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How does the stream-groundwater connectivity drive water chemistry in an agricultural drainage system?

Oscar Jimenez Fernandez (1,2), Marc Schwientek (2), Karsten Osenbrueck (2), Clarissa Glaser (2), Christian Schmidt (1), and Jan Fleckenstein (1)

(1) Department of Hydrogeology, Helmholtz-Centre for Environmental Research – UFZ Leipzig, Germany (oscar.jimenez-fernandez@ufz.de), (2) Department of Geosciences, University of Tuebingen, Germany

First order streams drain considerable proportions of river catchments and as they are normally well connected to shallow groundwater they are among the first receptors of agricultural effluents. Understanding the processes governing the water quality in agricultural areas requires identifying sources of potential pollutants, hotspots of biogeochemical reactivity and defining the different hydrologic flowpaths connecting sources, reactive hotspots and streams. In the present study, we have equipped an agricultural drainage system (Schönbrunnen) in south-western Germany with 23 piezometers in the shallow aquifer and 4 measurement stations along the stream. In order to identify hydrological flowpaths, sources of different groundwater bodies and to quantify the hydrologic turnover, data were collected covering an entire annual cycle from July 2017 to August 2018, applying hydrological and hydrochemical parameters as well as environmental and artificial tracers.

The 550 m long test segment of the Schönbrunnen stream, features an alternation of gaining and loosing reaches with strong seasonal variabilities: more than 15% of its volumetric discharge was lost in downstream direction during warmer periods, causing the relative hydrologic turnover to be larger. We hypothesized that when groundwater levels are high, the whole stream would get exfiltrating groundwater and vice versa. By contrast, this behavior only occurred on the lower segment under wetter conditions (especially during the winter months), when it was gaining from the groundwater bodies at both sides of the stream, which showed contrasting chemical signature. Also, a larger fraction of upstream water was remaining in the lowermost segment of the stream during this period, i.e. the hydrologic turnover was smaller than during summer months. Groundwater contour maps were interpolated on a monthly basis and indicated shifting groundwater flow directions. During the summer period, groundwater flowpaths run basically parallel to both streams, meaning that there is only a little fraction of exfiltrating groundwater into the stream, whereas in winter months the head contours showed the characteristic inversed-V shapes, especially towards the downstream end. The use of geochemical tracers proved that the different contributions from both groundwater bodies drive the stream chemistry. Furthermore, the alternating gaining/loosing situation affects streamwater composition and it may change the turnover capacity of the agricultural pollutants along the transition zone. In conclusion, hydrological turnover, i.e. exchanges with surrounding groundwater bodies, has been found to strongly influence streamwater chemistry of low order streams – an effect which is often overlooked.