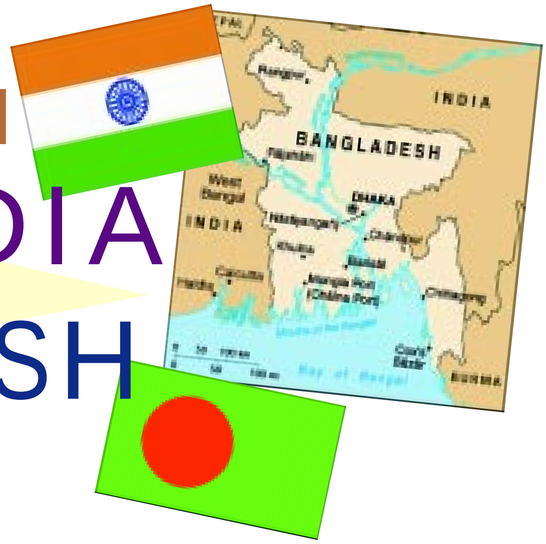
ARSENIC REDUCTION CHALLENGES IN INDIA AND BANGLADESH



By Greg Gilles and Sherry Odom

Millions of people in India and neighboring Bangladesh are currently at risk of consuming arsenic contaminated groundwater. Arsenic poisoning in these countries has become a disease of epidemic proportion, with some experts calling it the "largest mass poisoning in history."

The problem exists to a lesser degree in many other countries of the world also forced to depend on contaminated water as a public water supply source. Following an outbreak in the early 1970s, government health officials identified consumption of surface water as the cause for an alarming number of cholera- and dysentery-related illnesses. To alleviate the problem, local villages, the United Nations and the Indian district government of West Bengal, based in Calcutta, installed a large number of tube wells to supply groundwater for use in rural communities that, ideally, would be uncontaminated by humans and animals.

A problem with the solution

With the unfair advantage of hindsight, officials now realize many of the tube wells throughout India and Bangladesh retrieve drinking water from geological strata containing high levels of naturally occurring and extremely soluble arsenic. Testing performed by India's Public Health Engineering Directorate (PHED), the World Health Organization (WHO) and different universities indicates water from these tube wells contains arsenic in dangerously high levels, with some cases exceeding 2.0 milligrams per liter (mg/L) or 2,000 parts per billion (ppb)—40 times higher than the current U.S. acceptable maximum contaminant level (MCL) of 0.05 mg/L or 50 ppb. Within West Bengal alone, it's estimated 16,000-to-20,000 tube wells contain arsenic levels greater than 50 ppb. Over three million tube wells in the subcontinent have arsenic levels considered unsafe by WHO—which lowered its recommended guideline to less than 10 ppb (0.01 mg/L) from 50 ppb in 1993.

The health effects suffered by those ingesting these high levels of arsenic are frightening. Currently in West Bengal, more than 200,000 people suffer from some degree of arsenic poisoning or arsenocosis, with the majority of symptoms appearing within five to 10 years.

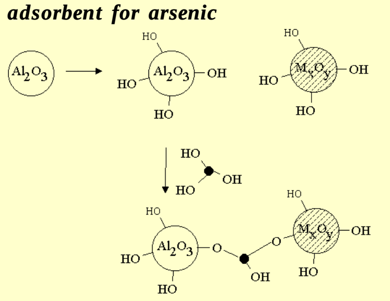
Soluble in water, arsenic exists in two primary forms: arsenite (As^{+3}) and arsenate (As^{+5}). Arsenate, the most common form, is quickly absorbed by the human body and has acute lethal effects at high doses. Long-term, high level exposure will cause arsenocosis symptoms that include thickening and discoloration of the skin; lesions; stomach pain; nausea; vomiting; diarrhea; loss of limbs or cancer of internal organs; and neurological disorders preceded by tingling and numbness in the extremities, hearing impairment and developmental effects. These symptoms usually begin to appear within five to 10 years of consumption, with fatality imminent after 15 to 20 years of exposure. Compounding physiological impairments is the social isolation experienced by those suffering from the disease. Women showing visual symptoms of the disease are often rejected or ostracized by their husbands and cut-off from family—in effect segregated from the remainder of the community.

