PHYS.ORG

Scientists find new solutions for the arsenic-poisoning crisis in Asia

March 24 2009, by Chelsea Anne Young

(PhysOrg.com) -- Every day, more than 140 million people in southern Asia drink groundwater contaminated with arsenic. Thousands of people in Bangladesh, Cambodia, India, Myanmar and Vietnam die of cancer each year from chronic exposure to arsenic, according to the World Health Organization. Some health experts call it the biggest mass poisoning in history.

More than 15 years ago, scientists pinpointed the source of the contamination in the Himalaya Mountains, where sediments containing naturally occurring arsenic were carried downstream to heavily populated river basins below.

But one mystery remained: Instead of remaining chemically trapped in the river sediments, arsenic was somehow working its way into the groundwater more than 100 feet below the surface. Solving that mystery could have significant implications for policymakers trying to reverse the mass poisoning, said Stanford University soil scientist Scott Fendorf.

"How does the arsenic go from being in the sediment loads, in solids, into the drinking water?" said Fendorf, a professor of environmental Earth system science and a senior fellow at Stanford's Woods Institute for the Environment.

To find out, he launched a field study in Asia in 2004 with two Stanford colleagues: Chris Francis, an assistant professor of geological and environmental sciences, and Karen Seto, now at Yale University. The initial study was funded with a two-year Woods Institute Environmental Venture Projects grant. Five years later, the research team appears to have solved the arsenic mystery and is working with policymakers and government officials to prevent the health crisis from escalating.

"The real thing is, how do we help the people who are there?" Fendorf said. "But first, we have to understand the coupling of hydrology—the way the water is flowing—with the chemistry and biology."

Finding a study site

Arsenic-laden rocks in the Himalayas feed into four major river systems: the Mekong, Ganges-Brahmaputra, Irrawaddy and Red. Epidemiologists first identified arsenic poisoning in the 1980s in the Ganges-Brahmaputra Delta in Bangladesh. The sudden occurrence of the disease was linked to the increased use of wells for drinking water.

Scientists had long assumed that the contamination process occurred deep underground, in buried sediments that release arsenic into aquifers 100 to 130 feet below the surface. But Fendorf and his colleagues had data suggesting otherwise. They suspected that the arsenic actually dissolved at a much higher depth, very close to the surface. "As the water starts to move down into the soil, it picks up arsenic. That was our hypothesis," he said. "We needed to follow the chemistry of the surface water as it moved down into the groundwater."

Fendorf and his colleagues began their fieldwork in the Brahmaputra River basin of Bangladesh. However, creating a hydrology model was a challenge, because the landscape was dotted with irrigation wells that alter the natural path of water. "When you draw out how the water might flow, it looks like spaghetti," Fendorf explained. "Before we even started we said there is no way this is going to be possible."

The researchers needed a less-developed site that was chemically, biologically and geologically similar to Bangladesh. The Mekong River in Cambodia offered a perfect alternative. Its headwaters are only 100 miles away from those of the Brahmaputra River. "All the chemistry up in the Himalayas is similar," Fendorf added. "The transport down the big river system is very similar as well."

More importantly, the Cambodia site was mostly undeveloped. "Cambodia had been under a 35-year civil war that had really repressed its development, so it was in essence Bangladesh 40 or 50 years ago," he said. "In some ways it would actually be setting the clock back and getting a snapshot back in time. By virtue of having this more simplistic system, we could really track the entire water flow."

Field results

The new field site was located just south of Cambodia's capital, Phnom Penh. Fendorf hired local workers to drill wells at three different depths throughout the 20-square-mile site. Testing the water for dissolved arsenic at various depths allowed the researchers to pinpoint where the toxin was migrating into the aquifer. To observe solids, they also installed water-sampling devices a foot or two below the surface. The data they collected allowed them to put together a model of arsenic cycling in the river delta.

"We found out that, sure enough, within the first 2 to 3 feet from the surface, arsenic was coming out of the solids—that is, the sediments transported down from the Himalayas—and into the water, and then it migrated down into the aquifer," Fendorf said. Aquifers are the source of drinking water for people who use wells throughout Cambodia, Bangladesh, Myanmar, India and Vietnam.

