

Characterization of Fate and Transport Processes and Contaminant Distribution in Karst Groundwater Systems

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Background/Objectives. Karst groundwater aquifers, characterized by highly permeable areas, are highly productive aquifers. The same characteristics that make those aquifers highly productive, make them highly vulnerable to contamination, which may be influenced by anthropogenic and/or hydrogeological factors. Their high heterogeneity and anisotropy prevents accurate prediction in contaminant fate and transport and efficient cleanup of contaminated sites. Even more challenging is to understand the impact of hydrologic conditions changes on fate and transport processes and remedial activities. Current technologies to characterize and quantify flow and transport processes at field-scale is limited by low resolution of spatiotemporal data. Laboratory scale studies can be applied to enhance the spatiotemporal resolution and provide the essential knowledge of karst groundwater system. This project aims at characterizing fate and transport processes and spatial and temporal contaminant distribution of chlorinated volatile organic compounds (CVOCs) in karst groundwater systems. The northern karst aquifer system of Puerto Rico, which has been affected by a long history of groundwater contamination, was selected as case study for this project.

Approach/Activities. The characterization of flow and fate and transport processes are studied using field scale tracer tests and an intermediate karstified lab-scale model (IKLPM). A spring was selected for the field scale tracer study, which includes injecting rhodamine and uranine under different hydrologic conditions, and monitoring their concentrations. At lab scale, transport experiment are conducted in the IKLPM using step injections of calcium chloride, uranine and rhodamine wt tracers. Temporal concentration distributions obtained from the experiments are analyzed using the method of moments and CXTFIT to quantify fate and transport parameters in the system at various flow rates. The CVOCs contaminant distribution at the field scale is assessed using geographic information system (GIS) technologies and statistical models using historical data and current field measurements from springs and wells in the study area. Correlation analysis and multivariate models are used to determine the most important factors on the detection of CVOCs in the study area.

Results/Lessons Learned. Results from the field-scale tracer tests show incomplete recovery of tracers, but enough resolution of breakthrough curves to estimate advective, dispersive and mass transfer characteristic of the karst system. Preliminary results suggest significant differences in fate and transport characteristics under different hydrologic conditions. At the lab scale, the spatial distribution of fate and transport parameters reveal high variability related to preferential flow heterogeneities and scale dependence. At the field scale, contaminant distribution analysis shows extensive spatial and temporal groundwater contamination with one or more CVOC. Contamination remains for long periods of time, even after active remediation. Multivariate statistical analysis indicates that the distribution of CVOCs in the karsts aquifers of NPR is influenced by a combination of contaminant source and hydrogeological factors. Results show that karst aquifers require high-resolution characterization to properly predict contaminant fate and transport, enhance remedial activities, and provide tools for better management of karst groundwater systems.