Few if any cost-effective technologies exist to address the magnitude of this problem. Conventional methods for removing arsenic from water—which include membrane filtration, ion exchange, iron/manganese removal processes, chemical precipitation, activated alumina and other technologies—often cannot meet the requirements mandated by the region's numerous remote locations and limited financial resources. As such, a recognized need exists to develop an affordable technology that could be applied in remote areas, operate with no electricity, require no chemical addition and be simple to operate and maintain.

Removing the offender

In answer to the challenge, a new, low-cost adsorbent technology has been developed for purifying arsenic-contaminated groundwater that can assist the government of India in removing this slow but steady poison from its midst. The selective arsenic adsorbent is incorporated into an integrated treatment system designed to meet the needs of the region and is easily adaptable to rural settings. The system is effective at removing arsenic over a wide range of water quality and is extremely cost-effective—with ongoing operational costs averaging less than four cents per family per day.

Figure 1.
Mixed metal oxide composite adsorbent for arsenic



A key component to the system is an inorganic granular metal oxide-based media that can selectively remove As^{+3} and As^{+5} from water. It's manufactured employing a unique binder technology, which greatly enhances its surface properties and creates a composite particle with a unique surface, pore properties and chemical characteristics that enable arsenic adsorption capacities up to five times greater than conventional materials. Figure 1 shows the chemical structure of an alumina-based oxide composite, and Figure 2 compares its adsorption capacity with other adsorbent media.

The selective capabilities of the media permit high adsorption capacities even in the presence of competing ions, which significantly extends the media life and reduces operating costs. Adsorption kinetics are also very rapid, allowing efficient removal of arsenic, often to levels below laboratory analytical detection limits.

Figure 2.
Arsenic removal media capacity compared to conventional adsorbents.

Material	As Uptake
Activated Alumina	(mg/g)
Activated Carbon	< 2
Specialty as Adsorbent	6.8
Iron based Adsorbent Media	27.5
Arsenic Selective Adsorption Media	44.0

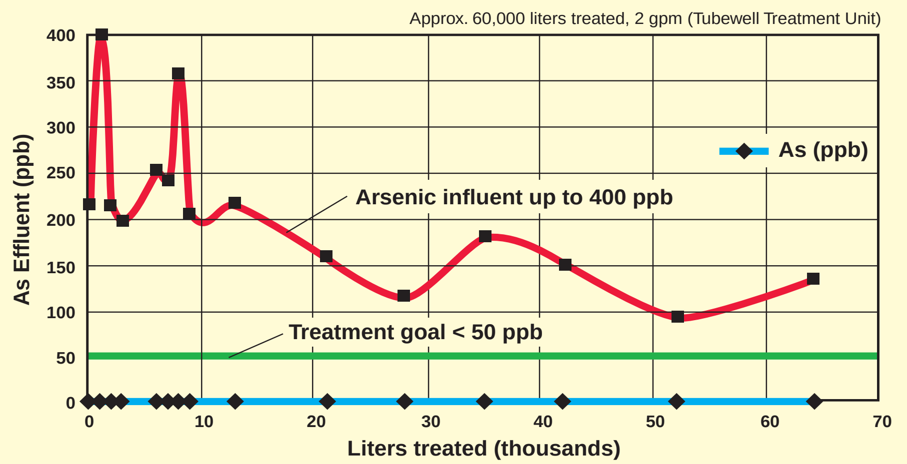
Test Parameters: 50ppm As (V) @ pH 7, 24 hrs.

Field demonstrations

To prove the efficacy of the technology for purifying contaminated groundwater, two major field demonstrations were completed in India.

In early 1998, a gravity-fed, field prototype unit was deployed in West Bengal utilizing the above-mentioned granular composite adsorption media. The unit operated successfully for three months, treating an estimated 60,000 liters of water (about 700 liters per day) at the rate of eight liters per minute. Arsenic levels of up to 400 ppb (0.4 mg / L) were successfully removed to below 10 ppb during this demonstration, which is illustrated in Figure 3. While testing, field personnel discovered wide variations in groundwater chemistry in the region and the need to address tube well water containing high concentrations of both dissolved iron and arsenic. Iron concentrations were observed at over 25,000 ppb (25 mg / L) in some wells.

