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A planet too rich in fibre

Microfibre pollution may have major consequences on the environment and human health

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Human waste is polluting the Earth: smog, raw sewage, chemical waste, clothes. You read correctly—clothes. Tiny plastic threads, known as microfibres, are coming off fleece pullovers and ending up all over the globe, from the Arctic to Antarctica. They are even found in seafood and drinking water. But, as microfibres inundate the planet, to what extent are they harmful to the environment and human health?

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Petroleum-based synthetic fibres are used to produce fabrics like polyester and spandex. Manufacturing, washing and drying these manmade materials shed microfibres smaller than 5 mm that can further fragment into nano-sized particles and enter ecosystems. As synthetic fibres do not easily dissolve in water, they are able to absorb other substances that leak into nature, including oil residue from combusted fuel and polychlorinated biphenyls that still lurk in the environment. Additionally, microfibres are often treated with additives, such as flame retardants.

A toxic cocktail

Some experts therefore believe it is critical to take a closer look at the health risks of microfibres and the chemical cocktails they carry around. For example, many pesticides, which can be sponged up by microfibres in the water, are neurotoxins that can cause neurological disorders. "There's a premise in chemistry that says like dissolves like, and those carbon-based materials tend to absorb carbon-based industrial chemicals," said Christopher Weis, a toxicology liaison at the US National Institute of Environmental Health Sciences. "If the materials are small enough, they may cross the blood-brain barrier."

Given their size, it is almost impossible to avoid consuming microfibres. In addition to being ubiquitous in water, microfibres have turned up in food products, including German beer and Chinese sea salt, as well as in people [1,2,3]. "Textile fibres were first noted in the lungs of humans in a publication in 1998 [4]," said Dick Vethaak, an ecotoxicologist at the water research institute Deltares (Delft, Netherlands). "What we know is that we are exposed […] through food and through breathing. But what we need to know is the extent of the exposure, what these fibres do in our body when inhaled or ingested, and in [the] case of translocation into our circulation, where do they go and how long do they stay in the body?" Although many questions still need answers, correlations exist between chemicals that leach off plastics and a laundry list of illnesses. And according to that 1998 study, "plastic fibres are candidate agents contributing to the risk of lung cancer."

However, Gary Schiltz, a professor of chemistry at Northwestern University in Evanston, IL, USA, believes there is not enough evidence to panic—yet. But he does agree that the size of the fibres being consumed could cause concerns. Smaller particles would remain in the body longer and possibly irritate the digestive tract. Conversely, larger microfibres may not cause much harm—and are likely defecated. "I think most fibres are going to pass unchanged through the digestive system. The amount of microfibres that you're ingesting is probably relatively small, and the amount of possible toxins is probably even smaller," Schiltz explained. "As of now, there hasn't really been any [definitive] documentation of this contamination's contribution to disease. I don't think it's likely having a significant impact on human health." He added that studying microfibres has its value; but other problems, like cancer and heart disease, merit more attention. "There are many more pressing biomedical questions," Schiltz said. "It doesn't seem like people are dying in the streets every day from ingesting microfibres."

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Not everyone concurs. A 2016 article by Dutch scientists, including Vethaak, warned that "plastic debris is a human health issue," and exposure to microfibres carrying pathogens increases risk of infection [5]. "We have enough reason to be concerned right now," said Sherri Mason, a chemistry professor at the State University of New York at Fredonia. "The chemicals are in us, there's no doubt about it. We just don't know the most prominent way that they're getting into us […] even if we ever get all the answers, by the time we got them, it would be too late."

Global abundance of fibres

While the effects of microfibres on human health are still being debated, scientists are

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also exploring their impact on the environment. In 2011, ecologist Mark Browne, now a senior research associate at The University of New South Wales in Sydney, Australia, published a seminal article on microfibre pollution [6]. Browne and his research team found that plastic fibres smaller than 1 mm comprised most of the shoreline debris on six continents. Their study was also the first to prove that clothing produces plastic waste on the microscale and concluded that a single synthetic garment could shed almost 2,000 fibres per wash. Building on Browne's work, scientists at Plymouth University in the UK, Browne's alma mater, determined that the wastewater from a 6-kg load of synthetic laundry could carry more than 720,000 microfibres.

