Karst aquifers – formed in areas underlain by soluble rocks – are critical freshwater resources in many parts of the US and the world (Fig. 1). These aquifers can be highly vulnerable to non-aqueous phase liquid (NAPL) contaminants (e.g., gasoline, solvents) due to their close connection to the land surface via sinkholes and sinking streams (Fig. 2). There are three key factors affecting NAPL transport in karst:

1. The physical configuration of karst aquifers can trap dense and light NAPLs behind physical barriers (Fig. 2).

2. In open-channel flow, light NAPL (LNAPL) can be transported faster than dissolved solutes (Fig. 3).

3. Contaminants may be stored or released episodically during storm surges or drought when the aquifer can undergo rapid and significant hydrologic-geochemical changes.

Despite the prevalence of karst aquifers worldwide and the strong dependence on them for water supply, we still understand very little about how contaminants are transported in karst systems.

Our goal is to develop tracers that can be used as experimental tools for investigating NAPL fate and transport in karst waters.
Development of methods to quantify the transport of NAPL-analog hydrogel tracer beads in karst systems

QUANTIFYING BEAD TRANSPORT

1. Video Acquisition

Beads containing fluorescent pigments are released in water. When they pass mounted underwater UV lights (24 watts, 395 nm λ), the pigment is excited and the images are captured on video.

For the beads to work for longer term or distance traces, we need an improved means of detection beyond manual collection. This new detection method provides these benefits:

• Automated data collection
• Works underwater
• Can compensate for the reflection from a turbulent water surface

A fluorescence-based detection method, modified from Tauro (2010), was selected for testing with floating beads with added pigment.

2. Image Pre-Processing Algorithm

An image analysis algorithm was developed in MATLAB® (R2013a, The Math works Inc., Natick, MA) using functions from the Image Processing Toolbox (IPT). When the algorithm runs, it takes each frame from a video recording and executes three pre-processing steps to each before analyzing their mean pixel intensity. Three steps are necessary to eliminate the pixels that correspond to ultraviolet light reflection from the water surface. The use of this algorithm is illustrated by a short test:

3. Algorithm to Breakthrough Curve

The mean pixel intensity of each pre-processed frame is calculated obtaining a value from 0 (black frame) to 255 (white frame). Because the tracers are used in dark environments, this means that pixel intensity records bead transit. The resulting breakthrough curve can be used to model flow parameters.

Fig. 9. Bead breakthrough curve generated using this method

UPCOMING RESEARCH

• Field and flume tests with the current detection method for LNAPL-proxies – conducted in combination with solute tracers
• Remote control for video filming
• Development of detection techniques using side-looking cameras for denser beads

REFERENCES


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