

THE ARSENIC CHALLENGE

Arsenic contamination of ground water is a world wide health problem

Arsenic is the twentieth most common element in nature. Arsenic in drinking water has this far been observed in the following countries: Argentina, Australia, Canada, Chile, China, Greece, Hungary, India, Japan, Mexico, Mongolia, New Zealand, South Africa, The Philippines, Taiwan, Thailand, USA and USSR. As awareness of the menace spreads, new sources are discovered. The frightening Arsenic poisoning in India and Bangladesh are the most spectacular examples.

The arsenic poisoning in Bangladesh and West Bengal

"Bangladesh is grappling with **the largest mass poisoning of a population in history** because groundwater used for drinking has been contaminated with naturally occurring inorganic arsenic", the United Nations World Health Organization (WHO) reported in September 2000.

The research by Allan H. Smith, professor of epidemiology at the University of California at Berkeley, said that between 33 and 77 million of Bangladesh's 125 million population was at risk.

Whereas the WHO recommendation is 10 micrograms per liter, concentrations in many areas are above 3000 micrograms per liter even up to 10 000. Some experts warn that it is a matter of time before contaminated water seeps through the entire country.

Remedies have been suggested from a large number of companies and international aid agencies. None of them has yet been proven viable and people are alarmed, even in areas that are not (yet) afflicted. The Bangladesh Government now finds the situation untenable and plans forceful measures. The Swedish company Scarab has recently been asked by the Bangladesh Government to establish a subsidiary in Bangladesh to develop proprietary MD-equipment, but also to survey other possible technologies and remedies that could be beneficial.

Also in large areas of the Indian state of West Bengal, groundwater contains Arsenic several hundred times the level recommended by WHO. Some 45 million people live in the inflicted area, and there are villages where as many as 40% of the people have visible symptoms of arsenic poisoning.

The World Bank has recognized the problem

The World Bank has allocated \$ 44.4 M to find a remedy In Bangladesh. The cost for the remedy itself may run into billions of dollars, independent experts say.

There are ways to avoid the contaminated water – by transporting well water from non-afflicted sources, by drilling new wells that, hopefully, do not go into the Arsenic carrying sediment, by using purified surface water and by supplying bottled water for drinking.

Considering the continuing spread of Arsenic, purifying the water is one of the long run options. However, another report from WHO, **Arsenic in Drinking Water**, May 2001, states that: *“There are no proven technologies for the removal of arsenic at water collections points such as wells, hand-pumps and springs.”*

Important research and findings in the US

Large portions of the water supply in the United States, mostly in the Midwest and West, contain arsenic. Because of this reason the Arsenic problem has been thoroughly studied in the US. The Safe Drinking Water Act (SDWA), as amended in 1996, requires the United States Environmental Protection Agency (EPA) to revise the existing drinking water standard for arsenic. EPA initially argued for a level of 2 micrograms per liter, which is not only considerably lower than the present 50 micrograms per liter, but also lower than the present WHO standard of 10 micrograms per liter.

A report from EPA in December 2000, **Technologies and Costs for Removal of Arsenic from Drinking Water**, shows that large purification plants may, at a cost, adapt to arsenic removal, but for small plants, private wells and households, there is no ready solution.

Since the industry will have difficulties to comply, the Scientific Advisory Board of EPA and the National Drinking Water Advisory Council have been ordered to review the scientific basis for the new levels and to reassess the earlier recommendations. This has been one of the most heatedly debated environmental issues in the US in 2001.

Characteristics of Arsenic

Organic Arsenic compounds that are found in foods pass through the body quickly and are therefore quite harmless. *Inorganic Arsenic* is deposited in the body and concentrated over time and therefore causes long-term damage.

Arsenic is difficult to detect. It is tasteless, odorless and colorless, and a person can absorb significant doses without immediate harm. A well-nourished and otherwise healthy person will withstand the poison for a long time while an undernourished will perish quickly. Babies and children are especially sensitive.

When solved in water, inorganic Arsenic forms ions, which are trivalent or pentavalent. Trivalent Arsenic As+3 is considered 60 times more toxic than pentavalent As+5.

It is easy to remove As+5 with known water technologies, but difficult to remove As+3. The latter ion is also much more difficult to detect and few Arsenic detection instruments can distinguish between As+3 and As+5. Most of the technologies that have been recommended this far for combating Arsenic do a good job at removing As+5 but not As+3.

Diseases caused by arsenic poisoning

The following diseases are suspected to be caused or aggravated by Arsenic in drinking water according to EPA in **Arsenic Rule Benefit Analysis**, August 9, 2001: Cancer of the Lung, Bladder, Skin, Prostate, Kidney, Nose and Liver, Stillbirths, Postneonatal mortality, Ischemic heart disease (heart attack), Diabetes mellitus, Nephritis (chronic inflammation of the kidneys), Nephrosis (degenerative kidney diseases), Hypertension, Hypertensive heart disease, Emphysema, Bronchitis, Chronic airway obstruction, Lymphoma (tumors in the lymph), Black-foot disease and Developmental deficits.

