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Microplastics in freshwater and soil: Evidence gaps

As microplastics research is such a new and emerging field, many evidence gaps remain. Here we aim to highlight some of the most pressing.

Microplastics in soil

Whilst we included the existing evidence regarding the impact of microplastics on soil within our recent evidence synthesis on this topic, this is a very new area and research in this space is limited.

Environmental monitoring of sources and fate

It is very difficult to find accurate estimates of the total amount of microplastics in the natural environment. There are two challenges. First, at a global scale, sources of microplastic are not well understood and there is very little monitoring on either the sources of microplastics or the pathways through which microplastics enter the environment. This is true both for intentional microplastics (such as industrial abrasives or microbeads) and for larger plastic items which then degrade into microplastics. Additionally, further understanding the mechanisms and kinetics of plastic degradation is important and little studied.

Secondly, the definition of plastic waste varies by country. Even when plastic is effectively 'disposed of' we do not know how much plastic waste from landfill eventually makes its way into the environment through erosion and runoff.

Once microplastics and larger plastics do enter the natural environment, it is very hard to monitor where they end up and their concentration, especially when these particles become too small to easily see with a microscope. It is likely that plastics move through the environment extensively, interacting with a range of different ecosystems and animals in the process, but these patterns are currently not well understood. The development of markers that trace plastics and microplastics through the environment, as well as identifying the source, would be extremely valuable.

Monitoring of exposure

Alongside sources and fate, there are also gaps in the monitoring of exposure. Many studies on the impact of microplastics are conducted in a laboratory environment, using acute short-term exposure at high concentrations. These studies are arguably not particularly environmentally realistic, as exposure to microplastics is more often likely to be chronic (longer term) and at low concentrations. Accurately understanding exposure is an important precursor to understanding the impacts of microplastics on animals. Longitudinal studies, which monitor species in their natural environment and record their exposure to and interactions with microplastics are required.

Further understanding the impact of the shape and texture of the microplastic

Microplastics become weathered in the natural environment, meaning that their surfaces are not uniformly smooth. However, many studies are based in the laboratory and use pristine microplastics or microbeads which have a smooth surface and often round shape. It is not known how surface texture affects (a) the release of chemicals, (b) the role of microplastics as a vector, (c) how likely they are to be ingested (ie different shapes may look more or less like food sources) and (d) their impact on an animal once ingested. From our synthesis, we saw evidence that microplastics of different shapes may have different effects (Box 1). For example, long and thin microplastics were ingested by goldfish whereas pellets and fragments were spat out[1]. Certain colours also seem to be more or less attractive to animals. Further consideration of the effects of texture, shape, size and colour is required in future research.

1. Jabeen, K, B W Li, Q Q Chen, L Su, C X Wu, H Hollert, and H H Shi. 2018. Effects of Virgin Microplastics on Goldfish (*Carassius auratus*). *Chemosphere* 213: 323–32. https://doi.org/10.1016/j.chemosphere.2018.09.031.

Population and ecosystem level effects

Despite a few examples[2], investigations on population level or wider ecosystem level effects of microplastics in freshwater and soils are almost entirely absent from the literature. The majority of research currently focuses on impacts on a single animal. However, if microplastics affect feeding and reproductive behaviour then it seems likely that they also have population level effects in terms of survival and fitness. If effects are seen at a population level for an entire species, it is also plausible that this may affect the functioning of the ecosystem more broadly. Identifying particularly vulnerable food-webs and then monitoring these in the natural environment should be a research priority, as well as further research into population level effects.

Effects of microplastic associated chemicals

There are a range of questions that would be worth exploring here. What additives (and in what concentrations) are present in different synthetic polymer products? How do additives behave (and leach) from plastics under different environmental conditions? What impacts can different additives cause to different receptor systems? How do individual toxicities interact? What are the critical exposures for each of these chemical additives?

Further to this, some have suggested that chemicals associated with microplastics may have a bigger effect on animals at critical stages of development due to their hormone related effects. Critical stages of development could include the embryonic phase or when changing form (such as from a tadpole to a frog). These types of effects have not been studied in detail and studies are required that look at the impact of these chemicals on the full life cycle of animals.

Microplastics as a vector for bacteria and pathogens

Much of the research examines microplastics as a vector for chemicals, however microplastics can also act a vector for bacteria and pathogens – transporting these far beyond their usual range and potentially increasing the likelihood they are ingested. Little is known about these mechanisms including how easily bacteria and pathogens bind to microplastics and how far microplastics may transport bacteria and pathogens. We also lack understanding of the relative importance of microplastics compared to other vectors; both in promoting the ingestion of bacteria and pathogens, and transporting bacteria and pathogens through the environment.

Microplastics as part of contaminant mixtures

Much of the research that we have summarised either focuses on the impact of microplastics themselves or the impact of the chemicals associated with microplastics. An evidence gap exists relating to the role of microplastics as part of contaminant mixtures. Within an aquatic environment, an animal is rarely exposed to just one contaminant at a time. There is a mixture of different microplastics, chemicals, pathogens, metals and other pollutants and the animal has to respond effectively to a range of these. The elements within these complex mixtures may interact with one another and the effect of these mixtures on feeding behaviour, reproductive behaviour and physical health has not been investigated.

We also do not know how much microplastics contribute to the negative effects observed relative to other non-digestible suspended organic matter and debris. Understanding the relative risk that microplastics poses, is also a current evidence gap.

2. For a summary of the importance of and challenges with ecosystem wide studies see Browne, M A, A J Underwood, M G Chapman, R Williams, R C. Thompson, and J A Van Franeker. 2015. Linking Effects of Anthropogenic Debris to Ecological Impacts. *Proceedings of the Royal Society B: Biological Sciences* 22 (1807): 20142929. Royal Society of London. https://doi.org/10.1098/rspb.2014.2929.

Nanoplastics

If research relating to microplastics is in its infancy, then nanoplastics research is embryonic. Here we have summarised the available literature, but there are still major challenges with understanding the impact of nanoplastics on animal health – including humans. In addition, hardly any information is available on measurement methods or sources.

Due to their small size, it is almost impossible to measure and record the sources, fate and impact of microplastics; both in the environment and once inside an animal[3] (especially one as comparatively large as a human).

The development of new measurement methods and techniques is required. Many mechanistic questions remain: what shape and size do plastics have to be, in order to be mistaken for food by different animals? How small do microplastics have to be before they are transported inside animals, or cross the blood brain barrier? There is also a poor understanding of how microplastics break down into nanoplastics.

There also remains a major gap in studies looking at particles between the micro and nano size range criteria.

3. Al-Sid-Cheikh, M, S J Rowland, K Stevenson, C Rouleau, T B Henry, and R C Thompson. 2018. Uptake, Whole-Body Distribution, and Depuration of Nanoplastics by the Scallop Pecten Maximus at Environmentally Realistic Concentrations. *Environmental Science & Technology* 52 (24): 14480–86. https://doi.org/10.1021/acs.est.8b05266.