



## **Submission to the Senate Inquiry into the impact of microplastics and other toxics on human health**

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## About the Heart Foundation

For more than 65 years, the National Heart Foundation of Australia (Heart Foundation) has been the trusted, independent, not-for-profit organisation fighting cardiovascular disease and helping to improve the heart health of people living in Australia. Despite significant advances in how we prevent and treat heart disease, it remains the leading cause of death globally and causes one in four deaths in Australia.<sup>1,2</sup>

We work across the spectrum of cardiovascular disease research, prevention, detection, care, and support. Our work is made possible through the generosity of our donors, and is delivered in partnership with health professionals, researchers, governments, and the community.

As part of our 25-year vision for Australia's heart health, *Health for Every Heart*, the Heart Foundation is committed to action that creates environments and systems that enable better heart health.<sup>3</sup> Through our work, we aim to better understand the environmental factors that influence heart health to guide development of effective prevention strategies and public health policy that will help to reduce risk of developing health conditions that could be prevented.

## Executive Summary

The Heart Foundation welcomes the opportunity to contribute to the Senate Standing Committee's inquiry into the impact of microplastics and other toxics on human health. Our submission focuses on the impact of micro- and nanoplastics on cardiovascular health and the risk to human health more broadly, contributing to items (b), (c) and (h) in the inquiry's terms of reference.

Plastics pollution, including micro- and nanoplastics, is globally driving calls for action to reduce its negative impacts on both the environment and human health, including calls led by the World Health Organization (WHO).<sup>4</sup> Approaches internationally have largely been driven by rising plastic production, poor management of plastics at end-of-life, and growing evidence of environmental and health harms. This has led to most policies focusing on reducing plastics waste like single-use plastic items and landfill disposal, rather than explicitly addressing pollution by micro- and nanoplastics.<sup>5</sup>

Micro- and nanoplastic particles are present and persistent in the environment, making human exposure unavoidable.<sup>6,7</sup> Australian studies have detected micro- and nanoplastics in the soil, air, oceans, fresh waterways and accumulation in the food chain, with detectable levels in the food and water that humans consume.<sup>8,9</sup> There is also a growing body of evidence demonstrating accumulation in human organs and tissues, generating concern about the potential harms to human health.<sup>10</sup>

Among the emerging health evidence is that micro- and nanoplastics have been found in cardiovascular tissues including atherosclerotic plaques, which are the main cause of heart attack, strokes and sudden cardiac death.<sup>11</sup> There is also emerging evidence that the presence of micro- and nanoplastics in these tissues is associated with higher rates or increased severity of these conditions.<sup>16-20</sup> However, there is no evidence currently available that can demonstrate if human exposure to environmental micro- and nanoplastics is able to directly cause cardiovascular disease.

Australia's capacity to regulate micro- and nanoplastics to protect public health has largely been constrained by these gaps in existing evidence, which will require long-term studies in humans to address. **We put forward the case in this submission that there is already sufficient evidence to demonstrate a plausible risk of harm to human cardiovascular health from exposure to micro- and nanoplastics, and that this risk, when combined with unavoidable human exposure, supports Australia to take immediate policy action that will reduce the potential long-term health impacts.**

There is an opportunity for the Australian Government to take a proactive approach to protect human health by coordinating, strengthening and expanding existing policies and regulations that reduce plastic waste and leakage by (i) including actions that explicitly address reducing micro- and nanoplastics pollution across the plastic life cycle, and (ii) by embedding protection of human health as a priority alongside environmental protection. Delaying policy action until long-term research studies are complete could unnecessarily risk people's health by giving the false impression that evidence can definitively show that there is no need for concern about long-term harm to human health from everyday exposure.

