Micro and Nano Plastics in our Soils: R&D Fellowship Summary

*Selected Key Findings*

- Prevention of pollution is more effective than remediation: at present, there are no viable large-scale options to remediate soil micro and nano plastics pollution (Barone et al., 2024)
- In 2019, 368 million tonnes of plastic waste was produced globally, 32% of which is thought to have been lost to the environment (Allen et al., 2021)
- Micro and nano plastics pollution in UK soils is increasing across all land use types, including remote areas through atmospheric deposition (Cusworth et al., 2024; Allen et al., 2021)
- Key pollution pathways in agricultural land include the spreading of waste-derived biosolids, plastic-coated agrichemicals and use of plastic mulches (Gasperi et al., 2018)
- Pollution with plastic fibres negatively impacts soil aggregation, as well as the capacity of soils to store water and support healthy plant growth, with negative implications for future food security (de Souza Machado et al., 2018)
- Micro and nano plastics pollution can decrease the diversity of soil micro-organisms, favouring those which are able to degrade plastics (Rillig et al., 2023)
- Greenhouse studies have shown that plant roots exhibit stress responses in soils contaminated with MNPs (de Souza Machado et al., 2019)
- Small micro and nano plastic particles can enter plant roots and may travel through tissue into edible components (Yu et al., 2022), but any significant impact on human health through transportation from soils to crops has not yet been established (Iqbal et al., 2023)

*Evidence Review Summary*

The fellowship has summarised strong evidence that micro and nano plastics (MNPs) have been accumulating in soils globally since their widespread production and use in the 1950s. MNP pollution alters soil properties, potentially reducing the capacity of soils to provide essential ecosystem services. Soil MNPs reduce microbial diversity to favour organisms capable of plastic degradation, while increasing microbial activity. Higher microbial activity increases decomposition of organic material, respiration and methanogenesis. This means that turnover of soil carbon and nitrogen occurs faster, resulting in higher greenhouse gas emissions and reduced soil organic matter. Ingesting MNPs causes physical harm and increased mortality in soil biota. MNPs can change the soil structure through hindering aggregate formation, thus decreasing aeration and reducing the capacity of soils to retain water and drain effectively. This negatively impacts plant growth, soil health and flood prevention. These disruptive impacts can also reduce plant nutrient uptake. Soil MNP pollution is essentially irreversible.

There are many and varied pathways for MNP soil contamination, including the use of plastics in agriculture, the breakdown of plastic debris from landfill and littering, and car tyre abrasion. Where soils are contaminated with MNPs, there is a risk of soil biophysical degradation, plant uptake of nano plastics and groundwater pollution through leaching. Research shows there is a risk of bioaccumulation of both the MNPs and associated contaminants in the food chain, potentially impacting humans through crops and livestock. MNPs act as carriers of other environmental pollutants (e.g. heavy metals, pesticides), which adhere to the MNP surface and can be transported through the soil profile. This is an important aspect of pollution because MNPs are comparatively easily transported through soil.

Options for remediation are extremely limited because MNPs can persist for 550 - >2190 years in soils. Once they have degraded to the point where they are smaller than the human eye can detect them, there is currently no practical means of removing them. While innovations in plastic degrading bacteria are showing some promising results, these are costly, still in development, have not been implemented at a field scale and have several associated ecological risks. This means that preventing or reducing the pollution is more effective than trying to remediate once it has already occurred. We make several recommendations for action to reduce risks posed by MNP pollution. These include monitoring to establish current pollution levels in the UK, regulation of amendments used in agricultural land, and improvements to waste collection and management systems.

*Future Research Needs*

| Need | Actions considered |
|---|---|
| 1. Standardised metrics for soil MNP quantification | • Review of methodologies<br>• Consultation with experts<br>• Field testing – living labs? |
| 2. Establishment of thresholds of MNP pollution | • Experimental work to establish concentrations at which soil functions are impaired<br>• Snapshot survey to establish current UK MNP levels; possibly differentiated by type/shape/additives |
| 3. Test field scale impacts of MNP contamination | • Field trials of MNP contamination based on established thresholds<br>• Assess key soil functions for future climate resilience<br>• Incorporate UK staple food crops |
| 4. Investigate implications of MNP pollution on the food chain and human health | • Experimental work to establish tipping point of plant productivity<br>• Focus on UK staple and fodder crops<br>• Investigation into livestock production<br>• Improve our understanding of human health implications |
| 5. Improve our understanding the impacts of MNP pollution on peat and peatland restoration efforts | • Literature review: but we know UK sources are lacking in this area<br>• Survey of restoration sites? |
| 6. Develop theoretical framework of MNP-pollutant interactions | • Review of literature concerning MNPs and pollutant interactions |
| 7. Innovation in prevention of plastics entering the environment | • Consultation with waste management regulators and water companies<br>• Workshopping of MNP reduction with academics, farmers and producers |
| 8. Social research to determine implications of proposed plastic reduction measures | • Economic analysis – what is the cost of reducing our virgin plastic usage?<br>• Social analysis – who will be most impacted by reductions? What would it mean for farmers/hospitals etc. |

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