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Estimating concentration rebounds in pumping wells and their impact on aquifer remediation and risk analysis

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Capturing the effects of aquifer heterogeneity is key to evaluating risk in groundwater related problems. In this work we analyze the potential failure of remediation due to the rebound of concentrations driven by back diffusion. Withdrawing polluted water from a contaminated aquifer by pumping is one of the most common components of many remediation actions. Pumping proceeds until concentrations of contaminants in the extracted water falls below some pre-specified value. In several cases, it has been observed that a rebound in the concentration signal takes place at the well after remediation pumping stops. For this reason, a conservative approach may be needed and pumping may have to last much longer than back of the envelope calculations might suggest.
It is well known and documented that spatial heterogeneity, ubiquitously found in the hydraulic properties of aquifers, leads to multiple mass transfer processes occurring at different time scales, both for conservative and reactive species. Heterogeneity thus plays a significant role in the interpretation of breakthrough curves and plays a driving role in controlling processes associated with concentration rebounds as described above. In this study we take a close look at this and lay the groundwork for a risk-based optimal operation methodology that is capable of estimating the time at which to end remediation pumping. Our model is built with aquifer parameters that characterize the role of a heterogeneous medium and the multiple scales of mass transfer as well as pumping rates and initial size of the polluted area. The results from this modeling framework will have a clear impact in economic terms on determining optimal and viable remediation strategies.