In this submission, we also draw on lessons from the findings and recommendations of the 2025 Senate Inquiry into per- and poly-fluoroalkyl substances (PFAS), also known as "forever chemicals", where a similar approach could be applied to micro- and nanoplastics. Specifically, the PFAS inquiry highlights the importance of recognising and communicating plausible, potential health risks in national advice, even when there is not yet any definitive evidence demonstrating if the pollutant can directly cause long-term harm to human health. Other relevant findings include identifying population groups likely to be most at risk of high exposure and/or who are likely to have additional

health risks that could amplify any potential harms to human health from micro- and nanoplastics exposure. We also highlight research areas that should be prioritised for investment because they address urgent evidence gaps that are essential for developing targeted policy action in the future that can better protect human health from the potential harms of micro- and nanoplastics.

The Heart Foundation's recommendations outlined in this submission are consistent with Australia's commitments to end plastic pollution as a member state of UN and WHO, and as a co-signatory of the High Ambition Coalition to End Plastic Pollution.<sup>4,12</sup> The Committee may also be aware of the WHO's ongoing work with member states to establish a legally binding international instrument on plastic pollution, including marine pollution, which has been driven by the need to address the potential health impacts.<sup>4</sup>

In this submission, the Heart Foundation provides the following recommendations for the Committee's consideration:

**Recommendation 1:** The Australian Government should establish a national coordinated policy approach to reducing the health risks of micro- and nanoplastics alongside the environmental impact by:

- (a) embedding health as an equal priority alongside environment in national policies, legislation and regulations aimed at reducing harm from plastics, including micro- and nanoplastics
- (b) integrating emerging evidence demonstrating the association between micro- and nanoplastics and health conditions, including cardiovascular disease, into national policies aimed at reducing plastics use, waste and pollution
- (c) ensuring that priority populations with higher exposure to microplastics are identified and prioritised in efforts to manage and reduce health risks
- (d) including First Nations peoples as a priority population to ensure that national micro- and nanoplastics monitoring and reduction measures account for the health, wellbeing and cultural risks related to environmental contamination with micro- and nanoplastics
- (e) referring the matter of micro- and nanoplastics as a potential health risk to the Environmental Health Standing Committee (enHealth) of the Australian Centre for Disease Control, requesting that they develop national guidance on human exposure to inform national policy development.

**Recommendation 2:** The Australian Government should ensure continued investment in research that addresses current evidence gaps, which is aimed at better understanding the impact of micro- and nanoplastics on human health. This includes investing in:

- (a) longitudinal human studies that will help to determine whether exposure to micro- and nanoplastics causes cardiovascular disease or other chronic conditions, and whether effects are dose-dependent
- (b) targeted calls for research through national research funders (NHMRC, MRFF) where urgent evidence gaps are not otherwise being addressed
- (c) developing improved detection methodologies for microplastics and nanoplastics that can better measure levels of human exposure and their presence in the environment
- (d) developing improved laboratory models for micro- and nanoplastics that better reflect real-world environmental characteristics and human exposure conditions.
- (e) research that identifies populations at higher risk of harm from micro- and nanoplastics based on geographic or socioeconomic considerations, and prioritising research that finds ways to reduce this risk and prevent disease.

# Issue 1: Lack of a national approach to reduce the impact of micro- and nanoplastics exposure on human health

## 1.1 Human exposure to micro- and nanoplastics and their potential health risks is unavoidable

Micro- and nanoplastic are ubiquitous in the environment, making exposure to them unavoidable.<sup>8,9</sup> Studies have shown that humans ingest these tiny plastic particles through contaminated food and water and inhale them from contamination in the atmosphere.<sup>6,7</sup> These studies have also shown that humans can also absorb micro- and nanoplastic through the skin from personal care products or other materials that include or generate plastic particles.

While the exact mechanism not fully known, micro- and nanoplastics find their way into the human body, where they can accumulate in different biological tissues.<sup>7,13,14,15</sup> Microplastics have been detected in atherosclerotic plaques, which are fatty, sticky buildups that form on the inside walls of arteries and are the main cause of heart attack, strokes and sudden cardiac death. There is a body of existing evidence that their presence is associated with higher rates of these cardiovascular conditions, and we have discussed these health risks in the following sections of this submission.

