Geophysical Research Abstracts
Vol. 14, EGU2012-17-1, 2012
EGU General Assembly 2012

Multitracer test for the determination of transport and in-situ degradation of organic micro-contaminants in karst aquifers on the example of caffeine

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The application of organic micro-contaminants as indicators for contamination sources in aquifers and surface-water bodies has been increasingly discussed in the literature over the last years. One of the proposed substances was caffeine. It served as indicator for wastewater-leakage to various systems. As well, wastewater volumes could be estimated from caffeine concentrations. Although caffeine is known to be degradable, the degradation rates are normally only determined from mass balances or laboratory experiments. Degradation rates obtained from mass balances are relatively uncertain, as the input-function is difficult to be assessed. Laboratory experiments are hardly capable to consider the full complexity of natural systems and can rarely be transferred to those. To solve this problem, in-situ degradation rates of reactive indicators have to be determined. Especially multitracer tests can be used to access compound-specific transport parameters and degradation rates, relative to conservative tracers.
A multitracer test with caffeine and uranine has been performed in a karst system (catchment of the Gallusquelle spring, SW Germany). From the breakthrough curves of the tracers, the transport behavior and the in-situ degradation rate of caffeine could be deduced. The tracers were injected into a sinkhole with a linear distance of 3000 m to the spring. The mean residence time of the tracers was found to be 84 h at a flow velocity of 35 m/h. Throughout the whole experiment, the spring discharge was constant at 187 L/s. Uranine served as conservative reference-tracer for the calibration of a one-dimensional transport model with respect to solute-unspecific parameters. Relative to that, the tracer breakthrough curve of caffeine was interpreted. As solute-specific parameters the retardation coefficient as well as degradation rate of caffeine in the investigated karst aquifer could be determined. The results indicate, that caffeine is slightly retarded in the investigated aquifer (R= 1.031-1.046) and is readily degradable (half-life t1/2= 90-105 h; temperature of the spring water T= 8-9 °C). The degradation rate is surprisingly high. In general, no significant degradation is believed to occur, during the rapid transport in karst systems.
The high degradation rates of caffeine illustrate the potential to use this substance as reactive tracer to indicate biological activity within the aquifer. Due to the good degradability of caffeine it does not pose a threat as long-time contamination and can therefore safely be used as reactive tracer in aquifer systems.