Scanning the Earth to Help Predict the Movement of Contaminants in Groundwater

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Kamini Singha sampling groundwater for the saltwater tracer she has injected in the subsurface.

Approximately 300,000 to 400,000 sites with contaminated groundwater exist in the United States. The estimated cost of cleaning these sites is around $1 trillion dollars over a 30-year period. In the interests of health and safety of the public, methods that can inexpensively characterize the subsurface of the Earth are desperately needed. My research focuses on using methods that allow us to "see" into the Earth, similar to a medical CAT scan, to help determine the movement of contaminants in groundwater. Because taking direct measurements of contaminant concentrations is often too expensive to be feasible, I use indirect, inexpensive methods to help guide the location of subsurface contaminants.

Common types of groundwater contamination include gasoline, solvents from dry-cleaning or plane degreasing, and saltwater intrusion along coasts. Direct measurements of contaminant concentration are ideally what we'd like to collect. We can drill a well, take a sample of the water in that well, and then measure the concentration of a contaminant in the sample. If there are a number of wells, and we sample them through time, we can get an idea of where the contaminants are moving. The problem is we often don't have enough wells to tell an accurate story, or the personnel to sample frequently enough. We need more data. Innovative uses of remote-sensing methods give indirect data that can help us define subsurface details inexpensively.

Detecting contaminants with remote-sensing methods is still a difficult problem that is aggressively being researched. These remote methods are similar to collecting gigantic CAT scans. CAT scans produce high energy electromagnetic waves, similar to visible light, but with higher energy that allows them to pass through our bodies. The resultant scan is basically a record of shadows; we have a light shined on one side of our bodies and the film records the shadows of our bones. We move the light around in three-dimensions to try to better reconstruct what we're seeing—a brain tumor or torn knee cartilage, for instance. In the Earth, we can't surround our patient to shine the light from all directions. As geologists, we're forced to work with partial views, reconstructing what's below the land surface from slices that might not tell the whole story. It's a difficult problem since we only get shadows from certain angles. Because we only get partial information, the indirect data need to be considered in conjunction with other direct data.

The other major problem with using remote-sensing methods is that they do not give measurements of concentration as sampling does. Instead we measure another property that we try to correlate with what we're interested in. In my case, I use electrical conductivity. I treat the Earth as a giant circuit: instead of shining light, I inject electrical current into the ground, and I measure the resultant voltage. By taking many measurements of current and voltage, we can reconstruct the electrical conductivity of the Earth. The question remains: how do we use electrical conductivity to give us contaminant concentration? We know water is more electrically conductive than rocks—we don't swim during lightning storms for a reason. Contaminants in the water, if they contain metals or ions, may be more electrically conductive than the natural groundwater, and therefore identifiable using a remote-sensing method. We use the few direct measurements of concentration we have to form a relationship with the remote-sensing data.

In my research I'm trying to understand the movement of groundwater contaminants in a sand and gravel aquifer in Cape Cod, Massachusetts. This aquifer serves as the only source of groundwater in the area, and has been contaminated by 60 years of military use, including a sewage-treatment center. The goal of my work is to improve models of contaminant flow and transport in the area by including data from these remote scanning methods. I introduce salt water as an artificial contaminant. The ions from the salt allow a greater current to pass through the subsurface than the natural water. The artificial tracer is convenient since I control the time and location of release. I can only collect limited direct measurements of the saltwater tracer, and wouldn't be able to reconstruct the movement of the tracer from those measurements. The indirect measurements, therefore, add a significant amount of information. I can monitor the movement of the tracer in three dimensions in time with little manual labor. By looking at all of the data together, I can reconstruct the movement of the saltwater tracer. By modeling the movement of this artificial contaminant, we can predict the movement of other real contaminants in the same area. This enhanced modeling can allow for better contaminant clean up and help monitor contaminated areas when local drinking water is endangered.