mixture toxicity of nickel and microplastics with different functional groups on Daphnia magna. Environ. Sci. Technol. 51, 21, 12852-12858: Mixture Toxicity of Nickel and Microplastics with Different Functional Groups on Daphnia magna | Environmental Science & Technology (acs.org)

Koelmans, A. A., Nor, N. H. M., Hermsen, E., Kooi, M., Mintenig, S. M., De France, J. (2019) Microplastics in freshwaters and drinking water: Critical review and assessment of data quality. Water Research 155, pp. 410-422.
Koelmans, A.A., Redondo-Hasselerharm, P.E., Nor, N.H.M., de Ruijter, V.N., Mintenig, S.M., Kooi, M. (2022a). Risk assessment of microplastic particles. Nature Review Materials, 7:138-152: Risk assessment of microplastic particles | Nature Reviews Materials

Koelmans, A.A., Diepens, N.J., Nor, N.H.M. (2022b). Weight of evidence for the microplastic vector effect in the context of chemical risk assessment. Chapter 6, Microplastic in the Environment: Pattern and Process (Editor Michael. S., Bank: 978-3-030-78627-4.pdf (oapen.org).

Kole, P. J., Löhr, A. J., Van Belleghem, F. G. A. J. and Ragas, A. M. J. (2017) Wear and Tear of Tyres: A stealthy source of microplastics in the environment. International Journal of Environmental Research and Public Health 14, 1265.

Kwon, J-H., Kim, J-W., Pham, T. D., Tarafdar, A., Hong, S., Chun, S-H., Lee, S-H., Kang, D-Y., Kimn, J-Y., Kim, S-B. and Jung, J. (2020) Microplastics in Food: A review on analytical methods and challenges. International Journal of Environmental Research and Public Health 17, 6710.

Li, D., Shi, Y., Yang, L., Xiao, Kehoe, D. K., Gun'ko, Y. K., Boland, J. J. and Wang, J. J. (2020) Microplastic release from the degradation of polypropylene feeding bottles during infant formula preparation. Nature Food 1, pp. 746-754.

Liebezeit, G. and Liebezeit, E. (2013) Non-pollen particulates in honey and sugar. Food Additives and Contaminants. Part A, Chemistry, Analysis, Control, Exposure and Risk Assessment 30, pp. 2136–2140.

Liebezeit, G. and Liebezeit, E. (2014) Synthetic particles as contaminants in German beers. Food Additives and Contaminants. Part A, Chemistry, Analysis, Control, Exposure and Risk Assessment 31, pp. 1574–1578.

Lim, D., Jeong, J., Song, K.S., Sung, J.H., Oh, S.M., Choi, J. (2021) Inhalation toxicity of polystyrene micro(nano)plastics using modified OECD TG 412. Chemosphere 262: 128330: Inhalation toxicity of polystyrene micro(nano)plastics using modified OECD TG 412 - ScienceDirect

Lu, L., Wan, Z., Luo, T., Fu, Z. and Jin, Y. (2018) Polystyrene microplastics induce gut microbiota dysbiosis and hepatic lipid metabolism disorder in mice. Science of the Total Environment 631-632, pp. 449-458.

Lu, L., Lou, T., Zhao, Y., Cai, C., Fu, Z. and Jin, Y. (2019) Interaction between microplastics and microorganism as well as gut microbiota: A consideration on environmental animal and human health. Science of the Total Environment 667, pp. 94-100.

Lusher, A., Hollman, P. and Mendoza-Hill, J. (2017) Microplastics in fisheries and aquaculture. Status of knowledge on their occurrence and implications for aquatic organisms and food safety. FAO Fisheries and Aquaculture Technical Paper No. 615: Microplastics in fisheries and aquaculture (fao.org)Accessed: 14/12/2020.

Merola, M. and Affatato, S. (2019) Materials for hip prostheses: A review of wear and loading considerations. Materials 12, 495.

