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Streambank exchange — physical and biogeochemical response of groundwater to flood events

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Hyporheic exchange flows (HEFs) between streams and shallow groundwater in river banks are key drivers of nutrient cycling and pollutant degradation rates (e.g., Boano et al., 2014). Hence, HEFs serve as self-purification mechanisms of freshwater bodies, and are of major importance for water quality and ecosystem functioning (e.g., Brunner et al., 2017).

Recent studies have identified transient river discharge and the hydraulic conductivity of streambanks as major controls on HEFs (e.g., Gomez-Velet et al., 2017). However, studies on the spatial and temporal variability of HEFs based on field data remain scarce.

We used a combination of established (e.g., radon, major ions, nitrate, water heads, slug tests) and novel (continuous dissolved (noble) gas measurements) methods to study the physical and biogeochemical response of shallow groundwater to flood events. Our experiments were conducted at a restored reach of a loosing stream in an urban area in Zurich, Switzerland.

Our data show that during normal flow conditions exchange between the stream and shallow groundwater is – contrary to our first hypothesis – only marginal. However, during flood events, we observe a rapid increase of enhanced river water infiltration delivering oxygen, nutrients and other solutes to the adjacent groundwater. The rate of enhanced streamwater infiltration depends on the frequency and intensity of the flood events as well as on the hydraulic conductivity of the streambed and -bank. This rapid delivery of streamwater seems to be attributed to the flushing of the clogged riverbed during intense enough flood events, which results in higher hydraulic conductivities of the streambed. Moreover, our continuous measurements of dissolved (noble) gases enable us to calculate the overall oxygen turnover in the groundwater. Such an estimate can only reliably be given by accounting not only for oxygen consumption but also for excess air. Therefore, oxygen turnover can only be quantified if argon (serving as a conservative proxy for oxygen) and oxygen concentrations are determined synchronously (Mächler et al., 2013).

Our findings show that flood events and the hydraulic conductivity of the streambed and -bank are key controls on hyporheic exchange flows, hence, governing gas exchange, nutrient cycling, and pollutant turnover within the near-stream environment.

References

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