Origin of arsenic in Bangladesh groundwater

May 29 2020, by Rajib Mozumder, Holly Michael, Peter Knappett, and Alexander Van Geen

A typical hand pumped drinking water well in rural Bangladesh. Credit: Peter Knappett

Twenty years ago, Smith and colleagues described groundwater arsenic (As) contamination in Bangladesh as the "largest mass poisoning of a population in history." An estimated 60 million people were unknowingly drinking groundwater containing dangerous concentrations of naturally occurring As. Today, despite a much-improved well water testing effort, an estimated 30–35 million are still chronically exposed to elevated levels of As in their drinking water, and hundreds of thousands are suffering from cardiovascular disease and cancers, leading to a staggering annual estimated death toll of 43,000.

We studied a rural area in Bangladesh where the villagers reduced their exposure to As over the past decade largely through installation of private wells at >50 m depth within a sandy, low-As aquifer. The low-As aquifer is seemingly protected from the intrusion of shallower (150 m) has been overexploited over the last 50 years to meet municipal demands. The Dhaka cone of depression has already expanded 30–40 km outside the city center, drawing water from beyond the city limits and lowering heads in distant rural aquifers.

Our field data show that the deep hydraulic head decline in the pumping center of Dhaka at a rate of >3 m/year is causing the head to decline by ~0.5 m/year at our study site in rural Araihazar. Water levels in the shallow aquifer (50-70 m).

Our new results indicate that, within only a decade, shallow groundwater can penetrate the top of the low-As aquifer in the study area. When there was no Dhaka pumping, the intrusion of shallow groundwater was likely delayed by hundreds of years, or even more. Therefore, distant urban pumping has drastically reduced shallow groundwater travel times to vulnerable low-As aquifers.

Groundwater velocity sets the lower limit for time of As transport. It is well established, however, that the transport of As is delayed relative to groundwater flow. Unlike water particles, As is strongly sorbed by the aquifer matrix. For example, if As is retarded by a factor of 10, As travel time will be 10 times longer than groundwater travel time. We conclude from field observations that As was retarded because otherwise, the entire low-As aquifer would have already been contaminated.

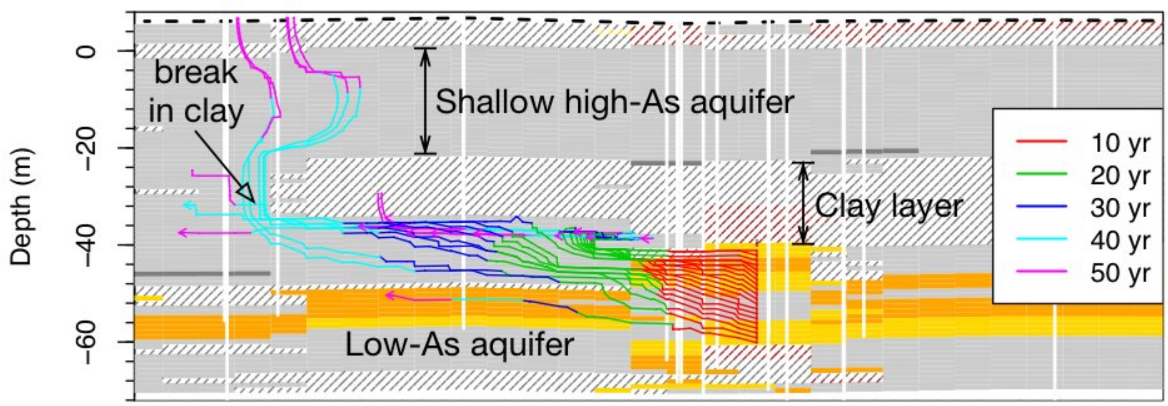
Geologic control on groundwater arsenic

We monitored several wells within the low-As aquifer where As concentrations recently rose to toxic levels. This is surprising, since a 10–15-meter-thick clay layer bars the inflow of As from the shallow aquifer. And at the same time, As is retarded with respect to groundwater flow. How was this dual protection against As intrusion breached?

We discovered several locations where the clay layer barring the downward intrusion of high-As groundwater was missing, which allowed accelerated transport of As through the breaks in the clay layer. We measured high As concentrations in young groundwater near those recharge "windows," confirming recent inflow of shallow groundwater.

We sought a different explanation for old groundwater containing elevated levels of As concentrations directly beneath the clay. A simple back-of-the-envelope calculation revealed that the clay layer itself was the likely source of a different groundwater constituent, reactive reduced carbon, that led to local release of As within a previously uncontaminated aquifer.

We believe the [thick clay layer was a hotspot for As contamination](#) over thousands of years. The effect is more apparent today in response to Dhaka pumping.



Simulation results showing water parcels preferentially flow through a break in a major clay layer. Credit: Water Resources Research

The remaining unknowns

The relative importance of the two pathways of As contamination remains elusive. The absence of the clay layer allows for fast migration of As into the low-As aquifer. Paradoxically, the presence of the clay layer also directly threatens the underlying groundwater.

On the one hand, the rate of As transport through breaks in the clay will be limited by the retardation of As. On the other hand, the spread of As from the less permeable clay layer appears to be localized, and is a much slower process, even under the current pumping condition.

Arsenic mitigation

We conclude that portions of the low-As aquifer are particularly vulnerable to As contamination in the region. Unfortunately, the vast majority of villagers in the study area and elsewhere in Bangladesh are targeting these intermediate (>50-90 m deep), low-As aquifers for their drinking water supply because these depths are far more affordable to reach than the deeper (>90 m), safer aquifers. Fortunately, the Bangladesh government is planning to launch a nationwide well-testing effort. The data from the new campaign will be very useful for reducing exposure by sharing safe wells and installing deeper low-arsenic wells, but repeated testing in vulnerable areas like the one studied here are required.

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Bio:
Dr. Mozumder is an environmental engineer specializing in the geochemistry, fate, and transport of environmental contaminants. He earned his Ph.D. in groundwater geochemistry at the Lamont-Doherty Earth Observatory (LDEO) of Columbia University, New York, NY. Dr. van Geen is a LDEO Research Professor of geochemistry. Dr. Michael is a Professor of Earth Sciences at the University of Delaware. Dr. Knappett is an Associate Professor of Hydrogeology at Texas A&M University.