A summary of the evidence about human exposure to microplastics in the environment that we have used to inform the recommendations in this submission has been provided in Appendix 1.

## 1.2 Micro- and nanoplastics have been associated with increased risk of cardiovascular health issues

Several human, animal and *in vitro* laboratory studies present emerging evidence of an association between micro- and nanoplastics exposure and cardiovascular diseases, including heart attack and stroke (Table 1, ref 11). However, this current body of evidence is not sufficient to demonstrate that micro- and nanoplastics can directly cause cardiovascular disease, nor whether disease is caused by the levels of exposure humans receive from environmental contamination.

The summary of existing evidence from human observational studies does show that there is an association between heart, stroke and vascular diseases and microplastics exposure (see Table 1 on the following page). The main findings are:

- Microplastics have been detected in cardiovascular tissues including atherosclerotic plaques, thrombi (blood clots in the heart) and arterial tissues.<sup>16,17,18,19,20</sup>
- Higher concentrations of microplastics in cardiovascular tissues could influence disease severity.<sup>16,20</sup> One study showed that there was a four-and-a-half times higher risk of heart attack, stroke or all-cause mortality for people who had microplastics present in plaques compared to people who had no detectable microplastics.<sup>16</sup>
- Microplastics at levels present in the environment could lead to higher prevalence of chronic conditions, including cardiovascular disease, particularly among populations living near contaminated sources.<sup>21</sup>

These human-based studies are limited by several confounding factors including small sample sizes and study participants that are limited to people who are being treated for one or more cardiovascular condition. This highlights the need for further long-term human studies to identify and clarify if there are causal impacts on health.

**Table 1: Summary of existing evidence for the association between micro- and nanoplastics and cardiovascular health in humans.**

Purpose of study	Research findings - Impact of microplastics	Type of microplastics (most to least common)	References
Detect the presence and possible impact of microplastics in plaques being removed (surgery) from arteries of 257 patients in a multicentre, prospective observational study	<b>4.53 times higher risk of myocardial infarction (heart attack), stroke or other causes of mortality</b> in patients with microplastics present in their plaques at follow up (average of 2 years and 10 months after the study). <b>Microplastics were present in plaques from more than half of the patients in the study:</b> <ul style="list-style-type: none"> <li>• 58.4% patients had PE present</li> <li>• 12.1% patients with PVC present</li> </ul> <b>Biological markers of inflammation were higher</b> in patients with microplastics in their plaques.	<ul style="list-style-type: none"> <li>• polyethylene (PE)</li> <li>• polyvinyl chloride (PVC)</li> </ul>	Ref 16
Detect the presence and possible impact of microplastics in blood samples from 82 patients with acute coronary syndromes (heart attack and unstable angina) in a cross-sectional study	<b>Patients with myocardial infarction (heart attack) had significantly higher microplastic burden</b> compared to patients with unstable angina.	<ul style="list-style-type: none"> <li>• PE</li> <li>• PVC</li> <li>• polystyrene (PS)</li> <li>• polypropylene (PP)</li> </ul>	Ref 17
Detect the presence and possible impact of microplastics in various human arterial tissues from 17 patients	<b>Higher concentrations of microplastics in arteries with plaques</b> than in arteries without plaques. <b>Likely connection between microplastics and atherosclerosis*</b>	<ul style="list-style-type: none"> <li>• polyethylene terephthalate (PET)</li> <li>• polyamide-66 (PA-66)</li> <li>• PVC</li> <li>• PE</li> </ul>	Ref 18
Detect presence and possible impact of microplastics in cardiac tissues from 15 cardiac surgery patients	<b>Microplastics were present in cardiovascular tissues.</b> Potential influence of medical interventions during surgical procedures causing changes in microplastic exposure.	<ul style="list-style-type: none"> <li>• PET</li> <li>• polyurethane (PU)</li> </ul>	Ref 19
Detect presence and possible impact of microplastics in thrombi (blood clots inside the heart) from patients with stroke, myocardial infarction (heart attack) and deep vein thrombosis	<b>Higher microplastic concentration was associated with greater disease severity</b> in thrombi samples from patients with stroke, myocardial infarction (heart attack) and deep vein thrombosis.	<ul style="list-style-type: none"> <li>• PE</li> <li>• PVC</li> <li>• PA-66</li> </ul>	Ref 20
Assess cardiovascular impacts of marine microplastic pollution in an ecological study of US coastal waters	<b>Higher prevalence of type 2 diabetes (18%), coronary artery disease (7%) and stroke (9%) among residents of counties adjacent to the most heavily microplastic-polluted waters</b> compared to similar counties located near waters with low levels of microplastic pollution.	Not reported	Ref 21

