Microplastics from textiles: Towards a circular economy for textiles in Europe

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Awareness is increasing about the presence of microplastics in our seas, land and air — and of their negative effects on ecosystems, animals and people. Microplastics can be released directly into the environment or can result from the degradation of larger pieces of plastic. The wearing and washing of textiles made from synthetic (plastic) fibers is one recognised source of microplastics in the environment. Textiles and plastics are among the key value chains in the EU circular economy action plan.

Key messages

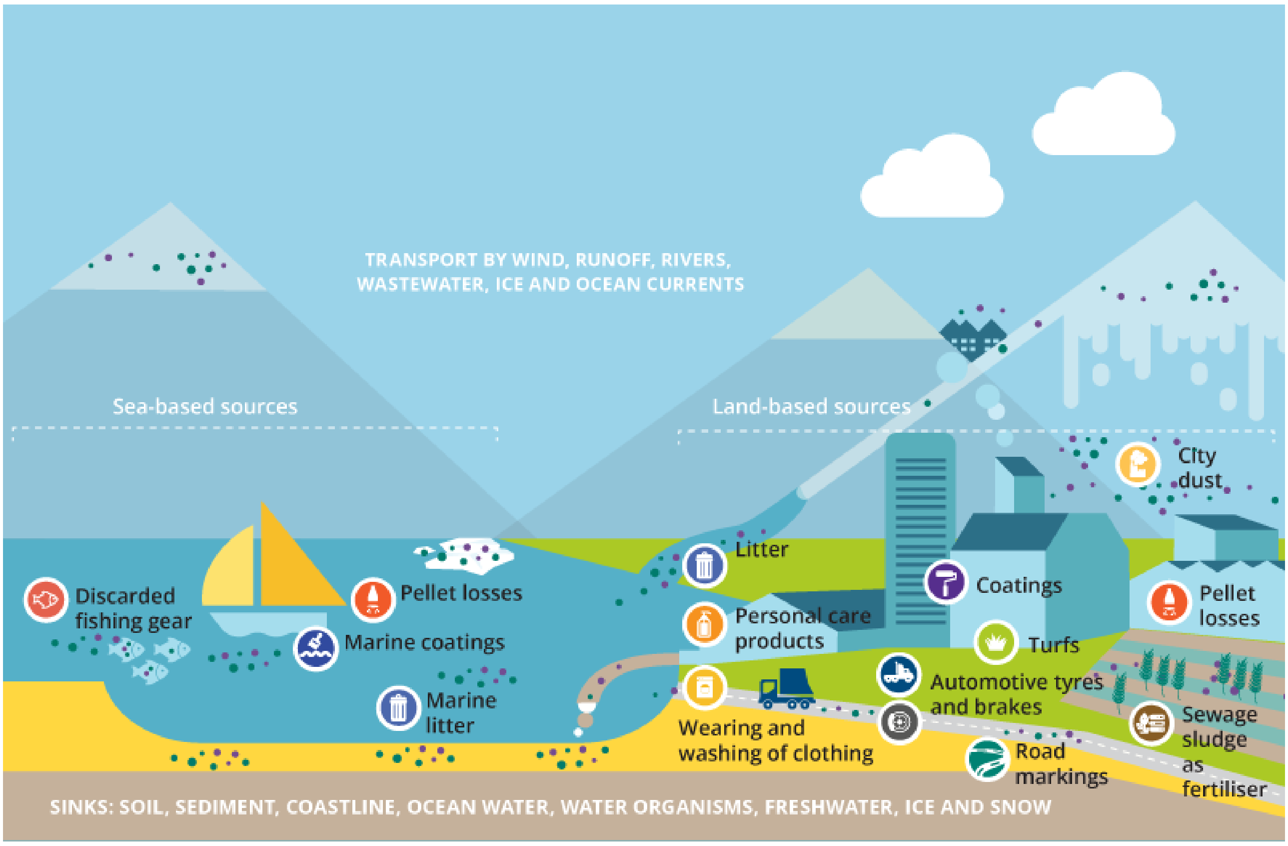
- Over 14 million tonnes of microplastics have accumulated on the world's ocean floor according to research estimates. The amounts are increasing every year — causing harm to ecosystems, animals and people.
- About 8% of European microplastics released to oceans are from synthetic textiles — globally, this figure is estimated at 16-35%. Between 200,000 and 500,000 tonnes of microplastics from textiles enter the global marine environment each year.
- The majority of microplastics from textiles are released the first few times textiles are washed. Fast fashion accounts for particularly high levels of such releases because fast fashion garments account for a high share of first washes, as they are used for only a short time and tend to wear out quickly due to their low quality.
- It is possible to reduce or prevent the release of microplastics from textiles, for instance by implementing sustainable design and production processes and caretaking measures that control microplastic emissions during use, and by improving disposal and end-of-life processing.

