Geophysical Research Abstracts
Vol. 20, EGU2018-2610-1, 2018
EGU General Assembly 2018

Predicting remediation efficiency of polluted aquifers by comprehensive data assimilation and forward modelling

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Reliable predictions of pollutant transport in aquifers have a major role in their management and protection, especially for a polluted site where remediation is being considered. However, due to the spatial sparsity of the data, both the heterogeneous structure of the aquifer, as well as the present contaminant distribution, are subject to uncertainty, which in turn, impinges on the remediation predictions. Geostatistical tools combined with Monte-Carlo simulations can be used to quantify those uncertainties and to provide a sound basis for decision making. These tools are used to generate a large set of realizations of the aquifer structure, which forms the basis for numerical simulations of flow and transport. Numerous works were able to reproduce the plume shape by following this approach, and several studies used it to examine the remediation of a polluted aquifer in a heterogeneous environment. However, uncertainty regarding the initial conditions of the plume, prior to remediation, was never considered in the literature for real contaminated sites. This work aims to predict the remediation efficiency under uncertainty associated with both the spatial variability of the aquifer structure, and the initial plume shape.

For this purpose, a case study of a contaminated site in the Coastal Aquifer of Israel is considered, where a Pump and Treat remediation scheme is being planned at a preassigned location. The aquifer structure is modeled by facies decomposition, characterized statistically by their volume fraction and indicator variograms, identified by drilling logs in the vicinity of the site. A modified SISIM code was used to generate the aquifer 3D structure conditioned on known facies locations in wells. Flow and transport were solved numerically using MODFLOW and MT3DMS. An initial forward predictive model was applied to reconstruct the plume shape and spatial hydraulic heads. Following, an additional forward model was used to simulate the remediation process. Remediation efficiency (i.e. the ratio between the pumped to the initial mass) and its uncertainty were quantified throughout the simulated period. In addition, the probabilities that the concentrations at selected spatial locations will exceed the standard (i.e. "the risk") were evaluated before and after the remediation.

The uncertainty reduction was achieved by screening the structure realizations and eliminating those which did not agree with the measured heads and concentrations, i.e. conditioning by these data in addition to the facies conditioning. The results showed that while 46% of the realizations have agreed with the measured hydraulic head, only 9% (115 realizations) have agreed with all of the dynamic data (i.e. measured hydraulic head and concentrations). Notably, these 115 realizations had a large variability in the plume spatial distribution prior to remediation. When comparing the outcome of the remediation efficiency with and without the conditioning on the dynamic data, we observe that the screening by dynamic data reduced the uncertainty in estimating remediation efficiency by more than 35%. Risk analysis for the migration of the plume showed that the proposed remediation plan will be capable to control the plume only in the shallow layers of the aquifer.