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Groundwater nitrate contamination modeling and clean-up strategy design: a case study in Nankou site, Beijing

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Nankou study area lies in a geographical unit commonly known as Wenyuhe Catchment, and belongs to Changping District of Beijing, China. Since the 1990s, a large part of the area was urbanized, leading to a significant increase of water consumption. According to Beijing Water Authority, about 70% of the drinking water supply comes from the local aquifer. The aquifer is thus under enormous stress. On the quantity side, increased pumping activities caused a drawdown of the groundwater table and on the quality side, the water hardness and nitrate concentration increased subsequently. Based on a long term monitoring of groundwater quality in this site, a heavily contaminated plume with high concentrations of nitrate was found in the north of this site. Therefore, understanding this local aquifer system is fundamental for the future sustainable water resources management and scenario analysis.

In this work, a numerical analysis of a 3D regional groundwater flow model for the Nankou area is presented. The hydrogeological system is reproduced according to sparsely distributed boreholes data. The numerical analysis is carried out using the scientific software OpenGeoSys (OGS), which is based on the finite element method. The model calibration and sensitivity analysis are accomplished with inverse methods by applying a model independent parameter estimation system (PEST). The results of the calibrated model show reasonable agreements with observed water levels. The transient groundwater flow simulations reflect the observed drawdown of the last 9 years and show the formation of a depression cone in an intensively pumped area.

The well calibrated 3-D groundwater model provides hydrogeological parameters and lateral fluxes from the adjacent mountain area for the following transport modeling and remediation scenarios analysis. In the nitrate contamination model the PEST code is also applied with OGS for the estimation of the pollution source loading. The discharge rate time series of ammonia from a fertilizer factory about 1.6 km away from the observation well are calibrated in order to fit the simulated concentrations with the measurements. The average spreading speed of the contaminant plume is about 6.0e-7 m/s.

Pump and treat methods are the conventional remediation techniques for large and small scale remediation of contaminated groundwater. The proper design of such operations is very important both economically and environmentally. In this study the method of capture zone type curves is used to estimate the pumping rate and the number of pumping wells needed for the contaminated aquifer cleanup. The analytical solutions of drawdown at the pumping wells (for both single pumping well and double wells) are compared with those calculated from the numerical model. The total pumping rate and the clean-up time are the two critical factors for the determination of an optimal remediation design. The optimization with these two objectives of multi-pumping wells will be carried out in the soon future. The present work can provide important baselines for the local government policy-making.