Microplastic pollution: the causes, consequences and issues for investors

First Sentier MUFG
Sustainable Investment Institute

Contents

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The First Sentier MUFG Sustainable Investment Institute (the Institute) aims to provide research on topics that can advance sustainable investing. The Institute is jointly supported by First Sentier Investors and Mitsubishi UFJ Trust and Banking Corporation, a consolidated subsidiary of MUFG.

Microplastic Pollution: The Causes, Consequences and Issues for Investors is the first report published by the Institute.

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About Chronos Sustainability

The Institute commissioned Chronos Sustainability to develop this document. Chronos Sustainability was established in 2017 with the objective of delivering transformative, systemic change in the social and environmental performance of key industry sectors through expert analysis of complex systems and effective multi-stakeholder partnerships. Chronos works extensively with global investors and global investor networks to build their understanding of the investment implications of sustainability related issues, developing tools and strategies to enable them to build sustainability into their investment research and engagement. For more information visit www. chronossustainability.com and @ChronosSustain

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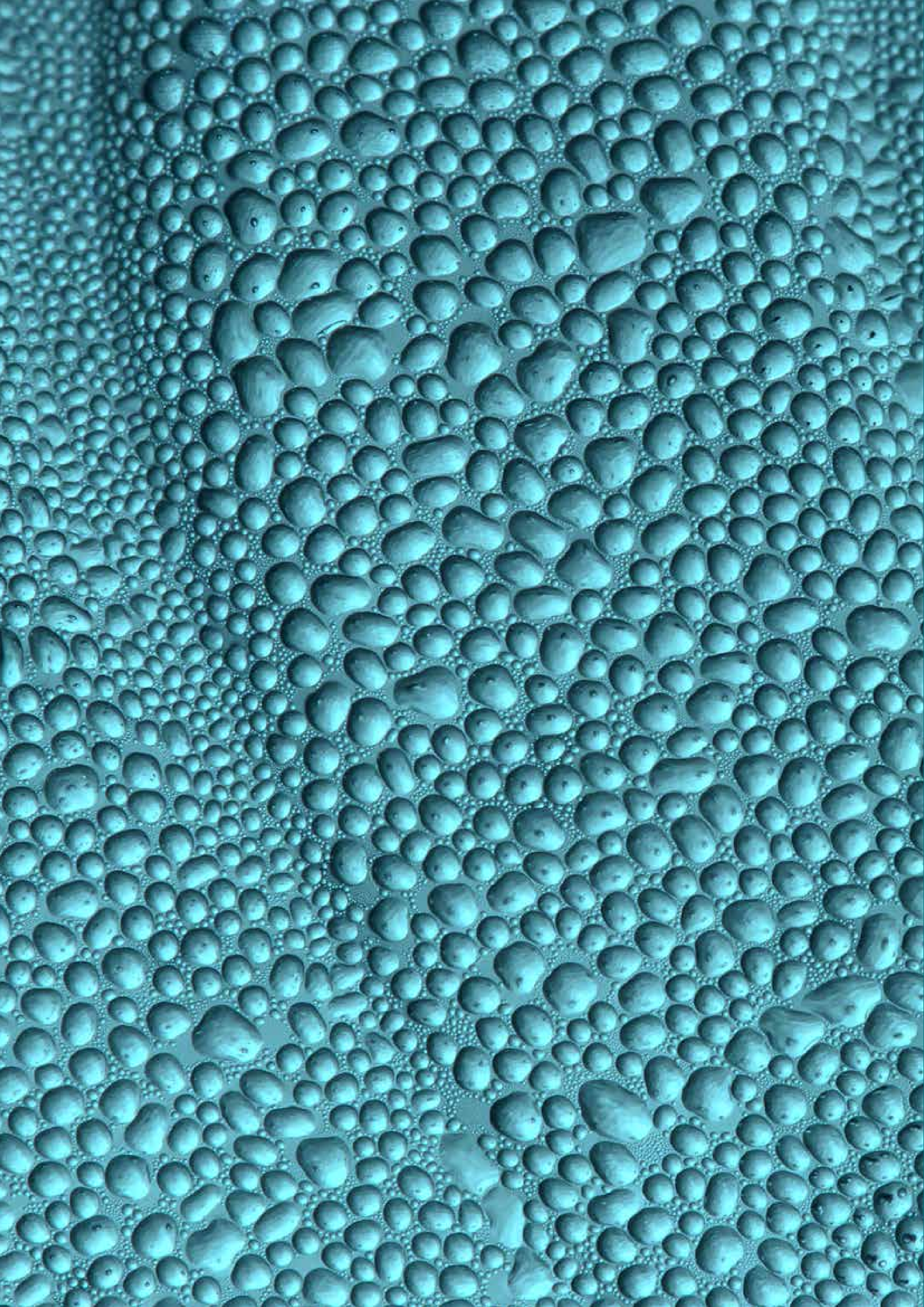


Setting the scene

Plastic has become embedded in nearly every facet of daily life due to its versatility and low cost of production. However, plastic pollution is also a major and growing environmental concern, as plastics are both abundant and ubiquitous in the environment.

The amount of plastic thought to enter the ocean every year exceeds 10 million tonnes, and approximately 1 million tonnes of this is classified as 'primary' microplastics. Primary microplastics refers to plastic pellets, fragments, and fibres that enter the environment less than 5mm in any dimension. The main sources of primary microplastics include vehicle tyres, synthetic textiles, paints, and personal care products. Plastics that enter the environment macro-sized but later degrade into micro-sized particles are referred to as 'secondary' microplastics, and also constitute a substantial portion of microplastic pollution.

Microplastics pose an environmental hazard because their ingestion by marine organisms has been shown to negatively impact these organisms' growth, development, and reproduction. This can, in turn, result in negative outcomes for human health. While there is growing understanding of the causes of microplastic pollution and of the solutions that might be adopted – in particular, the importance of preventing microplastics from entering the environment to begin with – microplastics have not received the same level of attention from policymakers, companies, or investors as have comparable issues such as marine macroplastic pollution and waste management.

This report therefore has four objectives:

1. To raise awareness among policymakers, companies, and investors about the environmental and public health risks associated with microplastic pollution

2. To analyse the major sources of microplastic pollution, the channels by which they enter the environment, and the pathways of microplastics into animal and human diets

3. To identify potential actions to reduce the flow of microplastics into the environment

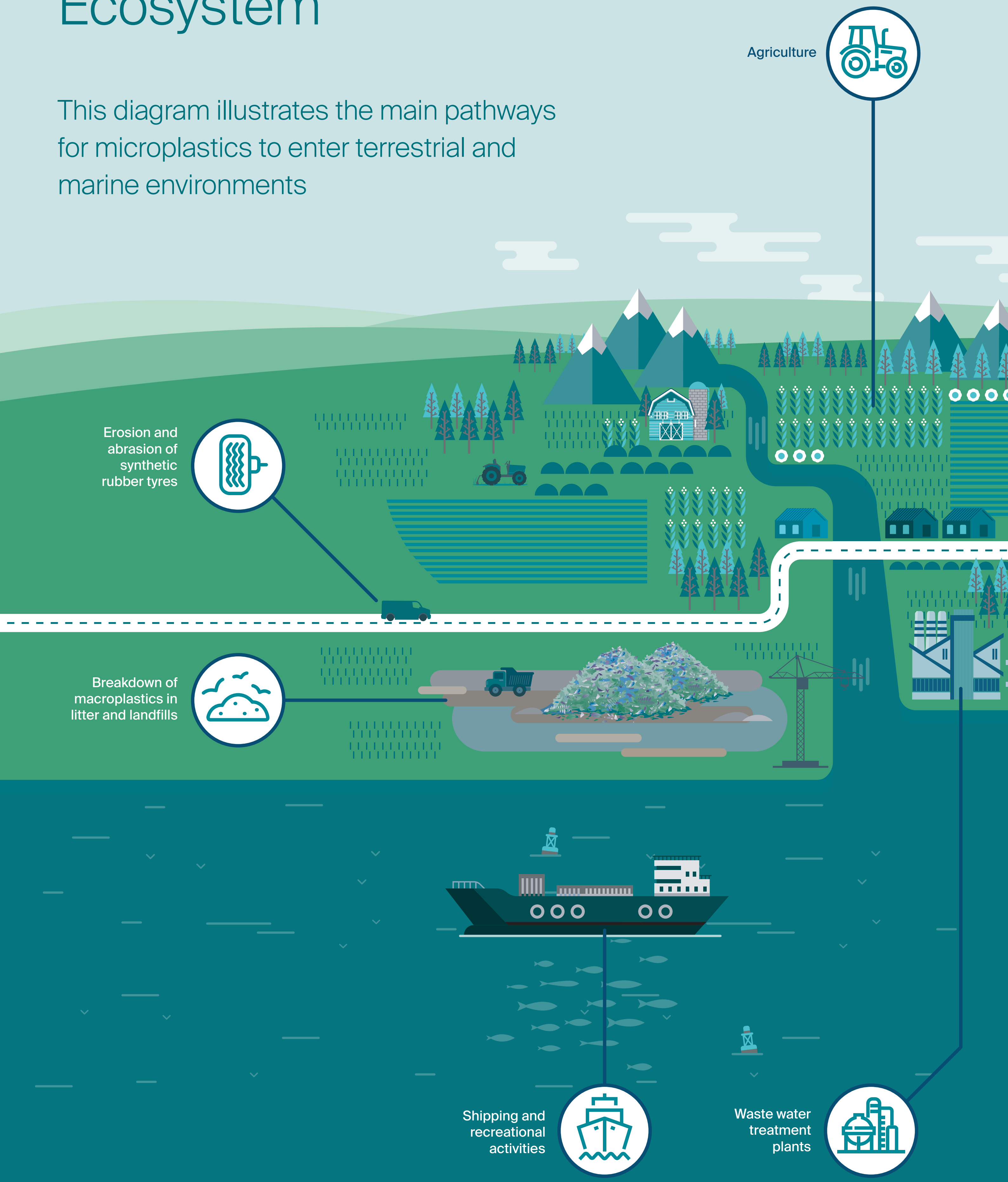
4. To consider the specific contributions that can be made by investors towards mitigating microplastic pollution

