Pumping draws arsenic toward a big-city aquifer

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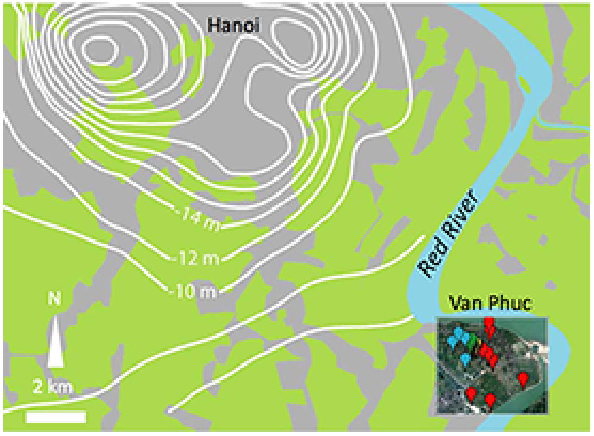
A well in the village of Van Phuc, outside Hanoi; the water is polluted with arsenic. Throughout south and southeast Asia, at least 100 million people are threatened by such wells. Credit: Benjamin Bostick/LDEO

Naturally occurring arsenic pollutes wells across the world, especially in south and southeast Asia, where an estimated 100 million people are exposed to levels that can cause heart, liver and kidney problems, diabetes and cancer. Now, scientists working in Vietnam have shown that massive pumping of groundwater from a clean aquifer is slowly but surely drawing the poison into the water. The study, done near the capital city of Hanoi, confirms suspicions that booming water usage there and elsewhere could eventually threaten millions more people. The study appears in the current issue of the leading journal *Nature*.

"This is the first time we have been able to show that a previously clean aquifer has been contaminated," said lead author Alexander van Geen, a geochemist at Columbia University's Lamont-Doherty Earth Observatory. "The amount of water being pumped really dominates the system. Arsenic is moving." The good news, he said: "It is not moving as fast as we had feared it might." This will buy time—perhaps decades—for water managers to try and deal with the problem, he said.

Arsenic is found in rocks across the world, but it seems to pollute groundwater only under specific conditions. The huge scale across south Asia came clear only in the 1990s, when researchers from universities, nonprofit agencies and governments started testing wells systematically. Van Geen has been working in the field for 13 years, and is leading a new collaborative effort in the region under the International Continental Scientific Drilling Program.

Researchers link natural arsenic pollution in south Asia to vast amounts of sediment eroding off the Himalayan plateau into basins below, from Pakistan and India to China and Vietnam. The constant fresh supply reacts rapidly with local water, though the exact mechanisms of arsenic release have remained unclear, along with the potential effects of groundwater pumping. The new study clarifies some of the chemical processes, and shows clearly for the first time that human activity can widen the problem.



Aquifers under the village of Van Phuc, on a river bend some five miles from Hanoi, are being affected by groundwater pumping for the city's water supply. Credit: Courtesy van Geen et al./*Nature*)

Hanoi, like many metropolitan areas, is mushrooming in size, and using ever more groundwater. Between 2000 and 2010, municipal pumping doubled, to some 240 million gallons a day. Much of the supply comes from an aquifer of iron-rich orange sands more than 12,000 years old that is largely free of arsenic. But patches of younger, greyish sand are contaminated. The city started filtering its water about 10 years ago. But in the suburbs, near the neighboring Red River and beyond, many residents rely on private wells drilled into a patchwork of clean or polluted sands, and no central filtering system is available.

Van Geen and colleagues, including a team from the Hanoi University of Science, studied 31 wells around the village of Van Phuc, about 5.5 miles southeast of the city, near the river, for several years. They found that in the parts closer to Hanoi, shallow wells go into the safe orange sediments; nearer the river, they go into the grey ones, and draw arsenic. Normally, high water levels in the safe aquifer would drain toward the river, and keep the polluted water at bay. But the team found that

Hanoi's pumping has reversed this; the safe aquifer is now, in effect, sucking water from the contaminated one, and from the river itself. Using helium and hydrogen isotope dating techniques, they showed that over the last 40 to 60 years, water from the contaminated aquifer has migrated inland some 2,000 meters (more than a mile). During the same time, substantial arsenic contamination has moved at a slower pace, going in about 120 meters, or 370 feet.

"Many people anticipated that pumping out these [good] aquifers would put them in jeopardy, but before this we didn't have proof," said Scott Fendorf, a soil geochemist at Stanford University who was not involved in the study. "This demonstrates that there is a threat." Fendorf said that in many areas from India to Vietnam, people are drilling wells deeper to get away from generally shallow arsenic-rich sediments. The study suggests that these deep wells, too, could eventually go bad. Recent studies by other groups suggest that wells in the Indian state of West Bengal are at risk, but in Bengal there are so many wells in so many places, it is hard for researchers to track exactly what is happening. The Hanoi study, by contrast, starkly demonstrates and quantifies the results, because municipal pumping is so centralized.

Study coauthor Michael Berg, a geochemist at the Swiss Federal Institute of Aquatic Science and Technology, called the Hanoi pumping "a huge, unintended experiment." Berg said that similar processes may be underway in other areas such as the megacities of Dhaka and Beijing, and widespread farming areas of Asia, along with parts of sub-Saharan Africa, and South and North America, where irrigation and municipal pumping are sucking aquifers dry. "We are altering systems all over the world," he said.

Left to right: A driller, and study coauthors Benjamin Bostick and Nguyen-Ngoc Mai work at a high-arsenic well near the village of Van Phuc. Credit: Charles Harvey/MIT

As for how the arsenic gets into water, van Geen says that around Van Phuc, like many other areas, the apparent key is dissolved organic carbon—bits of decayed plant matter and other detritus of living things. Water in the safe aquifer is relatively free of it, but water flowing in through the riverbed and organic-rich soil and clay on top of the aquifer is loaded with it. As water migrates into the safe aquifer, carbon reacts with the abundant iron rust sticking to the sand grains, and the rust dissolves into the water. Arsenic in the sediment tends to stick to this rust, but once the rust is dissolved, so is the arsenic, and people wind up drinking the brew. As the reactions proceed, orange sands fade to grey; indeed, a plume of grey sand seems to be creeping under Van Phuc, toward Hanoi.

The researchers point out that arsenic pollution moves about 16 to 20 times slower than the actual migration of outside water, apparently because it takes a while for the chemical reactions to get going. This confirms a short-term 2011 study in *Nature Geoscience* showing similar effects at a site in Bangladesh. But, said Berg, "it is constantly moving, and as it moves on and on, more people are exposed."

In affected parts of Van Phuc, arsenic is now 10 to 50 times over acceptable levels. Coauthor Pham Thi Kim Trang, vice director of the Hanoi university's Center for Environmental Technology and Sustainable Development, said that people are drilling deeper wells, and efforts are underway to install a filtering station. However, she said, "if people in the city keep drawing more water, the arsenic problem will become more serious." With the suburbs expanding so rapidly she said, more people are connected to private wells. "We are trying to find out more about the conditions in which the arsenic moves, and how to protect people," she said. Van Geen said the research may aid the design of remediation efforts in the United States and elsewhere, where carbon leaching from landfills is polluting some aquifers. Columbia's Superfund research program partially supported the Hanoi study.

More information: The paper, "Retardation of arsenic transport through a Pleistocene aquifer," is available from the authors or from Rebecca Walton at *Nature*. dx.doi.org/10.1038/nature12444

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