How we are contaminating our waters with microplastics and a multitude of chemicals

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A plastic sandwich wrapper bobs in the water where the Limmat River flows out of Lake Zurich. The current carries it downstream through Zurich's historic center before eventually depositing it on the bank of

Werd island. Exposed to sunlight, it gradually breaks down into smaller and smaller pieces, which the rain then washes back into the river. Pebbles on the bed of the Limmat grind the fragments of plastic into even smaller pieces until they are all but invisible to the naked eye. What started out as a sandwich wrapper has now turned into microplastic.

Microplastics—tiny pieces of plastic that are smaller than 5 millimeters in size—are now ubiquitous. "You find microplastic particles everywhere, from mountain lakes and spring water to the most remote regions of the world's oceans," says Denise Mitrano, Assistant Professor of Environmental Chemistry of Anthropogenic Materials at ETH Zurich. She studies where microplastics come from, how they behave in the environment and whether they pose a risk to aquatic organisms.

Microplastic pollution stems not only from discarded plastic waste, but also from tire abrasion, textiles and personal care products such as shower gels and toothpaste that use plastic microbeads as an exfoliating or scrubbing agent.

The entire nutrient cycle

Researchers are currently investigating how harmful microplastics are to humans, animals and the broader ecosystem. One of the biggest challenges is establishing how much microplastic is present in the environment. To make this task easier, Mitrano and her colleagues have developed a new analytical method involving a polymer to which a metal has been added. This metal-enhanced plastic is ground into particles on the micro and even nano scale, some of which are far smaller than a micrometer in size. By analyzing the metal contained in these particles, researchers can measure the quantity of microplastics in water, soil and tissue samples. This allows them to study the transport and fate of microplastic particles as they pass through organisms and accumulate there or in the environment.

In one of her experiments, Mitrano examined whether nanoplastics harm daphnia. Commonly known as water fleas, these tiny crustaceans filter plankton from the water for food. In doing so, they also ingest plastic particles. Her study confirmed that daphnia do indeed ingest nanoplastics but that they subsequently excrete them, seemingly unharmed. There appears to be no impact on their reproduction or growth. It is only after a few generations that impairments to their energy metabolism begin to show.

Mitrano's research has also shown how nanoplastics can cross the intestinal barrier in fish and end up in muscle tissue. "This didn't result in the fish dying, so it's likely that the particles are not acutely toxic," says Mitrano.

But that doesn't mean we can lower our guard, Mitrano adds. She explains how microplastics form clumps with planktonic algae in both freshwater and seawater, speeding up the algae's sedimentation rate. This is just one example of how microplastics can affect the entire nutrient cycle of a body of water—an indirect polluting effect that is often underestimated. "Microplastic research to date has primarily focused on direct effects. We need to expand our research to include evaluations of negative impacts at the ecosystem level and to analyze the ecological implications," says Mitrano.

Microplastics also have other indirect effects, such as their tendency to release toxic substances. Manufacturers incorporate hundreds of additives into polymers to give them the desired properties. "We should therefore be asking what's really causing the harm: the polymers themselves, the shape and size of the microplastic particles, or the additives released by the polymers," she says.

Countless chemicals

Substances that leach from microplastics are far from being the only chemicals in the water. Over the past few decades, the chemical industry has created hundreds of thousands of compounds. In Europe alone, 26,000 new substances in quantities of at least one metric ton come onto the market each year. In most cases, their eventual fate remains unclear.

Kris McNeill, Professor of Environmental Chemistry at ETH Zurich, has long been interested in such questions. His research focuses on how synthetic organic molecules—particularly, active pharmaceutical ingredients—act as toxins in the environment and how they degrade. "From drugs and cosmetics to pesticides and fertilizers, everything we use in everyday life eventually ends up in rivers and oceans," he says.

Triclosan, an antimicrobial agent, is a good example. Originally used in hospital hand sanitizers in the U.S., it gradually found its way into numerous consumer products during the 1970s. By early 2000, 95% of all liquid hand soaps in the U.S. contained triclosan. Only later did it become clear how unnecessary this ingredient actually was.

McNeill and his colleague William Arnold were able to demonstrate how sunlight breaks down triclosan in wastewater into dioxins, a group of highly toxic chemical compounds. "Sunlight can render many toxic substances harmless. But in this case, you end up with something much worse," says McNeill. Minnesota, where they conducted their research, became the first U.S. state to prohibit the use of triclosan in consumer products. In 2016, the Food and Drug Administration (FDA) announced a ban on triclosan and other antimicrobial agents in certain products—a rare victory for the environmental chemist. "It's great to see that our results played such an important role in that decision," he says.

This case illustrates how environmental chemistry tends to lag behind the chemical industry. First, chemical companies invent new substances that rapidly enter into widespread use. Years later, environmental chemists such as McNeill discover that the chemicals are harmful to humans, animals and the environment. "It takes 30 to 40 years for the authorities to put regulations in place or announce a complete ban based on scientific studies," says McNeill. He argues that the process should be reversed, requiring the chemicals to be scientifically assessed before they are used. "This is the only way that we as a society can prevent a repetition of tragedies caused by chemicals like triclosan and all the other environmental toxins such as the industrial chemical PCB and the insecticide DDT," he says.

Provided by ETH Zurich

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