\* Atherosclerosis is a condition caused by arterial plaques where arteries narrow and stiffen, making blood flow more difficult.

Because exposure to micro- and nanoplastics is unavoidable for people in Australia, the current body of evidence indicates that micro- and nanoplastics present a plausible biological risk to human health.<sup>13,22,23</sup> Some populations are likely to have higher levels of exposure to micro- and nanoplastics, and therefore at higher risk of any potential negative health impacts.

Priority areas for further research that can address these current evidence gaps are discussed in a following section of this submission (under Issue 2).

### 1.3 Lack of coordinated policy action for micro- and nanoplastics due to limitations in the current evidence

Australia's current approach to addressing the negative impacts of plastics is a range of different policies\* that guide waste management and reduction measures, and is predominantly focussed on large plastic products such as plastic bags, plastic bottles and single-use items. Reducing plastic pollution at the source is a common approach taken globally to address potential harm to both the environment and human health, particularly in the absence of definitive evidence that can identify any targeted preventive actions that would address specific risks of harm to human health.<sup>5</sup>

While a large proportion (up to 80%) of micro- and nanoplastics are estimated to originate from breaking down of large plastic items, use of microbeads and other primary microplastic pollutants in commercial products are also a key source causing pollution of soil, air and water environments.<sup>14,24</sup> Nanoplastics, which are plastic particles about 5,000 or more times smaller than microplastics, are formed through the fragmentation of microplastics and can also contribute to plastic pollution.<sup>24</sup> However, Australia's current policies aimed at reducing the impact of plastics do not include a harmonised approach to managing micro- and nanoplastics specifically, nor do they address preventing harm to human health as an equal priority to reducing environmental harms.

This policy gap is largely due to a lack of evidence from long-term research studies that could determine any direct causal impacts of micro and nanoplastics on human health, as discussed elsewhere in this submission. Despite these evidence gaps, there is an existing body of emerging evidence on the negative health impacts of micro- and nanoplastics that could be used immediately to inform better policy, regulation and management of these risks at a national level.

The exposure level that poses a risk to human health has not yet been established, yet people across Australia are exposed to micro- and nanoplastics everyday due to their widespread presence in foods, water, soil and air. Delaying policy and regulatory changes until evidence from long-term health studies is available risks downplaying the potential harm to human health, and could place the health of the people of Australia at unnecessary risk. An absence of advice about potential risks to health fails to help people living in Australia to manage their potential health risks until the long-term research studies are complete.

Findings from the 2025 Senate Select Committee's Inquiry into per- and polyfluoroalkyl substances (PFAS), which are "forever chemicals", led to two recommendations that could be applied to assessment of the current evidence for the impact of microplastics on human health.<sup>25</sup> While there is no existing evidence confirming a causal link between PFAS exposure and adverse health effects, there is a body of evidence demonstrating that PFAS is associated with several well-established biochemical risk factors for cardiovascular disease and other chronic conditions, including high blood pressure and high blood cholesterol levels. Recommendations 2 and 5 from the inquiry call for

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\*Australian plastics policies include [National Plastics Plan 2021](#), the [National Waste Policy Action Plan 2024](#), [National Packaging Targets 2025](#) and [National Roadmap: Harmonising action on problematic and unnecessary plastics 2025](#).

the current national advice from the Australian Centre for Disease Control's Environment and Health Committee (enHealth) to be revised to avoid downplaying the possible risks to human health, and acknowledging that the known risks could increase to harmful levels proportionate to increased levels of exposure (or dose).

