Microplastics in freshwater and soil

Executive summary

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Context

This synthesis presents the evidence of the impact of micoplastics on animals and humans, focusing on freshwater and soil environments, and identifies the most significant gaps in the evidence for future study.

Plastics have been gaining increased public attention due to a growing awareness of their impact on the natural environment. Political interest has mirrored public concern, with a number of policy measures introduced within the last few years to target plastic pollution in the UK, EU and internationally.

Despite this heightened profile, there is relatively little scientific evidence on the impacts of microplastics in the environment. Much of the research on plastics, including microplastics, has been in the marine environment and within the last few years. Therefore, while this topic is now seen as a priority and is increasingly being studied, research into the impacts of microplastics, especially in freshwater and soil, is still in its infancy. Major evidence gaps remain. This lack of knowledge is combined with the fact that plastics are persistent environmental pollutants and their use and subsequent presence in the environment is increasing.

This report considers three potential types of impact of microplastics on animals: direct physical harm caused by microplastics; harm caused by chemicals leaching from microplastics; and the potential for microplastics to act as a vector for other pollutants already in the environment and to transport these pollutants into animals. The report also considers potential impacts on human health.

Summary of findings

Our findings present a mixed picture due to the fact that significant evidence gaps exist in some areas. Moreover, where evidence does exist it is sometimes contradictory and/or based on results from laboratory studies using unrealistically high concentrations of microplastic and therefore difficult to translate to actual exposure in real-world environments[1]. This makes interpretation complicated and we have tried to caveat our findings as best as possible.

Despite these evidence gaps and the limitations with the published literature, the evidence does suggest that microplastics could cause harm at high concentrations and we do not yet know the implications of long-term exposure at low concentrations. Combined with the fact that once released into the environment microplastics are persistent, and given the high environmental concentrations expected in the future, the likelihood of negative consequences emerging is high. Without interventions to reduce plastic use and move towards a more circular economy, it is estimated that ecological risks from microplastics may be widespread within a century[2]. However, as with all diffuse pollutants, demonstrating significant effects in the environment will be difficult and even impossible in some cases.

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There is evidence demonstrating the presence of microplastics in freshwater and soil environments and within the organisms that inhabit them as well as in humans and the human diet.

There is currently a very limited amount of research into nanoplastics (which are smaller than microplastics), but initial evidence suggests that nanoplastics may be a particular concern. Laboratory studies, have shown that they are capable of entering tissues and crossing the blood-brain barrier. However, measuring exposure to nanoplastics in natural environments is very challenging due to their size so we do not yet understand real-world concentrations and impacts. Given that almost all plastics will gradually degrade into smaller and smaller micro and then nano sized particles, there is a risk that these particular impacts could increase in the future.

Direct impacts of microplastics on animals

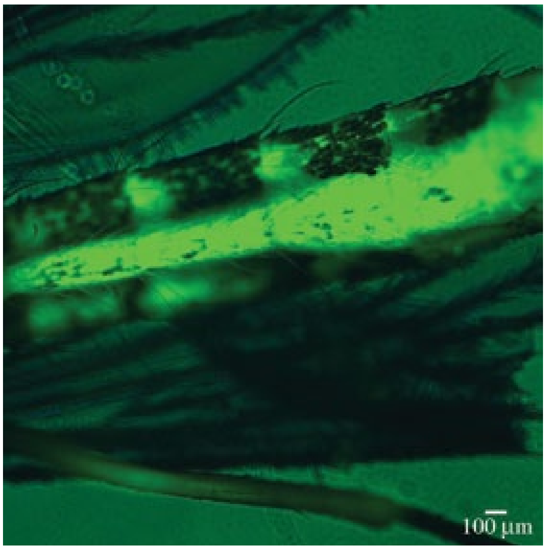
There is evidence demonstrating the presence of microplastics in freshwater and soil environments and within the organisms that inhabit them[3–6], as well as in humans and the human diet[7, 8].

