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Controlling processes for the fate of dissolved and sediment-associated micropollutants in rivers

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In industrialized countries, the assessment of water quality in rivers remains a timely topic. Especially hydrophobic organic pollutants that typically sorb to suspended sediments (e.g., PAH), and pharmaceuticals that are not completely removed by regular treatment in wastewater treatment plants (WWTP) have raised environmental concerns. These pollutants occur at concentrations of nano- to micrograms per liter in rivers. Continuous monitoring of these compounds is time- and cost-consuming. Thus we developed a particle-facilitated pollutant transport model and a reactive solute transport model with transient storage to understand the environmental processes that determine the fate of micropollutants in river systems. We applied the models to two small exemplary rivers, the Ammer and Steinlach River in southwest Germany. While the Ammer River is mainly fed by groundwater, the river Steinlach is substantially impacted by WWTP effluent. Results show that the supply and composition of sediments determine to a large extent the PAH load. At the river Ammer, the high contribution of urban particles with high PAH content results in the dominant contribution of PAHs from urban areas to the annual PAH load. Since the flow rate and river geometry determine the deposition and remobilization of sediments in the river, they control the in-stream redistribution of PAHs. In steep reaches, sediment turnover governs the turnover of PAH, whereas in very mild river segments diffusion of PAH from the river bed to the mobile water is relevant and reduces PAH turnover times. The simulated PAH legacy occurs in river segments with slow sediment turnover and may have remained 10-20 years after the environmental regulation in 1970s in the Ammer River. For the river Steinlach, transient storage plays a significant role for flow and solute transport, especially under low-flow conditions. The increase of the transient storage ratio increases the travel time and thus affects solute transport. Degradation processes of pharmaceuticals are affected by local conditions, e.g. pollutant transformation decreases with increasing flow rates. This influence is especially significant for pollutants that undergo biodegradation only. Overall, our study provides a framework to investigate the long-term fate of sediment-bound micropollutants (PAH) and the transport and transformation dynamics of dissolved micropollutants (pharmaceuticals). The framework is transferable to other small streams that are affected by anthropogenic micropollutants.