Microplastic pollution

Purpose

This Policy Position Statement (PPS) outlines issues relating to microplastic pollution and its prevention. Microplastics are particles that are smaller than 5mm. They have the potential to accumulate in soil, freshwater and marine environments and enter the food chain, where their size makes them easier to ingest than larger plastic contamination.

Context

Society's adoption of plastics as a substitute for traditional materials has expanded extremely rapidly since large-scale production began in the 1950s. Each year over 322 million tonnes of plastic are produced globally and this is increasing[1].

Plastics are an incredibly versatile material with many uses for which alternatives are not viable, either functionally or financially. They are made from a group of large molecules called polymers which vary in characteristics such as buoyancy, toxicity and degradability. Plastics may also contain additives designed to change the properties of the end product.

Durability is a common feature of most plastics, and it is this property, combined with an unwillingness or inability to manage end-of-life plastic effectively that has resulted in waste plastics and microplastics becoming a global problem. Many plastic items are so cheap they can be thrown away without financial consequence to the consumer. Less than a third of Europe's plastic waste was recycled in 2014, another third ended up in landfills and from the rest only the energy was recovered.

The plastic waste problem is growing rapidly in developing countries too, partly due to increased affordability of products made from plastic and partly due to vastly inadequate infrastructure to manage the waste problem. Over three billion people do not have access to waste collection and disposal facilities.

Microplastics are formed by the fragmentation and weathering of larger plastic items or are in the form of manufactured beads, granules, fibres and fragments. Each year billions of particles of microplastic find their way into the environment and being hard to degrade, they accumulate. They have become ubiquitous and are abundant not only in all of the five ocean's subtropical gyres but also in Arctic Sea-ice, deep sea sediments and uninhabited Pacific islands.

Microplastics consist of particles smaller than 5mm right down to microscopic particles. Those that are 1-5mm are usually referred to as large microplastics and <1mm are small microplastics.

They are categorised as primary or secondary:

- Primary microplastics include industrial scrubbers used in blast cleaning, plastic powders used in moulding, plastic nanoparticles used in a variety of industrial processes, micro-beads in cosmetic formulations and soaps and in detergents for washing machines.
- Secondary microplastics are formed by the fragmentation and weathering of larger plastic items during the use of products such as textiles, paint and tyres, or once these or other plastic items (bags, bottles etc.) have been released into the environment.

CIWEM considers

- Urgent measures are needed to address both primary and secondary microplastic pollution at source, as once released into the environment there is no prospect of any practicable means by which these pollutants can be removed. The largest proportion of particles stem from the laundering of synthetic textiles and from the abrasion of road markings and tyres while driving.
- Prevention is the best, and most likely cheapest, long term solution to reduce microplastic pollution. Plastics can easily form part of a circular economy with reuse or recycling if they are designed appropriately and are properly recovered and managed when they reach the end of their life. Methods include improved product design and substitution, extended producer responsibility and deposit return schemes.
- Tackling the issue of plastic and microplastic pollution will require an international protocol or regulatory framework to guide co-operation between governments, plastics manufacturers, the waste management and water industries, consumers and companies using plastics in their products to tackle the issues around design, manufacturing, use, reuse and disposal of plastics.
- Banning manufacturers from including primary microplastics such as microbeads in 'wash off' personal care products such as face scrubs, toothpastes and shower gels is welcome. However these plastics are a minor contributor to the overall problem and are one of the few cases where microplastics are released intentionally. As other losses are from product use and maintenance, through abrasion, weathering or unintended spills, preventing them will be all the more difficult.
- Whilst the accumulation of plastics in the marine environment has received worldwide attention, data on the quantities and biological effects of microplastics in freshwater environments is reasonably sparse as is the potential impact associated with the application of sewage sludge containing microplastics to farmland. Given that more than half of microplastic losses will remain on land and in soils this requires extensive research.
- There needs to be a better understanding of the current knowledge and research needs into which polymers are the most damaging and under what conditions so that these can be most effectively addressed and substituted. This will require a collaborative effort by environmental scientists from diverse disciplines.