The Microplastics Ecosystem

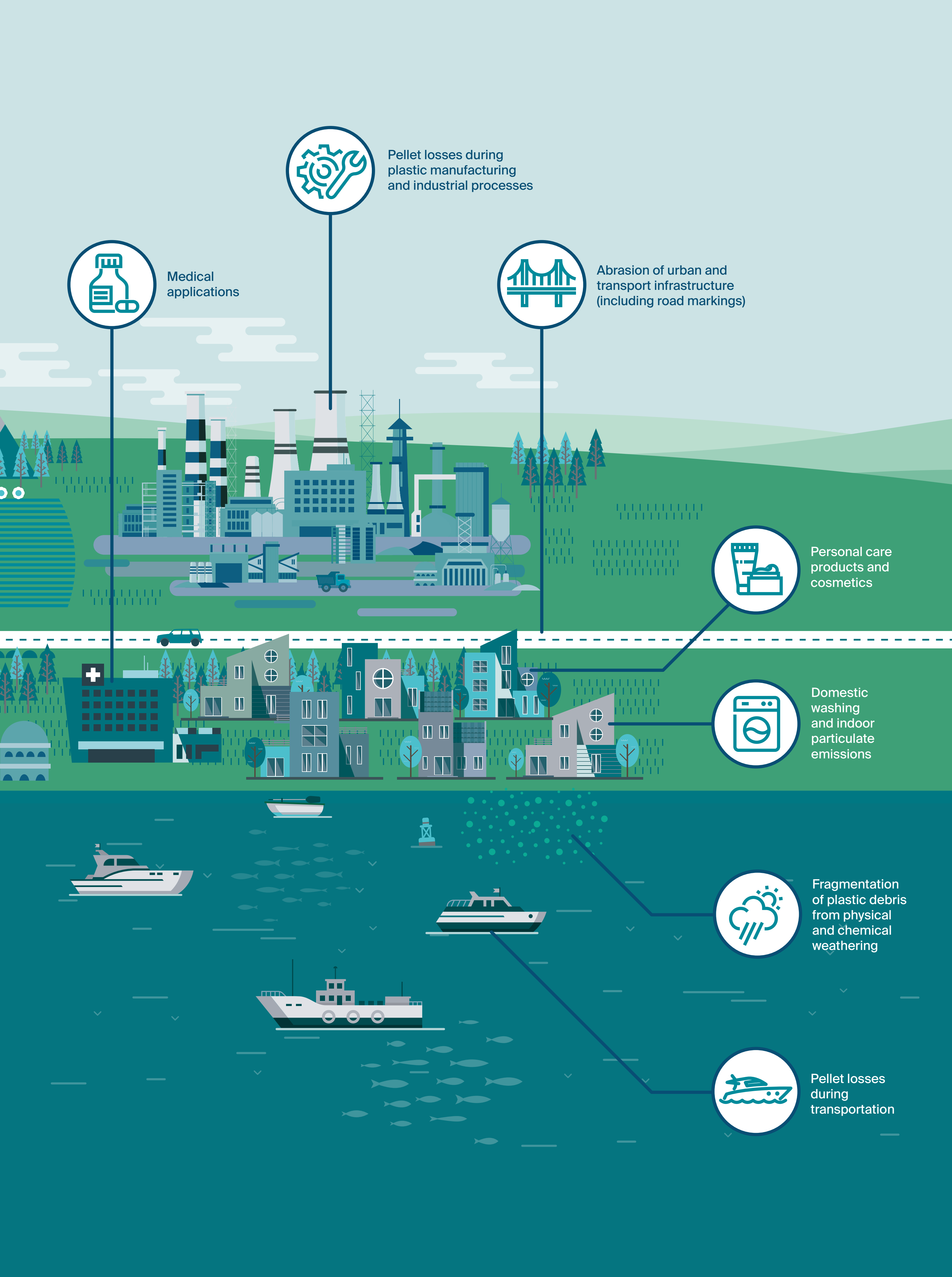
The terrestrial origin of the vast majority of plastic means that terrestrial ecosystems and wastewater infrastructure are major pathways for microplastics into the marine environment.

The Microplastics Ecosystem

This diagram illustrates the main pathways for microplastics to enter terrestrial and marine environments



Source: adapted from Karbalaei et al. (2018) Xu et al. (2020)


Pellet losses during plastic manufacturing and industrial processes
Medical applications
Abrasion of urban and transport infrastructure (including road markings)
Personal care products and cosmetics
Domestic washing and indoor particulate emissions
Fragmentation of plastic debris from physical and chemical weathering
Pellet losses during transportation

Microplastics: The issue

The presence of plastics in the natural environment carries substantial risks for global populations and ecosystems. Without intervention, these risks will grow and intensify.

1. Introduction

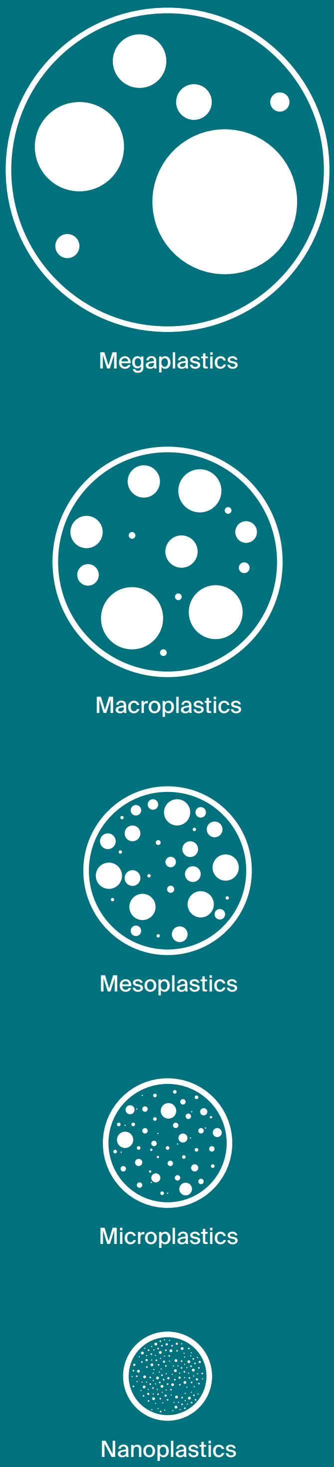
Plastics, or solid, synthetic polymer-based materials, are some of the most versatile products made by man. They are both durable and lightweight, which has led to their integration into nearly every facet of everyday life, from food packaging to toiletries to vehicles.

Plastics therefore constitute the main type of anthropogenic debris entering the marine environment. In 2017, the annual production of plastic products was 348 million tonnes worldwide,[1] and this is expected to increase to 33 billion tonnes by 2050.[2] However, out of the cumulative 8,000 million tonnes of plastic that have been produced since the 1950s, only nine percent has been recycled, 12 percent has been incinerated, and the remaining 79 percent has accumulated in landfills or the environment.[3] Further, approximately 10 million tonnes of plastic are thought to enter the ocean each year,[4] adding to an estimated 150 million tonnes that are there already.[5]

Due to their unique molecular properties, including high molecular weight and long-chain polymer structure, plastics are fairly resistant to biodegradation.[6] Plastics are therefore largely broken down in the environment by abiotic factors including UV radiation, temperature, and abrasion, and as a result may take hundreds of years to decompose. Therefore, their continued presence in the natural environment poses hazards to both humans and ecosystems.[7] Moreover, plastic pollution is expected to increase dramatically without significant intervention due to continued population growth, rising per capita plastic use, and continued shifts to low-value/nonrecyclable materials.[8]

Nested within the larger problem of plastics is the more intractable problem of microplastics. Microplastics are generally accepted to be plastics smaller than 5mm (approximately the length of an average red ant), with the potential for a lower size limit (see Microplastics definitions).[9] The global release of microplastics into the ocean is estimated to be between 0.8 and 2.5 million tonnes per year, which would fill roughly 66,000-200,000 average-sized refuse collection trucks.[10] Microplastics can either enter the environment at the micro-sized scale (primary microplastics) or fragment from larger, 'macro'-sized plastics already in the environment (secondary microplastics). Primary microplastics that are manufactured at the micro-scale are typically used in industrial and domestic products including cosmetics, cleansers/exfoliators, and air-blasting media, as well as pre-production pellets for microplastic generation. Conversely, secondary microplastics are plastic fragments resulting from the mechanical, chemical, or biodegradation of larger plastic debris[11], such as the particles resulting from the breakdown of plastic bags. Notably, IUCN (2017) defines primary microplastics as being plastics released into the environment in the form of small particulates, but not necessarily plastics manufactured to be microplastics. This definition of microplastics includes plastic fragments and fibres resulting from the abrasion of large plastic objects during manufacturing, use or maintenance. This report uses the IUCN definition for primary and secondary microplastics.

The global release of microplastics into the ocean is estimated to be between 0.8 and 2.5 million tonnes per year, which would fill roughly 66,000-200,000 average-sized refuse collection trucks



Microplastic definitions

Plastics in the environment come in at least 5 size classes: >100mm (megaplastics), 20-100mm (macroplastics), 5–20mm (mesoplastics), 1–5mm (microplastics), and <1mm (small microplastics, or nanoplastics)[12], although these classes have not been formally adopted by the international research community.[13]

The European Chemicals Agency (ECHA) proposed the following definition: "...a material consisting of solid polymer-containing particles, to which additives or other substances may have been added, and where ≥ 1% w/w of particles have (i) all dimensions 1nm ≤ x ≤5mm (ii) for fibres, a length of 3nm ≤ x ≤ 15mm and length to diameter ratio of >3...".[14]

Due to difficulties in the consistent identification of particles below 50 μm resulting from limited data on the distribution of particle sizes coupled with sampling inconsistencies between studies,[15] many available definitions articulated in relevant legislation do not include lower size limits.[16] However, IUPAC (International Union of Pure and Applied Chemistry) supports a lower size limit of 100 nm.

2. Microplastics as hazards to environmental and human health

Plastics are generally considered immune to biodegradation, hand are therefore concerning for environmental and human health for three reasons: 1) they act as sources of toxic chemicals, as hazardous additives including those which are non-intentionally added (NIAs) can leach from microplastics, 2) they act as sinks of persistent and bioaccumulative chemicals, as they can adsorb water-borne pollutants from the environment, and 3) their ingestion can cause damage by dint of their micro-sized nature.[17]

First, common additives to plastic products include plasticisers (e.g. bis-phenol A (BPA)) and flame retardants (e.g. polybrominated diphenyl ethers (PBDEs)), which are added to change properties of plastic products including their elasticity, rigidity, UV stability, lifespan, flame retardation/heat resistance, and colour.[18] Additives are generally either weakly chemically bound or not bound to the polymers and are thus able to leach out into an aqueous solution along a concentration gradient, especially when exposed to UV radiation and high temperatures.[19]

Second, the large surface area to volume ratio of microplastics, in combination with their hydrophobic molecular structure, facilitates the adsorption of hydrophobic organic contaminants and persistent organic pollutants (POPs) such as insecticides, pesticides and industrial chemicals, and metals from the surrounding environment.[20]

Third, microplastics can reach such small sizes that they have the potential to interfere with bodily processes,[21] and thus can also cause physical damage upon ingestion.

Microplastics pose an environmental hazard not only in their capacity to serve as a dispersal mechanism for invasive species and pathogens,[22] but also because they are often mistaken by marine and terrestrial organisms as food.[23] Therefore, a wide range of marine organisms have been documented to ingest microplastics, including zooplankton and other invertebrates important for ecosystem function.[24] In addition, some species, including crabs and mussels, can take up microplastics from the environment through their gills.[25] Indeed, over one third of UK-caught fish were found to contain microplastics in their gastrointestinal tracts.[26] There is also evidence that microfibres are retained more easily in organisms compared to spherical microplastics.[27]

The uptake of microplastics by invertebrates and other marine species has been shown to result in lacerations, inflammation, reproductive issues, intestinal blockages, and metabolic changes including endocrine disruption, thereby negatively impacting these organisms' growth, development, and reproduction.[28] Moreover, the uptake of microplastics allows for the transfer of innate and adsorbed toxins into the organism. In particular, plasticisers have been shown to affect reproduction, impair development, and induce genetic aberrations in invertebrates, fish and amphibians. Molluscs, crustaceans and amphibians appear to be especially vulnerable to these effects.[29] Moreover, the ingestion of prey containing microplastics by higher tropic levels (i.e. 'indirect ingestion' or 'secondary poisoning') can lead to the bioaccumulation of toxic chemicals.[30] Less research has been conducted on the effects of microplastics on terrestrial organisms, although it is likely that similar exposure pathways exist on land as soil biota, including earthworms and collembola, have been shown to carry microplastics in their gastrointestinal tracts.[31]

Microplastics pose a potential hazard to human health largely through dietary exposure, resulting predominantly from the ingestion of contaminated shellfish and fish, but also from some canned foods, honey, sugar, table salt, root crops, leaf crops, meat, and beverages including milk, drinking water, and beer.[32] As shellfish are generally eaten whole (whereas the gastrointestinal tract is removed before consumption of most fish), this path typically presents the most significant exposure pathway. Humans are also exposed via inhalation of airborne particles and dermal exposure, and the inhalation of microfibres has been reported to lead to respiratory irritation, inflammation and reduced lung capacity and fibrosis.[33] Moreover, plasticisers have been shown to have reproductive, carcinogenic, and mutagenic effects in humans.[34] There is also evidence that particles may even permeate biological membranes and be translocated to other body tissues. However, there is no definitive evidence that microplastics with environmental origins cause deleterious effects in humans.[35]

Finally, microplastic pollution can have negative economic and societal repercussions. For example, tourists aware of the health concerns regarding microplastic exposure may avoid engaging in water-based recreational activities or may avoid consuming local seafood from coastal regions where microplastic pollution is a problem.[36] The issue of microplastic pollution is a growing concern among consumers; as the BfR Consumer Monitor found, an increasing number of polled consumers in Germany were concerned about microplastics in food: 56% in August 2018, up from 46% six months prior.[37] Moreover, plastic removal efforts by public authorities pose significant costs on municipalities and their taxpayers, and microplastic uptake by seafood in aquacultures may reduce their availability for human consumption.[38]

Microplastics pose a potential hazard to human health largely through dietary exposure, resulting predominantly from the ingestion of contaminated shellfish and fish

3. Sources of primary microplastics

Primary and secondary microplastics come from many different sources, some being more substantial than others.