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Mason identified microfibres as the most pervasive microplastic from wastewater treatment plants, which, on average, release more than 4 million particles daily; these particles can end up in freshwater habitats and eventually seafood. "We looked at 25 species of Great Lakes fish, and every single species had plastic in their guts," Mason said, referencing unpublished results. "The dominant type of plastic that we found was microfibre." Chelsea Rochman, now an assistant professor at the University of Toronto in Canada, examined seafood contamination in American and Indonesian markets. Fish from both countries had ingested microplastics, and 80% of the debris contamination in the guts of American fish was from microfibres. But not a single microfibre was retrieved from any Indonesian fish [7]. "This was shocking to me because microfibres seem to be so common across studies," Rochman said. "Our results suggest the microplastic types we find in certain areas may depend on the source. In Indonesia, more clothing is hand-washed, and the hot weather would suggest they are not laundering as much fleece."

Despite Rochman not finding microfibres in her Indonesian samples, other scientists have detected them in African bird gizzards and the deep sea. "They seem to be one of the most common debris found in remote areas, which says to me that they may be circulating with atmospheric currents," Rochman said. "One study found microfibres in atmospheric fallout—or rain." Indeed, several studies have documented microfibre contamination in almost every type of water outlet, including freshwater reserves.

Environmental impact

After he discovered that microplastics are abundant in aquatic habitats, Browne decided to test the materials' effects on marine life. "Against modeling predictions from environmental chemists, when we give plastic particles to organisms, chemicals transfer from the plastic into the organisms and cause quite substantial impacts," Browne said. A 2015 study revealed crabs eat less and lack energy for growth after ingesting 1- to 5-mm-long polypropylene microfibres [8]. Researchers also found that the mortality of adult freshwater daphnid zooplankton increases after microfibre exposure [9]. Zooplankton are tied to microscopic aquatic plants called phytoplankton, and contrary to popular belief, the majority of Earth's oxygen comes from phytoplankton—not trees. "If zooplankton are adversely affected by plastic and that in turn affects phytoplankton, then less CO_2 is being taken in by the world's oceans, which means that more CO_2 is going to stay in the atmosphere," Mason said.

Even though the zooplankton analysis only evaluated the effects on a specific organism, it could lead to educated inferences. "If you can show that fish exposed to plastics with these chemical contaminants undergo certain impacts, then you can assume those things are probably also happening to people," Mason added. However, Schiltz disagrees with such assumptions. "We can take some clues from what's going on with various organisms, but I think there's limited use in studying the effects on humans," he said. "How fish behave, how they eat and how their bodies work is much different from people."

Global and national responses

It was Mason's research that eventually prompted the World Health Organization (WHO) to take a closer look at the effects of microplastics—and microfibres—on human health. In 2017, while collaborating with Orb Media, a non-profit journalism organization, Mason detected microplastics in 81% of tap water samples from across the world—98.3% of the debris consisted of microfibres. In 2018, she discovered microplastics in 242 out of 259 bottled-water samples from nine countries. "WHO, as part of its continuous review of new evidence on water quality, would review the very scarce available evidence with the objective of identifying evidence gaps and establishing a research agenda to inform a more thorough risk assessment," said WHO spokesperson Tarik Jašarević.

Back in the United States, federal legislation to curb the release of fibres into the environment is not on the horizon. "The microfibre issue is still emerging," said Nancy Wallace, chief of the Marine Debris Division in the US National Oceanic and Atmospheric Administration's (NOAA) Office of Response and Restoration. She explained the US government primarily takes non-regulatory approaches, mostly via research efforts. For example, NOAA funded a collaborative project with Clemson University in South Carolina, USA, and the US National Park Service to quantify microplastic pollution on beaches.

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At the state level, a 2018 bill introduced in California proposed that clothing primarily made of synthetic material must display a label that warns of microfibre shedding in the washing machine. Unfortunately, the bill did not pass. "We need to at least provide the public with the information about the problem so that they can decide if they want to take actions to reduce their personal impact," said Melissa Romero, a policy associate for one of the bill's co-sponsors, Californians Against Waste. "Some manufacturers haven't even acknowledged that [microfibre pollution is] a problem, and others have proposed solutions that put the burden on the consumer, not on the producer."

Despite no current plans to enforce microfibre legislation, the United States is taking action to limit other forms of microplastic waste. One effort is a federal ban on adding plastic microbeads to products like exfoliating cleansers and toothpaste. "This law expanded upon individual state laws banning microbeads [...] and addresses cosmetic product standards regulated by the Food and Drug Administration," the US Environmental Protection Agency (EPA) wrote in an emailed statement. "Legislation to regulate microfibers will be more complex than for microbeads in wash-off cosmetics because microfibers may form from the breakdown of a large range of products."

