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Clean water thanks to microplastics

He swam the entire length of the River Rhine to draw attention to the contamination of rivers and oceans with plastic waste. After completing his mammoth swim, Prof. Dr. Andreas Fath decided to kill two birds with one stone and do something useful with microplastics. At the Furtwangen University of Applied Sciences campus in Villingen-Schwenningen, Fath is working on a filter system made of plastic waste that can be used to remove pollutants from contaminated water.

Ein Chemiker im Wasser: Prof. Dr. Andreas Fath von der Hochschule Furtwangen.
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Seventy years ago, only one and half million tonnes of plastic were produced globally, now the figure stands at almost 400 million tonnes. Packaging material accounts for as much as 40 percent of the plastic produced. Every year, 28 million tonnes of plastic waste are produced in Europe, including eight to nine million tonnes in Germany alone. Depending on the type of plastic, it takes between 400 and 600 years to decompose. When it is discarded or deposited in landfills, plastic breaks up with the help of physical and chemical processes. Big pieces of plastic end up becoming microplastics that can no longer be collected and can therefore find their way into rivers.

Plastic: a blessing or a curse?

Plastic is a durable and lightweight smart material that has huge application potential. However, the material's advantages are also its downfall. It is very robust and cannot be broken. The additives that make plastic material soft and more durable, are often toxic to humans and animals. But there is no place on earth where microplastics have not yet been found. Microplastics are in our food, our meat, our drinking water and in salt. Our crops come into direct contact with microplastics as fertilisers spread on fields are made from compost that contains large quantities of plastic. Plastic materials that have been disposed of improperly are shredded along with the compost material. Research into the effects of plastics on rivers and lakes and the animals that live there has only just begun. A 70 percent loss in diversity has been recorded in rivers and lakes since the 1970s. Prof. Dr. Andreas Fath from Furtwangen University of Applied Sciences believes that this is due to trace substances.

Hormones, xenohormones and pesticides are omnipresent

Andreas Fath on an important mission: a journey along the Rhine in search of pollutants.
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Fath swam the Rhine in 2014 and the Tennessee River in 2018. "I had a passive sampler on my leg, a plastic membrane to which 128 different substances attached during the swim," says the chemist. Fath wanted to find out which substances are found in rivers while also drawing the public's attention to the pollution of the waterways. As a wastewater expert, Fath had already developed a process to mineralise pollutants in industrial wastewater using an electric current that renders the pollutants harmless. In 2011, Fath received the Fraunhofer UMSICHT Science Award for this invention. Trace substances such as antibiotics, hormones, pesticides and microplastics are found in all water courses in the world. It goes without saying that substance concentration is significantly higher at the mouth of the Rhine where it flows into the North Sea than at its source in Switzerland.

The hormone ethinylestradiol that is widely used in birth control pills, to name but one example, is not metabolised completely by the time it is eliminated from the body through urine, ending up in wastewater. Phthalates from plasticisers, some pesticides and UV stabilisers also behave like hormones and can disrupt the metabolism of living creatures. They cannot even be degraded completely in treatment plants. Although these substances are only present in very low concentrations, they are nevertheless biologically active substances that influence the reproduction of aquatic organisms. "As little as one nanogramme of hormones can affect the reproduction and growth of amphibians," explains Fath, "but we are unable to even detect such a small amount."

Microplastic as Trojan horse

Organic contaminants are attracted by nonpolar microplastics due to their nonpolar properties. ‘Same with the same dissolves’ as chemists say. Plastic particles act like magnets on many contaminants - they collect molecules on their surface and also ingest some. As particle size decreases, the surface area per unit volume increases. This is the reason why smaller particles have larger numbers of attachment sites than larger particles. Basically, microplastic, itself a major contaminant, acts like a passive sampler, accumulating even more harmful pollutants in water than are already present in sediment and suspended matter. Contaminated microplastics are so small that they can even be ingested by the smallest aquatic animals without realising or mistaking the pieces for food.

Microplastics can have a major effect on the hormone system in the body of aquatic organisms, as the hormone quantity in microplastic particles is many times higher than in the surrounding water. Fath found a 45,000-fold higher concentration of ethinylestradiol in polyamide particles compared to water. The gastrointestinal tract of these animals favours the release of substances attached to the microplastics, which are then delivered to the body. The effects on humans are unclear, as long-term studies are not yet available.

Plastic waste as a valuable material

We have plastic waste that clogs our water courses, seas and soils, and we have pollutants that we do not want in our drinking water. Fath has been looking to improve this situation and came up with the idea of processing plastic waste into microplastics in order to produce pollutant filters. The material for producing such filters is already floating around in the oceans; driftnets and fishing lines are well suited to Fath’s purpose. However, not all plastics are the same. "I cannot just empty the yellow plastic garbage bags (used in Germany for recycling plastic waste), disintegrate the plastic and make microplastic from it,” jokes the researcher. Different plastics adsorb different pollutants." So the idea is to use a special plastics mix for the filter,” Fath says. Large amounts of plastics waste accumulate in 3D printing or laser sintering. If this plastic waste could be used for producing the filters, garbage would become valuable. One possible solution would be a deposit system like the one we already use for bottles. “People would then be encouraged to return the garbage rather than throwing it into the water or discarding it in the countryside.”