By integrating emerging evidence into public health policies and regulations, Australia can take action to help to reduce health risks of microplastics in the immediate term, while long-term health studies are underway. Findings from inquiries into the impact of other persistent environmental pollutants should also be considered alongside the emerging evidence from research studies.

#### 1.4 Some populations are at higher risk of exposure and harm to their health from micro- and nanoplastics

Some population groups who may be at higher risk of negative health impacts due to micro- and nanoplastics have been summarised in Table 2, but this is unlikely to be an exhaustive list. Identifying at-risk populations should be established as a priority for research and monitoring measures.

In the recent Senate Inquiry into PFAS, the Committee found that PFAS contamination in the environment has caused disproportionate, multifaceted and enduring harm to First Nations communities, profoundly affecting cultural practices, health, wellbeing, and trust in government responses.<sup>25</sup> The inquiry also reported findings on higher PFAS exposure levels among people working in certain industries that manufacture or use PFAS-containing materials (e.g. fire-fighting foam), placing them at increased risk of potential health impacts.

Population groups who are identified as having a higher risk or confirmed higher levels of exposure to micro and nanoplastics should be prioritised in national monitoring measures and further research. This will assist the Australian Government and the affected groups in understanding how to manage this exposure and any associated health risks. Guided by the findings of the PFAS inquiry, First Nations communities should be prioritised in national environmental monitoring of micro- and nanoplastics, and in identifying additional impacts on Country that could cause cultural harm.

**Recommendation 1:** The Australian Government should establish a national coordinated policy approach to reducing the health risks of micro- and nanoplastics alongside the environmental impact by:

- (a) embedding health as an equal priority alongside environment in national policies, legislation and regulations aimed at reducing harm from plastics, including micro- and nano plastics
- (b) integrating emerging evidence demonstrating the association between micro and nanoplastics and health conditions, including cardiovascular disease, into national policies aimed at reducing plastics use, waste and pollution
- (c) ensuring that priority populations with higher exposure to microplastics are identified and prioritised in efforts to manage and reduce health risks
- (d) including First Nations peoples as a priority population to ensure that national monitoring and reduction measures can account for the health, wellbeing and cultural risks related to environmental contamination with micro- and nanoplastics
- (e) referring the matter of micro- and nanoplastics as a potential health risk to the Environmental Health Standing Committee (enHealth) of the Australian Centre for Disease Control, requesting that they develop national guidance on human exposure to inform national policy development.

## Issue 2: Limitations of existing evidence about the impact of micro- and nanoplastics on human health

Despite rapidly expanding research on micro- and nanoplastics, the evidence base remains fragmented and largely insufficient to support a causal link to disease. This is due to substantial limitations from variations in methodologies, difficulties in quantifying human exposure levels, and findings that are not directly translatable to real-world settings. We have provided a summary in this section of the limitations of existing evidence about the impact of microplastics on human health, including cardiovascular health, which have been sourced from three peer-reviewed articles from the last two years, with additional sources indicated in the text.<sup>6,22,23</sup>

The main limitations of existing research findings are:

### **Lack of data and evidence on long-term exposure to micro- and nanoplastics and the associated impacts on human health.**

Data on long-term and population-level exposure remains limited as discussed elsewhere in this submission. The lack of long-term, high-quality data makes it difficult to develop and implement precautionary approaches to regulate micro- and nanoplastics using production controls, chemical additives, and product-specific restrictions. A related critical gap is the absence of human biokinetic data describing micro- and nanoplastic absorption, distribution, metabolism, retention, and excretion.