The International Union for Conservation of Nature (IUCN) (2017) divides the global contribution of different primary sources of microplastics into the marine environment into seven categories: 1) Synthetic textiles, 2) Vehicle tyres, 3) Road markings, 4) Personal care products and cosmetics, 5) Plastic pellets, 6) Marine coatings, and 7) City dust. In addition to these principal sources, microplastics also enter the environment from a variety of other, smaller sources, including agriculture. Due to the fact that microplastics from certain sources tend to enter soil before being washed into the ocean, the sources of microplastics into the terrestrial environment are virtually the same.

3.1 Synthetic Textiles

IUCN (2017) estimates that synthetic textiles contribute over one third (35%) of the annual total primary microplastics entering the global marine environment, thus constituting one of the larger contributors to the microplastics problem. Textiles are often manufactured using both synthetic (e.g. acrylic, polyester, polyamide (nylon), acetate, and PPT) and natural (e.g. cotton, wool, linen) fibres, as well as semi-synthetic fibres that have a natural base but are chemically modified (e.g. rayon).[39] Synthetics are commonly combined with natural fibres to improve the comfort and fit of clothes, and synthetic textiles represent about 60% of the total yearly consumption of fibre for apparel.[40]

Both synthetic and natural fibres shed microfibres during normal wear and tear and whilst being washed. A single garment can produce >1900 fibres per wash,[41] so the total release of microfibres whilst washing an average load of laundry is calculated to be between 3.2 and 17 million fibres (or approximately 0.5-1.3 grams). Multiplying this figure by the total estimated loads of laundry in the EU gives an estimated total production of between 18,430 and 46,175 tonnes of microfibres per year in the EU alone.[42] Some textiles shed more fibres than others, with fleece shedding the most per m^2, and the use of detergent has been shown to increase shedding.[43] Natural microfibres are also shed from textiles, and make up the majority of fibres shed from clothing.[44] These natural microfibres are often coated in chemicals to increase UV resistance, reduce flammability, and provide colour, and therefore may pose similar risks to environmental and human health although their impacts are less well-established.[45] Microplastic pollution from synthetic textiles is expected to increase in future due to increasing consumption of synthetic fibres, particularly in developing economies.[46]

Synthetic textiles contribute 35% of the annual total primary microplastics entering the global marine environment

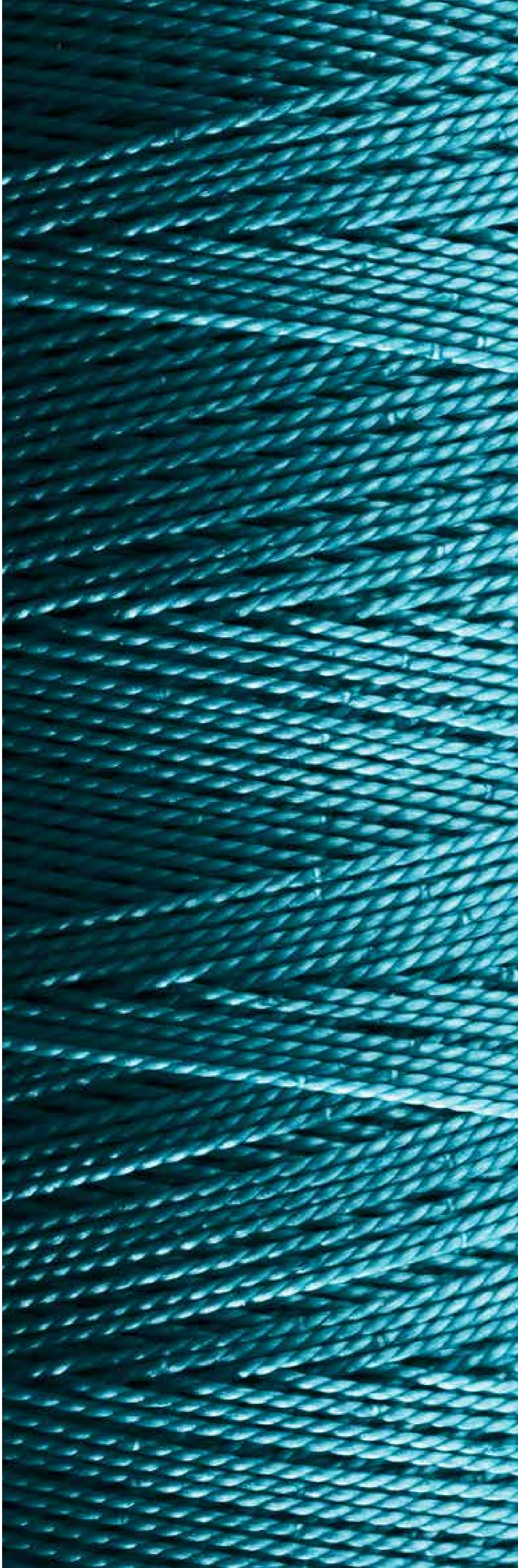
3.2 Vehicle tyres

A second major contributor to microplastic pollution is vehicle tyres. IUCN (2017) estimates that the abrasion of automotive tyres during use contributes the second most substantial portion of primary microplastics at 28% of the annual total primary microplastics entering the global marine environment. However, this figure only includes tyres made from synthetic rubber; if natural rubber is included, then the erosion of tyres would contribute to almost half of the releases of primary microplastics (46.2%). The wear from vehicle tyre treads is an unavoidable consequence of their use and is often understood by consumers as a component of the tyres' 'mileage'.[47] Rates of tyre wear are the result of a combination of factors, including composition, design, vehicle speed/acceleration, use of brakes, and road surface texture.[48] Eunomia and ICF (2018) estimated the total microplastics generated from the wear of automotive tyres in the EU to be 503,586 tonnes per year. Brake pads are also a source of microplastic pollution.[49] The expected increase in the proportion of electric vehicles (EVs) on the road is expected to increase total microplastic emissions from vehicle tyres, in part because current EVs typically weigh 20-30% more than their internal combustion engine (ICE) counterparts due to the weight of the battery.[50]

Vehicle tyre abrasion is responsible for 28% of the annual total primary microplastics entering the global marine environment

3.3 Road markings

Related to tyre abrasion, another significant source of microplastic emissions resulting from travel is the wear of road markings, which are materials placed on road surfaces to convey official information such as lane divisions, spaces in parking lots, and airport runways. IUCN (2017) estimates that the weathering and abrasion of road markings contributes 7% of the annual total primary microplastics entering the global marine environment, and Eunomia and ICF (2018) estimate that road markings in the EU alone generate 94,358 tonnes of microplastic waste annually. Commonly used road marking materials include hot-melt paints, which are composed of ~15-25% polymer binders (containing synthetic resins and plasticizers) and ~75-85% fillers (containing glass beads, aggregates, extenders, and pigments). The polymer binders contribute to microplastic pollution when worn away. While not all road markings are plastic-based, thermoplastic bases are the most commonly used material in road markings in certain places in the EU.[51]



3.4 Personal care products and cosmetics

Microplastics in personal care products make up a relatively small but well-recognised facet of microplastic pollution in the form of microbeads in various rinse-off personal care products such as exfoliants. Indeed, several countries have legislated bans against the manufacture and use of plastic microbeads in personal care products (see Appendix 1 and Appendix 4, Table 2). Despite these regulation, personal care products contribute the most to microbead load in the EU, with an estimated 6g per capita per year being emitted into the environment.[52] However, solid insoluble plastics of different types, typically polyethylene and polyurethane, are also commonly added to leave-on cosmetics for a wide range of other purposes including as viscosity controllers, thickeners, binders for powders, stabilisers, colours, opacifying agents, dispersants, and bulking agents.[53] These leave-on cosmetics represent an annual 540-1,120 tonnes of plastic in the EU.[54] IUCN (2017) estimates that personal care products make up 2% of total primary microplastics entering the global marine environment.

3.5 Plastic pellets

Plastic resin pellets (also known as ‘nibs’ or ‘nurdles’) are used as a feedstock for the manufacture of most plastic products.[55] They are typically spherical or cylindrical with a diameter of 5mm, and can be made out of a variety of polymers.[56] These pellets contribute to microplastic pollution through accidental losses occurring throughout the value chain, including during transport to the converters where they are processed, and during the plastic manufacturing process itself.[57] While pellets may enter the environment as relatively large compared to other microplastics, they grow increasingly small as they are worn down. While pre-production pellet loss has been estimated in specific regions, given the uncertainty in the rate of pellet loss during handling globally, it is difficult to precisely estimate the total amount of pre-production plastics entering the marine environment.[58] However, IUCN (2017) estimates that plastic pellet losses constitute <1% of total microplastic pollution.

3.6 Marine coatings

Many types of marine coatings applied to the hulls of commercial and recreational crafts include polyurethane, epoxy coatings, vinyl and/or lacquers, as well as other compounds such as metals. These coatings have a variety of purposes, including protection from UV radiation, corrosion, and biofouling.[59] When these coatings are weathered, scraped, sanded, disposed of, or spilled during application, they can contribute to microplastic load in the environment. Marine coatings are estimated to contribute 3.7% of total primary microplastics entering marine environments, generating between 1,993 and 4,525 tonnes of microplastic waste per year in the EU alone.[60]

3.7 Agricultural uses for primary microplastics

Polymer-based products potentially containing microplastics are directly applied to agricultural land in various forms, including mulches for temperature and moisture control, silage and fumigation films, and anti-bird and weed protection.[61] The main application of polymers in agriculture is in nutrient prills, which are polymer-coated nutrient mixtures that allow for the diffusion of nutrients into the surrounding soil over the course of several months, increasing yields while reducing the need for constant fertiliser application.[62] It is estimated that in the EU alone, up to 8,000 tonnes of polymers are used in fertiliser prills.[63] However, it is not known what percent of these polymers constitute microplastics.