Research needs

A review of existing research and undertaking new research is needed into:

1. The fate and transport mechanisms of microplastics within the environment.
2. The decomposition and fragmentation of plastics in the environment (how secondary microplastics are formed).
3. Environmental and health impacts including:
   i) the potential of microplastics to act as vectors for persistent organic pollutants within the environment (e.g. how and where organisms are exposed to these chemicals);
   ii) the physical effects of ingestion on wildlife;
   iii) following ingestion, the potential toxic effects of plastic additives and chemical contaminants present in the environment for which the microplastic can act as a vector;
   iv) following ingestion, the potential increased disease risk from the microplastic acting as a vector for pathogens present in the environment;
   v) the potential for human exposure from consumption of fauna that have accumulated microplastics;
   vi) the potential for leaching of plasticiser chemicals (e.g. the conditions and timescales over which this is likely to occur).
4. Water treatment: The efficacy of water treatment processes in removing microplastics and the likelihood of microplastics being ingested in drinking water. As many water treatment processes already have substantial capabilities for removing particles this requires a focus on very small microplastic fragments in particular those of less than 5μm.
5. Microplastic emissions from domestic and commercial appliances: What factors control the amount of fibres being released from washing synthetic clothing and how the removal by appliances such as washing machines can be improved to reduce the amount of plastic fibres ending up in wastewater.
6. The removal of microplastics in wastewater treatment: The difference between concentrations in discharges to surface waters and via sewage sludge as well as the effect of tertiary treatment methods on microplastic load.
7. Any methods to remove microplastics from biosolids and the consequences of applying biosolids containing microplastics to land.

CIWEM calls for

1. Governments to set high standards and improve recovery and recycling of plastics to minimise the quantity of secondary microplastics that reach the environment.
2. Industry to develop potentially commercially viable plastics and plastic alternatives that are less damaging to the environment, particularly around tyres, road markings and synthetic fabrics.

3. Governments to provide incentives (financial or otherwise) for the use of alternatives that are shown to be less damaging and tackle the issue of single-use packaging items like plastic film which can be neither reused nor recycled.
4. Local authorities to review road markings and highway drainage to prevent micro contaminants including microplastics entering the freshwater environment and into wastewater networks and treatment plants.
5. Regulators to enforce existing restrictions on the use of hazardous additives and polymer ingredients under the EU REACH, encourage producers to use more benign alternatives where possible, and in the longer term take a more sector-based approach to the assessment and regulation of chemicals related to plastics.
6. Governments to recognise good practice in plastic use and disposal and increase public awareness of plastic use (wider than personal care items e.g. littering, washing synthetic clothing, windblown litter), reuse and recycling capabilities.
7. Developed countries to target assistance to less developed counties on waste management to alleviate what in many parts of the world is an immense problem.

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Key issues

Sources of microplastics

The International Union for Conservation of Nature and Natural Resources (IUCN) describe seven major sources of microplastics: tyres, synthetic materials, marine coatings, road markings, personal care products, city dust and plastic pellets (incidents during the manufacturing, transport and recycling of plastics). Apart from personal care products, most microplastics are unintentionally lost through abrasion, weathering or unintended spills. Secondary microplastics largely originate from the mismanagement of waste during the disposal of products containing plastics.

Two thirds of primary microplastics originate from road runoff (tyres, road markings and pellets incidents on land) (figure 1). Another important source is from the washing of clothes made from synthetic materials. Research shows the washing of manmade fabrics can potentially release over 700,000 fibres from an average wash load of 6kg[2].

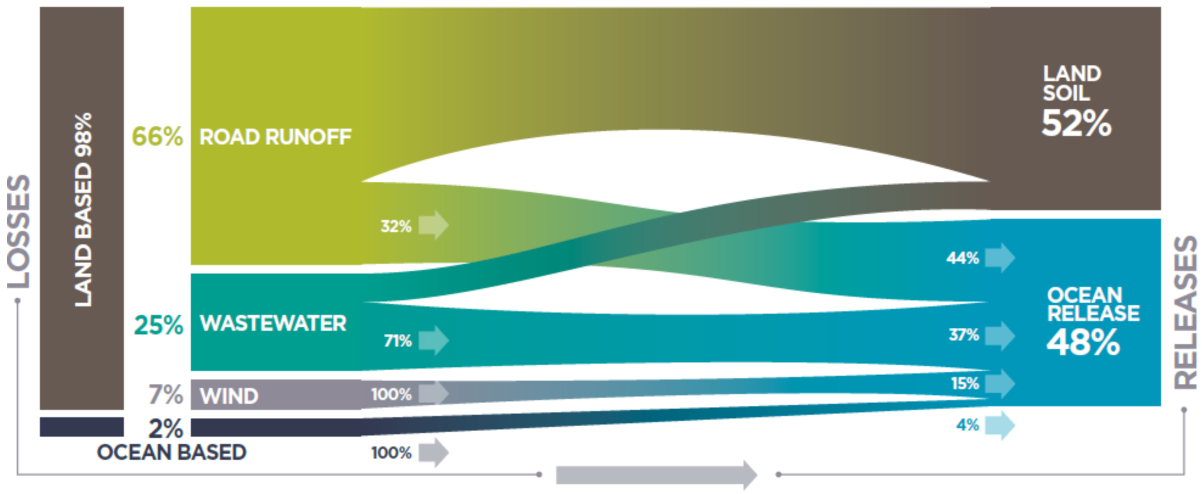

Figure 1. Global releases to the world oceans. IUCN[3]. Contribution of different pathways to the release of microplastics