This briefing aims to improve our understanding of microplastics released from textiles from a European perspective and identify pathways to reduce or prevent this release. The report by the EEA's European Topic Centre on Circular Economy and Resource Use (ETC/CE) on microplastics from textiles that underpins this briefing is also made available.

Sources of microplastics in the environment

Mismanaged plastic waste ends up on land and in rivers, waterways and coastal waters, and adds to the growing amount of marine litter that pollutes oceans and beaches worldwide. It is estimated that 6-15 million tonnes of plastics, representing 2-4% of global production, enters the environment every year (Velis et al., 2017). Land-based sources, such as uncontrolled dumping of waste and litter — much of which is plastic — account for about 80% of marine litter (Velis et al., 2017). Under the influence of sunlight, wind, waves and other factors, plastic degrades into small fragments known as microplastics, 0.001-5mm in size, or even nanoplastics, measuring less than 0.001mm (Velis et al., 2017). Some microplastics, such as microbeads in personal care products or plastics pellets, are produced deliberately and are subsequently released into wastewater, intentionally or unintentionally. Others are formed unintentionally as a result of the wear and tear of products, such as tire abrasion arising from road transport or microfiber release during the washing of synthetic textiles. The fragmentation of plastic litter into smaller particles is a third formation route (see Figure 1).

Figure 1. Sources of microplastics, release routes and sinks



Source: Illustration by the Collaborating Centre on Sustainable Consumption and Production (CSCP) for the European Topic Centre on Circular Economy and Resource Use (ETC/CE) and the EEA

It is challenging to estimate and measure the quantities of microplastics released into the environment. Estimates of the amounts of microplastics released and formed are highly uncertain because of the many primary and secondary sources of microplastics and the lack of standardised sampling and measurement methods. Research suggests that at least 14 million tonnes of microplastics have accumulated on the world's ocean floor thus far (Barrett et al., 2020), and that an additional approximately 1.5 million tonnes enter the oceans annually (Boucher and Friot, 2017).

The release of microplastics occurs throughout the whole plastics value chain, during production, transport and use, and at the end of product life. In general, microplastics can be divided into two major types, depending on the formation processes involved: primary and secondary microplastics.

Primary microplastics are directly released into the environment as plastic particles. They are added to products, for example as stabilisers or glitter in cosmetics, or as granular materials in artificial turf sports pitches. The European Chemicals Agency estimates that 145,000 tonnes of deliberately produced microplastics are used in Europe each year (ECHA, 2021). Primary microplastics can also be generated from spills during production; from wear and tear of plastic products during use, such as the abrasion of car tires; from the peeling and flaking of paints and coatings; or through the washing or wearing of synthetic textiles.

A study found that about 3 million tonnes of primary microplastics are released annually into the global environment, in addition to the 5.3 million tonnes larger plastic items that arise mainly from mismanaged waste and litter and degrade over time to become secondary microplastics (UNEP, 2018). Other estimates suggest that 3.2 million tonnes of primary microplastics are released by households and commercial activities each year, of which 1.5 million tonnes are released into the ocean (Boucher and Friot, 2017). Globally, this corresponds, on average, to 400 grams of primary microplastics being released into the environment per person each year — the equivalent of 80 plastic grocery bags — of which half end up in the ocean.