3.8 City dust

'City dust' is a term that applies broadly to a wide range of microplastic sources originating from urban areas. It includes, for example, artificial turf, building paint (internal and external), abrasion of objects (e.g. footwear) and infrastructure, industrial blasting of abrasives, and scrubbers in detergents, and is estimated to contribute 24% of total primary microplastics entering the marine environment.[64] Discussed below are three of the larger and more well-understood contributors to city dust: artificial turf, building paints, and industrial abrasives.

Artificial turf is largely used in contact sports as a means to absorb impact and thus prevent athlete injury. The shock-absorbing impact of the turf is generally achieved through the use of polymeric infill, which is comprised of plastic particles <5mm typically manufactured at least partially from recycled vehicle tyres.[65] This infill is located just beneath the artificial grass and on top of a stabilising infill such as sand. While the artificial grass fibres are eventually worn down into microfibres, the majority of microplastics from artificial turf come from the polymeric infill, which can be accidentally removed by athletes or during maintenance.[66]

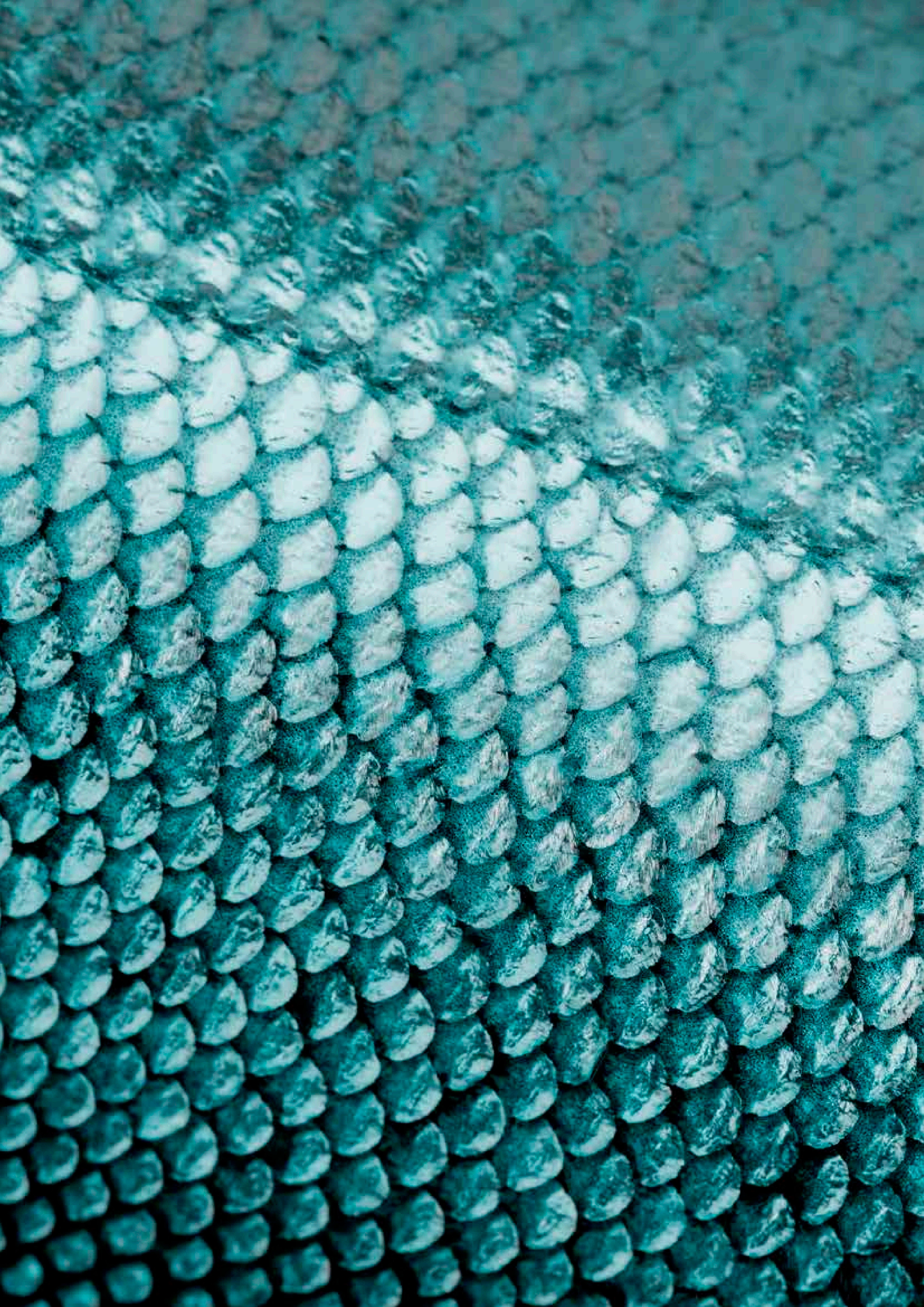
Eunomia and ICF (2018) estimate that between 18,000 and 72,000 tonnes of infill are lost per year in the EU. Artificial turf is also used for residential purposes, but this turf does not typically contain the polymeric infill. Although artificial turf in sports stadiums contributes a relatively small portion of overall microplastic pollution, it constitutes a point source of pollution which can be addressed.[67]

Interior and exterior building paints often contain microplastics in the form of microspheres or microfibres, which thicken paint and increase elasticity and resilience.[68] When dried paint is removed, when paint cracks or degrades, or when paintbrushes and rollers are washed (for water-based paints), these paints can release microplastics into the environment. Eunomia and ICF (2018) estimate that building paints generate between 21,100 and 34,900 metric tonnes of microplastics in the EU per year.

Plastic pellets are also used as an abrasive material in industrial processes and are therefore common in blasting media and scrubbers for machinery and other metallic surfaces, particularly when there is a need to gently clean surfaces.[69] For example, sandblasting is used in Denmark to sanitise and remove graffiti from buildings, remove paint from and clean airplanes, and clean moulds, tanks, and turbine blades.[70]

3.9 Other sources of primary microplastics

The sources of microplastics into the environment discussed above constitute the majority of well-understood sources of environmental microplastics, but primary microplastics have hundreds of other applications across many sectors. In the residential context, as noted above, dish detergents can contain microplastics such as polyurethane particles that are used to clean surfaces and are subsequently disposed of in wastewater.[71] For example, plastic bio-beads used as filter media in wastewater treatment plants (WWTPs) can be unintentionally released due to accidents and leaks at plants.[72] Due to a lack of data on the topic, it is unknown to what extent bio-beads are used globally, or the extent to which they contribute to the microplastic pollution problem.[73] There are also reported to be a variety of uses for microplastics in the healthcare and pharmaceutical sectors, including as vectors for drugs and dentist polish.[74] In addition, microplastics are commonly employed in the oil and gas sector as additives to drilling fluids, although it has proved difficult to estimate precisely the tonnage of microplastics used for this purpose.[75] Some other common uses for microplastics include: packaging, textile printing and automotive moulding, biomedical research insulation, furniture, pillows, buoys, 3D printing, ceramics, and adhesives.[76]



4. Sources of secondary microplastics

Unlike primary microplastics, secondary microplastics are defined as being microplastics that enter the environment macro-sized (i.e. >5mm) and then break down into microplastics whilst in the environment. Therefore, sources of secondary microplastics include macro-sized terrestrial and marine-based refuse (e.g. fishing gear and shipping waste and losses). While it is almost impossible to estimate the rate of secondary microplastics entering the environment, many estimates of macro-sized plastic waste have been generated. For example, The Pew Charitable Trust and SYSTEMIQ estimate that the total microplastic waste generation in 2016 was 215 million tonnes, and Eunomia and ICF estimate the total amount of microplastics entering the ocean from fishing nets to be between 478 and 4780 metric tonnes/year. While only a fraction of total plastic debris ends up in the ocean, as the majority of plastic pollution may be in terrestrial environments, the sources and fate of terrestrial microplastics are relatively unknown.

5. Channels for microplastics into the environment

Since the vast majority of plastic has a terrestrial origin, terrestrial ecosystems and wastewater infrastructure are major pathways of microplastics into the marine environment. The main channels by which primary microplastics enter the environment are: 1) through wastewater treatment plants (WWTPs), which account for 25% of the input globally, 2) via road runoff, which accounts for 66%, 3) via wind transfer, which accounts for 7%, and 4) via marine activities, which account for 2%.

Microplastics from domestic and industrial use can often be washed down industrial and/or domestic drainage systems into wastewater treatment streams.[77] In addition, roadside runoff devices[78] and road cleaning can result in debris such as tyre and road marking emissions ending up in residual waste treatment.[79]

WWTPs can be built to have primary, secondary, and tertiary treatment processes. Primary treatment refers to the first treatment stage, where heavy solids sink to the bottom and are removed, and buoyant compounds (e.g. oils, some plastics) rise to the top and are removed. Secondary treatment refers to biological processes whereby dissolved and suspended organic compounds are removed in the form of sludge. Tertiary treatment has no specific definition, but generally refers to the removal of chemicals before effluent is discharged into the environment.[80] While relatively dense microplastics are largely retained in sewage sludge during the primary and secondary treatment steps at WWTPs, and larger floating particles are removed during the tertiary filtration stage, small buoyant particles can be released in effluent.[81]

Although WWTPs are designed to filter and decontaminate wastewater, most mainstream water treatment facilities are not specifically designed to filter out microplastics. Therefore, WWTPs invariably allow a fraction of microplastics to pass through their filtration systems and into the environment. The majority of studies examining microplastic retention rates of WWTPs with tertiary treatment processes have been found to have a retention rate of >90%, with a range of 17% to >99.7%. Retention rates vary depending in part on 1) the type of treatment at the WWTP in question, 2) the amount of microplastics in the influent, and 3) the time of year.[82]

However, even with a microplastic retention of >90%, the sheer volume of wastewater being processed (and therefore the high number of microplastics in influent, or the untreated wastewater flowing into a WWTP) result in a significant number of microplastics bypassing filtration systems and being released into the environment with effluent.[83]

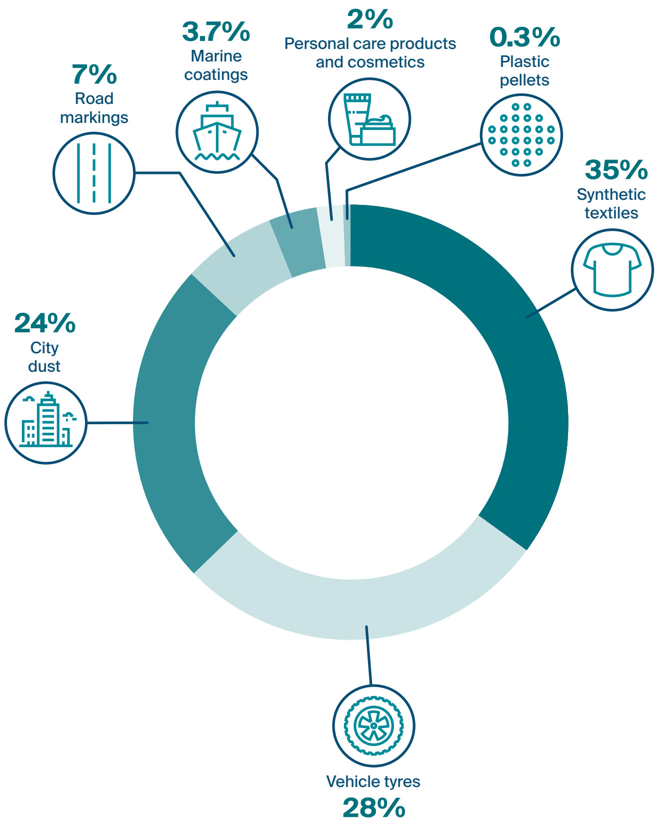
Since less than one third of the human population is connected to wastewater management infrastructure, wastewater is not always treated before it reaches the environment.[84] Moreover, wastewater connected to a combined sewer overflow (CSO) is also not always treated before it is discharged. CSOs are sewer collection systems that collect surface runoff and industrial and domestic sewage and wastewater, and they transport the entering wastewater to WWTPs. However, during periods of heavy precipitation, CSOs are designed to discharge overflow directly into the environment.[85] Therefore, CSOs can occasionally discharge a variety of pollutants of concern, including microplastics, into the environment. There are at least 746 CSOs in the United States alone, which release approximately 850 billion gallons of untreated wastewater into the environment every year.[86]

Even when wastewater is properly treated, the sludge containing the majority of the microplastic particles is generally either disposed of in landfill, incinerated, or added to cement.[87] It is also common practice in many North American and European countries to apply this sludge as agricultural fertiliser.[88] On average, about 50% of sewage sludge is processed for agricultural use in European and North American countries, representing between 125-850 tonnes of microplastics per million inhabitants added directly to agricultural soils.[89]

Oftentimes, terrestrial microplastics are not washed into wastewater management infrastructure, but are instead swept into the environment via unmanaged road runoff. When runoff is not captured by storm water management infrastructure, microplastics from automotive tyre wear, road markings, and building paint can be washed into natural waterways and soils or captured in asphalt or via road cleaning. In Europe, particles (including microplastics) suspended in road runoff are often captured through various means with varying rates of capture efficacy (e.g. gully pots).[92] However, particles suspended in road runoff are often not intercepted before they enter the environment.[93] Road run-off therefore presents a uniquely intractable problem as the emission sources of the microplastics are relatively diffuse.

