HYDROGEL TRACER BEADS: THE DEVELOPMENT, MODIFICATION, AND TESTING OF AN INNOVATIVE TRACER FOR BETTER UNDERSTANDING LNAPL TRANSPORT IN KARST AQUIFERS

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PROTECT
Puerto Rico Testsite for Exploring Contamination Threats

Goal for this Project

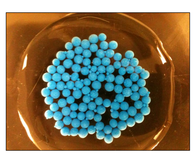
The goal of this specific research task is to develop proxy tracers that mimic contaminant movement to better understand and predict contaminant fate and transport in karst aquifers.

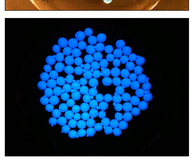
Hydrogel tracer beads are transported as a separate phase than water and can used as a proxy tracer to mimic the transport of non-aqueous phase liquids (NAPL). They can be constructed with different densities, sizes & chemical attributes.

Bead Creation and Optimization

How the beads are made:

- Make alginate solution
  - 3 grams of low viscosity sodium alginate is added to 97 grams of deionized water and mixed thoroughly on a stir plate to create a 3% alginate solution
- 3M™ Glass Bubbles and Risk Reactor © Fluorescent Pigment are added to the alginate solution at 1% w/w.
  - Glass Bubbles alter the bead density to allow for floatation
  - Fluorescent pigment color codes the beads and makes them more visible for detection
- Dropwise add alginate solution into curing solution (0.1 M $CaCl_2 \cdot H_2O$) using a syringe and needle with constant stirring
- Cure beads in $CaCl_2 \cdot 2H_2O$ solution





Scan to watch bead production!

Beads under regular light and UV light.

Beads next to fish (frog?) eggs

Sampling

Buckeye

Water: Collected in 250 mL plastic bottles and separated for bromide and fluorescein
Beads: Caught continuously over 20 seconds in pool skimmers

Rhine Creek

Water: Collected in 40 mL amber glass vials for fluorescein
Beads: Caught continuously over 20 seconds in 10 inch aquarium nets

Tracer Analysis

Bromide was analyzed at National Energy Technology Laboratory ion chromatography (IC).

Fluorescein concentrations were measured on a scanning Varian Cary Eclipse Fluorescence Spectrophotometer with a synchronous scan over 450-550 nm or a single excitation Turner Deigns 3100 Laboratory Fluorometer with an excitation of 486 nm and emission of 510-700 nm. Calibration standards were diluted in creek water that was collected prior to testing to account for matrix interference.

Beads were counted as total collected in the 20 second sampling interval

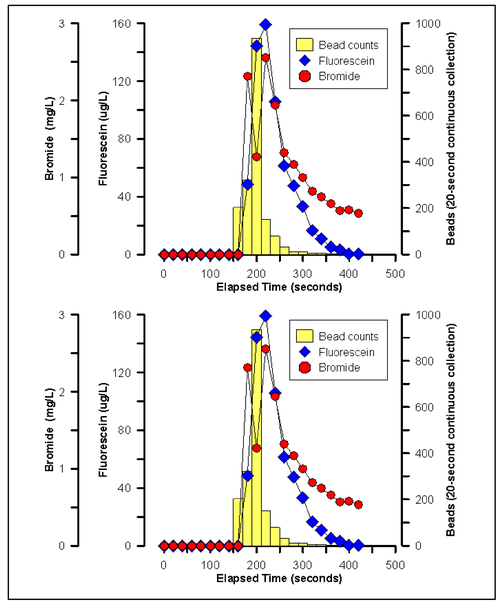
Quantitative Analysis

QTRACER2, a program developed by the U.S. EPA is being used for analysis of the breaktrough curves. A set of user input files are created and the program calculates properties such as time of first detection, peak time, peak concentration, mean velocity, peak velocity, mean tracer transit time and recovery.

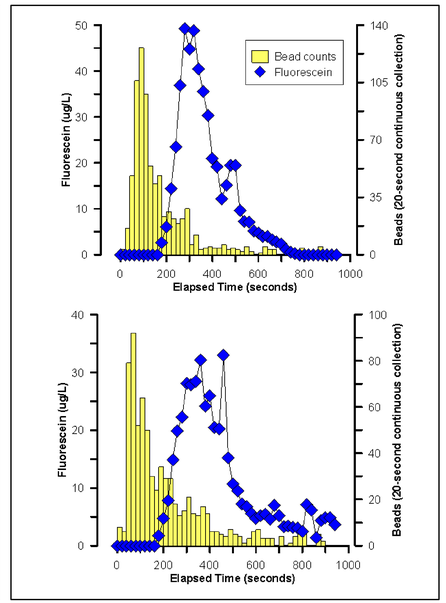
Bead collection in aquarium nets and pool skimmers.

Field Testing of Buoyant Beads

Buckeye Creek Cave



Rhine Creek



Test Location	Site description	Recovery	QTRACER2 details
Buckeye Creek Cave stream May 2012	Constricted cave passage (<1 m wide). 0.14 m^3/sec Tested over 64 m	Beads 58, 72% Fluorescein 92, 89% Bromide 123, 102 % 20 seconds lag between beads and dye	**Peak time (seconds)** Fluorescein 220,200 Bromide 220,200 Beads 200,180 **Mean transit time (minutes)** Fluorescein 3.91, 3.82 Bromide 4.96, 4.38 Beads 0.43 (?), 3.27
Rhine Creek October 2012	Low-flow meandering carbonate creek. 0.08 m^3/sec Tested over 64 m	Beads 52, 47% Fluorescein 86, 78% 160 and 180 second lag between beads and dye	**Peak time (seconds)** Fluorescein 660, 840 Beads 440, 460 **Mean transit time (minutes)** Fluorescein 12.4, 13.9 Beads 9.7, 10

The buoyant beads are transported ahead of the dissolved solutes, suggesting that LNAPL transport in karst may occur faster than predicted from traditional tracing techniques. The hydrogel beads were successful in illustrating this enhanced transport.

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