Secondary microplastics are formed from the breakdown of larger plastic items in the environment, typically mismanaged plastic waste such as discarded fishing gear, littered plastic packaging or plastic lost from open landfills. Wind can transport plastic waste from open landfills or dumpsites to rivers up to 10km away (Parker, 2021). A study by Meijer et al. (2021) estimated that, globally, 80% of plastic that ends up in the ocean can be explained by the discharge of more than 1,000 rivers, with small rivers that flow through densely populated urban areas, especially in Asia, being most polluted by plastic waste. Discarded fishing nets, estimated to amount to around 500,000 tonnes per year worldwide, are also a source of secondary microplastics directly emitted to the ocean (Boucher and Friot, 2017; UNEP, 2018). Estimates of how much plastic waste ends up in the ocean vary widely, from 1.15 to 12.7 million tonnes a year, or up to 1.8kg of plastic marine litter per person worldwide (Jambeck et al., 2015; Sherrington, 2016; Boucher and Friot, 2017; Lebreton et al., 2017; UNEP, 2018).

At the European level, a 2021 study estimated that between 307 and 925 million items of litter are released annually into the ocean. Plastics accounted for 82% of the items of litter observed (Gonzalez-Fernandez et al., 2021). The European Chemicals Agency (ECHA, 2021) calculated that 176,000 tonnes of unintentionally formed microplastics are released into European surface waters annually due to the abrasion and weathering of plastic products. An additional 42,000 tonnes of microplastics deliberately added to products are discharged to the environment each year. Granular infill material used on artificial turf pitches is the predominant source of these microplastics, accounting for 16,000 tonnes; other sources include additives to cosmetics, detergents and fertilisers. Eunomia and ICF (2018) estimated that 72,000-280,000 tonnes of primary microplastics are emitted to surface waters in Europe each year.

Microplastics from textiles: environmental and health impacts

Release throughout the whole life cycle

Textiles are a major source of microplastic pollution. Microplastics originating from textiles typically have a fibre shape, and are therefore often referred to as microfibres (Roos et al., 2017). Textiles made of fibres of natural origin (as opposed to the synthetic fibres that cause microplastic release) shed microfibres as well. Moreover, textiles can also be a source of other shapes of microplastics, originating from the various types of materials or accessories used in clothes and textile products, such as prints, coatings, buttons and glitter. It is estimated that synthetic textiles are responsible for a global discharge of between 0.2 and 0.5 million tonnes of microplastics into the oceans each year (Sherrington, 2016; Ellen MacArthur Foundation, 2017).

According to Boucher and Friot (2017), approximately 35% of microplastics released to oceans globally originate from washing synthetic textiles, while the United Nations Environment Programme (UNEP) estimates this figure to be around 16% [1] (UNEP, 2018). For Europe, where most households are connected to a sewage and waste water treatment system, it is estimated that 13,000 tonnes of textile microfibres, or 25 grams per person, are released to surface water every year, accounting for 8% of total primary microplastic releases to water (Eunomia and ICF, 2018).

Most research has focused on microfibre release through the washing of synthetic textiles, considering waste water to be the predominant pathway for leakage into the aquatic environment (Boucher and Friot, 2017). However, microfibres are also emitted during textile manufacturing, garment wearing and end-of-life disposal, and are dispersed in water, air and soil.

Although microfibre shedding decreases over successive washes, the wearing out of fabrics as garments age also leads to an increase in microfibre shedding (Hartline et al., 2016). As a result, fast fashion accounts for a particularly high level of microfibre release, as fast fashion garments typically contain a high share of synthetic fibres and account for a high share of first washes, as they tend to be used for a only short time and to wear out quickly.

Microfibres are not retained by washing machines; they are discharged with the washing machine effluent. Waste water treatment plants can filter out a large share —but not all — of microplastics. However, if adequate sewage and waste water treatment systems are not in place, microplastics will be emitted to the aquatic environment (Eunomia and ICF, 2018). A lot of research is being conducted to elucidate the washing parameters that cause microfibre shedding. Initial studies indicate that long wash cycles increase wear and tear, and using high temperatures tends to damage fabric structure, both of which result in relatively high levels of microfibre release. Washing powder tends to induce more shedding than liquid detergent, possibly because the powder granules work as an abrasive, damaging the fibres. On the other hand, the use of fabric softener results in lower microfibre shedding, possibly by reducing friction and fibre damage during washing.

Moreover, the type of washing machine has an influence on the rate of microfibre release, with top-loading models inducing significantly more shedding than front-loading ones, probably as a result of greater abrasion during tumbling in the former (Hartline et al., 2016).