On average, 50% of sewage sludge is processed for agricultural use in European and North American countries, representing between 125 and 850 tonnes of microplastics per million inhabitants added directly to agricultural soils

Certain microplastics (for example, city dust) can also be transported via wind. In urban areas, the deposition of plastic fibres has been recorded to reach 355 particles/m^2/day.[90] The possibility of airborne transfer highlights the potential for microplastics not only to travel long distances, but also to contaminate the air we breathe and the foods and beverages we consume. Finally, marine activities such as shipping, fishing, and tourism, are responsible for directly sweeping microplastics into the marine environment.[91]



Source: adapted from IUCN (2017)

6. Possible solutions and opportunities for action

The scope of the microplastics pollution issue and the potential and real damage it can cause warrants action by those who have the power to change the situation

This is especially pertinent as many of the sources of microplastics, especially vehicle tyres and pre-production plastics, are expected to increase over the next 15 years.[94] Thus, this section outlines actions than can be taken to minimise microplastics release into the environment. Due to their size and ubiquity, there are currently no cost-efficient mechanisms to collect microplastics from the environment at scale once they have been introduced to it. Therefore, the most efficient way to mitigate microplastic pollution is to prevent microplastics from entering the environment in the first place and by targeting actions to reduce emissions at the source. Given the multitude of microplastic sources, there are correspondingly many approaches for mitigating microplastic pollution. Several of the more well-developed approaches are discussed in detail below in sections 6.1-6.8, with a more complete list of solutions provided in section 6.9.

6.1. Prevent microfibre shedding in textiles

Given that plastic microfibres shed from synthetic textiles during washing and use contribute approximately one third of primary microplastic emissions into the ocean, mitigating this source of microplastic is key to reducing the overall load on the environment. For example, there are more than 840 million residential washing machines currently in use around the globe, and at least 700,000 fibres can be released in every wash.[95] As a result, over nine trillion microbfibres could be released in a single week in the UK alone.[96]

Options for reducing microfibre shedding at the source generally include encouraging textiles producers to manufacture products that shed fewer fibres and/or contain less plastic, and encouraging consumers to buy products that shed fewer fibres.[97] However, there is currently a lack of awareness among clothing manufacturers, retailers, and consumers about the issue of shedding from textiles, and there is also a lack of financial, regulatory, or reputational incentives for clothing manufacturers and retailers to manufacture products that shed fewer fibres.[98] Accordingly, there are at least two possible approaches by which to address microfibre shedding of textiles at the source: 1) setting a maximum allowable fibre release standard for textiles, and 2) facilitating consumer awareness by requiring textile products to have a label of fibre release.

Acting on microplastics will support the delivery of Sustainable Development Goal (SDG) 14: Life Below Water, in particular Target 14.1: “By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution.”

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SUSTAINABLE DEVELOPMENT GOALS

There are more than 840 million residential washing machines currently in use around the globe, and at least 700,000 fibres can be released in every wash

Starting with (1), setting a maximum allowable fibre release standard for textiles would require first developing an industry-wide textile testing standard to determine the rate of fibre release from different textiles under different conditions in a consistent and reproducible way.[99] Indeed, research efforts are already underway towards developing standard methods for the quantification of microfibre release.[100] Setting this testing standard would be the baseline measure for each material on which any policies and regulations are built. Once the testing standard has been established and a release standard[101] or voluntary industry association agreement has been implemented, manufacturers could then implement a self-certification process for fibre release. Textile manufacturers and retailers would then be allowed to only place products on the market that meet at least the minimum criteria, theoretically removing the textiles from the market that emit the highest number of fibres per cm^2. As a result, this approach has the potential to effectively prohibit certain types of textiles from manufacture and sale, especially those made from natural fibres, which could in turn negatively impact manufacturers who produce mainly textiles with high shedding rates. An additional concern linked to this approach is that manufacturers could, in order to comply with an established standard on microfibre release, coat fibres with a chemical substance to reduce shedding. Care would therefore be needed to ensure that the introduction of such requirements did not create other environmental problems.

Some legislative bodies have already taken action along this route. For example, the state of California's Assembly Bill (AB) No. 129 would have required the California State Water Resources Control Board to develop a methodology for evaluating domestic microfibre filtration systems and to conduct testing to quantify the amount of shedding that occurs from different types of clothing during laundering. If passed, the Bill would then have required best practices to be adopted by clothing manufacturers to reduce the number of microfibres released into the environment. However, AB-129 died in the California State Assembly in January 2020. Although this Bill would only affect clothing manufacturers based in the state of California, due to the nature of the global textile and clothing market, regulations in individual states and countries are likely to have implications beyond their immediate jurisdictions. This is because textile manufacturers generally tend to manufacture products that can be sold in every region where they participate in the marketplace.[102]

Moving on to (2), the development of labels indicating fibre release rates for all textile products on the market would be based on the same testing standard as (1). Under this approach, manufacturers would be required to attach labels to their products that state the product's level of fibre release during its lifecycle, preferably on a standardised rating scale. This approach would facilitate consumer awareness about microfibre shedding from textiles and could reduce the total volume of high-shedding textiles sold. Even despite the lack of standard testing measures, some areas have already started to require clothing labels on fibre release. For example, the New York State Assembly has introduced Bill A1549, which would require all local manufacturers of clothing to state on the label that "This garment sheds plastic microfibres when washed." However, while clothing labels may very well increase consumer awareness of the issue, they may not meaningfully affect consumer purchasing decisions.[103]

Another way to reduce total microfibres entering the environment is through textile recycling. Much research has been done on the possibilities around mechanical and chemical polymer recycling, and there are several existing and emerging technologies that would facilitate the recycling of old synthetic textiles and upcycling plastics into textiles.[104] For example, C-TECH and Wear2 collaborated to make technology that would enable the recycling of leftover textiles into new fabrics simply by exposing products made with a specialised yarn to microwave radiation.[105] However, it is generally not economic to scale these technologies up yet for synthetic materials.[106] In addition, low quality synthetic garments are generally not suitable for recycling, and there is a lack of incentive for R&D in this area.[107]

6.2 Interception of microplastics using laundry filters

While measures to reduce microfibre shedding from textiles have the potential to reduce the number of microplastics entering the environment, they are unlikely to completely eliminate them, at least in the near term. Therefore, another way to address microplastic pollution from textile shedding is to install filters to collect loose microfibres shed while washing clothing and other fabrics. Several types of laundry filter devices have been developed, including those that are built into the washing machine, those that can be retrofitted into older machines, and devices that are placed in the drum of the machine during the laundry cycle (Appendix 4, Table 1).

Although this approach has the potential to address 35% of the primary microplastic problem, it has several limitations. In addition to concerns over the added cost for consumers in implementing these devices, there is a lack of consumer awareness around the issue and the options that exist to address it, and there are concerns that even after capturing the fibres, consumers would not dispose of them properly or maintain proper upkeep of the filters. The installation of microfibre filters may also reduce a machine's water use efficiency, and the devices currently on the market range widely in terms of effectiveness.[108] Another limitation is a lack of incentive among washing machine manufacturers to develop integrated mechanisms to capture microfibres.

However, this lack of incentive can be addressed in part through regulation. For example, France recently passed legislation that requires all new domestic and commercial washing machines to be fitted with microfibre filters by January 2025, and California AB No. 129 would have required all industrial and commercial laundry systems to install filtration systems to capture microfibres.

6.3. Regulate vehicle tyre abrasion rates

Since the abrasion of vehicle tyre treads contributes at least 28% of the microplastic load on the environment,[109] ensuring that the tyres on the market meet a minimum standard of abrasion can have a large impact. For example, Eunomia and ICF (2018) found that 100% efficacy in source prevention for tyre wear abrasion could result in a cumulative microplastics emissions reduction of 500,000 tonnes annually in the EU alone. There is currently no regulation on vehicle tyre emission rates of microplastics, and consumers are generally unaware of the issue of vehicle tyres and microplastic emissions. However, regulation to enforce labels on tyres indicating abrasion rates, coupled with a minimum standard on abrasion rates, could remove the worst performing tyres from the market relatively quickly and cost-effectively. The first step towards implementing this legislation would be to develop a standard measure of tyre abrasion, after which the inclusion of abrasion rates on labels can be mandated. Once products in the market are differentiated, there is an opportunity for regulators to ban the tyres with abrasion rates above a certain threshold. In addition, it is possible that consumers would choose tyres with lower abrasion rates given that the lifespan of vehicle tyres is an important criterion in consumers' decision-making process for purchasing tyres.[110]

Of course, tyre abrasion rates are the result of more than simply the physical tyres themselves; they are also the product of a variety of factors, including road surface texture and tyre inflation. While many of these factors cannot be easily controlled, tyre pressure monitoring has been regulated in a number of countries through the legal requirement of Tyre Pressure Monitoring Systems (TPMS) installation in vehicles.[111] In addition, measures could be taken to design road pavement to reduce tyre abrasion.[112]

6.4. Regulate the microplastic contents of personal care products and cosmetics

Another way to prevent microplastic pollution at the source is to introduce regulations regarding the manufacture and sale of primary microplastics in personal care products (PCPs), cosmetics, and detergents.[113] For example, several countries have already implemented national bans on the manufacture and/or sale of PCPs containing microbeads (Appendix 4, Table 2). These bans have been effective in reducing the number of microbeads contained in the effluent of these countries, but their influence ends there, as the vast majority of countries have not instituted analogous bans. In addition, given that microplastics from PCPs only constitute 2% of global primary microplastic emissions (IUCN 2017), any regulation addressing specifically this source of microplastics is necessarily limited in scope.

