Development of advanced single-well applied tracer techniques for improving reliability of groundwater and contaminant mass flux monitoring

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Background

Assessing groundwater and contaminant mass fluxes is often challenging due to the inherent variability in the spatial distribution of hydraulic properties and groundwater levels in groundwater flow systems. Hydraulic gradients can also vary, especially in areas of active groundwater discharge or pumping. In addition, critical hydraulic conductivity information is often derived from slug tests, which tend to provide only order-of-magnitude estimates. Improving the reliability of the quantification and monitoring of groundwater fluxes is essential to inform risk assessment studies (particularly those based on mass-flux approaches) and to support the development of effective groundwater remediation plans.
In this context, classical estimates of groundwater fluxes based on Darcy's law have often been very inaccurate. Advanced field characterization technologies are thus required to more accurately quantify groundwater flux amplitude and variability in space and time.

Approach/Activities

The finite volume point dilution method (FVPDM) is single-well applied tracer technology that has been developed recently to monitor groundwater fluxes. The rate of tracer dilution that results from groundwater flow through the well is an in-situ measurement of the groundwater flux (Darcy flux). Analysis of flux using FVPDM does not depend upon prior estimates of hydraulic conductivity and hydraulic gradient, and is therefore markedly more accurate than other methods to assess groundwater flux. Another key advantage is its ability to monitor changes in groundwater fluxes with time as long as the system can be operated in the field. The approach has been tested in different hydrogeological contexts such as porous and fractured aquifers, including strong interactions with surface water and under contrasting groundwater flow regimes and dynamics. After 10 years of development and application, the FVPDM technique has been demonstrated to be applicable in many different contexts and applications.

Lessons Learned

Tracer test results obtained with the FVPDM approach enables the monitoring of groundwater fluxes across contrasting ranges, from a few centimetres per day to hundreds of metres per day. The tests have also revealed how spatially variable groundwater fluxes can be, with orders of magnitude difference observed between monitoring wells at a given site. A strong time variability was also observed at sites influenced by variable hydraulic conditions and groundwater-surface water interactions. Preliminary results of continuing work have also shown the potential for the FVPDM approach to be coupled with contaminant specific sensors and with passive sampling technologies to quantify contaminant mass fluxes in the subsurface. Future expected developments will also be discussed, including the ability to assess flow direction at the well scale.