At present, only activated carbon filters are used to remove hormones from water. However, producing activated carbon from biomass to form enough caverns for the attachment of organic substances is extremely expensive. Additionally, the caverns are quickly full, because all kinds of organic substances, even harmless ones, attach to them. Once the activated carbon filters are fully loaded with molecules, they need to be incinerated at 1400 degrees Celcius to remineralise the materials that have been recovered. This type of filter therefore has a very short lifetime and requires energy for combustion.

The advantage of a filter made of microplastics would be that the material is renewable. Once the plastic granules are loaded with pollutants, one idea would be to separate the pollutants from the surface of the granules using a solvent and then reuse the filters. “Even if I could not recover the plastic material, burning the plastic filters along with the pollutants would still be better than finding plastics in the sea or countryside,” says Fath.

Use and application

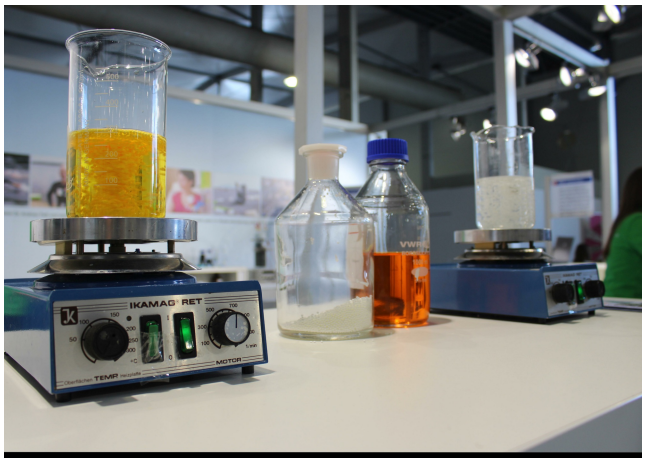
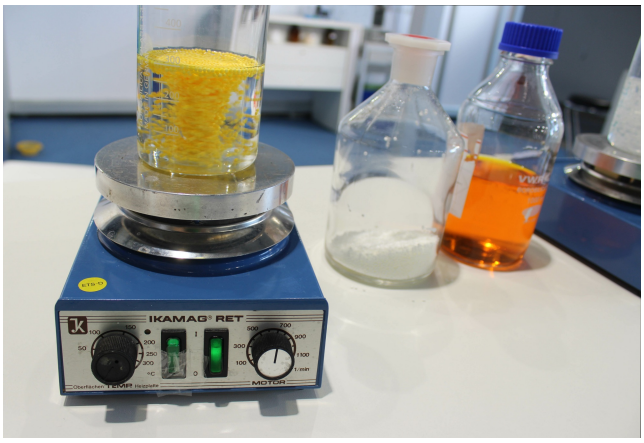


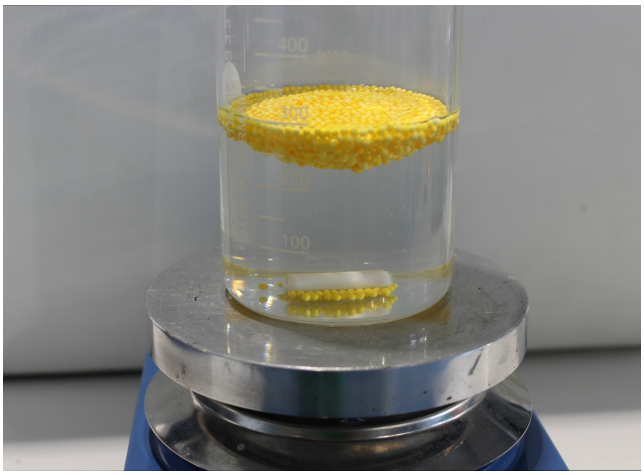
Photo showing how microplastics can act as magnets: white microplastic granules immersed in yellow dye.



Stirring the mixture causes the yellow dye to attach to the granules due to chemical interactions…

The microplastic filter can be imagined as a high column made of glass or plastics with a porous bottom to which microplastic granules are added and dirty water poured on top. “The

substances dissolved in the water accumulate on the plastic column and will subsequently no longer be found in the water phase," explains the scientist. Meanwhile, research continues: Raphael Bosch, a master's degree student in Fath's group, is working on finding more ways to increase the surface area of microplastic particles, thereby adding potential for attachment. The particles Bosch is working on look rather like golf balls or brains.



...and the result: clear water.

Fath has already been contacted by wastewater treatment plant operators. In Baden-Württemberg, the normal procedure for disposing of sewage sludge is to incinerate it. The sludge cannot be used for anything else as it is too contaminated. For every tonne of sewage sludge that needs to be disposed of there is obviously a financial cost. Therefore, sewage sludge is usually dewatered using belt filters or centrifuges in order to reduce costs. The separated water is heavily contaminated. The water could conceivably be filtered through a microplastic filter to extract most of the organic matter. But it would be much better to start at the source ("start of the pipe") where the pollutants enter the water instead of at the "end of the pipe" in sewage treatment plants. Hospitals, for example, release vast amounts of antibiotics and X-ray contrast media into the environment, which causes heavy contamination. Fath is clearly in favour of a start-of-the-pipe solution: "We should not just be looking at removing the pollutants in wastewater treatment plants, but rather hold them back where they occur, namely in industrial plants, hospitals and retirement and nursing homes."

Article

01-Aug-2019
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The article is part of the following dossiers

Bioökonomie: ein neues Modell für Industrie und Wirtschaft

antibiotics | water | pesticides | microplastics | additives | trace compound | xenobiotics | plasticiser