Once microbeads have been banned, a number of low environmental impact alternatives exist to replace them as exfoliants in PCPs and detergents. These alternatives include: jojoba beads, beeswax, rice bran wax, corn, tapioca and carnauba derivatives, seaweed, silica, clay, and walnut powder.[114] In particular, silica is often used due to its inert, non-toxic nature and its longer lifespan than some of its organic counterparts. However, there do not appear to be widely accepted, naturally occurring alternatives for the polymers in PCPs and cosmetics performing functions beyond exfoliation.[115]

Therefore, banning the use of all plastic polymers in all cosmetics and PCPs is very likely to have negative repercussions not only on the quality of products available in the market and therefore the market value of these products, but also on industry performance due to the capital costs associated with the replacement of plastic microbeads.[116]

In addition to government-mandated bans on microplastics in cosmetics and PCPs, industry has also started to take voluntary action (See appendix 3). For example, Cosmetics Europe (the European trade association for the cosmetics and personal care industry) recommended to its members that they discontinue the use of microbeads as exfoliants in personal care products by 2020.[117] By 2017, a Cosmetics Europe survey found a 97.6% decrease (relative to a 2012 baseline) in the use of plastic microbeads used as exfoliants in rinse-off products in Europe.[118] While voluntary agreements do not guarantee action, they can form the basis of future legally binding regulations.

Civil society has also promoted consumer awareness and accountability regarding the issue of microplastics in PCPs. For example, the “Beat the Microbead” (BTMB) campaign from the Netherlands allows consumers to check for the presence in microbeads in the products they purchase by scanning the bar code using an app. This campaign has gained support from 42 countries and is being developed for use around the globe. The BTMB campaign has also worked with corporates, including Unilever, L’Oréal, Colgate-Palmolive, Procter & Gamble, and Johnson & Johnson to phase out microbeads from their products.[119]

100% efficacy in source prevention for tyre wear abrasion could result in a cumulative microplastics emissions reduction of 500,000 tonnes annually in the EU alone

6.5 Reduce number of pre-production pellets lost during industrial practices

While any pellet loss represents a financial loss for industry, as well as a possible health and safety risk for workers, the cost of collecting and decontaminating the pellets once lost typically exceeds the cost of the pellets themselves.[120] Moreover, there are currently no legal requirements for industry to adopt best practices regarding the reduction of pellet loss. In addition, the public is generally unaware of the issue of pellet loss. Therefore, there are currently insufficient financial, regulatory, or reputational incentives for actors in the plastic pre-production logistics chain to reduce pellet loss.[121]

One of the most effective means by which to reduce losses of pre-production pellets is thought to be the adoption of best practices across the plastic supply chain and lifecycle. This approach would entail regulatory measures to require that best practices and corresponding best available technology (BAT) to prevent pellet spills and ensure efficient recapture of spilt pellets be adopted vertically throughout the plastic production supply chain. Standard tools designed to allow companies to demonstrate the adoption of best practice in pellet loss prevention measures are already under development, including in the UK.[122] In effect, such a regulation would mandate (at least initially) that plastic product retailers (both B2B and B2C) ensure that their supply chain follows best practices regarding pellet loss. Adherence to best practices across the supply chain could be demonstrated through an accreditation and audit process, similar to that in the timber industry.[123]

While industrial pellet losses can also be addressed with the introduction of a fee associated with pellet spills, which would reduce the financial incentive to allow pellet spills to go unaddressed, this option would be subject to constraints around enforcement. On the other hand, requiring plastic manufacturers to engage only with suppliers who had adopted best practices would result in a scheme that is effectively self-enforcing.

Regulation can also focus on specific portions of the supply chain. For example, regulation focused on the adoption of best practices by transport companies can be implemented to address spills occurring specifically during the transport to and from facilities. In addition, regulation could focus on polymer manufacturers or plastic converters to ensure that they implement BAT and best practices regarding pellet loss. One drawback of this approach is that every country would need to implement its own set of regulations and ensure compliance with the regulations of countries they are economically tied to. Therefore, the most efficient way to ensure the adoption of best practices across the supply chain is through an accreditation process that applies to the entire chain.

Best practice measures for mimimising pre-production microplastic loss have already been developed and include Operation Clean Sweep (OCS), an initiative by the American Chemistry Council (ACC) and Plastics Industry Association (PLASTICS). The OCS programme has been voluntarily adopted by companies in over 22 countries, with a particularly high adoption rate in the EU, although it is unclear how effective this programme has been in reducing pellet spills to date.[124] Moreover, given the tiny proportion that these pellets make up of total microplastic pollution (<1% of total primary microplastic entering the environment), any measures to address this will have only a small impact.[125]

6.6 Improving microplastic retention at wastewater treatment plants

Addressing microplastic pollution at wastewater treatment plants (WWTPs) has the potential to capture microplastics emitted into wastewater including personal care products, detergents, microfibres shed from clothes, water-based paints, and more. Introducing secondary and tertiary treatment steps at WWTPs can significantly reduce the number of microplastic particles in WWTP effluent.[126] In addition, given that two in three people in low and middle-income countries do not have access to a sewage connection, one approach could be to install a WWTP in locations where untreated sewage is directly dumped into the environment.[127] However, given the sizeable capital expenditure associated with installing WWTPs,[128] this may not be a feasible option in many areas.

One option for funding WWTP upgrades or installations is to implement extended producer responsibility (EPR) schemes that require those responsible for the sources of microplastics to cover the costs of remedial action. Any EPR policy would need to be based on data characterising the composition of microplastics in the WWTP influent and effluent so that relevant sources of microplastics for each WWTP can be identified. It may be impossible to identify the sources for all cases, but many types of microplastics are distinctive, including pellets, fibres from clothing, particles from tyres, and paint. Implementing EPR policies could be done by administering a fee for the quantity of every product entering the WWTP, thus resulting in unique requirements from the industries in each jurisdiction. The revenue raised from the fees would fund the most appropriate form of mitigation at the WWTP.[129]

A limitation of this approach is that the cost-effectiveness of infrastructure improvements to WWTPs diminishes as more measures are taken to reduce the key sources of microplastics into wastewater. Moreover, if microplastic-containing sludge continues to be applied to agricultural soils, then the prevention of microplastics entering the sludge is essential for mitigating this channel to the environment as there is currently no known method of removing microplastics from sludge.[130] In addition, efforts targeted at WWTPs will not address microplastics that are not washed into wastewater, nor will they address microplastics suspended in wastewater that is not treated at WWTPs, such as some of the wastewater from Combined Sewer Overflows (see section 5). The polluting potential of CSOs can be mitigated by advances in remote sensing and real-time decision support systems which minimise overflows using existing technology.[131]

6.7 Other measures to prevent primary microplastic pollution

The majority of remaining options for mitigating microplastic pollution constitute substituting the microplastic components of products with non-plastic alternatives with low environmental impact. For example, there is potential for the microspheres and microfibres in building paint to be replaced with either glass beads or cellulose-based microspheres; or for the microplastics used in industrial abrasives to be replaced with coconut shell, dry ice, silicon, or glass beads;[132] or for the plastic-coated nutrient prills used in agriculture to be substituted with nitrification inhibiters.[133] The use of any such replacement would be subject to the cost of R&D associated with reformulating products, as well as with any capital expenditures necessary for the substitution and loss in market for industry. In addition, the first step to generating incentives for industry to use non-plastic alternatives is to collect more data on the relative rates of microplastic emissions from different sources. This data would form the backbone of campaigns to increase consumer awareness of the issue, regulators' efforts to set standards for industry, and any voluntary action taken by industry to reduce microplastic content in products or to minimise microplastic loss from products.

Aside from finding non-plastic substitutes for existing products, primary microplastic pollution can also be reduced by prohibiting the application of sludge from WWTPs to agricultural soils. For example, Switzerland banned the use of biosolids (stabilised residues of sewage sludge) on agricultural soils in 2003.[134] One drawback of this strategy is that biosolids typically present a relatively inexpensive way to recycle nutrients back into agricultural soils. However, without a reliable means by which to remove the microplastics and other toxins known to commonly exist in sludge, this process will continue to contaminate agricultural soils with microplastics.

Finally, measures can be taken that would not reduce the environmental impact of microplastic pollution but could potentially benefit human health. An example could be installing special filters on drinking water taps.[135] However, a limitation of this approach is that both the additives innate in the plastics and the POPs adsorbed to them will have likely already partially leached out into the water by the time it reaches the tap. Moreover, given the grave environmental implications of microplastic pollution, the implications of this issue for humans likely extend beyond the dietary exposure to microplastics.

6.8 Measures to reduce secondary microplastic pollution

Since secondary microplastics enter the environment as macro-sized plastics, measures to reduce secondary microplastics in the environment necessarily include measures to reduce the total volume of macro-sized plastic entering the environment. Many efforts have already been undertaken with this goal in mind, including bans or taxes on the use of disposable plastic products and conventions on the disposal of fishing gear and related marine-based plastics at sea (Appendix 4, Table 2). One limitation of this approach is that these types of regulations and policies generally have limited scope for impact as they apply only to specific jurisdictions.

Other approaches for mitigating microplastic pollution include collecting plastic that has already entered the environment. Water-based approaches for collecting plastic litter have been recently inventoried by Schmaltz et al. (2020), and include large scale booms,[136] drones,[137] air barriers,[138] and waterway litter traps.[139] Research is also being done on the possibility of introducing plastic-consuming bacteria into the environment, although this is not yet a scalable option.[140] Beach clean-ups are likely to be the most effective in terms of plastic collection due to the relatively high density of plastic in coastal areas.

Finally, much research has been done into the use of 'biodegradable' plastic products as potential substitutes for much of the plastic we consume in our daily lives. For example, plant- and fossil-fuel based biodegradable polymers have been developed, and which have recently become available on an industrial scale.[141] However, these biodegradable plastics may also be a source of microplastic in the environment as they usually only partially decompose under natural conditions, especially in marine environments.[142] There is currently a lack of regulation around the minimum threshold for degradation under environmental conditions. While some private certification labels exist for biodegradable plastic products,[143] these certification processes may not be widely accessible due to their price. Moreover, when recycled, mixing plastic types can introduce issues for recycling processes by decreasing material integrity.[144] Therefore, the most efficient means by which to reduce secondary microplastic pollution is to simply reduce the amount of plastic entering the environment in the first place.

6.9 Summary

Many of the potential solutions for addressing the microplastic pollution problem currently lack sufficient regulatory, financial, and reputational incentive for widespread adoption by industry. Therefore, the first step for most measures is to develop standards for measuring the relative contribution of microplastics from each source, followed by defining minimum product criteria suitable for the market. Of the solutions proposed above, those with the largest potential scope for reducing primary microplastics entering the environment at the least cost are expected to be those that address the largest sources of microplastic emissions, namely the regulation of vehicle tyre abrasion rates and of synthetic textile shedding rates. In addition, the widespread domestic and industrial adoption of laundry filters could serve as a relatively cost-effective means of preventing a sizeable portion of plastic microfibres from entering the environment. Finally, while expensive, improving the microplastic retention at WWTPs could prove to be an effective measure to prevent microplastics from a wide range of diffuse and point sources from entering the environment. In addition, any measures to reduce the volume of macroplastics entering the environment are also important for reducing total microplastic load, as secondary microplastics play a significant if unquantified role in microplastic pollution.

Agenda for action

There is an immediate opportunity for the investment community to support action on microplastic pollution through sustained corporate action, investment selection, engagement and investor collaboration.

Agenda for action

There are clear areas for action, which can be grouped into three main categories: for individuals for companies and manufacturers, and for policymakers and regulators.

