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Application of Precipitation as a Groundwater Tracer – Laboratory Experiments with an “ideal” tracer (?)

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A key question in hydrogeological research is to find the “ideal” tracer – a substance that can be used to trace water’s movement and by that to deduce various aquifer characteristics, a substance that is chemically and biologically conservative, is traceable at low concentrations, doesn’t harm the environment, and is economically affordable.
One possible answer to that question is quite simple: water itself. Using the inherent characteristics of water, several tracer signals can be attributed to it: the water’s stable isotope signature regarding Hydrogen (δ2H i.e. Deuterium) and Oxygen (δ18O), the ionic composition (and by that the Electrical Conductivity as a sum parameter), as well as its temperature.
These signals can differ significantly between groundwater and locally corresponding precipitation. In moderate climates at sites with local groundwater recharge the stable isotopic composition of summer and winter precipitation shows the highest deviations from the mean and therefore from the local groundwater isotopic signatures. Applying sufficient amounts of such precipitation as an active groundwater tracer forms a novel approach towards answering the initial question.

Several laboratory experiments were conducted to systematically explore properties of precipitation as well as possibilities and limitations of its use as tracer substance.
Batch-tests with various aquifer materials of different grain size distributions and clay contents showed that, while the stable isotopic signatures are not subjected to fractionation processes, the Electrical Conductivity is altered depending on the ionic charge of sediment surfaces and ionic exchange capacities.
In column experiments (24 h-impulses and continuous injection) the breakthrough behavior of precipitation tracers was compared to that of conventional tracers like Sodium Chloride or Potassium Bromide. Concerning the ionic tracer component a major difference between conventional “positive” and “negative” (i.e. lower mineralization in tracer than in groundwater) breakthrough curves exists. From the isotopic point of view the breakthrough behavior can be considered conservative.

Up to now the experiments with the water’s inherent combination of different tracer signals produced promising results and will be continued in large scale laboratory tests and field experiments.