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Laboratory and numerical investigation of the factors controlling the residence time of microplastics in the water column of thermally stratified lakes

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Plastics are among the most widespread contaminants on Earth. They build up in fresh water bodies with high concentrations and migrate between different environmental compartments. In thermally stratified lakes, in summer, MPs pollutants can migrate between epilimnion, metalimnion and hypolimnion. This increases the probability of that microplastic will be filtered by filter feeders allowing MPs to migrate through different trophic levels. In this study, the transport of MPs in lake systems is presented through laboratory experiments as well as numerical modelling. The settling velocities of various biodegradable and non-biodegradable particles with various shapes and sizes were measured in the settling column under laminar conditions using particle image velocimetry (PIV). The particles used ranged between 150 to 2400 µm in diameter. The experimental results presented that shape, size and density of a particle are the key parameters controlling the sedimentation behavior of the particles. The measured settling velocities ranged between 0.4 to 50 mms^{-1}. In parallel, the transport of the particles used in the laboratory experiments was simulated using CFD. The laboratory experiments and CFD have shown consistent results. Subsequently, the same MPs used in the first lab experiments were incubated in a pond at the University of Bayreuth for 6, 8 and 10 weeks. The formation of biofilm on the incubated particles was investigated using confocal laser scanning microscopy. Also, the effect of biofouling of microplastics on the physical properties and thus settling velocity was investigated experimentally. It was observed that biofilm-building organisms has only colonized few regions on the surface of MPs and the whole surface was not coated with biofilm as it was anticipated. In addition, no changes in shape, size and density of the incubated were detected. After 6, 8 and 10 weeks of incubation, no significant change in the settling velocity of the incubated particles was observed. The detected changes in the settling velocity ranged between ± 5 % which was considered as a measurement error. Finally, the residence time in suspension and the distribution of MPs throughout a virtual lake water column was simulated using a simplified model. The effect of turbulences and the temperature gradient on the settling velocity were considered during the simulations. The model presented that turbulences, water temperature and layer depth control the settling velocity and thus the residence time of the MPs.