Geophysical Research Abstracts, Vol. 8, 06656, 2006
SRef-ID: 1607-7962/gra/EGU06-A-06656

Experiences from using an inversion technique on the basis of numerical modelling for the evaluation of pumping tests to investigate groundwater contamination plumes in urban areas

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Groundwater contamination plumes are well known in many urban areas. In many cases they result from human activities e.g. spill or accidents with hazardous substances. Generally they are associated with serious risks for groundwater as a natural resource, especially for municipal drinking water supply. Spatial distribution as well as the mass flux of hazardous substances in the contamination plumes is unknown, but important facts for further decisions or even an urgent call for action. The aim of this contribution is to demonstrate the experiences of an innovative approach to investigate the spatial distribution of contaminants in the groundwater for the location and quantification of the maximum concentrations and the identification of the input source. The core of this procedure is the application of a numerical groundwater flow and transport model in combination with an inversion technique (developed at the University of Tübingen) to evaluate the break through curves of contaminant concentrations sampled during so called “immission” pumping tests.

These “immission” pumping tests are conducted at a control plane perpendicular to the groundwater flow. The spacing of neighboured pumping tests is fixed depending on the range of the recharge area at the end of each pumping test in order to generate a slight intersection of the two recharge areas. During the pumping period water samples are taken in regular intervals (e.g. in exponential time periods to get an equidistant sampling) for the analysis of the contaminants of interest. The time varying concentrations are the basis of the inversion technique evaluated by the numerical model.

Depending on the hydraulic characteristics of the aquifer, which control the groundwater flow velocity, the time varying concentrations contain the spatial information of the contaminant distribution in the aquifer. The inversion technique is based on a back transformation of the measured concentration distribution in a forced gradient flow field. Using this method the contaminant distribution as well as the total mass flux over a control plane of the natural groundwater flow can be calculated. This enables to characterise the contaminant concentrations within the aquifer by a mean value and a maximum value. The measured concentrations are interpreted as a mixed concentration, represented by the aquifer volume between two isochrones of the pumping test, thus allowing to quantify and to locate the contamination plume.

For simple configurations the inversion method can be applied by using analytical solutions of the groundwater flow and transport equations. But in the most applications a numerical model has to be used to handle more complex hydrogelogical conditions (e.g. heterogeneities or transient boundary conditions). For the presented investigation a Finite Element model (using FEFLOW) is used which is able to calculate a transport simulation on a reversed flow field. This reverse transport computation of one pumping test does not result in a unique distribution of the contaminants. But the superposition of many tests leads to a probability distribution of initial concentrations. This is used as a basis for further hydrogeological investigations and interpretations.

The method described enables the evaluation of contaminant distribution in the aquifer as well as it helps to identify the original source area. It can be an important contribution to determine a call for action for future remediation measures to preserve groundwater as a natural resource and to protect drinking water supplies.