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Chloride mass balance to quantify the wastewater impact on karstified carbonate aquifers

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Groundwater resources are vulnerable to anthropogenic influences, like i.e. wastewater disposal in the environment. This is especially critical in karstified carbonate aquifers, because of the partially high flow velocities, resulting in an insufficient attenuation potential against pollutants.

To assess the health risk associated with the pollution of the groundwater and for remediation measures planning, the wastewater impact on groundwater resources needs to be quantified. For this purpose the analysis of conservative tracer substances, abundant in the wastewater, is considered a suitable technique. Among the substances considered as tracers, chloride exhibits superior characteristics, the only drawback being the usually high natural background concentration in groundwater. As the chloride ion is not removed by common wastewater treatment processes, it is indicative of both treated and untreated wastewater.

In this study, an example for a semi-arid karstified carbonate aquifer system is presented. The study area is located on the western margin of the Lower Jordan Valley (West Bank). The upper aquifer is discharged via several springs. For the springs in the study area, time series of chloride concentration in spring water from 1967-98 were interpreted. The study area displays a high population growth, which results in a steadily increasing wastewater discharge amount. The wastewater is mostly infiltrating into the karst system.

First, the long-term average groundwater recharge rate of the local aquifers that fed the springs was quantified with the chloride mass balance method from groundwater data that are little influenced by anthropogenic impacts. The chloride concentration in the local precipitation is 9-10 mg/l and the average value in groundwater is 31 mg/l. This yields a mean recharge rate of around 30 percent.

Second, the fraction of groundwater recharge, resulting from the infiltration of wastewater from leaky sewer systems and from wastewater disposal in the environment, is calculated from a classical end member mixing model. The chloride concentration of the wastewater is estimated to be 300 mg/l. From spring water sampling in autumn 2011, the springs exhibit wastewater-borne discharge fractions of several tenth of a percent up to 20 percent.

The spring “Sultan” in Jericho is an important domestic water source since thousands of years. For this spring, chloride concentration was determined over one hydrological year in a high time resolution. The results show, that the wastewater impact is time-variant. The highest mass flow of chloride is triggered by large precipitation events in the recharge area of the springs. The mean wastewater-borne fraction over the monitoring period was calculated to be about seven percent.

The results of the research enable the planning of remediation measures, however more exploration is needed to delineate the groundwater catchments. Furthermore, the study underlines the value of long-term monitoring, even at a comparatively low time resolution.