Microfibres from textiles - a key source of microplastics to the environment: *Fate, effects, and mitigation strategies*

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Background

It is estimated 12.7 million metric tons (MT) of plastic enter the environment as microplastics every year, the main sources being paint, tyres, pellets, textiles, and personal care products.[1] There are also substantial additional quantities from the fragmentation of larger items of plastic that have already entered the environment as debris. This document focuses on microfibres from textiles, which are estimated to account for an annual release of 1.02 MT of microplastic to the environment.[1]

Traditionally, textile fibres were produced from natural plant materials (e.g., cotton, linen) and animal materials (e.g., wool, silk). Other materials are semi-synthetic, or artificial fibres, such as regenerated cellulose. However, today the vast majority of textile fibres are synthetic or semi-synthetic (modified cellulosic fibres), and the market is dominated by polyester (polyethylene terephthalate, PET), followed by nylon (polyamide, PA) and acrylic (polyacrylonitrile, PAN), amongst others [2]. In other words, the majority of textile fibres are plastics.

Figure 1. Microfibers mixed with natural debris from water sampled from the Pacific Ocean off the coast of Oregon (photo credit: Anna Bolm, Oregon State University). Polycarbonate filter imaged via Leica stereoscope at 20x magnification.

Further, thousands of chemicals are used in production of textile fibres (natural, semi-synthetic and synthetic). This includes substances used in polymer production, additives like flame retardants, dyes, metals, surfactants, and antimicrobial agents, anti-wrinkle chemicals (e.g., PFAS), and non-intentionally added substances (NIAS) [3].

The plastic proportion in textiles is increasing, and consequently the plastic pollution problem is growing. The global consumption of synthetic fibres increased from a few thousand tonnes in 1940 to 67 million tonnes in 2022, and it continues to rise [4].

Microfibres are most commonly defined as fibre with a length ≤ 5 mm, that are released from textiles (natural, semi-synthetic and synthetic) during their entire life cycle (from production, to use and disposal). However, due to their unique dimensions in comparison to other microplastic types, the European Chemicals Agency (ECHA) defines them as having a length of between 0.3μm and 15mm and a length to diameter ratio of >3 [5].

Pathways and Sources

Microfibers from textiles are a key source of microplastics (MPs) in air, soil, food, and water [6,7]. Due to their low density, they are easily transported across large distances by air or water. [8,9]. Microfibre shedding occurs throughout the whole life cycle of textile products, from manufacturing to use and disposal, including recycling (Figure 1). Substantial shedding occurs during laundering, with a typical load of washing generating over 9 million microfibres. Dryers may release even more per load, particularly those that vent externally. [10,11]. The quantities of microfibres released while wearing a garment are similar to those released during machine-washing [12]. In addition, many of the world's population do not have access to washing machines and microfibres are also readily released during hand-washing, often in rivers and streams[13]. Upstream interventions will be essential to address these multiple pathways to the environment.

Impacts

The majority of wastewater treatment plants are unable to remove microfibres completely from treated effluent. Some microfibres are discharged to the aquatic environment in wastewater, but the majority are retained in sludge, which in many countries is applied as a fertiliser in agricultural settings, turning a water pollutant into a soil pollutant [14]. They can affect soil health by impacting the soil microbiome, water dynamics, and ecosystem engineers such as earthworms, [15,16] and they have deleterious effects on invertebrates such as causing reduced growth or oxidative stress [17]. Evidence suggests that compared to other shapes, fibres can more easily move from an animal's gut to other tissues and may be more difficult to excrete [18]. Under environmentally relevant exposure scenarios, aquatic organisms ingesting microfibres suffered deleterious effects on survival, reproduction, and embryo development, [21] and fibres may also have greater toxicity than other MPs. [19,20] Chemical treatments, dyes and finishes to all fibres may reduce their biodegradability [24] and can also contain toxic additives, such as bisphenols [25]. Further, despite being made from cellulosic material, semi-synthetic microfibres are found in high quantities in the environment and also have ecotoxicological effects [22,23]. Moreover, the production of these fibres requires land use, substantial energy, water consumption, and generates CO_2 emissions [26].

Potential interventions

The complexity of microfibre sources and pathways to the environment calls for a focus on upstream interventions [27]. These include reducing production and changing the way textiles are designed. Annual textile production is predicted to reach 102 million tonnes by 2030, [28] and the global fashion industry accounts for 8-10% of global CO_2 emissions and generates over 92 million tonnes of waste [26]. Thus, reducing textile production would result in multiple environmental benefits, beyond decreasing only microfibre release. Considering that similar quantities of microfibres are released both during wearing and washing [12], upstream measures are key to reduce microfibre emissions and prioritising textile features (e.g. compact structures), and manufacturing processes could reduce microfibre shedding throughout life in service [29,30]. Downstream solutions include using shorter and colder washing cycles, [29, 31] installing washing machine filters, [32] and improving wastewater treatment plants (WWTPs) [27]. However, tests indicate that some washing machine filters are ineffective [33]. In addition it has been estimated that annually 63,000 - 430,000 tonnes of microplastic are added to farmlands in Europe through the application of biosolids from WWTPs. Hence better design of textiles and innovation to reduce the microfiber content in sewage sludge being used as fertiliser are needed [34].

Key messages

- The global consumption of synthetic fibres increased from a few thousand tonnes in 1940 to more than 60 million tonnes in 2018, and it continues to rise.
- Fibres are shed throughout the whole life cycle of textile products, from manufacturing to use (laundering, drying, and wearing) and disposal. They readily disperse via water and air due to their lightweight nature and are transported across large distances.
- Microfibres from textiles are a key source of anthropogenic particles to air, soil, food, and water.
- Fibres can translocate from an organism's gut to other tissues and may be more difficult to excrete. Studies suggest that fibres may cause higher toxicity in comparison to other MPs.
- Substantial quantities of microfibers enter the environment through the application of sewage-biosolid, leading to the potential for localised accumulation in soil and effects on terrestrial organisms.
- Prioritising upstream interventions (at the textile production level) will be most effective in achieving an overall reduction of microfibre emissions.

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