In other literature, the following additional conditions suspected to be caused by Arsenic in drinking water are cited: Bowen's disease, Basal cell carcinoma, Squamous cell carcinoma, Enlargement of liver, Jaundice, Cirrhosis, Non-cirrhotic portal hypertension, Hearing loss, Acrocyanosis, Raynaud's Phenomenon, Megablastosis, Goiter and it is suspected to contribute to various other cardiovascular, pulmonary, immunological, neurological, peripheral vascular and endocrine diseases.

However, the epidemiological study of diseases caused by Arsenic poisoning is only in its infancy. For instance, a report from the United States National Academy of Sciences (NAS) from September 12, 2001, says EPA has this far greatly underestimated the cancer risks of Arsenic in drinking water.

According to a news report in April 19, 2001, a team of EPA scientists at EPA's Office of Research and Development laboratory in North Carolina has discovered that arsenic may cause genetic damage.

Sources of arsenic in water

Arsenic is and has been used in many activities throughout human history, as medicine, as poison, and in industry. Ever since industrialization, thousands of tons of arsenic have been poured out as waste from industrial processing, from livestock farming, from cotton and wool processing, from wood preservation and from mining and metal industry.

Arsenic is also used for killing weeds, insects and rats. Runoff from such activities has contaminated surface- and groundwater in many parts of the world, like lake Yangbup in Australia, or the Ogallala aquifer in Texas, USA.

In West Bengal and Bangladesh, as in many other areas, the Arsenic is from natural sources in the ground. As watertables have been lowered by drawing water for irrigation, air is introduced in the sediments and arsenic is released and dissolved in water.

Safe limits

There is debate on how much arsenic the human body can handle without being harmed. A common figure is 12 micrograms per day. A generally agreed maximum contaminant level for safe drinking water has earlier been 50 micrograms per liter. This is obviously too high compared to the 12 micrograms per day assumption.

In the 1960's, a large poisoning in Taiwan, involving 20,000 people, allowed detailed study, the analysis of which eventually led the WHO to lower the recommended maximum level to 10 micrograms per liter. Although WHO found that for health reasons a level of 2 would have been preferable, difficulties in measuring at those levels at that time prevented such ruling.

Technologies for arsenic removal

In large-scale applications, such as municipal or industrial treatment plants, there are established technologies for achieving reliable separation of Arsenic. To remove As^{+3} in a large plant, it is first oxidized into As^{+5} . This oxidation is usually accomplished with chlorine or hydrogen peroxide. The second step is precipitation with lime or coagulation/flocculation with some salt while controlling water's pH. Then follows filtration. Activated alumina is often recommended as a complementary adsorptive media in the filtration process.

EPA's report from December 2000, mentioned above, shows that As^{+3} no doubt is the most difficult substance ever encountered in the water purification business. When I first heard of the Arsenic disaster in 1996 as a request for information on behalf of an Indian Development Bank in West Bengal, my immediate advise was to try reverse osmosis, RO, which, as far as I knew then, removes all ions to a high degree.

When it was reported back that RO did not accomplish desired results I was full of disbelief. Later I have seen results from tests made for EPA in 1998 where the RO equipment tested removes 96% of As^{+5} , but, surprisingly enough, only 5% of As^{+3} .

It is however possible to achieve good removal with RO, if combined with pre-oxidation and then some form of after-treatment such as anion exchange or activated

alumina adsorption/filtration. The large number of steps may make operation complicated. To this are added the difficulties in monitoring the result and the problems of disposal of the resulting hazardous waste.

A new method holds promise

Because of these findings, we have set out to design equipment for arsenic removal based on a new technology, membrane distillation, MD, which actually removes arsenic completely in a simple and reliable way. We have now developed this technology to prototype and pilot stages. Laboratory tests certify that the technology removes As+3 as well as As+5 to below the detection level (< 3 micrograms per liter) of state-of-the-art measuring instruments (AAS Graphite), i.e. more than 99.97% removal of both As+5 and As+3.

An added advantage of the technology is that it does not require expert monitoring and is easy to maintain and service and therefore could be used in small plants, at wellheads and in individual households.

Finally, it is of course also an advantage that the technology not only removes Arsenic completely, but any other possible contaminant.

The arsenic challenges to science and industry

For us to be able to refine the methods to combat the Arsenic disaster I challenge all water chemists to explain what makes the ion As+3 so different from other ions. What makes it so difficult to remove? And to all water equipment manufacturers, the challenge is of course to devise new methods and new equipment that remove AS+3 in an efficient way.

Aapo Säask, 2001

More information on www.scarab.se

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