Actions for individuals

This includes consumer choice around purchasing products that contain or shed microfibres, such as personal care products, vehicle tyres, and clothing. This category also includes fitting filters into domestic (and commercial) washing machines to capture microfibres shed from clothes. Individuals can also help mitigate secondary microplastic pollution by consuming fewer or properly disposing of macroplastics. However, we note that these consumer-facing solutions often require individuals to have access to information on the issue of microplastics in the environment and in the products they consume.

Actions for companies and manufacturers

This refers not only to the design and manufacture of products that either do not contain microplastics or do not shed microplastics, but also to the implementation of best practices across plastic production supply chains to ensure zero pellet loss. This category also refers to voluntary action taken by corporates to label the microplastic content of their products to facilitate consumer awareness. We note that these actions are often driven by a business case for action, which can be influenced by consumer demand, by the regulatory environment, and by shareholder pressure.

Actions for policymakers and regulators

This category of action includes the regulation of microplastic content of products, setting minimum standards for microplastic shedding, and municipal actions to improve the microplastic retention at wastewater treatment plants (WWTPs). These types of actions rely heavily on political support for action from the public and key stakeholders, including industry.

Actions for investors

Investors in particular can incorporate microplastic concerns into their investment strategy and procurement of investment services across all asset classes. In addition, the investment community can support action on microplastic pollution prevention via the following routes:

Generating awareness of the microplastics issue for industry and consumers alike

- Encouraging companies involved in plastic production to make commitments to reduce their own microplastics releases (for examples of corporate commitments to eliminate microbeads from products, see Appendix 5.)
- Requesting corporate disclosure of microplastic emissions from companies' product lifecycles.
- Recommending participation in voluntary schemes for the personal care product and cosmetic industries aimed at the removal of microbeads from these products and recommending the substitution of the microplastic components of products with non-plastic alternatives. See for example, Project MinShed and the BeadRecede campaign in Australia (see Appendix 3).

Encouraging corporate action

Investor opportunities for supporting corporate action on microplastic pollution include:

- Engaging with companies involved in the plastic production supply chain to adopt pellet loss best practices and to partner only with suppliers who have made similar commitments.
- Encouraging tyre manufacturers to produce vehicle tyres that meet a minimum threshold of abrasion and encouraging automotive manufacturers to require tyres that meet a minimum threshold of abrasion.
- Encouraging textile manufacturers to design and manufacture products that meet a minimum threshold for microfibre shedding.
- Requesting that the manufacturers of commercial and domestic washing machines fit, as standard, microfibre filters into their products.
- Requesting that textile and tyre manufacturers and retailers add labels to their products indicating microplastic shedding rates.
- Encouraging synthetic textile recycling and upcycling with textile manufacturers.

Encouraging policy action where policy intervention is needed

Broadly speaking, this category involves the incorporation of microplastic pollution concerns into dialogue with policymakers at the subnational, national and international levels. Relevant policy actions that investors can support include:

- Establishing a single, scientific and precise definition for microplastics.
- Developing and adopting a standard method for the testing of the contaminant (microplastics) (e.g. ASTM D8333).
- Setting maximum allowable fibre release standards for textiles and maximum allowable abrasion rates for tyres.
- Requiring textile and tyre manufacturers and retailers to add to labels indicating microplastic release rates from products to improve the quality of information readily available to consumers.

- Requiring laundromats and other commercial users of washing machines to install microfibre filters on the machines they use.
- Introducing regulations regarding the addition of primary microplastics to personal care products, cosmetics, and detergents.
- Regulation focused on the adoption of best practices for pre-production pellet loss by companies involved in the plastic production supply chain, including transport companies, polymer manufacturers, and plastic converters.
- Installing or upgrading wastewater treatment plants (WWTPs) to incorporate microplastic retention technology and implementing extended producer responsibility schemes to cover the costs of these upgrades.
- Prohibiting the application of sludge from WWTPs to agricultural soils.
- Banning or taxing the manufacture, use, or disposal of single-use plastic products.
- Implementing conventions on the disposal of fishing gear and related marine-based plastics at sea.

Building partnerships and collaborating with other investors and with key stakeholders such as NGOs with a focus on microplastic pollution

Such partnerships could be focused on:

- Providing accessible information on the microplastic content of products and the microplastic pollution issue more broadly through consumer awareness campaigns such as the “Beat the Microbead” campaign.
- Installing infrastructure in public spaces to collect or degrade microplastics that have already entered the environment.
- Coordinating investor engagement. For example, the NGO, As You Sow, coordinates investor engagement through its Plastic Solutions Investor Alliance.

'Stop Ocean Threads' Campaign by MCS

The Marine Conservation Society (MCS), the UK's leading marine charity, launched a petition in 2020 to ask the UK government to require washing machine manufacturers to fit microfibre filters in all new domestic and commercial machines by 2023, and to require that all commercial machines be retrofitted with microfibre filters by 2024. As of early 2021, more than 12,000 people had signed the petition. MCS will use the petition to demonstrate to the UK government that the UK public is concerned about the amount of microfibres being lost into the environment and that it expects the government to take action to reduce these losses. The MCS is also raising awareness of their campaign by encouraging members of the public to increase the pressure on washing machine manufacturers via social media through the use of the hashtag #StopOceanThreads.

Investor Collaboration: Marine Microplastics Engagement Programme

As discussed in Section 3.1, microfibres shed from synthetic textiles make up at least one third of total primary microplastics entering the ocean. The widespread adoption of filters for both commercial and domestic washing machines, therefore, presents a practical solution for addressing a major source of microplastic pollution.

First Sentier Investors (FSI), in collaboration with the UK's Marine Conservation Society, has convened an investor engagement programme to encourage the manufacturers of domestic and commercial washing machines to fit as standard, microfibre filters for their products. As of December 2020, a group of 30 institutional investors representing $5.6 trillion in AUM are collaborating to support this initiative. The programme involves the investors engaging directly with the target companies, and with their respective trade associations, and its specific objectives are to:

- Encourage the target companies to commit to having factory-fitted plastic microfibre filters fitted as standard in all new machines by the end of 2023.
- Encourage policymakers to implement legislation prohibiting the sale of new commercial and domestic washing machines without filter mechanisms built in.

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74 Sundt, Schulze and Syversen 2014; Cole et al. 2011

75 Scudo 2017

76 European Chemicals Agency (ECHA) 2019; Environment Canada, 2015; Lassen et al. 2015; GESAMP, 2015

77 Horton et al. 2017

78 See for example gully pots, which are used to trap solids from road runoff and are widely used in Europe (Eunomia and ICF, 2018)

79 Eunomia and ICF 2018

80 Carr, Liu and Tesoro 2016; Eunomia and ICF 2018

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93 IUCN 2017

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95 De Falco et al. 2019; Napper, Barrett and Thompson 2020

96 National Federation of Women's Institutes 2018

97 Manshoven et al. 2019

98 Eunomia and ICF 2018

99 Eunomia and ICF 2018

100 See for example Tiffin et al. 2021

101 For an example of an existing regulatory standard on ecological requirements for energy-using and/or energy-related products sold in the EU, see the Ecodesign Directive (2009/125/EC)

102 UL 2019

103 Eunomia and ICF 2018

104 Ellen MacArthur Foundation 2017

105 Wear2Go 2021

106 Ellen MacArthur Foundation 2017; M. Spuijbroek 2019

107 Platform for Accelerating the Circular Economy (PACE) 2021

108 Napper, Barrett and Thompson 2020

109 IUCN 2017

110 European Commission 2008

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112 IUCN 2017

113 Excell et al. 2018

114 Cosmetics Europe 2021

115 Eunomia 2016b

116 Scudo 2017

117 Cosmetics Europe 2021

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119 Lassen et al 2015; Plastic Soup Foundation 2021

120 Eunomia 2016a

121 Eunomia and ICF 2018

122 See the BSI's Publicly Available Specification (PAS) 510 - Plastic pellets, flakes and powders – Handling and management throughout the supply chain to prevent their leakage to the environment

123 See the Forest Stewardship Council's Chain of Custody Certification as an example of supply chain accreditation for forest products (https://us.fsc.org/en-us/certification/chain-of-custody-certification)

124 Operation Clean Sweep 2021

125 IUCN 2017

126 Carr, Liu and Tesoro,2016; Murphy et al. 2016; Eunomia and ICF 2018

127 World Health Organization 2019

128 Samco Technologies (no date)

129 Eunomia and ICF 2018

130 Eunomia and ICF 2018

131 Montestruque and Lemmon 2015

132 See for example Reade's coconut-based products (https://www.reade.com/products/coconut-shell-powder-coconut-shell-flour) and Fiven's silicon carbide products (https://www.fiven.com)

133 Scudo 2017

134 Federal Department of the Environment Transport Energy and Communications 2003

135 See for example the LifeStraw filters (https://www.lifestraw.com) and the TAPP2 filter (AKA Flo Faucet in the US) (https://home.drinkflowater.com/products/faucet-filter)

136 See for example the Ocean Cleanup Project (https://theoceancleanup.com)

137 See for example the WasteShark drone (https://www.wevolver.com/wevolver.staff/wasteshark)

138 See for example Amsterdam's Bubble Barrier (https://thegreatbubblebarrier.com)

139 See for example the Netherlands' Clear River Water Trap (https://www.clearrivers.eu)

140 Saxena 2018; Sheth et al. 2019

141 European Bioplastics 2018

142 Cole et al. 2011

143 See for example the Tuv Austria OK Biodegradable marine label (https://www.tuv-at.be/green-marks/certifications/ok-biodegradable/)

144 Samper et al. 2018

Appendix 1. Examples of existing regulations on primary microplastics

Note that this appendix is not comprehensive and does not include regulation of macroplastics

Argentina

- The Argentine National Senate passed a ban on the production, import, and marketing of cosmetics and care products with plastic microbeads in December 2020.

China

- The Inventory of Existing Chemical Substances in China (IECSC) requires that new entrants to the market meet criteria for import and manufacture if not IECSC listed. This covers products that include microplastics.
- Order No. 29 of the National Development and Reform Commission of the People's Republic of China is a national ban on the production (by 2020) and sale (by 2022) of daily chemical products containing plastic microbeads.

Canada

- The Microbeads in Toiletries Regulations (SOR/2017-111) (June 2, 2017) is a national ban prohibiting the manufacture, import, and sale of toiletries that contain plastic microbeads, unless the toiletries are also natural health products or non-prescription drugs.
- Microbeads have also been added to of the toxic substances list (Schedule 1) under the Canadian Environmental protection Act 1999 (CEPA).

Denmark

- Plastik uden spild—Regeringens Plastikhandlingsplan (2020) is a ban on intentionally added microplastics in rinse-off cosmetics in Denmark.

France

- Reclaiming Biodiversity, Nature and Landscapes Act No 2016-1087 of 8, Article 124, August 2016 is a national ban on the marketing of rinse-off cosmetics for exfoliating containing solid plastic particles, with the exception of particles of natural origin. This regulation defines microplastics as "Any solid particle, in particular microparticles of size < 5 mm, composed wholly or partly of plastic material and obtained by a hot forming process."

India

- The Bureau of Indian Standards (BIS) banned the use of microbeads in cosmetics in October 2017.

International Waters

- The 1972 Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Dumping Convention) is one of the two only international legally binding agreements that directly addresses marine pollution (and therefore plastics) on a global scale (Booth et al., 2020). This convention bans the dumping of all wastes. The second agreement is the 1973 Annex V of the International Convention for the Prevention of Pollution from Ships, as modified by the Protocol of 1978 (MARPOL), and adopted by the International Maritime Organization (IMO). MARPOL bans ships from dumping plastic waste into the oceans. With both of these agreements, enforcement is a challenge as international waters are beyond national jurisdictions.
- The Port Waste Reception Facilities Regulations (2003) consolidate plans for responsible management of ship-generated waste and cargo residues. These regulations were updated in 2019 to mandate an indirect fee to remove the financial incentive to dump wastes at sea.