Among the human observational studies in the existing evidence base, many show inconsistent controls for confounding factors, including dietary patterns, occupational exposures and co-pollutant exposures. Sample sizes are often small and drawn from selected clinical populations, including patients with pre-existing cardiovascular disease or undergoing surgery, introducing selection bias and limiting the ability of results to be generalised to other scenarios or populations.

These evidence gaps make it difficult to conduct dose-response assessments and quantitative evaluation of risk that can be confidently applied to real-world scenarios. It also limits Australia's ability to set evidence-based limits or safety benchmarks for micro- and nanoplastics in water, food, air, or consumer products.

**Lack of standardisation for methods used to detect, quantify and characterise micro- and nanoplastics.** The methods currently in use for monitoring and research are highly variable with non-standardised protocols, limiting reproducibility, comparability, and confidence in reported findings. Detection of nanoplastics is particularly challenging due to their extremely small size, complex distribution within tissues, dynamic physicochemical properties, and the absence of sufficiently sensitive and standardised analytical methods.<sup>26</sup> Contamination during sampling and analysis remains a persistent concern, with uneven use of clean-room procedures and control measures.

**Limited ability to compare current micro- and nanoplastic research models with real-world environmental micro- and nanoplastic contamination.** Most experimental studies rely on synthetic, commercially produced particles, often at concentrations far exceeding typical environmental or human exposure levels. These particles differ from real-world micro- and nanoplastics, which are biologically contaminated. High-dose laboratory exposures are useful for identifying potential mechanisms but may not accurately reflect chronic, low-dose human exposures, adaptive responses, or cumulative effects over time.

**Limited ability to compare across studies and an incomplete understanding of the biological mechanisms by which micro- and nanoplastics affect the human body.** Current evidence on the biological mechanism of action shows that micro- and nanoplastic can induce oxidative stress, inflammation, and immune dysregulation. Due to other limitations with research models, confounding factors and inherent differences in research design, it is difficult to compare research findings to gain clarity about these effects depending on exposure routes, particle characteristics, and co-exposures. This leaves a critical gap in existing evidence about which particle types or properties are most harmful and how they drive disease in humans.

**Limited geographic and socioeconomic representation among the existing evidence:** Most data originate from high-income settings, which limits understanding of global exposure patterns, vulnerability, and disease burden, particularly in low- and middle-income countries where exposure profiles may differ substantially.

**Recommendation 2:** The Australian Government should ensure continued investment in research that addresses current evidence gaps, which is aimed at better understanding the impact of micro- and nanoplastics on human health. This includes investing in:

- (f) longitudinal human studies that will help to determine whether exposure to micro- and nanoplastics causes cardiovascular disease or other chronic conditions, and whether effects are dose-dependent
- (g) targeted calls for research through national research funders (NHMRC, MRFF) where urgent evidence gaps are not otherwise being addressed
- (h) developing improved detection methodologies for microplastics and nanoplastics that can better measure levels of human exposure and their presence in the environment
- (i) developing improved laboratory models for micro- and nanoplastics that better reflect real-world environmental characteristics and human exposure conditions.
- (a) research that identifies populations at higher risk of harm from micro- and nanoplastics based on geographic or socioeconomic considerations, and prioritising research that finds ways to reduce this risk and prevent disease.

## Appendix 1:

### Summary of evidence of micro- and nanoplastics in the environment that was used to inform the recommendations in this submission

#### Micro- and nanoplastics are widespread in the environment

Micro- and nanoplastics are ubiquitous as an environmental pollutant, which has raised concerns about the potential for harm to human health through environmental exposure. They can exist in various forms including beads, fibres and films, and have characteristics that vary according to their size and shape.<sup>14</sup> Microplastics are generally defined as plastic particles smaller than 5 mm in diameter, while nanoplastics are about 5,000 times smaller, with an upper size limit of about 1,000 nanometres ( $10^9$  m) in diameter.<sup>11</sup>

Evidence from Australian studies demonstrates that microplastics are widespread in the environment.<sup>8,9</sup>

- Microplastics have been detected in indoor air, soil, road dust, sediment, freshwater, marine water and living organisms, with microplastic fibres of less than 1 mm observed most frequently.
- Microplastics can accumulate in sediments and aquatic organisms along the marine food chain. They are widely present in seafood, with particularly high levels observed in filter-feeding species such as shellfish varieties that are commonly consumed by humans.
- Urbanisation, traffic density and industrial activity are strong drivers of microplastic concentrations.
- Road dust entering freshwater systems is a major pathway for microplastics to enter the marine environment.

