Project on Removing Microplastics from Wastewater and Environment

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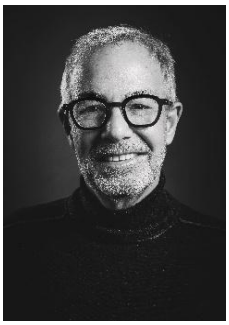

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Preface - Microplastic Elimination

For a healthy environment

Awareness of the impact of microplastics on aquatic, oceanic and terrestrial environmental systems is increasing. According to the unanimous opinion of renowned experts worldwide microplastics in the terrestrial environment and especially in inland aquatic waters pose as great a threat to biodiversity and the health of terrestrial ecosystems as they do to the oceans, with negative feedback effects on the food chain and ultimately on human health. The problem of microplastics (MPs) is linked to another problem caused by climate change: the lack of fresh water. Clean water is becoming increasingly scarce and therefore serious consideration must be given to whether this clean water can continue to be used to irrigate fields. Around 75% of the world's fresh water is used in agriculture. Against this backdrop, more and more treated wastewater is being used in agriculture.

Although the two issues are often not associated with each other, climate change and plastic and microplastic pollution are directly and indirectly linked, and both are among the biggest environmental problems facing humanity today. (Bergmann et al. 2022).”

Plastic as a player in climate change

Plastic generates greenhouse gas emissions throughout its production and life cycle, including fossil fuel extraction and transport, refining, manufacturing, distribution, use, disposal, waste management and plastic in the environment. According to research, plastic can account for up to 20% of the global annual greenhouse gas budget (Hamilton et al., 2019). Plastic production is also increasing, leading to a rise in plastic pollution. The OECD predicts that plastic waste in water bodies will increase from 140 million tonnes in 2019 to 493 million tonnes in 2060 (OECD, 2021, 2022).

Plastic particles as small as 1.0 µm can penetrate cell walls. In 2022, a Dutch working group (Heather et al., 2022) reported the detection and quantification of microplastics in human blood. In 2024, a research group (Sheng-Han Lee et al., 2024) from Taiwan reported on studies in mice. The experiments showed that exposure to microplastics (0.2 µm and 0.8 µm) caused dysbiosis and metabolic disorders in the intestines and brains of mice.

The climate crisis is exacerbating plastic pollution of ecosystems

Research results worldwide clearly show that extreme weather events release large quantities of plastic and microplastic waste from terrestrial sources such as landfills, riverbanks and coasts, which then enter the marine environment (van Emmerik et al., 2023; Meijer et al., 2021) and have a massive impact on biodiversity and the food chain.

The implications and solutions must apply to the entire pathway of macro- and microplastics

By consistently implementing technological, political, economic and behavioural solutions, it is possible to reduce plastic pollution by up to 80 % in the short term (UNEP 2021, 2023). Solutions should not only address the immediate problem, but also take into account possible interactions with other planetary crises, such as the loss of biodiversity, which is accelerated by plastic pollution. It should also be borne in mind that the progressive decomposition of microplastics in the natural environment releases heavy metals and organic compounds such as phthalates, so-called plasticisers with hormone-like effects (Passarelli et al. 2021).

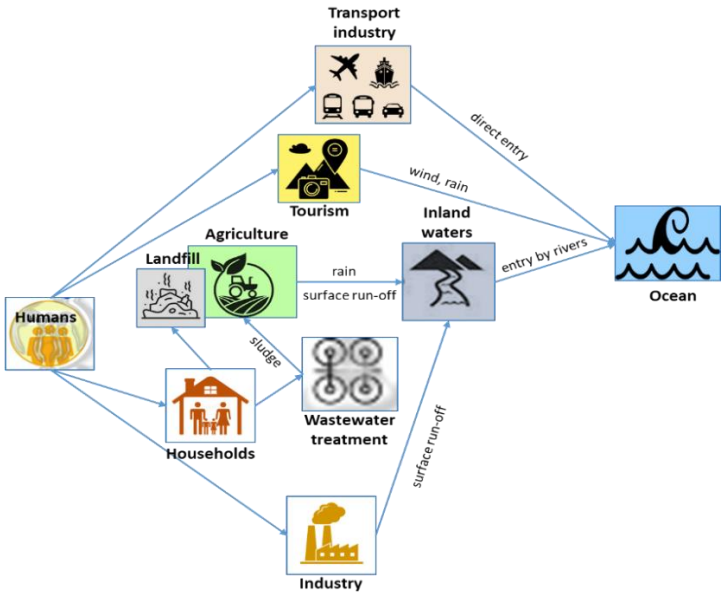

Fig. 1 Polluters and plastic/microplastic pathways

When considering sources that contribute to the pollution of surface waters with microplastics, the focus is not only on the processing industry, public spaces or landfills, but also on

wastewater treatment plants. Figure 1 provides an overview of the most common input pathways.

Microplastics are defined as plastic particles from sizes smaller than 5 mm (Andrady, 2011; Fendall & Sewell, 2009; Moore, 2008; Parliament, 2008). A lower size limit of MP was defined as 0.33 mm, which corresponds to the usual opening size of manta trawls used for sampling in surface waters (Setälä et al., 2016). However, in more recent studies, the lower limit of 0.33 mm MPs is not generally applicable and a lower size of 1 µm diameter was agreed upon (Kershaw & Rochman, 2015). MP particles with a size range between 5 mm and 1 µm originate from different sources and can be divided into primary and secondary MPs. Primary MP are produced industrially, such as microspheres in cosmetic products and resin pellets. Secondary MP are produced by the degradation of large plastic particles through physical and chemical processes in the natural environment (Andrady, 2011).

