Screening-Level Assessments of Public Water Supply Well Vulnerability to Natural Contaminants

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Biographical Sketches of Authors

All eight authors are hydrologists with the USGS. They have worked on numerous water-quality and water-quantity projects at local, regional and national scales, focusing on topics such as anthropogenic and natural contaminant source and fate, flow and transport modeling, ground-water age-dating, nutrient cycling, and many other topics. The authors are part of a larger team of USGS National Water-Quality Assessment Program hydrologists currently studying factors affecting the transport of natural and anthropogenic contaminants to public water supply wells at multiple scales.

Abstract

Geochemical data and ground-water flow models (particle tracking) were used to identify process-based variables for use in quantitative screening-level vulnerability assessments for uranium and arsenic in public water supply wells. These results, from eight USGS National Water-Quality Assessment Program study areas in principal aquifers, demonstrate an approach that can be undertaken with existing tools and data and applied to these or other natural contaminants. Such assessments may be useful for prioritizing locations and types of more refined vulnerability assessments.

Principal components analysis suggests that uranium is associated with oxidizing water, and arsenic with both oxidizing and reducing water. These statistical relations are consistent with the geochemistry of these elements: uranium generally is mobilized under oxidizing conditions but attenuated under reducing conditions, whereas arsenic can be mobilized under both oxidizing and reducing conditions. Spearman correlation analysis of variables from particle-tracking simulations indicates that uranium is positively correlated with variables that represent (1) overall ground water time-of-travel (TOT), (2) TOT through oxidizing regions, and (3) water fluxes to wells from oxidizing regions. Uranium also is inversely correlated with variables representing TOT through reducing regions. TOT may be an important variable because many geochemical reactions are kinetically limited. Arsenic was positively correlated with variables representing overall TOT, but correlations with redox TOT variables were ambiguous in the combined (eight aquifer) dataset, likely resulting from the presence of both oxidizing and reducing arsenic mobilization processes.

Classification tree analysis (a nonparametric method in which data are partitioned recursively into increasingly homogeneous subsets, similar to dichotomous classification keys) on arsenic concentrations yielded a quantitative categorical model using two TOT variables and a variable representing solid-phase arsenic concentrations. The classification tree model accuracy on the learning data subset was 70%, and on the testing data subset, 79%, demonstrating the usefulness of TOT variables in vulnerability assessments.