Merski, J. A., Johnson, W. D., Muzzio, M., Lyang, N. L. and Gaworski, C. L. (2008) Oral toxicity and bacterial mutagenicity studies with a spun bound polyethylene and polyethylene terephthalate polymer fabric. International Journal of Toxicology 27, pp. 387-395.

MILC. (2016) Mothers' information on lactation and collection (MILC) study: The MILC Study Accessed: 14/08/2020.

Nel, A. E., Mädler, L., Velegol, D., Xia, T., Hoek, E. M. V., Somasundaran, P., Klaessig, F., Castranova, V. and Thompson, M. (2009) Understanding biophysicochemical interactions at the nano-bio interface. Nature Materials 8, pp. 543–557.

Ng, E-L., Huerta Lwanga, E., Eldridge, S. M., Johnston, P., Hu, H-W., Geissen, V., Chen. D. (2018) An overview of microplastic and nanoplastic pollution in agroecosystems. Science of the Total Environment 627, pp. 1377-1388.

Nguyen, B., Claveau-Mallet, D., Hernandez, L. M., Xu, E. G., Farner, J. M. and Tufenkji, N. (2019) Separation and analysis of microplastics and nanoplastics in complex environmental samples. Accounts of Chemical Research 52, pp. 858-866.

O'Brien, S., Rauert, C., Ribeiro, F., Okoffo, E.D., Burrows, S.D., O'Briend, J.W., Wang, X., Wright, S.L., Thomas, K.V. (2023). There's something in the air: A review of sources, prevalence and behaviour of microplastics in the atmosphere. Science of the Total Environment 874, 162193: There's something in the air: A review of sources, prevalence and behaviour of microplastics in the atmosphere (sciencedirectassets.com)

Pauly, J. L., Stegmeier, S. J., Allaart, H. A., Cheney, R. T., Zhang, P. J., Mayer, A. G. and Streck, R. J. (1998) Inhaled cellulosic and plastic fibres found in human lung tissue. Cancer Epidemiology, Biomarkers and Prevention 7, pp. 419-428.

Peez, N., Janiska, M-C. and Imhof, W. (2019) The first application of quantitative ^{1}H NMR spectroscopy as a simple and fast method of identification and quantification of microplastic particles (PE, PET, and PS). Analytical and Bioanalytical Chemistry 411, pp. 823-833.

Pimentel, J. C., Avila, R. and Lourenço, A. G. (1975) Respiratory disease caused by synthetic fibres: a new occupational disease. Thorax 30, pp. 204-219.

Pivonsky, M., Cermakova, L., Novotna, K., Peer, P., Cajthaml, T. and Janda, V. (2018) Occurrence of microplastics in raw and treated drinking-water. Science of the Total Environment 643, pp. 1644-1651.

Prata, J.C. (2018). Airborne microplastics: Consequences to human health? Environmental Pollution, 234, 115-126: Airborne microplastics: Consequences to human health? - ScienceDirect

Qui, L., Lu, W., Tu, C., Li, X., Zhang, H., Wang, S., Chen, M., Zheng, X., Wang, Z., Lin, M., Zhang, Y., Zhong, C., Li, S., Liu, Y., Liu, J., Zhou, Y. (2023). Evidence of microplastics in broncoalveolar lavage fluid among never-smokers: A prospective case series. Environ Sci Technol, 57(6):2435-2444: Evidence of Microplastics in Bronchoalveolar Lavage Fluid among Never-Smokers: A Prospective Case Series - PubMed (nih.gov)

RAC. (2020) Opinion on an Annex XV dossier proposing restrictions on intentionally added microplastics: b4d383cd-24fc-82e9-cccf-6d9f66ee9089 (europa.eu). Accessed: 14/12/2020.

