Bacteria Linked to "Worst Mass Poisoning in History"

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Bacteria are the major culprits in the arsenic poisoning of well water in Bangladesh and the Indian state of West Bengal. This discovery by researchers at England's University of Manchester may play an important role in reducing the widespread poisoning.

Over the past 20 years, dangerous levels of arsenic in well water have slowly and steadily poisoned millions of people living in the delta region of the Ganges River. In fact, according to the World Health Organization (WHO), 35 million to 77 million people may be drinking arsenic-contaminated water in Bangladesh, a country with a population of 125 million. WHO has called the crisis "the worst mass poisoning in history."
Arsenic, a silvery-white element that has some properties of a metal, comprises about 0.0001 percent of the Earth's crust, but is rarely found in its pure form. Long-term exposure to arsenic causes fatal cancers of the skin, lung and urinary bladder, as well as wart-like growths and sores. Some scientists estimate that at least 270,000 people in Bangladesh alone will die from cancers associated with drinking the contaminated water. At least 100,000 people in the region are already suffering from skin lesions caused by arsenic poisoning, according to WHO.

The arsenic-contaminated water in Bangladesh and West Bengal comes primarily from shallow tube-wells. These wells—tubes 5 centimeters (2 inches) wide and usually less than 200 meters (660 feet) deep—are topped with hand
pumps, and are used to draw water from aquifers (underground rock layers saturated with water). Water from aquifers is generally considered safer than surface water from sources such as ponds, lakes and streams, as surface water is often contaminated with pathogens (disease-causing organisms). Outbreaks of cholera (a bacterial disease that causes symptoms including diarrhea, vomiting, muscle cramps and severe dehydration) are common in regions where inhabitants depend on surface water.

In the 1970s, millions of shallow tube-wells were drilled in Bangladesh as part of an effort led by the United Nations Children's Fund (UNICEF) and the World Bank to reduce outbreaks of water-borne diseases. When wells are dug, it is standard procedure to test the groundwater (water from aquifers) to make sure it's drinkable; though groundwater is less likely than surface water to contain pathogens, it may contain dangerously high levels of minerals, salts or other chemicals. However, since authorities weren't expecting arsenic to be a problem in the West Bengal and Bangladeshi wells, the water wasn't tested for it.

The arsenic level in many of these wells is now more than five times the level of 10 mg/l (10 milligrams of arsenic per liter of water) permitted by WHO. For the past decade, scientists around the world have been trying to find out why the arsenic levels are so high. The Ganges River sediment is known to contain a form of arsenic called arsenate or As(V); it tends to combine with metal ores and other minerals. But the form of arsenic found in the well water is a more poisonous and water-soluble form called arsenite or As(III).

The Manchester team suspected that "arsenic-reducing" bacteria might be the source of the arsenite. These bacteria take in As(V) and give out As(III) as a waste product. This is similar to the way humans breathe in oxygen and give out carbon dioxide. In humans (and other oxygen-breathing organisms), oxygen is used to break down food (organic matter containing carbon and hydrogen). During this breakdown, the organic material loses electrons, a process called oxidation. Meanwhile, oxygen gains electrons, a process known as reduction. Arsenic-reducing bacteria are "anaerobic," which means that they don't reduce oxygen. Instead, to break down food, these bacteria reduce arsenate. And when electrons are added to arsenate, it becomes arsenite.

To test their hypothesis, the researchers obtained sediment samples from an aquifer in West Bengal known to contain contaminated water. They then stored their samples in the lab under different conditions. Some of them were placed in an oxygen-free (anaerobic) environment, just like the underground environment from which the sediments were obtained. Others were stored in an oxygen-rich environment. The remaining samples were placed in an autoclave—a chamber used to destroy bacteria and other microorganisms—and then stored under anaerobic conditions.

After about 5 weeks, the researchers analyzed the samples and found that, in both the autoclaved samples and those stored in the oxygen-rich environment, the levels of arsenate and arsenite in the soil had not changed. This finding fit with their hypothesis. The autoclave would have killed any arsenic-reducing bacteria, and thus the arsenate in the sample would not have been reduced to arsenite. Similarly, many anaerobic bacteria cannot survive in the presence of oxygen, so it made sense that the arsenic-reducing bacteria in the samples that were exposed to oxygen would have died as well.

However, in the remaining samples (those stored in an anaerobic environment but not placed in the autoclave), the amount of arsenite rose significantly over the course of the 5 weeks, while the amount of arsenate dropped. This suggested that arsenic-reducing bacteria were indeed thriving in the soil, converting arsenate to arsenite.
Moreover, the scientists found that arsenic release was boosted when they added acetate, or vinegar, to samples stored in the anaerobic environment. They used acetate as a substitute for the organic, or carbon-containing, matter that might be found in the aquifer sediment and serve as food for the bacteria. In the West Bengal and Bangladeshi sediments, organic material could come from peat (decomposing plant matter) deposits and human waste. Organic carbon is also introduced into soil by digging irrigation wells. The shallow tube-wells that were dug to provide safe water to Bangladeshis could thus be facilitating the harmful activity of bacteria.

Now that the Manchester study has offered a clue to the biological processes that might be causing this large-scale groundwater poisoning, scientists are trying to find ways to reverse the process. “This research means we now have a much better idea how arsenic is released into drinking water in aquifers in the region,” said Farhana Islam, a Bangladeshi PhD candidate at the University of Manchester and a key member of the research team. "The results will help to inform ways to remedy the water, leading to a healthier supply of water for thousands of people."

The study offered some possible solutions. One approach could be reducing the flow of organic material that feeds the bacteria. Another idea is bubbling air through contaminated water, thereby oxidizing the arsenite back to the less harmful arsenate form.

A further possibility the Manchester team is looking at is called bioremediation. This involves the introduction of microorganisms that could decrease arsenic levels by reversing its reduction and release into groundwater.

Arsenic poisoning suggests an English butler at work, not a tiny, anaerobic microbe. But with the health of millions at stake, scientists trying to solve the problem of poisoned wells in Bangladesh and West Bengal have as strong an incentive to succeed as any fictional detective.

Further Reading


Internet Sites


Keywords
bacteria, arsenic, World Health Organization, Bangladesh, aquifer, anaerobic

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