The culprits responsible for dissolving the arsenic turned out to be bacteria that live in the soil and sediment of the river basin. The researchers discovered that arsenic flowing down the river from the Himalayas sticks to rust particles called iron oxides. Upon reaching the river delta, these arsenic-laden particles are buried by several layers of soil, creating an oxygen-free, or anaerobic, environment. Normally, bacteria use oxygen to breathe. But in an anaerobic environment, they can use other chemicals, including rust and arsenic. As the bacteria metabolize the iron and arsenic, they convert it to a form that readily dissolves in water.

"As these sediments get buried very rapidly, the bacteria go through an anaerobic metabolism that dissolves the iron minerals and the arsenic with it," Fendorf said. "The arsenic goes into the water and the problem starts."

The results, published in the journal Nature, confirmed Fendorf's hypothesis: Arsenic contamination was occurring near the surface and, in fact, would take at least 100 years to reach the aquifer below. The Stanford team also showed that the 100-year-scale cycling of arsenic into the aquifer was a natural process that had been occurring for thousands of years, preceding any human influence. "We showed that there is a perpetual source of arsenic that replenishes from the surface," Fendorf said.

Solutions to the crisis

Understanding the area's hydrology will allow developers to strategically install wells that draw from areas free of dissolved arsenic, providing clean, drinkable water. Such targeted excavation can be extremely accurate, Fendorf said.

But what if a village needs a well but is unable to find an arsenic-free location to install it? Fendorf has proposed several solutions, including installing arsenic filters, collecting rainwater and purifying surface water. Each option has pros and cons, he said.

Filtering arsenic from well water raises the problem of how to dispose of leftover waste. "There aren't hazardous waste landfill sites," he noted. Additionally, the filter approach requires a dependable monitoring system. "If you do have a failure of the filter, how do you know when it occurs, and how are you going to be testing for that?" he asked.

Harvesting rainwater with collection tanks or rooftop gutters can be effective in certain locations and for certain people, he said. But areas with longer dry seasons require big tanks that are often too expensive. "These are areas where people are making less than $2 a day," Fendorf noted.

Another option is to use a disinfectant to purify surface water collected from ponds or rivers. The problem, he said, is that the filters have to be very cheap and easy to use. To solve the problem, Fendorf has been collaborating with Resource Development International (RDI), a non-governmental organization in Cambodia that makes affordable filters from locally discarded clay and rice hulls.

With these challenges in mind, Fendorf and Stanford post-doctoral scholar Matt Polizzotto have proposed finding the best option on a village-by-village basis. Beginning March 24, Fendorf will co-host a four-day meeting on arsenic poisoning in Siam Reap, Cambodia, with about 60 experts, including government officials, scholars, NGOs and funding agencies, such as the World Bank. The meeting was convened by the American Geophysical Union and the Woods Institute.

"The first three days will be devoted to the arsenic groundwater problem," Fendorf said. "We hope to converge on a resolution, as a scientific body, on what we agree about the problem, what remains unresolved and what needs to be done to fill the gap. The final day of the meeting will look more holistically at the water problem, examining best options for bringing safe drinking water to the populace."

Land-use changes

According to Fendorf, the new understanding of arsenic cycling comes at a critical time for Cambodia, which is finally recovering from years of political unrest and is looking to bolster its economy by installing wells for drinking water and irrigation, and excavating soil to make roads and bricks. Such land-use changes could affect arsenic flow patterns throughout the delta, he warned, although in some cases, this may not be a bad thing. "The land-use changes will definitely modify the arsenic levels," he said. "Sometimes they might increase the level, and sometimes they might decrease it, depending on where they are situated and what the surrounding environment is like."

Although Fendorf and his colleagues came to Cambodia focused on understanding the science of arsenic contamination, they soon realized that what mattered most was the potential to make a difference in the lives of individuals. For example, the researchers tested each well they drilled for arsenic contamination. If it tested clean, they installed an additional well for domestic use and offered it to the landowner. If a well proved contaminated, the researchers would buy the landowner a rainwater-harvesting unit locally made by RDI.

"If we can give people a clean well or a rainwater harvesting unit, that's going to go a lot further, in the short term at least, than any of our study results," Fendorf said.

Provided by Stanford University (news : web)