Rahman, A., Sarkar, A., Yadav, O.P., Achari, G., Slobodnik,J. (2021) Potential human health risks due to environmental exposure to nano- and microplastics and knowledge gaps: A scoping review. Sci Total Environ. 25; 757: 143872: Potential human health risks due to environmental exposure to nano- and microplastics and knowledge gaps: A scoping review - PubMed (nih.gov)

Rochman, C., M., Brookson, C., Bikker, J., Djuric. N., Earn, A., Bucci, K., Athey, S., Huntington, A., McIlwraith, H., Munno, K., De Frond, H., Kolomijeca, A., Erdle, L., Grbic, J., Bayoumi, M., Borrelle, S. B., Wu, T., Santoro, S., Werbowski, L. M., Zhu, X., Giles, R. K., Hamilton, B. M., Thaysen, C., Kaura, A., Klasios, N., Ead, L, Kim, J., Sherlock, C., Ho, A. and Hung, C. (2019) Rethinking microplastics as a diverse contaminant suite. Environmental Toxicology and Chemistry 38, pp. 703-711.
RUBIAC. (2007) RUBIAC statement on occupational cancers: HSE - Rubber - RUBIAC Statement on Occupational Cancers. Accessed: 17/07/2020.

SAM. (2019) Environmental and Health Risks of Microplastic Pollution: ec_rtd_sam-mnp-opinion_042019.pdf (europa.eu) Accessed: 17/08/2020.

SAPEA. (2019) A scientific perspective on microplastics in nature and society: report.pdf (sapea.info). Accessed: 23/12/2020.

SEAC. (2020) Opinion on an Annex XV dossier proposing restrictions on intentionally added microplastics: 5a730193-cb17-2972-b595-93084c4f39c8 (europa.eu). Accessed: 14/12/2020.

Schneider, T., Burdett, G., Martinon, L., Brochard, P., Guillemin, M., Teichert, U. and Draeger, U. (1996) Ubiquitous fiber exposure in selected sampling

sites in Europe. Scandinavian Journal of Work, Environment and Health 22(4), pp. 274-284.
Sun, X-D., Yuan, X-Z., Jia, Y., Feng, L-J., Zhu, F-P., Dong, S-S., Liu, J., Kong, X., Tian, H., Duan, J-L., Ding, Z., Wang, S-G., Xing, B. (2020) Differentially charged nanoplastics demonstrate distinct accumulation in Arabidopsis thaliana. Nature Nanotechnology, 15, 755-760: Differentially charged nanoplastics demonstrate distinct accumulation in Arabidopsis thaliana | Nature Nanotechnology

Teuten, E. L., Saquing, J. M., Knappe, D. R. U., Barlaz, M. A., Jonsson, S., Björn, A., Rowland, S. J., Thompson, R. C., Galloway, T. S., Yamashita, R., Ochi, D., Watanuki, Y., Moore, C., Viet, P. H., Tana, T. S., Prudente, M. P., Boonyatumanond, R., Zakaria, M. P., Akkhavong, K., Ogata, Y., Hirai, H., Iwasa, S., Mizukawa, K., Hagino, Y., Imamura, A., Saha, M. andTakada, H. (2009) Transport and release of chemicals from plastics to the environment and to wildlife. Philosophical Transactions of the Royal Society B 364. Article ID: 20080284.

Toussaint, B., Raffael, B., Angers-Loustau, A., Gilliland, D., Kestens, V., Petrillo, M., Rio-Echevarria, I.M. and Van den Eede, G. (2019) Review of micro-and nanoplastic contamination in the food chain. Food Additives & Contaminants: Part A, 36(5), pp. 639-673.

Tsuda, A., Henry, F.S., Butler, J.P. (2013). Particle transport and deposition: basic physics and particle kinetics. Compr Physiol, 3(4): 1437-1471: Particle transport and deposition: basic physics of particle kinetics - PMC (nih.gov)

UKWIR. (2019) Sink to river – River to tap: A review of potential risks from nanoparticles and microplastics: Sink to River - River to Tap - A review of potential risks from nano-particles & microplastics (ukwir.org). Accessed: 10/09/2019.