#### Human exposure to micro- and nanoplastics is unavoidable

Micro- and nanoplastics have gradually penetrated the food chain and into human diets, making human exposure largely unavoidable.<sup>6,7</sup> They have been detected in a wide range of commonly consumed foods and beverages, including bottled water, salt, sugar, honey, and beer, which could have become contaminated with micro- and nanoplastics during processing or packaging.<sup>7,13</sup>

As well as ingesting micro- and nanoplastics in food, people can also be exposed by ingesting contaminated drinking water, direct contact with consumer and medical materials, and through the atmosphere via inhalation of airborne particles.<sup>14,15</sup> Airborne microplastics are present in both indoor and outdoor environments from construction materials, synthetic textiles, road-wear particles, landfills, plastic abrasions, waste incineration, and sewage sludge.<sup>27</sup> A summary of studies that have estimated levels of human exposure to microplastics through the most common pathways is provided in Table 2 on the following page.

**Table 2: Estimated levels of human exposure to microplastics, by exposure route.**

Estimated exposure or risk of exposure	Populations likely at higher risk of exposure	References
<b>Ingestion of contaminated food and water</b>		
0.1–5 g of microplastics per week (global average)	No groups specified	Ref 28
<b>Inhalation of indoor and outdoor airborne microplastics</b>		
<ul style="list-style-type: none"> <li>• Can be continuously inhaled</li> <li>• Smaller or fibrous particles less than 5 micrometres can likely penetrate more deeply into the respiratory tract</li> </ul>	<ul style="list-style-type: none"> <li>• Workers in the plastics manufacturing, waste management, and recycling industries</li> <li>• People living in highly contaminated environments</li> </ul>	Refs 14,29,30,27
<b>Direct skin contact through water, surfaces, or personal care products containing plastic particles</b>		
Extent and clinical significance remain uncertain <ul style="list-style-type: none"> <li>• Microplastics – likely limited ability to penetrate intact skin</li> <li>• Nanoplastics – may be capable of crossing the skin barrier under certain conditions</li> </ul>	<ul style="list-style-type: none"> <li>• Workers in the plastics industry and waste management industries</li> <li>• People engaging in leisure activities in contaminated environments</li> </ul>	Ref 14
<b>Multiple exposure routes</b>		
<b>Ingestion of contaminated food and water</b> 39,000–52,000 particles per capita annually <b>Inhalation</b> 74,000–121,000 particles per capita annually	No groups specified	Ref 31 <sup>a</sup>
<b>Ingestion and inhalation</b> Children: 184 ng per capita per day Adults: 583 ng per capita per day	No groups specified	Ref 32 <sup>b</sup>

<sup>a</sup> United States based modelling study; <sup>b</sup> Probabilistic model of lifetime exposure

### Micro- and nanoplastics can make other harmful chemicals more toxic

A further potential risk to the environment and human health is that micro- and nanoplastics can accumulate in organisms and amplify the toxicity of other harmful agents. As well as their inherent toxicity and potential for bioaccumulation, micro- and nanoplastics can adsorb and transport hazardous substances.<sup>33</sup> They can bind to and transform other toxic chemicals and pollutants, including persistent organic pollutants and toxic metals, into a form that is more readily absorbed by humans and other organisms. This means that they can increase exposure to or bioaccumulation of co-contaminants found in the same environments as microplastics. The health risks associated with exposure to micro- and nanoplastics can vary depending on the particle size, shape, surface chemistry, dose, and polymer composition.<sup>15</sup>

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