

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

This is a paper for discussion.

This does not represent the views of the Committee and should not be cited.

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 and provided a high-level overview of the current state of knowledge, data gaps and research requirements with regards to this topic.

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

3. 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 current 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.

Questions for the Committee

4. The Committee are asked to consider the following questions:
- Do the Committee have any comments on the content or structure of this sub-statement?
 - Are Members content with information presented on tyre wear?
 - Does the Committee have any further comments?

Secretariat

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Annex A to TOX/2022/64

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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](#)).
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 of others 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 57) there is still limited information regarding the concentrations of airborne microplastics. However, Dris et al., (2016, 2017) studies carried out in Greater Paris found indoor concentrations of 1-60 fibres/m³ and outdoor concentrations of 0.3-1.5 fibres/m³ (see paragraph 57 for further details).

5. The fate and dispersion of microplastics in outdoor environments is dependent on several factors (see paragraph 58).

6. 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 61).

7. 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, a total annual estimated exposure of ~120,00 and ~98,000 MPPs annually was calculated in male and female adults, respectively (see paragraph 62 below).

8. 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 in paragraph 64.

9. 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 65.

10. 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 Pollution (COMEAP, 2015; 2020), WHO (WHO, 2013), National Institute for Public Health and the Environment (Verschoor et al., 2016),

and ECHA (ECHA, 2017).

11. The COT concluded that the literature data on exposure to particles from tyre wear would need separate consideration from microplastic exposure from food, 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). The COT was of the opinion that uptake by plants, with subsequent dietary exposure, was unlikely to be a major route of exposure. Risk assessments of such materials was considered outside of the scope of the current exercise; however some information has been included to provide context.

12. 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).

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 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 $\geq 1\%$ w/w have (i) all dimensions $1\text{ nm} \leq x \leq 5\text{ mm}$ or (ii) for fibres, a length of $3\text{ nm} \leq x \leq 15\text{ mm}$ 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 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 $5,000\text{ }\mu\text{m}$. 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 (0.1 to $5,000\text{ }\mu\text{m}$ or micrometres). Plastics that are below this size range are classed as nanoplastics (i.e. 1 nm to $0.1\text{ }\mu\text{m}$).

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 process lengthens, the particle size continues to decrease due to fragmentation.

Nanoplastics

21. Nanoplastics are plastic particles with a diameter from 1 nm to $0.1\text{ }\mu\text{m}$. 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,
- 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 complement the EFSA 2018 guidance (as described above) (EFSA, 2020).

28. The definitions of nanomaterials above (paragraphs 21-24) 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 synthesised 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 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).

Toxicity

32. 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, 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).

33. Due to the small size of some nano-/microplastics, (NMPs) 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.

34. The UK FSA has completed a critical literature review on the microbiological colonisation of micro- and nanoplastics and their significance to the food chain (FS307021); the project was completed and published in early 2022 (Walker et al. 2022). The critical review presented an overview of NMPs in the environment, the interaction of NMPs and micro-organisms, the identification of key pathways by which these microbiologically contaminated materials could enter the food chain from environmental sources (e.g. water, soil, and air), and the risk(s) that these might pose to the consumer (FSA, 2020).

Analytical detection methodologies

35. 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).

36. 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.

37. Personal communications with National Reference Laboratories in the UK revealed that organic contaminant analysis usually applies only to the edible portions of food and that contaminants adsorbed to microplastics are generally not taken into account when measuring residues in foodstuff. Although it was noted that this would be method dependent rather than an intrinsic property (Gilbert, personal communication, 2020).

38. For example, when analysing fish - the head, digestive tract, offal and bones are removed before analysis. It is expected that the majority of microplastics will be in the GIT; therefore, any contaminants associated with them would not directly contribute to measured contaminant levels. However, depending on the nature of the microplastic contaminants may be desorbed in the stomach and may contribute to the measured concentration in the edible parts of the fish.

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: H₂O₂ = hydrogen peroxide; HNO₃ = nitric acid; KOH = potassium hydroxide; HCl = hydrochloric acid; SEM = Scanning electron microscope; TEM = Transmission electron microscopy; FT-IR = Fourier-transmission 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](#)).

39. 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.

40. 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).

41. 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 study concluded that there was a correlation between the inhalation of these plastic fibres with lung cancer, whereas the cellulosic fibres were relatively inert.

42. 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 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.

43. According to Panko et al., (2019), particulate matter (PM) from tyre abrasion may represent between 0.8 and 8.5 % mass fraction of PM₁₀ and 1 to

10% of PM_{2.5} in the air. However, it is unknown what percentage of the PM_{2.5} burden consist of microplastics (Zhang et al., 2020).

44. 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).

45. 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.

46. 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)

Physicochemical properties

47. Currently there are only limited analytical methods available to detect and quantify the presence NMPs 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).

48. Additionally, there are neither standardised testing protocols for different matrices (i.e. air, soil, food and water), nor standard reference 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.

49. 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.

50. 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.

Physical properties

51. NMPs can differ in their 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.

52. 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

53. 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.

54. 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 intracellular fluid, adsorbed chemicals from the environment or microbiological organisms (see Figure 2.).

Figure 2. Diagram showing the different corona development across the decade. (Image obtained from Wheeler et al. 2021).

55. 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.

Exposure from air

56. 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 tyres is a secondary source of airborne microplastics. Wind transfer is estimated to be responsible for 7% of the ocean's contamination (Boucher & Friot, 2017).

57. There is limited information regarding the concentrations of airborne microplastics, however, the Dris et al., (2016, 2017) studies carried out in Greater Paris found indoor concentrations of 1-60 fibres/m³ and outdoor concentrations of 0.3-1.5 fibres/m³. Data for Central London on deposition rates of microplastics have also been reported, and these range from 575-1,008 fibres/m²/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.

