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Closing Microplastic Pathways Before They Open: A Model Approach

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In a recent viewpoint paper, the issue of microplastic pollution was discussed with a view that the environmental threat of such pollution is overstated.[1] While somewhat divisive, some ideas expressed (i.e., that ex-situ toxicology studies should examine microplastic-biota interactions at concentrations similar to what are recorded in natural environments) have considerable merit. However, one statement hinted at a more worrying stance for toxicologists to take. This was that the weight of research and media coverage of microplastics has led to adverse legislative moves, such as the ban on microbeads. While it is understandable that there are perhaps greater toxicological pollutants that are more deserving of legislative action, it is difficult to see this ban as an adverse move. Although microplastics are not yet occurring at toxic levels in most environments, it should not be considered poor policy to attempt to prevent microplastics reaching such toxic levels in the future. Without doubt, banning microbeads in rinse-off cosmetics does not solve microplastic pollution, but a proactive stance to prevent some environmental damage before such damage is scientifically recorded must be seen as a positive move. Often, environmental science takes the route of monitoring and reporting environmental damage that is, or has, occurred rather than developing tools to predict and prevent threats before they occur. To this end, logical theories combined with modeling tools may be far more effective at solving microplastic-pollution problems, compared to existing monitoring approaches. In this article, we present how theoretical microplastic pathways could be combined with existing modeling approaches to proactively prevent environmental microplastic exposure before they are even studied.

There is general acceptance about the conventional pathway by which microplastics enter the aquatic environment. Microplastics are carried from various sources (i.e., residential wastewater or road runoff) to municipal wastewater treatment plants (WWTPs). This water is ineffectively treated by these plants and an amount of microplastics are released into the environment in effluent water. However, environmental exposure from WWTP outputs are more convoluted than this. Nizetto et al.,[2] demonstrated that by using simple calculations based on available data, as much as 430 000 tons of microplastics may be applied to European fields annually through the agricultural use of WWTP-derived sludge as a fertilizer. While this is already concerning, exposure to agricultural soils may be even greater, for instance, due to biogas practises.

Co-substrates such as food waste from industry or households are often used to increase methane yields in biogas production.[3] However, when operating on a large or partly automated scale, plastic food-packaging could be easily incorporated into these co-substrates. Additionally, due to being marketed as "biodegradable", oxo-degradable plastics which combine traditional (nondegradable) plastic polymers with natural (degradable) polymers, like starch, may well be included in household compostable waste. These plastics quickly disintegrate and can be a huge source of microplastics.[4] The consequent application of such biogas digestate to arable land constitutes a new theoretical microplastic-pollution pathway. However, the environmental exposure of microplastics in compost-like outputs (CLOs), such as biogas digestate or wastewater sludge, does not necessarily end here.

Soil erosion is a major concern for environmental ecologists. In this process, wind or water transports topsoil particulates, often into aquatic environments. There are a multitude of factors which influence the rate of soil erosion, but particle dynamics play an important role, where the most mobile particles are the first to be eroded. This is concerning from a microplastic-pollution perspective given what we can learn, for example, from the fact that microplastic particles concentrate in WWTP sludge. Usually, the first stage of wastewater treatment is a grit removal stage. This stage is where much of the silicate quotient of inlet water is removed. Particles that are sufficiently mobile in suspension move on to the next treatment stage. It can be assumed that microplastics ultimately residing in WWTP sludge were sufficiently mobile to proceed past grit removal treatment. This may therefore indicate that microplastics applied to agricultural fields in WWTP-derived sludge may also be sufficiently mobile to be washed toward a drainage point during an erosion event (i.e., high rainfall). If numbers of microplastics applied to fields is as high, or higher than

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suggested by Nizetto et al.,[2] and if microplastics particles present on fields are mobile enough to be transported during extreme erosion events, then there is a clear alternative pathway for microplastics to enter aquatic environments. Based on these theoretical concerns, there is an obvious case for reassessing the practice of applying CLOs to agricultural fields.

More research investigating these pathways is undoubtedly needed. However, this could be a circumstance where proactive regulation could be the answer to preventing such exposure before real environmental damage can be visualized. Many aspects concerning the toxicity potential that microplastics may have on the natural environment are still to be determined. Yet, despite this, proactive legislative steps have been made to prevent further environmental exposure. The recent UK ban on microplastic content ("microbeads") in rinse-off cosmetics[5] demonstrates the steps that can be made to protect the environment from unproven detrimental consequences. The issue of microplastic-containing CLO application combined with soil erosion could again be a circumstance where regulation or legislation could be proactive rather than reactive. Models are already in place that are able to predict areas where high rates of soil erosion are expected.[6] Using these models, combined with particle-dynamic models of common microplastics found in CLOs (although more data may be needed), candidate fields could be eliminated from CLO application where aquatic exposure of microplastics is a risk. While this would not stop the accumulation of microplastics on low-erosion-risk arable land, it would at least act as a starting point before better steps could be introduced (such as the screening or removal of microplastics in CLOs for agricultural application). This is an opportunity to use moves such as the "ban on microbeads" as a precedent to get ahead of plastic pollution problems; to close possible exposure pathways before damage is done.

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Notes

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