Microfibres from textiles – a key source of microplastics to the environment

Fate, effects, and mitigation strategies

Introduction

Microplastics are small pieces of plastic (longest dimension ≤ 5 mm). They are widely distributed in the environment, with evidence of harm at multiple levels of biological organisation[1,2]. Microplastics originate from multiple sources; subdivided as primary microplastics, which are manufactured to be < 5 mm, including: preproduction pellets[3] and particles that are intentionally added to products such as paints[4], household and industrial cleaning products, and cosmetics. Secondary microplastics are generated by the wear of larger items including tyres[5], textiles[6] and plastic debris. It is estimated that 12.7 million tonnes of microplastics enter the environment annually[7]. They are persistent and cannot effectively be removed, hence, interventions to minimise releases are key.

This document focuses on microfibres from textiles, which are estimated to account for an annual release of 1.02 million tonnes of microplastic to the environment[7].

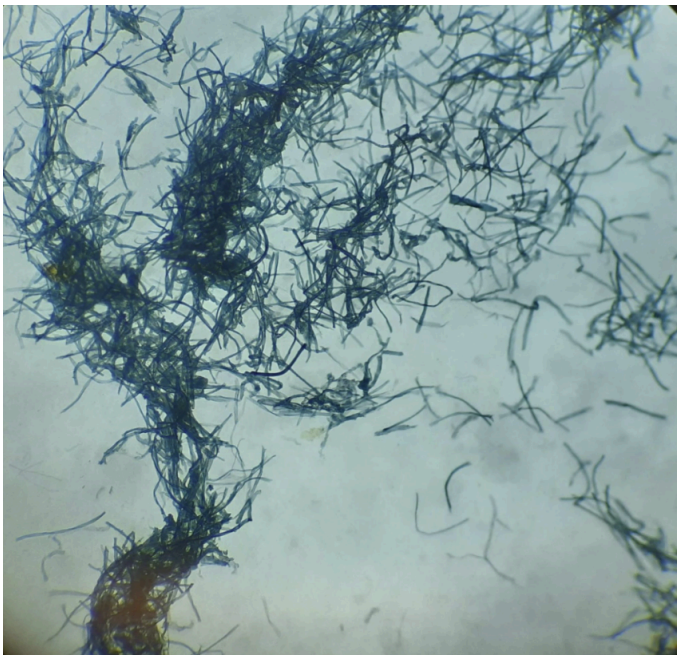

Figure 1. Microfibres visualised under a microscope.

Microfibres are fibres with a diameter of ≤ 5 mm. Fibres are released from textiles (natural, semi-synthetic and synthetic) during their entire life cycle (from production, to use and disposal).

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 such as regenerated cellulose (e.g. viscose), or artificial fibres (e.g. polyester). Today the vast majority of textile fibres are synthetic or semi-synthetic, and the market is dominated by polyester (polyethylene terephthalate, PET), followed by nylon (polyamide, PA) and acrylic (polyacrylonitrile, PAN) which are often present as copolymers, amongst others[8]. In other words, the majority of textile fibres are plastics. Synthetic fibres have dominated the fibre market since the mid-1990s. At around 91.0 million tonnes, this fibre category comprised approximately 69% of global fibre production in 2024[9]. Further, thousands of chemicals are used in production of textile fibres (natural, semi-synthetic and synthetic)[10].

Sources and pathways

Microfibres from textiles are a key source of microplastics (MPs) in air, soil, food, and water[11,12]. Due to their low density, they are easily transported across large distances by air or water[13,14]. Microfibre shedding (**Figure 1**) occurs throughout the whole life cycle of textile products, from manufacturing to use, recycling and disposal.

Substantial shedding occurs during laundering, a typical load of washing has been estimated to release over 9 million microfibres[15]. Mechanical dryers may release even more per load, particularly those that vent externally[16]. The quantities of microfibres released while wearing a garment are similar to those released during machine-washing[17]. Many of the world's population do not have access to washing machines and microfibres are also readily released during handwashing, often in rivers and streams[18]. 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[19]. 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[20]. It is also important to acknowledge that on average, while high income countries treat approximately 70% of municipal and industrial wastewater generated, this figure falls to around 38% in middle and lower middle-income countries, with only 8% treated in low-income nations[21].

Microfibres can affect soil health by impacting the soil microbiome, water dynamics, and ecosystem engineers such as earthworms,[22,23] and they have deleterious effects on invertebrates such as causing reduced growth or oxidative stress[24]. Evidence suggests that compared to other shapes, microfibres can more easily move from an animal's gut to other tissues and may be more difficult to excrete[25]. Under environmentally relevant exposure scenarios, aquatic organisms ingesting microfibres suffered deleterious effects on survival, reproduction, and embryo development[26] and microfibres may also have greater toxicity than other microplastics[27,28].

Chemical treatments, dyes and finishes added to all fibres may reduce their biodegradability[29], and microfibers can also contain toxic chemicals, such as bisphenols[30]. Further, despite being made from cellulosic material, semi-synthetic microfibres are found in high quantities in the environment and also have ecotoxicological effects[31,32,33]. Moreover, the production of these fibres requires land use, substantial energy, water consumption, and generates CO2 emissions[34].

Potential interventions

The complexity of microfibre sources and pathways to the environment calls for a focus on upstream interventions[35]. These include reducing production and changing the way textiles are designed. Annual textile production is predicted to reach 169 million tonnes by 2030[9], in addition the global fashion industry accounts for 8-10% of global CO2 emissions and generates over 92 million tonnes of waste[34]. Thus, reducing textile production would result in multiple environmental benefits, beyond decreasing microfibre release alone. Considering that similar quantities of microfibres are released both during wearing and washing[18], upstream measures are key to reduce microfibre emissions and prioritising textile features (e.g. compact structures), and manufacturing processes could substantially reduce microfibre shedding throughout life in service[16,29].

Downstream solutions include using shorter and colder washing cycles[36], installing washing machine filters[37], improving wastewater treatment plants (WWTPs)[38] and supporting infrastructure subsidies and global programmes to improve and increase WWTP coverage and capability, particularly in low and middle-income countries[35]. It is important to note that tests indicate that some washing machine filters are ineffective[39]. Hence better design of textiles and innovation to reduce the microfibre content in sewage sludge are needed.

Key messages

- The global consumption of synthetic fibres increased from a few thousand tonnes in 1940 to a predicted 169 million tonnes by 2030.
- Fibres are shed throughout the entire textile lifecycle, 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.
- Microfibres can translocate from an organism's gut to other tissues and may be more difficult to excrete. Studies suggest that microfibres may cause higher toxicity in comparison to other microplastics.
- Substantial quantities of microfibres 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 (yarn and textile design and production), will be most effective in achieving an overall reduction of microfibre emissions.

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