Uoginte, I., Vailionyte, A., Skapas, M., Bolanos, D., Bagurskiene, E., Gruslys, V., Aldonyte, R., Bycenkiene, S. (2023). New evidence of the presence of micro- and nanoplastic particles in bronchioalveolar lavage samples of clinical trial subjects. Heliyon, 9 e19665: New evidence of the presence of micro- and nanoplastic particles in bronchioalveolar lavage samples of clinical trial subjects (cell.com)

van Raamsdonk, L. W. D., van der Zande, M., Koelmans, A. A., Hoogenboom, R. L. A. P., Peters, R. J. B., Groot, M. J., Peijnenburg, A. A. C. M. and Weesepoel, Y. J. A. (2020) Current insights into monitoring, bioaccumulation, and potential health effects of microplastics present in the food chain. Foods 9, 72.

Verschoor, A. J. (2015) Towards a definition of microplastics: Towards a definition of microplastics (rivm.nl). Accessed: 04/08/2020.

Verschoor, A., de Valk, E. (2016) Emission of microplastics and potential mitigation measures: Abrasive cleaning agents, paints and tyre wear RIVM Report 2016-0026: Emission of microplastics and potential mitigation measures (rivm.nl). Accessed: 17/08/2020.

Villarrubia-Gómez, P., Cornell, S.E. and Fabres, J. (2018). Marine plastic pollution as a planetary boundary threat–The drifting piece in the sustainability puzzle. Marine Policy, 96, pp. 213-220.

Wagner, S., Hüffer, T. Klöckner, P., Wehrhahn, M., Hofmann, T. and Reemtsma, T. (2018) Tire wear particles in the aquatic environment - A review on generation, analysis, occurrence, fate and effects. Water Research, 139, pp. 83-100.

Walker, D.I., Baker-Austin, C., Smith, A., Thorpe, K., Bakir, A., Galloway, T., Ganther, S., Gaze, W., Lewis, C., Quill, E., Russel, J., van Hoytema, N. (2022). A critical review of microbiological colonisation of nano- and microplastics (NMP) and their significance to the food chain. Available at: A critical review of microbiological colonisation of nano and microplastics and their significance to the food chain

Wheeler, K.E., Chetwynd, A.J., Fahy, K.M., Hong, B.S., Tochihuitl. J.A., Foster, L.A., Lynch, I. (2021). Environmental dimensions of the protein corona. Nature Nanotechnology, **16**,617-629 Environmental dimensions of the protein corona | Nature Nanotechnology

Winkler, A., Santo, N., Ortenzi, M. A., Bolzoni, E., Bacchetta, R. and Tremolada, P. (2019) Does mechanical stress cause microplastic release from plastic water bottles? Water Research 116, 115082.

Winkler, A.S., Cherubini, A., Rusconi, F., Santo, N., Madaschi, L., Pistoni, C., Moschetti, G., Sarnicola, M.L., Crosti, M., Rosso, L., Tremolada, P., Lazzari, L., Bacchetta, R. (2022). Human airway organoids and microplastic fibers: A mew exposure model for emerging contaminants. Environment International, 163, 107200: Human airway organoids and microplastic fibers: A new exposure model for emerging contaminants | Elsevier Enhanced Reader

WHO. (2013) Review of evidence on health aspects of air pollution – REVIHAAP Project Technical Report: REVIHAAP Final technical report final version (who.int). Accessed: 03/01/2020.

WHO. (2019) Microplastics in drinking-water: Microplastics in drinking-water (who.int) Accessed: 17/08/2020.

WHO. (2022) Dietary and inhalation exposure to nano- and microplastic and potential implications for human health particles: 9789240054608-eng.pdf (who.int)

Wright, S., L., Ulke, J., Font, A., Chan, K. L. A. and Kelly, F. J. (2020) Atmospheric microplastic deposition in an urban environment and an evaluation of transport. Environment International 136, 105411: Atmospheric microplastic deposition in an urban environment and an evaluation of transport (sciencedirectassets.com)

Yao, J., Wen, J., Li, H., Yang, Y. (2022) Surface functional groups determine adsorption of pharmaceuticals and personal care products on polypropylene microplastics. Journal of Hazardous Materials, Vol 423, Part B, 127131: Surface functional groups determine adsorption of pharmaceuticals and personal care products on polypropylene microplastics - ScienceDirect