Microplastics once in the environment can be transported via wind, commercial and domestic discharges to sewers, runoff into rivers, runoff into combined sewer systems and runoff directly into lakes and oceans (figure 2). The IUCN estimate that of the microplastics losses, 48% end up in the ocean and around 52% are trapped in soils when wastewater sewage sludge is used as fertiliser and/ or when particulates are washed from the road surface.

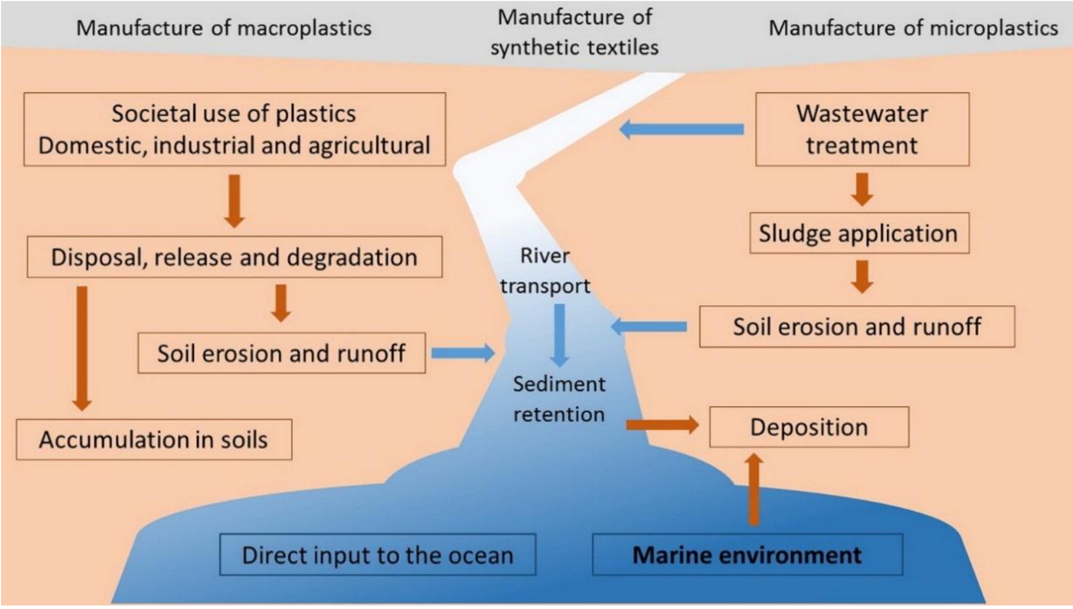

Figure 2. Possible environmental transport of microplastics, CEH[4].

Their presence on land and in rivers, lakes, groundwater and the ocean is influenced by a combination of environmental factors including exposure to UV radiation, buoyancy and by the properties of the polymer from which they are made. The properties of microplastics in the oceans differs substantially from those in sewage and run off as there has generally been more opportunity for the breakdown of larger plastic fragments into secondary microplastics.

Removal of microplastics through water treatment processes

Drinking water

The process of turning raw water into drinking water involves a three stage treatment which includes coagulation, flocculation and filtration. This is primarily to remove cryptosporidium spores (5μm) from drinking water and so water treatment plants should therefore remove microplastics down to this size and prevent them going into drinking water. Treatment would not generally remove particles below this size so there could be implications for nanoplastics entering drinking water (<100nm).

Wastewater

Removal at wastewater treatment works is highly dependent on the density and size of the particle[5]. Microplastics that are dense enough to settle are periodically removed from settling tanks along with other settled solids. Those that float are scraped from the surface of settling tanks before being mixed with the settled solids. Microplastics that remain in suspension may escape further treatment filters, such as those used in tertiary treatment plants, and are therefore discharged from the works into surface water or rivers as part of effluent discharge.

Wastewater treatment works are not specifically designed to remove microplastics. However removal by conventional primary and secondary wastewater treatment technologies have shown to be very effective overall, (studies show around 97-99% are removed)[6]. Yet despite this large reduction, due to the large volumes of wastewater processed each day, a large treatment works could still release approximately 900,000 to 3600 million microplastics per day to freshwater and marine environments[7].

