Tennessee State University
Department of Biological Sciences

2007 SPRING SEMINAR/
CHALK TALK FORUM SERIES

Frontiers in Ecology and Evolutionary Biology

February 15	Tom Byl Visiting Research Professor Civil and Environmental Engineering Tennessee State University	Advances in Water Quality Research made by TSU Students over the past Ten Years

Seminar **Holland Hall Room 102** **11:30 – 12:30PM**

Approximately 40 percent of the United States east of the Mississippi River is underlain by various types of karst aquifers (Quinlan, 1989) and more than two-thirds of the State of Tennessee is underlain by carbonate rocks and can be classified as karst (Wolfe and others, 1997). Potential industrial sources of ground-water contamination are common in karst regions; however, the fate and transport of contaminants such as fuels in karst areas are poorly understood because of the distinctive hydraulic characteristics of karst aquifers (Field, 1993). Ground-water models that predict the fate and transport of contaminants in sandy aquifers have limited application to karst aquifers. Most natural attenuation and bioremediation guidelines specify that they are not applicable in fractured rock or karst aquifers (U.S. Environmental Protection Agency, 1997).

The lack of studies examining biodegradation in karst aquifers may be because of the widespread perception that contaminants are rapidly flushed out of karst aquifers. In highly developed and well-connected conduit systems, the rate of contaminant migration is expected to be much faster than the rate of biodegradation. Field (1993) states that remediation techniques such as ground-water extraction or bioremediation are impractical in karst aquifers dominated by conduit flow; however, he also states that the belief that contaminants are rapidly flushed out of karst aquifers is a popular misconception. Large volumes of water may be trapped in fractures along bedding planes and other features isolated from active ground-water flowpaths in karst aquifers (Wolfe and others, 1997). In areas isolated from the major ground-water flowpaths, contaminant migration possibly may be slow enough that biodegradation could reduce contaminant mass if favorable microorganisms, food sources, and geochemical conditions are present (Byl and Williams, 2000; Byl and others, 2001). The capacity for biodegradation processes in a karst setting was evaluated at sites in Tennessee and Kentucky.

A karst-aquifer site contaminated with jet fuel was investigated. The site is located at an airfield in southern Kentucky. Ground-water samples were collected for bacteria and geochemical analysis from several contaminated monitoring wells in an unconsolidated regolith and karst aquifer that had varying concentrations of dissolved fuel. Bacteria counts ranged from approximately 700,000 bacteria per milliliter to 1.2 million depending on the well and sample collection time. These bacteria counts were derived using two methods, direct counts and BART growth tests, and the results of the two tests were within 20 percent of each other. These numbers are much greater than previously reported when tryptic soy agar was used to quantify heterotrophic bacteria in the same wells (Byl and others, 2001). Bacteria from the fuel-contaminated part of the karst aquifer had a 5 percent lighter buoyant density and a wider range of sizes than the bacteria from the non-contaminated well. Additionally, bacteria isolated from fuel-contaminated ground-water samples readily grew with dissolved gasoline as the only source of food. Static microcosms (n=3) set up using aerated raw karst water spiked with benzene at 1 milligram per liter (mg/L) established a biodegradation rate of 50 percent loss ($T_{1/2}$) in 1.2 days. Sterile control microcosms had less than 10 percent benzene loss over the same time period. Additional field evidence that biodegradation was taking place in the aquifer was established by measuring geochemical indicators. The wells with screens intersecting non-contaminated sections of the aquifer had greater dissolved oxygen concentrations (generally above 2 mg/L) than those intersecting more contaminated sections (dissolved oxygen less than 0.1 mg/L). Also, where the oxygen concentrations were diminished, geochemical evidence indicated that anaerobic processes were active. This evidence includes elevated levels of ammonia, sulfide, and ferrous iron in the fuel-contaminated ground-water samples. Based on these results, biodegradation of fuel constituents in the karst aquifer is indicated, and therefore, bioremediation should not be disregarded because of preconceptions about low microbial activity in karst aquifers.

Before bioremediation can be accepted as a remediation strategy, a method would have to be developed that could help predict the fate and transport of the contaminants in the karst aquifer. Predicting the fate and transport of organic contaminants in a karst aquifer is especially challenging because of the complex hydrogeology and uncertainties in residence time. A recent objective of this research was to adapt the residence-time distribution (RTD) biodegradation model, which was developed to predict the biotransformation of a single spill in a karst aquifer, for a continuous input of contaminants. Theoretically, the RTD for a karst system calculated from either a pulse- or a continuous-input tracer study would be identical, but mathematical manipulation of the data for the two approaches is quite different. Determination of the RTD from a continuous input requires numerical differentiation of tracer response data as opposed to numerical integration for the pulse approach. Three experimental runs were conducted involving the application of a continuous input: (1) rhodamine dye alone to establish RTDs for the systems, (2) sterile toluene (25 micrograms per liter) to quantify abiotic sorption, and (3) toluene with karst bacteria to quantify biodegradation. The three replicate karst systems were each 5 liters and had a continuous flow rate of 3.3 milliliters per minute. The difference between the RTD-based model prediction and the experimental toluene conversions was 17 percent. The continuous-input approach (numerical differentiation) had the tendency to magnify experimental and random errors in the tracer response data as compared to the pulse-input method (numerical integration).

REFERENCES

Byl, T.D., and Williams, S.D., 2000, Biodegradation of Chorinated ethenes at a karst site in Middle Tennessee. U.S. Geological Survey Water-Resources Investigations Report 99-4285, 58 pages. Also available at http://pubs.water.usgs.gov/wri994285

Byl, T.D., Hileman, G.E., Williams, S.D., and Farmer, J.J., 2001, Geochemical and microbial evidence of fuel biodegradation in a contaminated karst aquifer in southern Kentucky, June 1999, *in* U.S. Geological Survey Karst Interest Group Proceedings, St. Petersburg, Florida, February 13-16, 2001. E.L. Kuniansky, ed., WRIR 01-4011, pages 151-156.

Field, M.S., 1993, Karst hydrology and chemical contamination: Journal of Environmental Systems, v. 22, no.1, p. 1-26.

Quinlan, J.F., 1989, Ground-water monitoring in karst terranes: recommended protocols and implicit assumptions: Las Vegas, Nev., U.S. Environmental Protection Agency, Environmental Monitoring Systems Laboratory, EPA/600/X-89/050, 100 p.

U.S. Environmental Protection Agency, Region 4, 1997, Draft EPA Region 4 Suggested practices for evaluation of a site for natural attenuation (biological degradation) of chlorinated solvents, Version 3.0: Atlanta, Ga., U.S. Environmental Protection Agency, Region 4, 41 p.

Wolfe, W.J., Haugh, C.J., Webbers, Ank, and Diehl, T.H., 1997, Preliminary conceptual models of the occurrence, fate, and transport of chlorinated solvents in karst aquifers of Tennessee: U.S. Geological Survey Water-Resources Investigations Report 97-4097, 80 p.

Chalk Talk Holland Hall Room 124 2:00 – 5:00PM