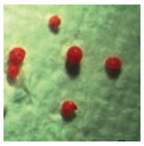
micro plastics

Microplastics are tiny plastic particles up to 5 mm in diameter. In the last four decades, concentrations of these particles appear to have increased significantly in the surface waters of the ocean.

Concern about the potential impact of microplastics in the marine environment has gathered momentum during the past few years. The number of scientific investigations has increased, along with public interest and pressure on decision-makers to respond.

Despite a rapidly growing knowledge base, the extent to which microplastics represent a hazard to marine life – and may provide a pathway for transport of harmful chemicals through the food web – is still being assessed. A number of international initiatives are under way to determine the physical and chemical effects of microplastics in the ocean, and to identify ways to address this emerging issue.



UNEP

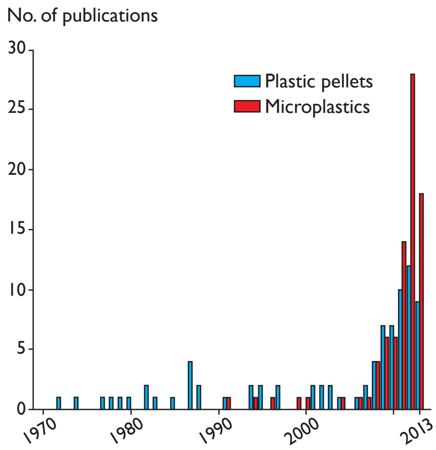
EMERGING ISSUES

Marine litter

Marine litter can be defined as any persistent, manufactured or processed solid material that is discarded, disposed of, or abandoned in the marine environment. Globally, plastic items (including microplastics) are the most abundant type of marine litter. Plastic is also the most frequently reported material in encounters between debris and marine organisms.

Plastic and other types of marine litter can have an impact on biodiversity through entanglement in – or ingestion of – debris items; facilitation of the transport of organisms that 'raft' on marine litter; provision of new habitats for colonization; and ecosystem level effects. The impact will vary according to the type and size of the debris and the organisms that encounter this debris.

Source: CBD and STAP-GEF



The number of publications in scientific journals and reports show the surge in interest in microplastics by scientists over time. *Source: Sarah Gall, Plymouth University, pers. comm.*

1 What are microplastics?

Plastic debris is found in the environment in a very wide range of sizes. Researchers first reported finding tiny beads and fragments of plastic, especially polystyrene, in the ocean in the early 1970s. The term 'microplastics' was introduced in the mid-2000s. Today, it is used extensively to describe plastic particles with an upper size limit of 5 mm.

2 Why are microplastics in the ocean receiving increasing attention?

Marine litter – especially plastic debris in the ocean – is a major global environmental issue. There is growing awareness by the scientific community, governments, industry, the general public, the media and non-governmental organizations (NGOs) of the potential for microplastics to harm the environment. The scale of the problem has driven a large number of scientific investigations; initiatives at governmental, regional and international level; and activities led by NGOs, including education and awareness raising, lobbying, removal of litter from shorelines, and ocean expeditions.

While a mounting body of scientific evidence suggests that society should be concerned about the potential effects of microplastics in the ocean, the evidence is as yet insufficient to quantify the nature and full extent of these effects.

Physical effects

The physical effects of plastic debris due to both entanglement and ingestion have been clearly demonstrated. However, it has proved more difficult to demonstrate these effects for microplastics.

Studies have shown that microparticles can be ingested by filter-feeding marine organisms such as oysters and mussels. They have been observed to close the gut wall and induce a reaction within the tissue. On a different scale, surface-skimming baleen whales such as the endangered North Atlantic right whale (*Eubalaena glacialis*) feed on copepods and other small invertebrates by filtering enormous volumes of seawater. It is possible that microplastics in the seawater present an additional stressor if they affect the filter-feeder system inside the whale's mouth.

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Chemical effects

The ecotoxicological profiles of compounds added to plastics to achieve certain properties (e.g. durability, flexibility, UV resistance) are generally well known. What is not known with enough certainty is the degree to which these additives can be transferred from a plastic particle into an organism, and whether this takes place at a level that will result in a significant impact of chemicals on the organism.

Seawater is contaminated with a wide variety of organic and inorganic pollutants. Many plastics absorb organic contaminants, such as the pesticide DDT and polychlorinated biphenols (PCBs), to a high degree. These compounds can cause chronic human health effects, including disruption of the hormonal system (endocrine disruption), inducing genetic changes (mutagenicity) and cancer (carcinogenicity).

