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Modelling the fate of six common pharmaceuticals in a small stream: quantification of attenuation and retention in different stream-specific environments

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Detection of pharmaceutical residues in streaming waters is common in urbanized areas. Although the occurrence and source of these micropollutants is known, their behavior in these aquatic ecosystems is still only partly understood. Specifically, quantitative information of biogeochemical processes in stream-specific environments where predominant reactions occur is often missing. In an attempt to address this knowledge gap, we performed simultaneous tracer tests in Säva Brook, Sweden, with bezafibrate, clofibric acid, diclofenac, ibuprofen, metoprolol and naproxen, as well as with the more inert solutes uranine and Rhodamine WT. The breakthrough curves at five successive sampling stations along a 16 km long stream reach were evaluated using a coupled physical-biogeochemical model framework containing surface water transport together with a representation of transient storage in slow/immobile zones of the stream. The multi-tracer experiment opens for decoupling of hydrological and biogeochemical contribution to the fate, and by linking impact and sensitivity analyses to relative significance of model parameters the most important processes for each contaminant were elucidated. Specifically for Säva Brook, the proposed methodology revealed that the pharmaceutical-contaminated stream water remained in the storage zones for times corresponding to 5-25% of the flow time of the stream. Furthermore, the results indicate a great variability in terms of predominant biogeochemical processes between the different contaminants. Rapid reactions occurring in the transient storage zone attenuated both ibuprofen and clofibric acid, and we conclude that a major degradation pathway for these contaminants was biodegradation in the hyporheic zone. In contrast, bezafibrate, metoprolol, and naproxen were mainly affected by sorption both in the storage zone and the main channel, while diclofenac displayed negligible effects of biogeochemical reactions.