As treatment can leave 99% of microplastics in sludge, this is a potentially large source of pollution. Microplastic retention in sewage sludge and subsequent application of sewage sludge to terrestrial systems for agricultural reasons may lead to the transfer of microplastics and/or chemicals to soil used in growing food[8]. EU legislation requires sludge to be treated to protect against health hazards, for example by lime stabilisation, anaerobic digestion, composting, or thermal drying, but there is limited evidence of these being able to remove microplastics[9] and there is currently no specific regulation for microplastics. Anaerobic digestion should be further investigated as a remediation technique.

Accumulation of microplastics

The majority of microplastics' research to date has focussed on the marine environment; in 2017 a survey of 279 UK shorelines found 73% contained plastic pellets[10]. Yet each year it is believed that between 473,000 and 910,000 metric tonnes of plastic waste is released and retained within land-based environments in Europe. This equates to between 4 and 23 times the amount estimated to be deposited in oceans[11]. The only way they may be naturally removed is by wind or run-off so once incorporated beneath the surface into the soil there may be limited chance of this happening. They may eventually, in part be returned to the aquatic environment[12].

If they are not skimmed from the surface, microplastics that are removed in wastewater treatment plants become concentrated in sewage sludge. The possible negative environmental impact associated with the application of sewage sludge containing microplastics to farmland has not been extensively researched. However microplastics degrade slowly and as a result can accumulate in the soil. Both plasticisers and POPs (persistent organic pollutants) could be released from plastics, and thereby have the potential to enter the human food chain via crops or livestock grazing. POPs have been shown to be taken up by plants, but at a lower rate than heavy metals, for example.

Impacts of microplastics

In the ocean many microplastic particles are found suspended in water, where they can enter the food chain by being ingested by filter feeders, ranging from zooplankton to baleen whales, or ingested by benthic species where denser particles sink to the bottom. Although most research has focused on marine environments, freshwater systems may be at greater risk from primary microplastic contamination due to them being closer to point sources (such as wastewater treatment plants and plastic processing factories).

Organisms that ingest microplastics particles lack a digestive system that can degrade them. Fibres can clump and knot blocking the digestive tract of small organisms in a similar way that larger plastics do in larger organisms. Also the nutrition of small organisms is potentially undermined if they mistake plastics for food.

Data on the biological effects of microplastics in freshwater species is reasonably sparse. Of the few available studies, a study on anchovies has suggested that plastics are mistaken for food due to the chemical signature plastic debris acquires in the ocean[13], another that polystyrene nanoparticles have severe effects on both behaviour and metabolism in fish[14].

There are some studies demonstrating chemical adsorption to microplastics and desorption in the gut following ingestion, based on chemical analyses and also whole organism effects[15].

The accumulation of other freshwater contaminants on microplastics' surfaces is of special interest because ingestion has the potential to increase the chemical exposure. Aquatic living organisms are continuously exposed to microplastics, and associated contaminants, and could suffer from its contamination but also introduce them into the food chain[16].

The adverse environmental effects of the polymers and additives which make up the microplastics following dietary uptake are not fully known. Although additives will have been tested as a requirement under the EU REACH regulation, these will have been aquatic ecotoxicity studies with waterborne exposure, and not dietary studies.

The potential for toxic or hormonal disruptive effects of microplastics are attributed by UNEP to persistent organic pollutants (POPs) and other persistent, bioaccumulative and toxic chemicals that may have been used as additives in plastic manufacture, and to the ability of microplastic particles to attract and concentrate harmful such organic pollutants with which they come into contact. Microplastics could also provide a medium for exotic species and pathogens, for example microorganisms developing biofilms on microplastic particles.

Initiatives to date

International

A responsibility to protect the marine environment is enshrined in the 1994 United Nations Convention on the Law of the Sea (UNCLOS). Article 194 requires that 'states shall take, individually or jointly as appropriate, all measures within this Convention that are necessary to prevent, reduce and control pollution of the marine environment from any source'. Member States are, however, failing to take responsibility for primary and secondary plastic pollution.

The UN Sustainable Development Goals include a target to prevent and significantly reduce marine pollution of all kinds, including marine litter. At the 2017 UN Ocean Conference voluntary commitments were made by a number of countries whose rivers transport plastic waste to the ocean. Thailand pledged to implement proper waste disposal and encourage environmentally-friendly alternatives to plastic packaging as part of its recent 20-year pollution management strategy and Indonesia pledged to reduce plastic waste by 70 per cent by 2025. Microbead bans are under consideration in Australia and the USA[17].

