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Spatial variability in river-catchment interaction: Combining radon measurements and salt tracer experiments

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Hydrological modeling is commonly based on a discharge calibration. This approach, however, is often insufficient to properly reproduce conditions that exceed the range of calibrated conditions and is therefore inadequate for predicting reactions to a changing environment. Small headwater catchments are often characterized by manifold morphological attributes (e.g. changes in river course, variable depth to bedrock...) and complex topography, resulting in potentially high spatial variability of river-catchment interactions. Such systems are often poorly represented by simple rainfall runoff models. For that reason, increasing effort is taken to investigate the functional organization of river catchments. From a river's point of view, the first questions to be solved are: How variable is river-catchment interaction in space? Where along the river do we find exfiltrating or infiltrating conditions? Which pathway did the water take before entering the stream?

To investigate these questions we used an approach that combined salt tracer experiments with Radon-222 (referred to as radon) measurements. Radon is a natural occurring radionuclide that is accumulated in water traveling through saturated bedrock and mineral material. In contact with air the inert noble gas degases quickly and is thus a reliable environmental tracer for groundwater-surface water interactions.

Measurements were carried out at a 650 m long tributary of the Colpach, which is part of the Attert basin in Luxembourg. In the first phase of the experiment radon was sampled every 50 m along the tributary. At the same time, salt tracer experiments were conducted over 100 m sections, providing information on discharge at the up- and downstream end of each 100 m section, absolute gain and loss along the 100 m section and travel times between all radon sampling sites. In the second phase, three sections where investigated in more detail. The chosen sections were divided according to changes of morphological attributes like river course (e.g. braided, meandering, straight), changes in stream bed substrate (e.g. loam, gravel, bedrock) or certain landmarks (e.g. ephemeral tributaries, river widening). Radon was sampled at the beginning and end of every subsection and the travel time between every radon sampling site was determined with salt tracer injections. Based on this information we accomplished a simple mass balance calculation to distinguish the respective groundwater and event water components of the measured gain and loss along all river sections.

The results show that there is a high spatial variability in discharge quantity and composition down to the scale of few meters. With regard to the functional organization of river catchments, these observations imply that the interpretation of both, discharge dynamics as well as catchment processes requires a thorough understanding of the spatially varying connectedness between river, catchment and groundwater.