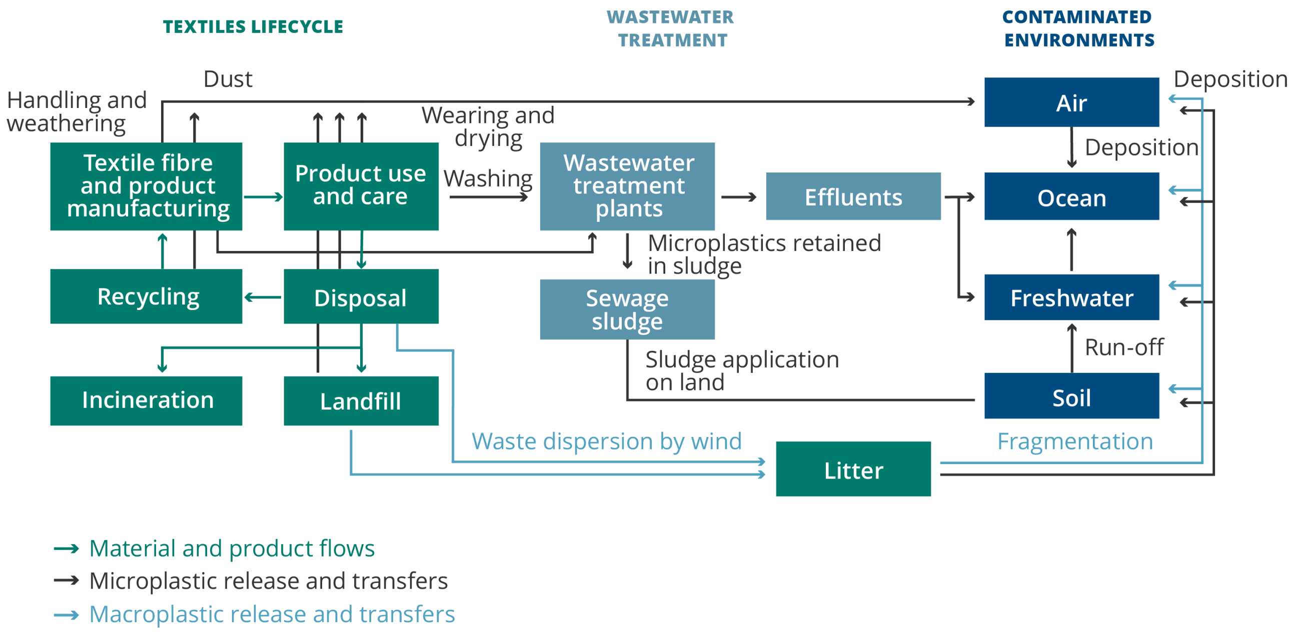
Environmental and health impacts

In recent years, concerns have grown about the environmental and health impacts associated with microplastic pollution. There is a lot of uncertainty about these impacts, but a certain degree of chronic exposure to microplastics is unfortunately an integral part of contemporary life (Henry et al., 2019; OECD, 2020). Microplastics are ingested by all kinds of living organisms, ranging from plankton, fish and large mammals in marine environments to land animals and humans. In addition to the ingestion of microplastics from water and soil, airborne particles both indoors and outdoors are inhaled (Henry et al., 2019; SAPEA, 2019). Microplastics have been reported in a wide range of human foods and beverages, including seafood, drinking water, beer, salt and sugar (WHO, 2019; Shruti et al., 2020; Ghosh et al., 2021).

The long-term effects of microplastics, including on the economic viability of agriculture, fisheries and other livelihoods, are still largely unknown (Gasperi et al., 2018; Waring et al., 2018; OECD, 2020). Apart from the physical effects of microplastics, another source of concern is the potentially toxic chemicals they contain — additives, monomers, catalysts and reaction by-products from manufacture. These can leach out once microplastics have been released into the environment, with the degradation and fragmentation of particles expected to further increase the potential for the leaching of chemicals (Wang et al., 2018). High levels of exposure to microplastics are believed to induce inflammatory reactions and toxicity, and microplastics can be vectors for the spread of pathogens and microbes (Henry et al., 2019; SAPEA, 2019).

