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Unknown Groundwater Pollution Source Characterization in Contaminated Mine Sites Using Optimal Monitoring Network Design

Authors : H. K. Esfahani, B. Datta

Abstract : Groundwater is one of the most important natural resources in many parts of the world; however it is widely polluted due to human activities. Currently, effective and reliable groundwater management and remediation strategies are obtained using characterization of groundwater pollution sources, where the measured data in monitoring locations are utilized to estimate the unknown pollutant source location and magnitude. However, accurately identifying characteristics of contaminant sources is a challenging task due to uncertainties in terms of predicting source flux injection, hydro-geological and geo-chemical parameters, and the concentration field measurement. Reactive transport of chemical species in contaminated groundwater systems, especially with multiple species, is a complex and highly non-linear geochemical process. Although sufficient concentration measurement data is essential to accurately identify sources characteristics, available data are often sparse and limited in quantity. Therefore, this inverse problem-solving method for characterizing unknown groundwater pollution sources is often considered ill-posed, complex and non- unique. Different methods have been utilized to identify pollution sources; however, the linked simulation-optimization approach is one effective method to obtain acceptable results under uncertainties in complex real life scenarios. With this approach, the numerical flow and contaminant transport simulation models are externally linked to an optimization algorithm, with the objective of minimizing the difference between measured concentration and estimated pollutant concentration at observation locations. Concentration measurement data are very important to accurately estimate pollution source properties; therefore, optimal design of the monitoring network is essential to gather adequate measured data at desired times and locations. Due to budget and physical restrictions, an efficient and effective approach for groundwater pollutant source characterization is to design an optimal monitoring network, especially when only inadequate and arbitrary concentration measurement data are initially available. In this approach, preliminary concentration observation data are utilized for preliminary source location, magnitude and duration of source activity identification, and these results are utilized for monitoring network design. Further, feedback information from the monitoring network is used as inputs for sequential monitoring network design, to improve the identification of unknown source characteristics. To design an effective monitoring network of observation wells, optimization and interpolation techniques are used. A simulation model should be utilized to accurately describe the aquifer properties in terms of hydro-geochemical parameters and boundary conditions. However, the simulation of the transport processes becomes complex when the pollutants are chemically reactive. Three dimensional transient flow and reactive contaminant transport process is considered. The proposed methodology uses HYDROGEOCHEM 5.0 (HGCH) as the simulation model for flow and transport processes with chemically multiple reactive species. Adaptive Simulated Annealing (ASA) is used as optimization algorithm in linked simulation-optimization methodology to identify the unknown source characteristics. Therefore, the aim of the present study is to develop a methodology to optimally design an effective monitoring network for pollution source characterization with reactive species in polluted aquifers. The performance of the developed methodology will be evaluated for an illustrative polluted aquifer sites, for example an abandoned mine site in Queensland, Australia.

Keywords : monitoring network design, source characterization, chemical reactive transport process, contaminated mine site
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