Clay Layers May Worsen Arsenic Contamination

Layers of clay are widely thought to protect groundwater aquifers from above-ground contaminants. But according to a new NIEHS Superfund Research Program study, these clay layers may play a role in increasing groundwater arsenic contamination.

Arsenic, naturally found in earth's crust, is known to cause a variety of health problems in humans. Because shallow groundwater aquifers are contaminated with high levels of arsenic in certain regions of Bangladesh, deeper wells were installed to supply low-arsenic drinking water. The deeper aquifers are separated from the arsenic-contaminated shallow aquifers by a thick layer of clay.

However, at a site near the village of Baylakandi, Bangladesh, Columbia University SRP Center researchers and colleagues found unexpected results. Led by Alexander van Geen, Ph.D., the team observed increasing concentrations of arsenic over time in deeper wells, revealing that clay layers rich in organic carbon may enhance arsenic contamination, rather than protect against it.

The scientists monitored wells of different depths within the deep aquifer to understand why arsenic levels were increasing over time.

By examining the drill cuttings collected during well installation, the scientists found the deeper aquifer contained two different types of sediment beneath the clay confining layer. They observed orange sediment containing iron(III) oxides, and gray sediment containing reduced iron(II) oxides, which are created from iron(III) oxides in the presence of organic carbon. In the drill cuttings, orange sediment was found between two layers of gray sediment in the deep aquifer.

The team documented an increase in arsenic concentrations in the deeper aquifer using monitoring wells between 2011 and 2018. Arsenic concentrations were higher in samples taken in the gray sediment near the clay layer compared to samples taken further below.

Results showed increases in arsenic concentrations mirrored dissolved iron, which was higher in the gray sediment close to the clay layer and steadily decreased with depth. Dissolved organic carbon in the clay pore-water was an order of magnitude higher than most of the groundwater sampled in the monitoring wells and was also higher in the gray sediment compared to the orange sediment.

Arsenic tends to bind to sediments, making it less mobile in the environment. However, through interactions between organic carbon and iron oxides, arsenic can be mobilized and released into water.

To further clarify the mechanism of arsenic contamination in the deep aquifer, the team analyzed sediment and pore-water from the monitoring wells and used advanced tracing

techniques. They also measured changes in pressure related to water levels and well pumping from surrounding areas.

They expected arsenic from the shallow arsenic-contaminated aquifer to infiltrate gaps in the clay layer; however, their results suggested chemical interactions just below the clay played a more important role. Specifically, they found that organic carbon released by the clay layers likely drives chemistry changes with iron that trigger the release of arsenic to underlying groundwater.

Their results also linked higher arsenic contamination with over-pumping to meet the municipal water demands of nearby Dhaka, the capital of Bangladesh, which has depleted the deep aquifer far below normal levels. The over-pumping and resulting lowered water table further strain access to safe drinking water, as it can alter the flow of groundwater and distribution of pollutants.

The scientists stressed that two decades of sustained research in the region was critical to their discovery. According to the authors, these findings are also relevant to other regions, such as the upper midwestern U.S., where high levels of arsenic have been measured beneath clay layers. Their findings shed light on why private wells screened just below a clay layer are more likely to be contaminated with arsenic than those that are deeper and further from the clay.

If you'd like to learn more about this research, visit the Superfund Research Program website at niehs.nih.gov/srp. From there, click on the Research Brief title under the banner, and refer to the additional information listed under the research brief. If you have any questions or comments about this month's podcast, send an email to srpinfo@niehs.nih.gov.

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