THE ARSENIC DISASTER

The largest mass poisoning in history

"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 monthly bulletin of the United Nations World Health Organization (WHO) reports 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. "The scale of this environmental disaster is greater than any seen before", wrote Smith. "It is beyond the accidents at Bhopal, India, in 1984 and Chernobyl, Ukraine, in 1986."

The study was based on visits to Bangladesh by Smith in 1997 and 1998 and adds to the warnings by the UN Children's Fund, the US government and other agencies.

In the past three decades, the Bangladesh government has dug approximately 5 million wells to provide drinking water and save millions of people from cholera, diarrhea and other waterborne diseases. But the naturally occurring arsenic poison in the ground water now threatens to overturn these health benefits.

What can be done?

The World Bank has allocated $ 44.4 M for a project to remedy the Arsenic catastrophe in Bangladesh. There are many remedial options to choose from but it is a very difficult task.

One way is to avoid the contaminated water – by transporting well water from non-afflicted wells or areas, by drilling new wells locally 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 must, however, be the long run option.

But this is not easy. A later report from WHO, **Arsenic in Drinking Water, M**ay 2001, states that: *The technology for Arsenic removal…is inapplicable in some urban areas of developing countries and in most rural areas word-wide. There are no proven technologies for the removal of arsenic at water collections points such as wells, hand-pumps and springs.*

Similarly, a report from United States Environmental Protection Agency (EPA) in December 2000, **Technologies and Costs for Removal of Arsenic from Drinking Water,** has scrutinized all technologies available for Arsenic removal. The conclusion is that large purification plants may, at a cost, adapt to arsenic removal, but for small plants, private wells and households, there is no simple solution.

Characteristics of Arsenic

Arsenic, a semi-metal, is the twentieth most common element in nature. *Organic Arsenic* compounds that are found in foods are quite harmless. They pass through the body quickly. *Inorganic Arsenic* is more toxic. It is deposited in the body and concentrated over time and therefore causes long-term damage.

The effects are not immediately visible. Arsenic is difficult to detect for those ingesting it. It is tasteless, odorless and colorless, and people can absorb significant 'dangerous' doses without any apparent major breakdown in their systems. However, there is an inevitable price to pay in the end and babies, especially new-borns, are the worst affected. As with all trace-toxins a well-nourished and otherwise healthy person will withstand the poison for a long time while an undernourished will perish quickly. Children are especially sensitive.

The inorganic Arsenic appears in compounds with Oxygen, Sodium, Potassium, Copper and other elements. Solved in ground water it forms ions, which are trivalent or pentavalent, which means they have positive charges of either three or five (can attach three or five electrons). Arsenic in general is said to be about four times as poisonous as Mercury and the trivalent Arsenic As+3 is considered 60 times more toxic than the pentavalent As+5.

It is very easy to remove As+5 with known water technologies, but very 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 cannot even distinguish between inorganic Arsenic and organic Arsenic.

Unfortunately, many of the Arsenic combating technologies that have been recommended this far do a good job at removing the relatively harmless type of Arsenic (As+5) but not the very poisonous type (As+3) and therefore there is no simple solution in sight.

Diseases caused by arsenic poisoning

Arsenic can damage the nervous system and is a known carcinogen. It is also teratogen, meaning it can enter the metabolic system of unborn children.

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.

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 a possible, direct link to DNA damage caused by arsenic compounds. The research demonstrates how a human cell's own metabolic responses to arsenic exposure produce compounds that cause genetic damage.

Arsenic is also suspected to contribute to various other cardiovascular, pulmonary, immunological, neurological, peripheral vascular and endocrine diseases but as with the above symptoms, 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 that the US Environmental Protection Agency (EPA) has this far greatly underestimated the cancer risks of arsenic in drinking water.

Dr Azad of Hokkaido University in Japan has made the following classification of diseases caused by Arsenic in Bangladesh:

Initial Stage:	Melanosis, Keratosis, Conjunctivitis, Bronchitis, Gastroenteritis
Second Stage:	Depigmentation, Hyperkeratosis, Non-pitting edema of legs, Peripheral nephropathy, Hepatopathy
Final stage:	Nephropathy, Hepatopathy, Gangrene, Cancer of skin, bladder and lung

In Bangladesh, the majority of patients are still at initial and second stages according to Dr Azad. He also mentions the following additional conditions suspected to be caused by Arsenic in drinking water, as reported from other countries than Bangladesh: 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 and Goiter.

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. In many places in North America and elsewhere, runoff from gold mining has contaminated river sediment and groundwater wells.

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 Yangebup in Australia, or the Ogallala aquifer in Texas, USA, and, to give an indication of the magnitude of the problem, in the 1970'ies one Swedish metallurgic industry on the coast of the Baltic Sea used to dump, among many other pollutants, as much as 2,700 tons of arsenic into the sea every year.

In West Bengal and Bangladesh, as in many other areas, the Arsenic is however from "natural" sources in the ground and the contamination has occurred as an undesired effect of a most well-motivated and laudable conquest of a natural resource – water for drinking and irrigation.