Figure 2 shows the release routes and fates of microplastics from textiles in freshwater, marine water, air and soil. As can be seen, microplastics can be released at any point in the textile value chain, from production to use and care, through to disposal.

Figure 2. Release and fates of microplastic fibres from textiles



Source: European Topic Centre on Circular Economy and Resource Use (ETC/CE) for the EEA (2021)

Microfibres in water

Microplastic contamination of freshwater and marine environments is the result of both direct emissions to surface water and the transport of particles through wind, run-off, waste water and waste disposal. Microfibres, mainly originating from synthetic textiles, appear to have a higher potential than other fibres to enter the food chain, because their size and shape allow them to be readily consumed by aquatic organisms, and are more prone to becoming entangled in large clots inside the gut, causing blockages (Jemec et al., 2016).

The World Health Organization (WHO) published a study in 2019 on microplastics in drinking water, reviewing studies that had analysed microplastic particles in water, freshwater and tap and bottled drinking water (WHO, 2019). Shruti et al. (2020) found that approximately 84% of 57 samples of soft drinks, cold tea and energy drinks contained microplastics.

Microfibres in air

Textiles have also been reported to release microplastics into the air, which are then deposited in soil, during garment wearing (De Falco et al., 2020; Napper et al., 2020). A study suggested that up to 65% of microplastics may be emitted to aerial environments during the drying and wearing of garments (OECD, 2020).

Although concentrations remain unclear, it has been shown that microplastics are present in both ambient and indoor air, with microfibres released from textiles appearing to be predominant (Dris et al., 2017; Gasperi et al., 2018; SAPEA, 2019). The highest levels are likely to be found indoors (Dris et al., 2017), as some studies indicate that the amounts of microfibres deposited on household surfaces from, for example, wearing and drying clothes, and household textiles were of the same order of magnitude as when textiles are washed (Henry et al., 2019).

Microfibres in soil

Microplastics have been detected in terrestrial ecosystems. Many pathways can lead to microplastics ending up in soil. Airborne microplastics are deposited on roads and pavements. Run-off then transports them to roadsides and sewers, and they are then transported to waste water treatment plants, the sewage sludge from which is used as fertiliser on fields. Textile waste that is dropped as litter, for example single-use face masks, ropes, tarpaulins and lost garments, or discarded in landfill sites can degrade and lead to microfibres leaking into soil (Henry et al., 2019). These are all important microplastic exposure pathways (SAPEA, 2019), and it is assumed that organisms such as earthworms have the capacity to transport significant amounts of microplastics from the soil surface to deeper layers (Henry et al., 2019).

Pathways to prevent the release of microplastics from textiles in Europe

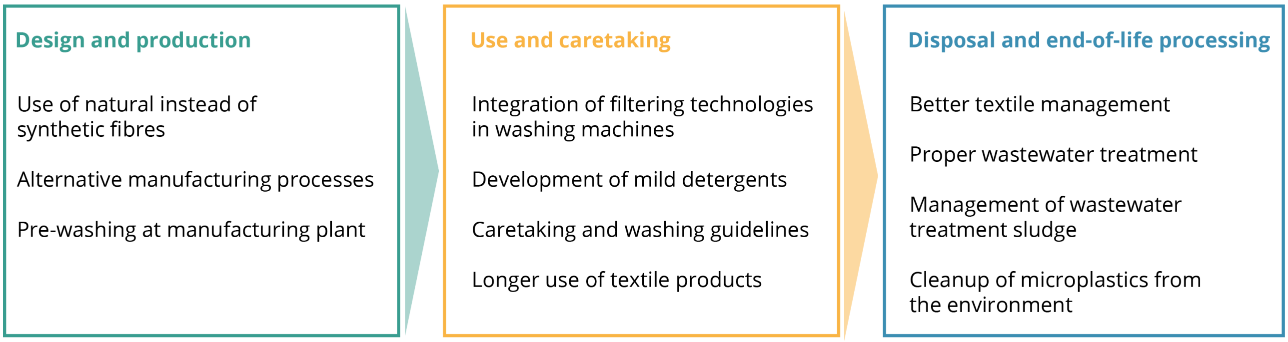
Although the knowledge base is evolving quickly, a recurrent finding is that the formation of microplastics and mechanisms for their release and the effects of this on the environment and human health are complex and there are still many unknowns. This is particularly the case for the release mechanisms and impacts related to microfibres from textile sources. Because of their composition, fibre shape and additives, these microplastics might be associated with a wide range of behaviours and impacts of their own (Jemec et al., 2016; Henry et al., 2019). Unfortunately, their fates and effects are currently largely unknown, making it hard to determine the severity of the issue and the measures required.