Once ingested by fish, birds or sea mammals, the compounds – which penetrate the structure of the plastic – may start to leach out. The rate and direction of transfer of persistent, bioaccumulating and toxic compounds will depend on the chemical environment in the gut and the existing levels of those compounds in the tissue.

Organisms become continuously contaminated by contact with their environment and by ingestion of contaminated food. Separating the potential additional contaminant burden due to microplastics as vectors for pollutants remains extremely problematic.

The International Whaling Commission is conducting a two-year investigation into the interaction of marine debris with cetaceans, including whales and dolphins. Microplastics have been recognized as having a potential impact on baleen whales, including through digestion of associated chemical pollutants and microbes. The overall objective is to assess, by 2014, the extent of the problem and to propose potential mitigation and management solutions.

Plastic resin pellets as indicators of persistent organic pollutants (POPs)

Plastic resin pellets are durable and accumulate persistent organic pollutants (POPs). Therefore, they are a good vehicle for tracking POPs in marine environments, their spatial concentrations, and how they enter the food web.

The Global Environment Facility (GEF) Transboundary Water Assessment Programme (TWAP) evaluates the use of plastic resin pellets as an indicator of POPs in coastal waters. It collates available information on the distribution of pellets and concentrations of these pollutants. It will produce time-series and distribution maps of floating litter where data are available. UNEP will publish the TWAP findings in early 2015.

For several years, the International Pellet Watch (IPW) has coordinated and collated information on POPs in pellets collected from shorelines worldwide. Among other results, its activities have demonstrated that the quantities of these pellets released to the environment are reduced when improvements are made in industrial and waste management practices.

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Sources of plastic debris (including microplastics) in the ocean

Sea-based sources include:

- Merchant shipping – rope, galley waste
- Fishing – nets, boxes, rope, wrapping bands, galley waste
- Aquaculture – nets, floats, rope
- Offshore oil and gas platforms – galley waste, sewage-related
- Cruise ships – galley waste, sewage-related (may be equivalent to a medium-sized town)
- Recreational boating – galley waste, sewage-related

Land-based sources include:

- Coastal tourism – packaging, cigarette filters
- Population centres – sewage-related, storm drains, street litter
- Horticulture/agriculture – plastic sheeting, tubing
- Poorly controlled waste sites and illegal dumping – all waste types
- Industrial sites – plastic production and conversion, packaging
- Ship-breaking

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3 Where are microplastics found?

Plastic debris (including microplastics) is found in greater abundance close to its sources, and all plastic debris tends to be found in higher quantities near population centres. However, every part of the ocean examined so far, from the remotest regions of the Arctic and Antarctica to the deep seafloor, has revealed the presence of plastic. Based on the limited data available, there appears to have been a significant increase in concentrations of microplastics in surface waters of the ocean during the past four decades.

The ocean circulation transports floating plastic around the globe over the course of the years. Ocean circulation produces convergence zones, where microplastics tend to accumulate. These large-scale sub-tropical ocean gyres occur in the North and South Atlantic, North and South Pacific, and the Indian Ocean. Plastic debris is a classic transboundary issue. Once this debris is in the ocean, it may be possible to retrieve a small proportion through cleaning shorelines, but much remains out of sight in the ocean and on the seafloor. With existing technology, it is not possible to remove microplastics from the ocean.

4 Where do microplastics in the ocean come from?

Microplastics in consumer products

Microplastics (e.g. polyethylene spheres) are included in personal care products such as toothpaste and skin care products, although many consumers are unaware of it. In some cases microplastics have replaced natural ingredients, such as pumice or ground seeds and shells in skin cleansers and scrubs. They tend not to be filtered out during sewage treatment, but to be released directly to the ocean or other water bodies such as lakes and rivers.

Microplastics are also found in synthetic textiles. Wastewater collected after synthetic blankets, fleeces or shirts were washed in a washing machine contained more than 100 fibres per litre of water. According to a study by Brown and others (2011), on average some 1900 microplastic fibres can be discarded by a synthetic item during one washing. Similar fibres have been observed in sewage effluent and sludge on shorelines near large population centres.