58. 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.

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

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

61. 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. 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 cm², 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 cm² 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).

62. 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.”

63. Inhalation of microplastics can result in toxicity due either to the particles (a physical effect) or their leachates (a chemical effect). 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.

64. 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 mucus progresses towards the pharynx caused by the beating of cilia), alveolar macrophage phagocytosis and migration, and by lymphatic transport.

65. 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.

Inhalation studies (2020-present)

In vitro

66. 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 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 influence 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

67. 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 3.00×10^5 particles/cm³) of polystyrene NMPs. There was 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 results 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.

Risk assessment tools

68. 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.

69. 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 as the use of read-across, computational models and “omics” cannot only reduce the number of animals used and the traditional testing methodologies, but also provide a more robust decision-making process (Halappanavar and Mallach 2021).

Toxicokinetics

70. 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.

71. 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).
72. Deposition of respirable fibres occurs in the lung as a function of its 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).
73. Inertial impaction occurs for particles with a diameter $> 5 \mu\text{m}$ 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.
74. For particles with a diameter between 0.5 to $5 \mu\text{m}$, 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.
75. Diffusion occurs by chance when particles with diameters $0.5 \mu\text{m}$ collide with gas molecules causing them to settle on the surface of the lung via Brownian motion. Diffusion occurs mainly in the small airways and alveoli, although the particles can deposit in the upper airways by this mechanism if their diameter is $0.01 \mu\text{m}$ (Tsuda et al., 2013).
76. 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.
77. Clearance mechanisms for inhaled MPs $> 5 \mu\text{m}$, is 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.

78. 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 $> 20 \mu\text{m}$ 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.

79. It has been suggested that microplastics may contain ROS as a by-product of processing and polymerization depending on their chemical structure and surface. The amount of ROS present may also be increased following weathering of the MPs by ultraviolet (UV) radiation or the presence of reactive metals shown in Figure 3 (Rahman et al., 2021; Zhu et al. 2019; Zhu et al. 2022; Yu et al. 2022).

Figure 3. Diagram showing how microplastics exposed to solar light irradiation show contamination with environmentally persistent free radicals (EPFRs). Accompanying the formation of EPFRs, reactive oxygen species (ROS) were also detected. Image obtained from Zhu et al. 2019.

80. 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 (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

81. 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.

Indoor exposure

82. 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/m³. 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.

83. 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 m³ per day as 1.9×10^3 - 1.0×10^5 and 0 - 3.0×10^7 respectively, confirming that there is increased exposure to microplastics in the indoor environment. Whereas Fang et al., (2022), calculated the atmospheric deposition of MPs as 3.5×10^5 - 2.2×10^7 (Figure 4).

Figure 4. Diagram of microplastics (MPs) via the inhalation and ingestion routes of exposure showing that ingestion of microplastics is minimal in comparison to the inhalation route(Taken from Fang et al., 2022).

84. A recent study conducted in Hull, UK sampled 20 households each month for a 6 month period detecting an average of 1414 microplastics/m² 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).

85. Microplastics have been identified in all areas of the lung from tissue samples obtained from following surgical resection for cancer or lung reduction surgery. 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).

86. The concentration of microplastics in indoor air is dependent on what occurs in the environment is, for example, whether it is a home or occupational setting (discussed below in para. 90-91).

Outdoor exposure

87. 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).

88. Dris et al., (2017) investigated outdoor air samples (from one of the locations mentioned above) in the city centre of Paris. The concentration found in the outdoor sample was 0.3 to 1.5 fibres/m³.

89. As stated above, the data available on outdoor exposure is limited. However, studies have shown that when comparing inhalation and ingestion routes indoors, microplastic exposure via ingestion is minimal in comparison to inhalation.

Occupational exposure

90. 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. Burkhardt 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/m³.

91. 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 MPs are more likely to affect human health from occupational exposure

compared to indoor exposure at home and the concentration is dependent on the atmospheric conditions (Prata, 2018).

COT evaluation

92. 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).

93. 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.

94. 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.

95. In terms of the toxicity of NMPs, there is no identified 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 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.

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

97. 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.

98. 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. 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.

99. 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 in the environment, 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.

100. 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 is no identified NOAEL for the different polymer types except possibly for PET powder at 2,500 mg/kg bw/day in rats, (see paragraph 97), 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.

101. 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 (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

102. 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 lung disease states may be involved in the observed effects from microplastic exposure and;
- How available occupational data should be extrapolated to the general population.
- Data on inhalation exposure to MPs that are resuspended in an indoor environment.

Research priorities

103. The COT recommends the following research priorities 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.

- 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.
- 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.
- Comprehensive assessment of MPs and their associated contaminant concentrations and matrices (such as air, soil, food and water) and the impact of the effect of cooking on the desorption and subsequent bioavailability of contaminants/leachates in relevant matrices is required.
- 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.

- 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.
- Studies on the persistence and potential accumulation of NMPs in the human body, and on the extent to which NMPs are digestible.
- 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).
- 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). 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 best be shared by collaboration among academia, researchers and government bodies at a national and international level.

COT conclusions

104. 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.

105. 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, WHO, ECCC and HC, SAPEA, SAM, as described in the COT overarching statement on the potential risks from exposure to microplastics : [COT Statement 2021/02](#), paragraphs 101-129).

106. The COT concluded that the literature data on exposure to particles from tyre wear 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.

107. 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.

108. 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.

109. 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. These range of particle types should also take account of emerging/novel plastic-based materials such as bioplastics.

Statement

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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	Polycyclic aromatic hydrocarbons
PCBs	Polychlorinated biphenyls
PE	Polyethylene
PET	Polyethylene terephthalate
PM10	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

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Annex B to TOX/2022/64

[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.