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Quantification of hyporheic exchange using conservative and reactive tracers

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The transition zone between groundwater and surface water is commonly referred to as the hyporheic zone. In the so-called hyporheic exchange river water penetrates into the subsurface, remains there for a certain time, and then returns into the active water channel at a location further downstream. Hence, solutes enter the sediment where they can potentially be retained or degraded so that the hyporheic exchange is of particular importance for the prediction of reactive solute transport in rivers.

In the past, tracer experiments where a conservative tracer is added into the river and measured further downstream were used to characterize hyporheic exchange. The problem is that the hyporheic exchange has similar effects on the measured tracer breakthrough curves than mixing processes in the river itself (e.g. dispersion). In order to separate these processes, we carried out tracer tests where the compound resazurin was used as a reactive tracer in addition to a conservative tracer (uranine). Resazurin degrades selectively and irreversibly in the hyporheic zone and thus provides additional information specifically on the hyporheic exchange.

We performed a total of five tracer tests at two different tributaries of the river Neckar (Goldersbach and Steinlach) and at the river Selke in Germany. We used three-channel fluorometers that are able to measure resazurin, resorufin and uranine simultaneously and directly in the field. The high temporal resolution of the measurements and the avoidance of possible errors related to sample storage and contamination led to high quality data sets that were used as input for the subsequent modeling.

The breakthrough curves of uranine and resazurin were analyzed simultaneously using a shape-free method for the determination of hyporheic travel time distributions (deconvolution). In comparison to the analysis of uranine alone, we were able to improve the determination of the strength of hyporheic exchange and hyporheic travel time distributions considerably. In particular, we could obtain consistent sets of parameters for river sections of different lengths. These parameters will be used in reactive transport models for biogeochemical major constituents (e.g. dissolved oxygen) in river water.