How can microplastics be effectively eliminated?

The urgent need to reduce microplastic emissions is now undisputed. However, the approaches for this are extensive and must be adapted to the respective emission pathway. One of these emission pathways of MP into the environment is wastewater and sewage sludge from wastewater treatment plants.

In industrialised countries, but also in developing countries with efficient wastewater treatment plants, wastewater from households and public spaces (streets) is usually collected in the sewage system. During periods of low rainfall, wastewater is mainly contaminated with primary MP, such as from cosmetics and personal care products, as well as secondary MP, which is released when clothes are washed. During rainy periods, MP from the air, from traffic (tyre abrasion) and from the weathering of plastics also enters the sewage system. This MP load enters the wastewater treatment plant where it is distributed in the wastewater and sewage sludge. Important questions that arise here concern the residence time of the MP particles and their distribution in the treatment stages and how much of it is later released into the environment, especially the aquatic environment (Kvale et al., 2021), via the treated wastewater.

Weiyi Liu et al. (2021) report in their review, which is based on data from 38 wastewater treatment plants worldwide (developing and industrialised countries), that primary and secondary treatment processes achieve similar efficiency in removing microplastics. However, all reports emphasised that as much as 95-97% of microplastics are retained in sewage sludge. The tertiary treatment process achieved only limited removal efficiency. Due to the differences between oxidative processes (advanced oxidation processes (AOP)) and adsorption technologies (e.g., activated carbon), there was a wide range of efficiency. The overall comparison of microplastic removal from treated wastewater before discharge into surface waters resulted in the following ranking of technologies: activated carbon filters, pre-treatment, bioreactors (except A^2O and biofilters), sand and grease separation with pre-treatment, and AOP.

A promising technology for removing microplastic from wastewater and surface water

However, the aforementioned elimination processes require a considerable amount of energy, chemical additives and the reprocessing of the adsorption material. A promising technology

that can replace these processes is based on microflotation. Its use requires neither chemical additives nor a high energy input for the removal of microplastics.

As part of a cooperation project between the University of Braunschweig (Germany), the University of Jordan and the technology developer Microbubbles GmbH (https://microbubbles.org/en/mainpage/), the use of microflotation technology in sewage treatment plants and surface waters such as reservoirs is being investigated (Haarstrick et al., 2025; Kaur et al., 2026). This technology utilises the physical properties of microbubbles to capture the MP in the water and transport it to the surface (Figure 2). The hydrophobic properties of the microbubbles enable microplastic particles and pollutants to be eliminated. Microflotation works purely physically, without the use of chemicals and significant energy savings. It can be used not only in open waters, but also semi-stationary in various areas of wastewater treatment plants. The technology also harbours great opportunities for a new, modular approach in wastewater treatment plant architecture.

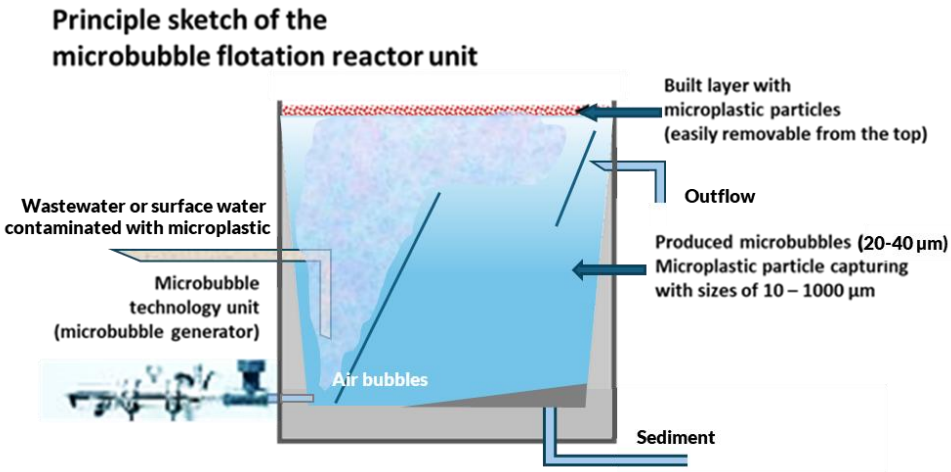

Fig. 2 Microflotation reactor unit

The aim of the cooperation between the partners from the University of Braunschweig (Germany), the University of Jordan, the Royal Science Society, and the technology developer Microbubbles GmbH (Germany) is to investigate the efficiency of microflotation technology and to demonstrate how this technological approach can be used to purify contaminated inflows into surface waters (rivers, lakes, dams) without chemical additives in such a way that it can be safely used for irrigation in agriculture. This also has a social dimension, as the quality of water used for irrigation can be improved while minimising the risk to human health from microplastics.

Further activities

The collection of data on microplastics in collaboration with Jordan's largest wastewater treatment plant, AS-Samra, has shown that despite the high microplastic retention by the treatment plant, a considerable amount of microplastics can still enter surface waters via the effluent wastewater.

The considerable amount becomes particularly clear when one considers the plant's capacity of 360,000 m^3/d to 400,000 m^3/d. Another issue is the use of the treated wastewater for irrigating agricultural land. This water is first collected via a canal in a reservoir (King Talal Dam) and from there directed into various canals and smaller rivers that are used for irrigation. One idea that could accompany the next project step would be to treat the water from the reservoir outlet

using microflotation technology to remove up to 99% of the microplastic particles, or to install a system at the effluent outlet of the wastewater treatment plant.

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