It is evident that more knowledge is needed regarding microplastics from textiles in Europe, in particular about the factors affecting microfibre release and the release mechanisms, the transport and fates of microfibres, the associated ecosystem and health impacts, and potential solutions that are scalable. While knowledge is being developed, and considering the precautionary principle, policies are already being considered and put in place in the EU to minimise the release of microplastics from textiles.

The European strategy for plastics — adopted in 2018 — identified microplastics as one of the challenges to be dealt with (EC, 2018). Two years later, in the 2020 EU circular economy action plan, the European Commission identified the textiles value chain as a key priority because of, for instance, its contribution to the release of microplastics into the environment (EC, 2020). The action plan envisages a comprehensive EU strategy for sustainable textiles.

In line with EU plastic and textiles policies, this EEA briefing highlights three pathways to prevent microfibre release from textiles: (1) sustainable design and production; (2) caretaking measures to control microplastic emissions during use; and (3) improved disposal and end-of-life processing. These pathways are illustrated in Figure 3.

Figure 3. Pathways to prevent the release of microfibres from textiles



Source: ETC/CE and the EEA.

The design and production pathway

Shifting textile designs towards natural fibres has been suggested as a pathway for tackling microfibre shedding (Henry et al., 2019). Questions have, however, been raised about whether or not such an approach could deliver a viable alternative to using synthetic fibres, which currently make up about 60% of textile fibres used (ETC/CE, 2021b). Not only would textile properties change considerably if natural fibres were used, but the substitution would not necessarily lead to a reduction in microfibre formation, as natural fibres can also shed microfibres as a result of wear and tear (Gesamp, 2015). Some concerns have also been raised as to whether or not the rapid biodegradation of natural fibres could lead to the release of chemical additives, such as dyes, with adverse effects (Henry et al., 2019). Finally, it is important to note that not all microfibres made from natural resources are biodegradable. For example, bio-based polyester is chemically equivalent to fossil-based polyester and does not biodegrade, and therefore it contributes to the build-up of microfibres in the environment (ETC/CE, 2021b).

The production processes of synthetic fibres, yarns, fabrics and products may be responsible for increased release of microfibres. In particular, the application of abrasive friction during production is an important factor in microplastic formation (Cai et al., 2020). By using alternative production processes or textile construction methods, microfibre release during use could be reduced. Although much research is focused on microfibre release during washing by households, the textile manufacturing industry is also a major source of microfibre pollution, especially if industrial waste water treatment is inadequate.

Since synthetic fabrics tend to release the highest amounts of microplastics in the first 5-10 washes, pre-washing at manufacturing plants could capture a large share of released microfibres (Roos et al., 2017; Mermaids, 2019; OECD, 2020). In industrial plants, microfibres are more likely to be captured, since the plants are generally connected to waste water treatment, especially in Europe.

The use and caretaking pathway

With regard to washing machine manufacture, one option is to include filters to prevent microfibre release. In 2020, France was the first country to introduce an obligation for all washing machines to be equipped with a dedicated microfibre filter as of January 2025 (Sánchez, 2020). A study showed that the release of microfibres can be reduced by up to 80% by using a washing machine filter (Williams, 2020).

The use of detergent and fabric softener also has an effect on microfibre release. Detergent manufacturers can contribute to reducing microfibre shedding by developing non-aggressive, liquid detergents that are effective at low temperatures and do not rinse off fabric finishes, some of which protect against fibre breakage. Using powder detergents for synthetics should be discouraged, since they increase friction, causing fibre breakage.