The Stockholm Convention is an international treaty that aims to eliminate or restrict the production and use of persistent organic pollutants (POPs) and has been adopted in the EU Regulation 850/2004 on POPs.

Europe

The European Marine Strategy Framework Directive (MSFD, 2008/56/EC) addresses the issue of marine litter, including plastics. Microplastics are covered by Descriptor 10 of Commission Decision 2010/477/EU, which defines the good environmental status of marine waters[18]. It recommends that ideally microplastics are reduced at origin. In contrast, the Water Framework Directive (WFD, 20/60/EC) applying to European inland waters does not specifically refer to plastic litter. As microplastics are an emerging issue they may be considered within the Water Framework Directive's list of Priority Substances or under the Hazardous Substances Directive in the future which would have significant implications for the water industry.

A number of substances are controlled under EU chemicals policy (REACH), a prominent example is use of bisphenol A as a co-monomer, plastics of which are restricted from some uses.

A directive to reduce the use of light-weight plastic carrier bags was adopted in 2015 to reduce the consumption of and to phase out bags that fragment rather than degrade[19]. Plastics are now one of the five priority areas addressed in the EU action plan for the Circular Economy. Plastic waste is already needed to be collected separately, but the Package proposes raising the recycling target for plastic packaging to 55%, and reducing landfilling to no more than 10% by 2030. It will set out a strategy to assess the challenges across the entire life cycle of plastics, improve recycling, cut marine litter, and remove potentially dangerous chemicals towards the end of 2017.

Some effort is being made to reduce the occurrence of microbeads added to 'wash off' personal care products such as face scrubs, toothpastes and shower gels. A joint statement to the European Commission by Sweden, Belgium, The Netherlands, Austria and Luxemburg, urged a ban on microplastics in cosmetics and detergents. Bans are under consideration in individual EU Member States, including Ireland, France and the UK. At the time of writing some large cosmetic manufacturers had removed microbeads from their personal care products ahead of imminent bans.

UK

The UK has committed to introducing a microbead ban in cosmetics and personal care products starting in 2018[20]. Although welcome, this is an easy win as the microplastics are easily be replaced with far less damaging alternatives and they are a minor contributor to the overall problem (estimates range from 0.01 to 4.1% of plastics in the marine environment[21]). Measures should also be taken to avoid redefinition of the plastic beads used in personal care products so that they are able to continue under another guise.

Outside of the European Union the UK will need to address plastics with its own strategy. Following the publication of the Litter Strategy for England the government will follow with a new national anti-littering campaign in 2018, working with industry and the voluntary sector to drive behaviour change. Charging for single-use plastic bags to reduce consumption has been highly successful in the UK with more than nine million fewer plastic bags used (around 83 per cent reduction) since the government introduced a 5p charge and around a 40% reduction found on beaches[22]. The government should now consider plastic bottle deposit return schemes which have shown to have extremely high recovery rates (~90 per cent) in Germany, Sweden and Norway.

Defra is reviewing standards for the biodegradability of plastic carrier bags to be able to exempt "super biodegradable bags" from the charge. Any bag would have to be able to biodegrade in a wide range of environments (land, freshwater and sea) to be exempt. Complete biodegradation of plastic occurs when none of the original polymer remains, i.e. it has been broken down to carbon dioxide, methane and water. The process is temperature dependent and some plastics labelled as 'biodegradable' require the conditions that typically occur in industrial compositing units, with prolonged temperatures of above 50°C, to be completely broken down. Such conditions are rarely if ever met in the natural environment[23]. There is an ISO standard for biodegradability in soil, however there is no one material that would break down in all environments at the current time.

Initiatives to date, whilst welcome, fall far short of what is needed to bring the problem of microplastics under control. Prevention is the best, and most likely the cheapest, long term solution to reduce microplastic pollution. Controlling plastics at source, improved product design and relevant changes to highway drainage to prevent micro contaminants including micro-plastics entering the wastewater networks and treatment plants will all be needed. It is significant in this context that many plastics manufacturers are multinational firms with substantial research and development capabilities.

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Note: CIWEM Policy Position Statements (PPS) represents the Institution's views on issues at a particular point in time. It is accepted that situations change as research provides new evidence. It should be understood, therefore, that CIWEM PPS's are under constant review and that previously held views may alter and lead to revised PPS's. PPSs are produced as a consensus report and do not represent the view of individual members of CIWEM.

Further reading

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