Figure 3.
Arsenic removal kinetics graph from India field demonstration.



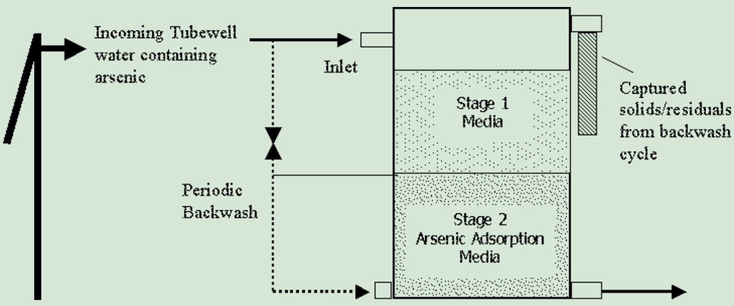
A second field test was conducted in August 1999 at a new location near Calcutta, with an enhanced new modular system designed to address high concentrations of co-existing iron and arsenic. The system successfully treated approximately 1,300 liters per day with influent arsenic concentrations as high as 900 ppb (0.9 mg / L) and iron concentrations as high as 10,000 ppb (10 mg / L). Effluent water levels after purification through the adsorption system were consistently below the recognized PHED treatment goal of 50 ppb, equating to 95 percent removal efficiency. Iron was also removed consistently by more than 96 percent to less than 50 ppb.

A global solution

Incorporating lessons learned, performance data, field operating experience and feedback from the PHED, the modular treatment system including the media composition and housing design were further optimized for use in India. A schematic of the final system is shown in Figure 4. Delighted with its cost effectiveness as well as the operational simplicity of the unit, the Indian government requested a turnkey proposal in February of this year for installation, operation and ongoing maintenance of an initial order of several thousand arsenic treatment units in West Bengal. The proposed system, which will operate for six months before requiring a change in media, is designed to treat 1,000

Figure 4.

Process schematic of an integrated arsenic treatment unit.



liters of water per day with influent levels of arsenic ranging from 50 ppb to 1,200 ppb (1.2 mg/L) and iron up to 15 mg/L. The treatment unit is fed by a conventional hand lift pump delivering 8-to-12 liters per minute of product water. The unit is also equipped with a backwashing feature that can be performed approximately every two weeks by the local villagers to remove entrained suspended solids.

Arsenic treatment in the United States is also receiving considerable attention. USEPA is preparing to lower the MCL for arsenic below the current drinking water standard of 50 ppb. Existing arsenic problems in public and private water supplies are identified in a number of U.S. geographic regions. The USEPA estimates over 2,000 public water systems and hundreds of thousands of private wells may require additional arsenic removal capabilities once regulation is finalized in 2001. Postponed since December, the new final proposed arsenic rule is to be released this month.

Conclusion

As a result of extensive research and development efforts over the past three years, successful field demonstrations, and subsequent system improvements, this integrated adsorption system appears to be the best available technology for removing arsenic in tube wells. Unique arsenic treatment challenges in India and Bangladesh demanded a custom solution that achieves high performance in varying water quality, is affordable, simple to operate, easy to maintain and requires no electrical power to operate.

Selected rural villages in West Bengal will soon be supplied with long-awaited remedial technology to mitigate the arsenic crisis, one that will provide high quality drinking water for the consumer. The adsorbent technology is easily adaptable and transferable to other water applications with arsenic concerns including municipal treatment plants, commercial or centralized water treatment systems and home water filters. q

About the authors

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FYI Arsenic

For additional information on arsenic in drinking water, visit the following websites:

- World Health Organization—www.who.int/water_sanitation_health/Water_quality/arsenic.htm
- U.S. Environmental Protection Agency—www.epa.gov/safewater/arsenic.html