Italy

- The General Budget Law 2018: Law no. 205 of 27, Art.1, Sections 543 to 548, December 2017) is a national ban on marketing of rinse-off cosmetic products with exfoliating or cleansing action and detergents containing microbeads, with an exception of water-soluble particles.

Japan

- In June 2018, Japan revised the 2009 Coastal Debris Treatment Promotion Law to restrict the use of microbeads with the goal of reducing microplastic pollution. This law stipulates that business operators must endeavor to restrict the use of microplastics in products discharged into rivers and to curb the discharge of waste plastics. This is the first bill to be passed in Japan that targets microplastic production.

New Zealand

- The Waste Minimisation (Microbeads) Regulations 2017, under section 23(1)(b) of the Waste Minimisation Act 2008 bans the manufacture and sale of rinsed cosmetic products.

Republic of Ireland

- The Microbeads (Prohibition) Act (2019) prohibits the manufacture, sale, and import of cosmetic products containing microplastics in the Republic of Ireland.

South Korea

- Regulations on safety standards for cosmetics [Annex 1] No. 2017-114, Notice, Article 3, Dec. 29, 2017 bans the manufacture and sale of microbeads in cosmetics.
- The Act on Registration and Evaluation of Chemicals in South Korea (K-REACH) requires that additives and polymers be registered when manufactured or imported.

Sweden

- Ordinance (1998: 944) on prohibition etc. in certain cases in connection with handling, import and export of chemical products is a national ban on the sale of cosmetics containing plastic microbeads, including rinse-off products. The ban applies to plastic microbeads in solid phase that are <than 5 mm in any dimension (with no lower size limit) and are insoluble in water. Plastic microbeads that only consist of naturally occurring polymers such as cellulose are not covered by the ban.

Taiwan

- Huan-Shu-Fei-Tzu No. 1060059207 is a ban on solid plastic particles smaller than 5 mm used for exfoliation or cleaning.

United Kingdom

- The Environmental Protection (Microbeads) (England) Regulations (2017) is a national ban on the use of plastic microbeads (defined as “any water-insoluble solid plastic particle of less than or equal to 5 mm in any dimension") in cosmetic products.
- The Environmental Protection (Microbeads) (Scotland) Regulations (2017) is a national ban on the use of plastic microbeads (defined as “any water-insoluble solid plastic particle of less than or equal to 5 mm in any dimension") in cosmetic products.
- The Environmental Protection (Microbeads) (Wales) Regulations (2017) is a national ban on the use of plastic microbeads (defined as “any water-insoluble solid plastic particle of less than or equal to 5 mm in any dimension") in cosmetic products.
- The Environmental Protection (Microbeads) (Northern Ireland) Regulations (2017) is a national ban on the use of plastic microbeads (defined as “any water-insoluble solid plastic particle of less than or equal to 5 mm in any dimension") in cosmetic products.

United States**

- The Microbead Free Waters Act (2015) is a federal law that bans the use of primary microbeads in cosmetics, and defines primary microbeads as “any solid plastic particle less than 5mm in size and intended to be used to exfoliate or cleanse.”
- The Toxic Substances Control Act (TSCA) regulates additives to plastics. Polymers that meet the polymer of low concern criteria (PLC) are exempted from the TSCA and can be commercialised.
- The California Safe Drinking Water Act: Microplastics requires the California State Water Resources Control Board (SWRCB) to adopt requirements for the testing and reporting of the amount of microplastics in drinking water for forty years.

** Several other subnational regulations have been passed within the United States. For examples, please refer to Excell et al. (2018) and European Chemicals Agency (EHCA) (2019).

Appendix 2. Proposed regulations and agreements on primary microplastics

Note that this appendix is not comprehensive and does not include regulation of macroplastics.

Belgium

- The Federal Minister of Environment and the DETIC (Belgian and Luxembourg association for producers and distributors of cosmetics, cleaning and maintenance products, adhesives and sealants) prepared a sectoral agreement to eliminate microplastics from consumer products that are covered by the association. The agreement would result in the substitution of plastic microbeads as exfoliants or cleansers from rinse off cosmetic products present on the Belgian market.

Brazil:

- If passed into law, the draft bill PL 6528/16 would ban the use of microbeads in personal care products. This bill specifically prohibits the handling, manufacture, importation and marketing of toiletries, cosmetics and perfumes containing microbeads. The law defines microbeads as any solid plastic <5 mm, used for cleaning, lightening, or exfoliating the body.

China

- The Chinese government has indicated a general plan to prohibit "Microplastic" manufacturing after 31 Dec. 2020, and for sale after 31 Dec. 2022 (Mitrano and Wohlleben, 2020).

European Union

- In 2017, the European Commission requested ECHA to prepare an Annex XV restriction dossier concerning the use of intentionally added microplastic particles to consumer or professional use products of any kind (i.e. including both substances and mixtures). In 2019, ECHA proposed a wide-ranging restriction on microplastics in products placed on the EU/EEA market. A consultation on the restriction proposal was organised from March to September 2019. The Commission's proposal to amend the list of substances restricted under Annex XVII of REACH (Registration, Evaluation, Authorization and Restriction of Chemicals) will be submitted to a vote by the EU Member States in the REACH Committee in 2021.
- REACH (Registration, Evaluation, Authorization and Restriction of Chemicals) Regulation regulates additives if more than 1 ton is manufactured or imported. Polymers, including solid plastics, are exempted from REACH due to low bioavailability. Primary microplastics have been proposed to be restricted under REACH.

South Africa

- The South African Water Research Commission recommended that the manufacture, import and use of microbeads be banned in South Africa. The government has set up a task force to explore this possibility.

Appendix 3. Voluntary Commitments and Agreements from Industry

Note that this appendix is not comprehensive and does not include regulation macroplastics.

Australian Government

- The Australian government plans to work with the textiles sectors on an industry-led phase-in of microfibre filters on new residential and commercial washing machines by July 1, 2030 (Australian Government: Department of Agriculture Water and the Environment, 2021).
- The Australian Meeting of Environment Ministers have supported a voluntary industry phase-out of plastic microbeads found in rinse-off personal care, cosmetic, and cleaning products since 2016. The initiative targets rinse-off products containing microbeads and is led by Accord Australasia (Accord) through their BeadRecede campaign. The initiative is overseen by the Commonwealth Department of Agriculture, Water and the Environment and the NSW Environment Protection Authority. This voluntary initiative has able to successfully remove most primary microplastics from target products, as >99% of products tested in 2020 were found to be microbead-free (Farrell and Harney, 2020).

Project MinShed

- Project MinShed is a three-year research project with the aim to create guidelines to help the textile industry to design and create clothes made of synthetic fabrics that do not emit microplastics. This project will also look into fitting washing machines with filters to reduce the emissions of microplastics.

Japanese Cosmetics Industry

- In March 2016, the Japanese Cosmetic Industry Association formally requested that its ~1,100 member companies take prompt action to discontinue the use of microplastic beads in the wash-off products they manufacture and sell. As a result, many Japanese cosmetics companies have begun to self-regulate the use and sale of microbeads.

Appendix 4. Examples of existing devices for capturing microfibres shed from textiles during washing

Table 1. Examples of existing devices for capturing microfibres shed from textiles during washing. (Effectiveness is given by Napper, Barrett and Thompson (2020)).

Type of device	Examples	Approximate cost (USD)	Effectiveness
In-drum devices	Cora Ball	$31	31%
	GuppyFriend washing bag	$36	54%
	Fibre Free	Not currently available for individual sale	Not tested
	Eleanos Reusable Washing Machine Floating Net Bags	$8	Not tested
External (add-on) filters	Xfiltra	Not currently available for individual sale	78%
	Lint LUV-R (microplastics kit)	$180	29%
	Planetcare	$13	25%
	The Microfiber Filter (Girlfriend)	$45	Not tested
	Filtrol	$140	Not tested
Washers with built-in filters	Arçelik's FiberCatcher	Not currently available for individual sale	Not tested

Table 2. Summary of global regulatory landscape on microplastics. See Appendices 1 and 2 for detailed explanations.

Type of regulation	Countries	Reference(s)
Existing ban on plastic microbead manufacture and/or sale	Argentina, China, Canada, Denmark, France, India, Italy, New Zealand, Republic of Ireland, South Korea, Sweden, Taiwan, UK England, Wales, Scotland, and Northern Ireland), United States	(European Chemicals Agency (EHCA), 2019a; Anagnosti et al., 2021)
Proposed ban on plastic microbead manufacture and/or sale	Belgium, Brazil, European Union, South Africa	(Anagnosti et al., 2021)
Regulation of plastic additives	EU (REACH), USA (TSCA), China (IECSC), South Korea (K-REACH), UK (PVC ban)	(Mitrano and Wohlleben, 2020)
Regulation of macroplastic pollution	e.g. plastic bag bans or fees in…UK, US states, etc.	
Regulation on disposable plastic product (macro)	EU Directive on single-use plastics	
Regulation on disposal of wastes (including plastics) at sea	London Dumping Convention, MARPOL, The Port Waste Reception Facilities Regulations	(Booth et al., 2020)

Appendix 5. Examples of companies with commitments to eliminate microbeads from their products

Table 3. Examples of companies with commitments to eliminate microbeads from their products. (Based in part on research by Greenpeace (2016)).

Company	Country	Deadline	Notable brands
Beiersdorf	Germany	Dec 2015	Nivea, La Prairie, Eucerin
Colgate-Palmolive	USA	Dec 2014	Sanex, Palmolive and Colgate
L Brands	USA	Jan 2016	Victoria's Secret, PINK, Bath & Body Works and La Senza
Henkel AG & Co	Germany	Start of 2016	Persil, Schwarzkopf
Clarins	France	Dec 2014	n/a
Unilever Group	Netherlands	Dec 2014	Dove, Vaseline, VO5
Botica Comercial Farmacêutica	Brazil	July 2016	n/a
Oriflame cosmetics	Sweden	Dec 2016	Nature's Secret, Optimals, Love Nature
Shiseido	Japan	2018	Nars, Tsubaki, Bare Minerals
Coty Inc	USA	2017	Adidas, Calvin Klein, Chloe, Marc Jacobs
Kao Corp	Japan	Dec 2016	Biore, John Frieda, Curél
Natura & Co	Brazil	2017	Avon, The Body Shop, Aesop, Ekos, Chronos
Reckitt Benckiser	UK	2018	Dettol, Vanish, Veet
Amore-Pacific	Korea	Dec 2015	Sulwhasoo, Innisfree, Etude House
L'Oreal*	France	Dec 2017	Lancôme, YSL, Biotherm
Procter & Gamble	USA	EOY 2017	Oral-B, Downy, SK-II, Pantene, Olay
Johnson & Johnson	USA	EOY 2017	Neutrogena, Clean & Clear, Listerine, Aveeno
LG Household & Health Care	South Korea	EOY 2016	Whoo, OHUI, The Face Shop, Perioe, Bamboo Salt Toothpaste
GlaxoSmithKline	UK	TBD	Sensodyne, Parodontax, Lamisil, Physiogel
Estée Lauder	USA	Not stated	Estée Lauder, MAC, Origins
Amway	USA	Early 2017	n/a
Revlon	USA	Not stated	n/a

*Several of L'Oreal's subsidiaries have made commitments to phase out or halt the use of microbeads in their products.

Important Information