For example, studies have demonstrated that 33% of roach sampled in the River Thames contain microplastics[9] and that animals such as earthworms[10–12], mice[13], and ducks[14] ingest microplastics. The likelihood that microplastics will be ingested by an organism seems to relate to its ability to distinguish between microplastics and actual food sources. Microplastics are found predominantly in the gut of animals, with a few examples of them passing into tissues or other organs at very high concentrations.

Laboratory studies have shown that the presence of microplastics in animals can affect their behaviour in a range of ways. Examples include decreased feeding (due to a false feeling of satiation), decreased movement, and increased buoyancy which affects feeding and swimming behaviour.

FIGURE 1

Fluorescent microplastic in the stomach of an adult mosquito glows green under a microscope. Researchers found an average of 40 microplastic particles in the belly of each adult mosquito they studied[28].



A reduction in feeding success following exposure to microplastics has been observed in a number of species, including fish[15–17] and crustaceans[18, 19]. Microplastics can also cause physical damage to animals, for example to the mouth cavity[20] or internal organs such as the gut, liver[21–25] or stomach due to gut blockages[26, 27] (Figure 1). However, we do not know how much microplastics contribute to these negative effects relative to other non-digestible suspended organic matter and debris. Also, as we have noted, the applicability of these high-concentration laboratory studies to real-world environments is not straightforward.

There is a need to formulate viable and testable hypotheses to address current knowledge gaps. For example, whilst some have suggested that microplastics may have wider effects on whole populations or ecosystems – such as gut blockages in worms subsequently affecting soil structure and plant growth[29] – there are currently few studies that explore these systems-level effects in any detail.

Microplastics and chemicals

This synthesis examines both the impact of chemicals added to microplastics, and the impact of pollutants already in the environment that bind to microplastics.

Chemicals such as bisphenol A (BPA) and phthalates are routinely added to plastics during the manufacturing process to improve its strength and flexibility. It is widely known that these chemicals can be harmful to humans and animals at high concentrations. Effects of phthalates and BPA mostly relate to the functioning of hormones, leading to negative effects on reproduction and development[30, 31]. Both amphibians and crustaceans appear to be particularly sensitive to the presence of chemicals in freshwater. However, it is not yet clear how significant a role microplastics play in contributing to exposure to these chemicals in freshwater and soil.

Microplastics may also act as a vector for chemical pollutants and pathogens. Whilst we know that these pollutants do bind to microplastics, what is less clear is whether they have the potential to leave the microplastic once inside the animal or whether they just pass straight through[32 – 34].

Some research suggests that pollutants can be released from microplastics inside organisms, particularly in laboratory conditions where high concentrations are used[35 – 46]. Other research suggests that the microplastics themselves are such an attractive surface for hydrophobic pollutants that these pollutants are very unlikely to leave the plastics whilst inside an organism[47 – 59] and that microplastics may even have a detoxifying effect. Whether or not a chemical pollutant is released from the microplastics is likely to be very context dependent. It might depend the type of pollutant, the type and shape of the microplastic particle, the type of animal, and the experimental concentrations. It is not known how significant a vector for pollutants microplastics might be in freshwater and soil environments when compared to organic debris or normal food sources such as plankton or sediment[60], nor how this compares to the risk of direct exposure to pollutants. Further research is required and in an environmentally realistic context before any firm conclusions can be drawn.

Priorities for research and next steps

As well as synthesising the available evidence, we have also highlighted the evidence gaps. Most significant among these is the lack of research into the effects of long-term exposure to microplastics at environmentally realistic concentrations, and the lack of understanding of exposure rates in the natural environment. As with all diffuse pollutants, measuring exposure and demonstrating significant effects in the natural environment will be very challenging and we do not currently have the methods available to do this.

This synthesis does not look at potential solutions in detail. It is impossible to disentangle the control of microplastics from wider plastic debates. Moving towards a more circular economy is likely to be the single biggest influencer in terms of limiting the amount of plastics and therefore microplastics in freshwater and soil environments. It is likely that this will require a combination of regulation, incentives, penalties, voluntary agreements and new solutions, as well as collaborative and collective action by many different countries, industries, sectors and government departments.

Whilst we know that these pollutants do bind to microplastics, what is less clear is whether they have the potential to leave the microplastic once inside the animal or whether they just pass straight through.

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