The introduction of deep-drilled tube wells some decades ago not only supplied farmers with irrigation water throughout the dry season but also provided families and villages with a "reliable" source of drinking water. This has resulted in a lowering of the watertable, resulting in arsenic present in the sulphide rock and sediments to be released by intruding oxygen and subsequently 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 upon 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.

In the West Bengal case, about a million people may be consuming water in excess of 500 micrograms per liter, and wells have been found which contain as much as 10,000 micrograms per liter.

Technologies for arsenic removal

In large-scale applications, such as municipal or industrial treatment plants, there are complicated and costly, yet 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 at the filtration process. All in all a complicated process, but feasible.

EPA's report from December 2000, mentioned above, shows that As+3 probably is the most difficult substance ever encountered in the water purification industry. When I first heard of the Arsenic disaster in 1996 as a request for information on behalf of an Indian Development Bank in the West Bengal from one of my associates, my immediate advise was to try reverse osmosis, RO, also called hyperfiltration, which, as far as I knew then, always removes ions to a very high degree because of its very tight membrane structure.

At first I was full of disbelief when it was reported back that RO did not accomplish desired results. Continued investigations did however convince me. For instance, a test made for EPA in 1998 in which the same RO equipment removes 96% of As+5, but, surprisingly enough, only 5% of As+3.

It may however be possible to achieve good removal with RO, if combined with first preoxidation and then some form of after-treatment such as anion exchange or activated alumina adsorption/filtration. The large number of steps makes 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 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. Laboratory tests certify that the equipment 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.

Another advantage of the equipment is that it does not require expert monitoring and is very easy to maintain and service and therefore, in different versions, can be used in small plants, at wellheads and in individual households.

This technology is today in prototype or pilot stages and it will take more than a year and probably two before commercial equipment is available to make dents in the present disaster.

West Bengal

In West Bengal, tube-well groundwater has been found to contain high levels of Arsenic, in places several hundred times the level recommended by WHO for acceptable drinking water. Some 45 million people live in the inflicted area, and there are villages where as many as 40% of the villagers have visible symptoms of arsenic poisoning.

The West Bengal State Government has appealed to the Indian Government to make the problem a national one and the Central Government has agreed to pay for 75% of remedial measures.

Bangladesh

The situation in Bangladesh is even worse than in the case of West Bengal. It all began in the '60s, with the Green Revolution when groundwater was tapped for agricultural use. Until the early 1970s, the inhabitants of Bangladesh drank water from shallow hand-dug wells, rivers and ponds. But pollution was causing epidemics of cholera, and this persuaded aid agencies to spend a great deal sinking tubewells to tap the plentiful, and apparently clean, water in the sands and silt of the Ganges floodplain. Many more were sunk privately.

For the past two decades and more, water from several million wells has been slowly poisoning Bangladeshi villagers. A report by the WHO predicts that within a few years one in ten adult deaths across much of southern Bangladesh could be caused by cancers triggered by arsenic. With people using deep tube-wells for daily consumption in most areas, the problem has reached alarming levels (there are an estimated 5 million tubewells in Bangladesh, providing 95% of the drinking water). Whereas the permissible level of arsenic is 10 micrograms per liter, high concentrations in many areas may be above 3000 micrograms per liter. Experts warn that it is a matter of time before contaminated water seeps through the entire country, as the rise in toxicity every year is 20 per cent.

The government of Bangladesh has been suggested a large number of remedies from companies and international aid agencies that have not proven to be viable and now finds the situation untenable. People everywhere in the country are alarmed, even in areas that are not (yet) afflicted and the steps taken this far have been to start an inventory of the wells and paint the dangerous ones red. Much more is of course being planned.

USA

Large portions of the water supply in the United States, mostly in the Midwest and West, contain arsenic. The US Geological Survey (USGS) has tried to quantify and pinpoint the extent of the arsenic problem in drinking water. But one of the study's authors admits the study still may under-report the level of contamination. David Westjohn, an associate professor at Michigan State University, and part of a team of arsenic experts working on the USGS study, simply says that arsenic occurs more frequently in the environment than most people, or authorities, suspect.

The Safe Drinking Water Act (SDWA), as amended in 1996, requires the 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.

In 2001 the new US government decided not to ratify the proposal to lower the standard that had been prepared for years. The main reason is that 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 2001.

The Arsenic challenge

Arsenic is the twentieth most common element in nature. In most countries there is natural Arsenic in the environment. In some countries large amounts of Arsenic have contaminated the groundwater due to mining and other industrial pollution. The countries in the world can therefore probably be divided into two groups – one where Arsenic problems have surfaced and one where problems are latent.

The more people become aware of the menace and look to examining their own waters, the more evidence is emerging that Arsenic contamination of water is very widespread. Problems have already been observed in among others the following countries: Argentina, Canada, Chile, China, Greece, India, Japan, Mexico, Mongolia, New Zealand, South Africa, The Philippines, Taiwan, Thailand, USA and USSR.

Arsenic poisoning is thus a global problem with the problems in India and Bangladesh just being the most spectacular examples.

To all water chemists the challenge is to find out what makes the ion As+3 so different from other ions that it becomes so difficult to remove. Then we will be able to refine the methods to combat the Arsenic disaster. 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 Sääsk, September 23, 2001 More information on www.scarab.se