Yu, X., Xu, Y., Lang, M., Huang, D., Guo, X., Zhu, L. (2022). New insights on metal ions accelerating the aging behavior of polystyrene microplastics: Effects of different excess reactive oxygen species. Science of The Total Environment. Volume 821, 153457: New insights on metal ions accelerating the aging behavior of polystyrene microplastics: Effects of different excess reactive oxygen species - ScienceDirect

Zhang, Q., Xu, E.G., Li, J., Chen, Q., Ma, L., Zeng, E.Y., Shi, H. (2020). A review of microplastics in table salt, drinking water and air: Direct human exposure. Environmental Science & Technology, 54(7), 3740-3751: A Review of Microplastics in Table Salt, Drinking Water, and Air: Direct Human Exposure | Environmental Science & Technology (acs.org)

Zhao, Q., Ma, C., White, J. C., Dhankher, O. P., Zhang, X., Zhang, S. and Xing, B. (2017) Quantitative evaluation of multi-wall carbon nanotube uptake by terrestrial plants. Carbon 114, pp. 661-670.

Zhu, K., Hanzhong, J., Jiang, W., Sun, Y., Zhang, C., Liu, Z., Wang, T., Guo, X., Zhu, L. (2022). The first observation of the formation of persistent aminoxyl radicals and reactive nitrogen species on photoirradiated nitrogen-containing microplastics. Environ. Sci. Technol. 56, 2, 779-789: The First Observation of the Formation of Persistent Aminoxyl Radicals and Reactive Nitrogen Species on Photoirradiated Nitrogen-Containing Microplastics | Environmental Science & Technology (acs.org)

Zhu, K., Hanzhong, J., Zhao, S., Xia, T., Guo, X., Wang, T., Zhu, L. (2019). Formation of environmentally persistent free radicals on microplastics under light irradiation. Environ. Sci. Technol. 52, 14, 8177-8186. Available at : Formation of Environmentally Persistent Free Radicals on Microplastics under Light Irradiation | Environmental Science & Technology (acs.org)

Zhu, K., Jia, H., Sun, Y., Dai, Y., Zhang,C., Gua, X., Wang, T., Zhu, L. (2020). Long-term phototransformation of miroplastics under stimulated sunlight irradiation in aquatic environments : Roles of reactive oxygen species. Water Research, Volume 173, 115564: Long-term phototransformation of microplastics under simulated sunlight irradiation in aquatic environments: Roles of reactive oxygen species - ScienceDirect

Zucarello, P., Ferrante, M., Cristaldi, A., Copat, C., Grasso, A., Sangregorio, D., Fiore, M., and Oliveri Conti, G. (2019) Exposure to microplastics (<10 μm) associated to plastic bottles mineral water consumption: The first quantitative study. Water Research 157, pp. 365-371.

Annex B to TOX/2022/xx

Committee on Toxicity of Chemicals in Food, Consumer Products and the Environment

Discussion papers presented to the COT on the potential risks from exposure to microplastics

TOX/2019/62 (22/10/2019)

Paper 1: Scoping paper on the potential risks from exposure to microplastics.

TOX/2020/15 (11/03/2020)

Paper 2: Potential risks from exposure to microplastics: First draft overarching statement (Cover page).

Annex A1

First draft overarching statement on the potential risks from exposure to microplastics.

Annex B1

Paper for information: Background on tyre wear.

Annex C1

Paper for information: Update on literature.

TOX/2020/40 (15/09/2020)
Follow-up to Paper 2: Overarching statement on the potential risks from exposure to microplastics (Cover page).

Annex A2
Second draft overarching statement on the potential risks from exposure to microplastics.

TOX/2020/58 (01/12/2020)
Follow-up to September 2020 meeting: Overarching statement on the potential risks from exposure to microplastics: Third draft (Cover page).

Annex A3
Third draft overarching statement on the potential risks to microplastics.

COT Statement Number 2021/02
Follow-up to December 2020 meeting: Overarching statement on the potential risks from exposure to microplastics.

COT Statement Number 2021/05
Sub-statement on the potential risk(s) from exposure to microplastics: Oral Route.