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Estimating the groundwater flow velocity in single-well tests by using radon-222 as environmental tracer

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Assessment of the groundwater flow velocity is generally being done on basis of Darcy's Law employing data from at least two groundwater monitoring wells. That approach, however, is based on the assumption that the slope of the water piezometric surface between the employed wells is constant. Thus, assessing small-scale changes in groundwater migration patterns necessitates groundwater wells set in distances to each other that are appropriate for representing the small-scale changes in the hydrological situation. By using data taken from wells with larger interstitial distances, small-scale spatial variations in the groundwater migration pattern are not resolved sufficiently. In such cases single-well tracer tests can be applied as potential alternative to multi-well approaches.

Several natural or artificial tracers that can potentially be used as indicators in single-well tracer tests can be named. In a study, carried out at the Helmholtz Centre for Environmental Research in Leipzig, Germany, it was shown that the naturally occurring radioisotope radon-222, if applied as environmental aqueous tracer in a single-well test, allows quantitative estimation of the groundwater flow velocity. The suitability of radon as aqueous tracer in the given context results from its chemically inert behavior (radon is a noble gas) and its radioactive nature (radon-222 decays with a half-life of 3.8 days).

Radon is produced in the aquifer matrix and emanates constantly into the groundwater that occupies the pore space, leading to a production/decay equilibrium concentration there. Equilibrium concentrations in groundwater usually range between values of about 5 and 50 Bq/l. In contrast, the radon in groundwater that enters a monitoring well and flows through its screened section is, due to the lacking direct contact to the aquifer matrix, not balanced by radon production. As a result the initial radon equilibrium concentration found in the groundwater (C_{GW}) decreases in the well water (C_{WW}) with regard to the radon decay constant (λ_{Rn} = 2.1 x 10-6 s-1) as a function of the residence time of the well water in the monitoring well (t). The respective relationship is given with Eq. 1.

$C_{WW} = C_{GW} \exp(-\lambda_{Rn}\ t)$ (Eq. 1)

As shown in Eq. 1 the radon deficit in the well water can be expressed as a function of the residence time of the well water in the monitoring well. The residence time of the well water in the well depends on the radius of the well and on the groundwater flow velocity. Since the well radius can be determined easily the radon deficit in the well water can be used as quantitative measure for assessing the groundwater flow velocity applicable for the aquifer domain represented by the well investigated.

General advantages of the radon method are its low cost, the possibility of immediate on-site determination of the groundwater flow velocity using only a single well, and the use of a naturally occurring radio-tracer.