Can we use theoretical approaches from natural sediment to describe the transport behaviour of microplastics?

Kryss Waldschläger[1]

[1]Institute of Hydraulic Engineering and Water Resources Management, RWTH Aachen University, Mies-van-der-Rohe-Str. 17, 52074 Aachen, Germany

Phone: +49-(0)-241-80-25752
E-mail: waldschlaeger@iww.rwth-aachen.de

Introduction: Microplastics are known to be ubiquitous contaminants and although our knowledge about them is constantly increasing, we know little about the basic transport processes of microplastics in the aquatic environment.

Fig. 1: Microplastic particles

However, since hydronumeric simulations are an indispensable part of microplastics research, and since theoretical approaches to transport behaviour are necessary to use them, the basics of classical sediment transport were simply adapted to the properties of microplastics. But do the theoretical principles of sediment transport provide sufficiently accurate results for describing the transport of microplastics? The differences are undeniable: While sediment has an average density of 2.65 kg/cm³, microplastics can be both lighter and heavier than water. Moreover, microplastics come in very variable shapes, so they can appear either as pellets or microbeads, but also as fragments, fibers or films, as shown in Fig. 1. Sediment, on the other hand, consists mainly of granular grains.

Based on these differences in their particle properties, a transferability of the theoretical principles from sediment transport must therefore at least be questioned. Thus, we compared the behavior of microplastics with the theoretical calculations from classical sediment transport by using physical model experiments. The transport process was broken down into resuspension, sedimentation and rise as well as infiltration into the river bed. Furthermore, we have paid particular emphasis to the effects of microplastic particle properties such as density, diameter and shape on the transport mechanisms.

Methods and Results: The sedimentation and rise behavior was examined by experiments in a sedimentation column, in which the terminal settling and rise velocities of 52 different microplastic particles were determined. When comparing these velocities with calculated values using typical formulas from sediment transport (e.g. Stokes settling formula), it became clear that these are hardly suitable for microplastics. Therefore, new theoretical approaches based on the physical model experiments were determined to describe the settling and rising velocities of microplastic particles with varying particle properties [1].

The erosion behavior was investigated in an annular flume by placing microplastic particles on sediment beds, followed by slowly increasing the shear stress on the bottom of the channel until the particle started to move. Based on these experiments, we were able to determine the critical shear stresses of 15 different microplastic particles on four different sediment beds. When comparing the results with the calculation methods from classical sediment transport, namely Shields diagram and the hiding-exposure effect, it became clear that these are, again, not suitable for describing microplastic particles. Microplastics appear to move earlier than determined by the theoretical approaches so that a greater mobility of microplastics than previously thought is to be expected. Finally, we developed new approaches to describe the erosion behavior of microplastics as a function of their particle properties and the grain size of the sediment bed [2].

The infiltration behavior of microplastics into fluvial sediment was studied in an infiltration column that was filled with glass spheres of different diameters (1.5 - 11 mm) as substitutes for natural sediment and sprinkled evenly with water from above. 21 different microplastic particles were applied to the surface of the glass spheres, so that we could determine their infiltration depth as a function of their shape, density, and size and the grain size of the glass spheres. When comparing the results to the basic principles of fine sediment infiltration, it became clear that these were suitable to be transferred to microplastics. Based on these basics, we were able to create a matrix that can be used to determine the ideal sampling depths of fluvial sediment when looking for microplastics [3].

Discussion: This work offers a first systematic investigation as well as new calculation methods for the transport behaviour of microplastics in the fluvial environment. It has been shown that microplastics behave significantly different from natural sediments and should therefore be treated differently in future hydronumeric simulations.

References: [1] Waldschläger & Schüttrumpf (2019) *Environ. Sci.* **53(4)**:1958-2066; [2] Waldschläger & Schüttrumpf (2019) *Environ. Sci.* **53(22)**:13219-13227. [3] Waldschläger & Schüttrumpf (2020) *Environ. Sci.* **54(15)**:9366-9373