Avoiding such uses and releases of microplastics would reduce the quantities entering the marine and coastal environment. As the world population grows and more products containing microplastics are placed on the market, the amounts found there are likely to increase.

Industrial sources of microplastics

Plastic resin pellets are industrial feedstock for plastic products. They are typically spherical or cylindrical and only a few millimetres in diameter. In addition, plastic microbeads are used in many industrial applications, including as ingredients in printer inks, spray paints, injection mouldings and abrasives.

A proportion of the microplastics used in industrial applications enter the environment. Plastic resin pellets, for example, are sometimes lost during transport or through poor management of operations. Improving the management of operations in which plastic pellets and microbeads are used (and improving industrial waste handling) is an obvious way to prevent them entering the environment.

Plastic debris as a source of microplastics

Secondary microplastics are formed when plastic items fragment and disintegrate. The rate at which fragmentation occurs is highly dependent on the environmental setting, especially temperature and the amount of UV light available. Any sea-based or land-based human activity can result in litter being released to the environment. Plastic debris may enter the ocean directly, or it may find its way there via other water bodies or the atmosphere. The key to stemming flows of plastic debris to the ocean is to prevent this debris entering the environment. Larger items are much easier to identify and potentially to control than small ones.

About half the global population lives within 100 km of a coastline, and population growth is greatest in that zone. This means the amount of plastic debris entering the ocean from land-based sources is likely to increase unless significant changes are made to waste management practices on land.

Common applications and specific gravity of some plastics found in the marine environment

Categories or classes	Common applications	Specific gravity	
Polyethylene (PE)	Plastic bags, six-pack rings, gear	0.91-0.94	Floating
Polypropylene (PP)	Rope, bottle caps, gear, strapping	0.90-0.92	
Polystyrene (expanded) (PS)	Bait boxes, floats, cups	0.01-1.05	
Seawater		~ 1.02	
Polystyrene (PS)	Utensils, containers	1.04-1.09	Sinking
Polyvinyl chloride (PVC)	Film, pipe, containers	1.16-1.30	
Polyamide or nylon	Gear, rope	1.13-1.15	
Polyethylene terephthalate (PET)	Bottles, strapping, gear	1.34-1.39	
Polyester resin + glass fibres	Textiles	>1.35	
Cellulose acetate	Cigarette filters	1.22-1.24	

Source: Andrady 2011

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What happens to plastic debris in the environment?

Many different plastics are manufactured, with different properties. Only a few categories or classes are produced in high volumes. What happens to plastic debris largely depends on the properties of the types of plastics in the debris. For many applications, durability is the most desirable property. However, durability is also the reason plastic debris is such a problem.

Each type of plastic has different weathering properties that depend on additives compounded into them, such as UV stabilizers. Photo-induced (UV) and thermo-oxidative breakdown are the main mechanisms that result in plastics fragmenting and degrading.

Beaches are ideal environments for mechanical fragmentation, especially when combined with physical abrasion from wave action. Once plastics are buried or submerged, UV light penetration and temperature are greatly reduced and degradation proceeds much more slowly.

Typically, soft drinks and mineral water are supplied in PET bottles, which are often seen on beaches or floating in rivers because air remains in the bottle. Once a bottle begins to break up, individual fragments sink since the specific gravity of PET is higher than that of seawater. Even low-density plastics may sink once a biofilm starts to grow on the surface. Below the sea surface, fragments take much longer to break down further.

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Biodegradable plastics?

Complete biodegradation is achieved when plastics are broken down into their constituent molecules: water, carbon dioxide, and often methane. For most common plastics this normally occurs only in an industrial composter, where the required temperature of 70° C can be achieved.

Many products labelled 'biodegradable' are not. Some of these products are designed to break into smaller fragments, but the fragments retain their original polymer properties. A few plastics labelled 'biodegradable' break down more easily, but they tend to have limited uses and are more expensive than many other plastics.

UV radiation (e.g. on beaches) enhances the rate at which plastic particles fragment. However, once the particles are covered by sand, water or biofilms, this rate greatly decreases. Thus, most plastics in common use will not biodegrade in the marine environment.

Getting the message across

The concept of microplastics in the ocean and their potential impact can be difficult to communicate to non-specialists. This imaginative booklet, designed for Chilean school children, describes the migration of Jurella fish off the coast of South America and their encounters with microplastics.

