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Microfibers in the Riverine Environment

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Abstract Both the cellulose-based (CB) natural and petroleum-based (PB) artificial microfibers originating from wastewater treatment plants and atmospheric deposition are characteristic contaminants in the riverine environment. Due to their extremely slow degradation and long resident time, the research interest is focused first of all on the PB-microfibers. However, if we consider the similar harmful effect of the ingested natural or artificial microfibers on the microorganisms, first of all on the zooplanktons (e.g. cladocerans, rotifers, copepods) and the fact, that the biodegradation of CB-microfibers also needs a few months or half a year, it is evident that both type of these contaminants have negative effect on the aquatic ecosystem. Namely, the endangered zooplanktons form the base of the aquatic food web and its stability is threated by the ingested microfibers. Our investigations in this topic were focused at first on the microfiber emission of a wastewater treatment plant (WWTP) in Budapest studying the microplastic and microfiber concentrations in the effluent.

Keywords: microfiber, WWTP, river

1. Introduction

"The effluents of municipal wastewater treatment plants located along riverbanks are the main sources of various solid particles (fibers, fragments, and pellets) influencing the aquatic life in the riverine environment. Due to their resilience and extended life cycle, microplastic particles (less than 5000 μm in size) have been in focus during the last decade. However, in the treated communal wastewater, a variety of anthropogenic fibers, including natural cellulose-based and petroleum-based fibers are the predominant solid particles" (Tserendorj et al. 2024).

2. Materials and methods

The treated wastewater was passed through a three-stage steel sieve system with mesh sizes of 710, 180 and 63 μm, driven only by gravitation. Owing to the clogging of the 63 μm sieve, the collected particles represent nearly 125-145 L of treated wastewater. The solid particles and the dark braun organic matter from the sieves were washed into glass bottles with bidistilled water and the suspension passed through this finest sieve were also added and filtered using glass fiber filters with pore size of 0.7 μm. The biofilms and other organic matter were removed from the filters by hydrogen-peroxide (30%) treatment for seven days. For characterization of microfibers according to length, diameter and colour, the fibers were hand-picked individually from the dried glass fiber filters using a tweezer and fixed on a gel lifter. Stereo- and fluorescence microscopes were used for morphological investigations. The chemical composition of microfibers was identified by FTIR spectrometer in transflection mode.

3. Results

To characterize the microfiber transport, 3056 fibers were individually investigated. The microfiber concentration in the effluent varied in the range of 1.88-6.79 items/L and the proportion of microfibers among the solid particles changed between 78 and 95%. In all cases the CB-microfibers were dominant (53-91 %). This is an unexpected result, if we consider that the man-made, PB fibers (polyester, polypropylene, polyamide etc.) are dominant in the textile market over the world. The median length and diameter of CB-microfibers varied between 650-1250 μm and 21-29 μm, respectively. The daily microfiber transport from the investigated WWTP to the Danube River changed in the range of 0.44-1.53 billion. The higher occurrence of CB-microfibers can be explained by the presence of disintegrating toilet paper made of wood-based materials or recycled papers. Their proportion is strongly depends on the efficiency of the pre-filtration step in the WWTP.

Considering these results, it would be necessary to decrease the microfiber emission of municipal WWTPs into the rivers applying modern technologies in the following industrial domains:

1. the textile industry must develop new fabrics with lower shedding and reduced mass loss during the washing procedure,

2. the washing machine manufacturers must develop efficient filtration system and optimize the agitation,

3. the toilet paper manufacturers need to develop new paper structures that reduce disintegration and facilitate the removal of larger pieces during the pre-treatment process in WWTPs,

4. fine bar screens measuring 3 or 1 mm and fine mesh sieves with a size of 0.1 mm should be applied in the technology to enhance the recovery of cellulose-based materials from the wastewater. Due to the lower cellulose content, the aeration demand and thereby the operating cost can be reduced.

In addition to the WWTPs as point sources, the aerosol deposition play also a dominant role in the formation of microfiber contamination of rivers. During our study along the Tiber River we wanted to determine the effect of Rome as a highly populated city on the microplastic and microfiber contaminants (Sandil et al. 2025). Surprisingly the highest CB-microfiber concentration (391items/L) was detected in the upstream, while in the city centre and downstream a decreasing tendency was observable represented by CB-microfiber concentrations of 64 and 26 items/L, respectively. It means the proportion of CB-microfibers in downstream decreased from 96% to 80%. The concentration of PB-microfibers was considerably lower decreasing from 16.3 to 8.3 and 6.8 items/L however, their proportion increased from 4 to 20%. Evaluating the potential environmental effects of microfibers it should be emphasized that both type of microfibers contain dyes and finishing chemicals, as well as adsorbed contaminants, therefore the ingested microfibers can generate toxical chemical reactions in the microorganisms influencing their lifetime.

4. Conclusion

Since both the cellulose-based and the petroleum-based microfibers are harmful for the aquatic microorganisms due to the blockage of their digestive tract, as well as the toxic effect of their paint and finishing chemical contents, it would be necessary to minimize the emission of these fibrous contaminants by modernization of yarn production, weaving technologies and industrial and municipal wastewater treatment processes.

References

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