The EPA noted there are no regulations addressing microplastics or microbeads under the agency's statutory authorities. However, there are attempts to decrease the amount of plastics in the ocean on a larger scale. In August 2017, the US Senate passed the Save Our Seas Act, a bipartisan bill to globally reduce marine debris. Though a step in the right direction, some believe such legislation has to reach further. "It's disturbing that there's not much movement to reduce rates of input and understand impacts caused by the most abundant form of plastic debris that we find on the planet," Browne said. "Large amounts of resources are being put into banning plastic bags and microbeads even though microfibres occur in much larger quantities and are being ignored."

Other countries are also taking tentative steps to decrease plastic waste. Similar to the USA, Canada and the UK have enforced microbead bans but still lack restrictions on microfibres. The German Federal Institute for Risk Assessment (Bundesinstitut für Risikobewertung) had asked the European Food Safety Authority for a report on microplastics and nanoplastics—including fibres—in seafood. The report, published in 2016, ultimately concluded that further research is needed due to insufficient data. In February 2018, the European Union proposed to amend the Drinking Water Directive by adding, "...microplastics which are considered relevant based on a hazard assessment will be regularly monitored in water bodies used for the abstraction of drinking water [sic]." Earlier, in 2013, the European Union commissioned a 2-year project called Mermaids Life+ to find ways of reducing microplastic and nanoplastic pollution. It concluded that fabric softener can "reduce the friction between the fibres and decrease their probability to break," and using liquid detergent and lower water temperatures is also effective.

The Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP), an advisory body of the United Nations (UN) that provides counsel on "the scientific aspects of marine environmental protection," started investigating microplastics in 2008 and formed a group of experts in 2012 to provide an authoritative assessment on microfibre effects. "This is a global issue, so we've been treating it as such and bringing scientists from various countries together, and with them, not just expertise, but different perspectives," said GESAMP Chair Peter Kershaw, who specializes in marine environmental research.

Although international organizations like the UN and WHO are now taking microfibre pollution more seriously, there still is not enough public demand for regulating fibre production. "It's far too early to talk about legislation because you cannot stop people from wearing artificial fabrics," Kershaw added. According to Rochman, legally curbing microfibre production would be hard because of limited alternatives. "How do you ban microbeads? Super easy. There's no need for them, and there's a replacement ready to go. How you ban microfibres? That's difficult. We're not going to stop wearing clothes, and we're not going to stop washing them," she said.

Reducing pollution

Some eco-conscious companies are already taking action. Patagonia, which manufactures sustainable outdoor clothing, commissioned researchers from the University of California, Santa Barbara, to determine the quantity of microfibres released by washing machines. A team of graduate students and their advising professor, Patricia Holden, found that washing a new synthetic garment releases up to 2 g of microfibre sheddings (more than 0.3% of a garment's mass) [10]. Patagonia also encourages not washing artificial clothes too frequently and using special laundry bags to catch microfibres. Other companies have developed washing machine filters to capture microfibres before they go down the drain.

"Putting something in your washing machine is doable," Holden said. "Solutions you could use on a mass scale need to be easy and affordable." However, "it would be almost impossible to prevent clothing made of microfibres from shedding, and it would be impossible to catch all those fibres in any kind of trap that's in a domestic washing machine," Weis noted. "These things are small enough to go right through a vacuum cleaner bag, and while some of them are caught, many blow right through the bag and back into the air."

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But that does not mean hanging up artificial clothes in the closet for good. Kershaw advises against finding organic alternatives without fully understanding potential disadvantages. "If you want everyone to wear cotton instead of acrylic, you have to look at what that means in terms of cotton production," Kershaw said. "Cotton uses huge amounts of water. It uses huge amounts of pesticides and herbicides, and it's often grown in countries where there's little legislation for things like environmental and human health."

Conversely, synthetic fabrics are more polluting than natural textiles because they do not decompose easily. Plastics are designed to resist degradation and can take thousands of years to disintegrate. "Microfibres slowly break down into smaller and smaller components, including nanosized pieces," Weis said. "The smaller they get, the more difficult they are to remove from the environment."

Solving the problem

The good news is that there may be a solution. In April 2018, a paper in the *Proceedings of the National Academy of Sciences* described an engineered enzyme that can break down polyethylene terephthalate—commonly known as PET—in the water [11]; after an earlier discovery of a PET-degrading bacterium by Japanese scientists [12]. However, only time will tell if the enzyme is successful on a large scale and whether similar methods can be used for other plastics.

Whereas most microfibre research focuses on reducing pollution, the existing

waste is met with silence. For now, the only option is to wait for the fibres to be buried under deep layers of sediment. "We really have to focus on eliminating microfibres at the source and give Mother Nature time to clean herself out," Mason said.

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