As many studies highlight, the release of microfibres is especially high during the first few washes of new clothes (Lant et al., 2020), meaning that fast fashion, with garments being used for a short time and replaced often, accounts for a high level of microfibre releases. Consequently, changes in consumer buying behaviour are needed along with an awareness of the impact that new clothing items have on microplastic pollution. Such a shift could be facilitated by more circular business models, which promote reduced consumption and longer use. This could decrease both the number new purchases and waste generation, while also having the additional benefit of the reused articles generally shedding fewer microfibres when washed than new ones. Furthermore, preparing an old article for reuse requires fewer resources than the production of a new similar one, thus providing a further environmental benefit. A recent EEA briefing and an Eionet report of the European Topic Centre on Circular Economy and Resource Use (EEA, 2021; ETC/CE, 2021a) discussed several business models for a more circular textile system.

The disposal and end-of life processing pathway

Apart from increasing the reuse and recycling of textiles, which would reduce microplastic emissions during production and use, textile waste collection and end-of-life treatment can also prevent littering, mismanaged waste and textiles being blown by the wind from open landfills, reducing secondary microplastic contamination. However, it is important to note that a large share of textile waste is exported from Europe for reuse or recycling. The fates of those exported textiles, however, are unclear, and many receiving countries do not possess high-quality waste management systems. This poses the risk of microfibres spreading from the washing of synthetic garments through untreated waste water, release of waste from open landfills or inadequate disposal.

Waste water treatment is an important step in capturing microplastics released from the washing of textiles. Although conventional waste water treatment plants are not equipped to entirely remove microplastics (Salvador Cesa et al., 2017), technologies and techniques are available that could remove up to 98% of microplastics from effluents (Poerio et al., 2019). However, although connection to waste water treatment is widespread in the EU, only about 56% of households are connected to such high-performing ‘tertiary’ treatment processes (Crini and Lichtfouse, 2018; Eunomia and ICF, 2018). Moreover, many challenges still need to be overcome to filter out the remaining percentages of microplastics, especially those particles smaller than 0.02mm (Iyare et al., 2020).

It is important to note that the majority of microplastics removed from waste water end up in sewage sludge (Iyare et al., 2020). This sludge, which is often used as an agricultural fertiliser across the EU, represents an important route for microplastics to enter aquatic and terrestrial ecosystems. Knowledge of and regulations on the treatment and use of sludge are needed, taking microplastics into account. Innovative solutions are needed to post treat and deal with sludge, to recover nutrients but prevent microplastics from spreading.

Putting in place sufficient end-of-life textile waste collection and treatment is important, but cannot replace prevention measures, as is it unlikely that waste water treatment will be able to filter out all micro- and nanofibers and cost-effective large-scale removal of microplastics from the ocean seems unrealistic (Gesamp, 2015).

Increasing knowledge and awareness

To further extend the knowledge of microfibres released from textiles, some priority areas for further research an studies include:

- the development of standardised sampling methods and metrics for the identification and quantification of micro- and nanofibres in environmental samples
- the development of standardised research methods to study shedding resulting from textile manufacturing, wearing, washing and waste treatment
- research on innovative production processes and waste treatment technologies that prevent, reduce and capture microplastics across the textile lifecycle
- studies to clarify the environmental spread of microfibres and contamination in air and soil, and the ecotoxicity and health effects of microfibres, especially from accumulation in the food chain, long-term chronic effects and the effects of textile chemicals that are released from microplastics
- research into ways to promote the sustainable consumption of textiles, including sustainable purchasing and use behaviour, washing habits and end-of-life management.

Continued public and industry support is needed to advance research aimed at closing these knowledge gaps on the release, spread and impacts of nano- and microplastics. Moreover, a close interdisciplinary collaboration between technical, behavioural and regulatory measures is needed to address the complex issues associated with microfibre pollution from textiles.

Publications

The EU strategy on sustainable textiles will be important in facilitating a move towards the more sustainable production, use and end-of-life management of textiles and a gradual move away from fast fashion, short garment lifespans and waste generation. Moreover, the EU circular economy action plan targets microplastics by highlighting the need to tackle the unintentional release of microplastics by labelling and standardisation, and by harmonising measurement methods.

Notes

[1] UNEP (2018) estimates the contribution of washing textiles to releases of microplastics to the environment to be 9%. If, however, it is assumed that 50% of microplastics from tyre abrasion, road markings and city dust are trapped in soil, asphalt and on river banks and thus do not reach the oceans, the share of textile microplastics discharges to the ocean increases to 16%.

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