Source: Científicos de la Basura

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5 Closing the knowledge gap

The United Nations Environment Programme (UNEP) cited plastic debris in the ocean as an emerging environmental issue in the UNEP Year Book 2011. Since then, further scientific evidence has been gathered on the sources and impacts of microplastics. The Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) has established a working group to bring together this new knowledge and prepare a global assessment of the sources, fate and effects of microplastics in the marine environment. The overall objectives are to assess:

- Sources and quantities of 'primary' microplastic particles (e.g. resin pellets, abrasives, personal care products) and macroplastic debris (including the main polymer types) in the ocean
- Surface distribution, transport, distribution and potential areas of accumulation of plastics and microplastics, over a range of space- and time-scales
- Properties and processes (physical, chemical and biological) controlling the rate of fragmentation and degradation of plastic in the ocean, and the rate of production of 'secondary' microplastic fragments
- Longer-term fate of microplastics, including an estimate of seabed and water column distributions
- Uptake of particles and their contaminant/additive load by biota, as well as their physical and biological impacts at a population level
- Societal aspects, including education and public awareness

UNESCO-IOC is the lead UN Agency for the working group (WG40*). Support is provided by IMO, UNEP and UNIDO, as well as the United States National Oceanic and Atmospheric Administration (NOAA), the American Chemistry Council and Plastics Europe. The Assessment Report is scheduled for launching at the 2nd International Ocean Research Conference in Barcelona, Spain, in November 2014.

* For further information about WG40, please contact the chair of the working group: Peter Kershaw – peter@pjkershaw.com

6 Taking action

An increasing number of initiatives support policy-making and other actions to address the problem of plastic debris in the ocean. They range from providing participatory research and education to groups of young people, to collecting innovative ideas from individuals and businesses; and from beach clean-ups involving communities, to policy advocacy directed at governments.

Recognizing the significance of this emerging issue, more than 60 governments have stressed the relevance of a global framework for prevention and management of marine litter. The Global Partnership on Marine Litter (GPML) is a voluntary, open-ended partnership for governments, international agencies, businesses, academia, local authorities, NGOs and individuals, launched during the United Nations Conference on Sustainable Development (Rio+20) in June 2012. Its main objective is protecting human health and the global environment though reduction and management of marine litter.

This global partnership works as a coordinating forum to increase awareness of the impacts of marine litter at various levels (e.g. by policy-makers, industry, and the general public); enhance knowledge of best practices to address marine litter around the world; identify and address knowledge gaps related to marine litter management; coordinate global and regional networks; and improve synergy among actors.

Some activities of this partnership include developing and maintaining an on-line marine litter network; regional activities; demonstration projects with a focus on reducing the inflow of solid waste into the marine environment; a life cycle approach and plastics recycling/redesign; and public-private partnership which promotes source reduction and corporate social responsibility. A specific objective of the GPML is to enhance international cooperation and coordination through promotion and implementation of the Honolulu Strategy.

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The Honolulu Strategy and the 4Rs

The Honolulu Strategy is a framework for a comprehensive and global effort to reduce the ecological, human health and economic impacts of marine debris. Its successful implementation will require participation and support on multiple levels (global, regional, national and local), involving the full spectrum of civil society, government and intergovernmental organizations as well as the private sector.

The framework consists of three goals and associated strategies:

- Goal A: Reduced amount and impact of land-based sources of marine debris introduced into the sea
- Goal B: Reduced amount and impact of sea-based sources of marine debris introduced into the sea, including solid waste; lost cargo; abandoned, lost or otherwise discarded fishing gear; and abandoned vessels
- Goal C: Reduced amount and impact of accumulated marine debris on shorelines, in benthic habitats, and in pelagic waters

A key action proposed for strategies under Goal A is to promote an assortment of behaviours and actions, the "4Rs" related to waste management (reduce, reuse, recycle, and recover).

In view of the nature of microplastics – and their increasing use in personal care products – there may be a need to add a fifth "R": redesign. Redesigning products could, for example, avoid the use of primary microplastics and stimulate innovation in more sustainable directions.

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Microplastics collected from beaches in Hawaii
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Primary microplastic particles
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Lids of plastic bottles
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United Nations Environment Programme
P.O. Box 30552 - 00100 Nairobi, Kenya
Tel.: +254 20 762 1234
Fax: +254 20 762 3927
e-mail: uneppub@unep.org
www.unep.org

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