Arsenic Removal Processes on Trial in Bangladesh

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Abstract

Arsenic in groundwater is present in excess of the safe limit set for Bangladesh. It is now recognized that arsenic is a serious health hazard. It reviews some of the arsenic removal technologies being tried and tested in Bangladesh.

INTRODUCTION

The rural people of Bangladesh are mostly dependent on hand tubewells for drinking water. The groundwater was, in the past, considered to be a source of safe drinking water. Unfortunately it is now established that this water contains arsenic at concentrations higher than the safe limit set for drinking purpose. This paper reviews some of the arsenic removal technologies so far tried and tested in Bangladesh.

DRINKING WATER IN RURAL BANGLADESH

Until 1970s most rural people obtained and consumed water from the hand-dug wells, ponds, rivers or canals. These waters were usually consumed directly without any treatment. So epidemics of diarrhea and other water-borne diseases were very common. Hundreds of people particularly the infants died only because of drinking these unsafe waters. The idea of tapping groundwater, which seemed to be clean, plentiful and pathogen-free under anaerobic condition, was accepted and hand tubewells were considered reliable means for extracting groundwater at an affordable cost. Approximately 90 percent of the rural population of Bangladesh get their drinking water from around 4-5 million tubewells that have been sunk over the last 30 years.

DRINKING WATER STANDARDS

Table1 lists the standards set for drinking water by USEPA, WHO and Bangladesh. The standard set by Bangladesh is less stringent in respect of parameters such as iron, chloride, hardness, sulfate, TDS and Arsenic. Canada and other countries have set 0.01 ppm limit for Arsenic.

Table 1: Drinking water quality standards

Parameter	USEPA (2000) (mg/l)	WHO (1993) (mg/l)	Bangladesh (GoB, 1997) (mg/l)
pH	6.5-8.5	7-8.5	6.5-8.5
Iron	0.3	0.3	0.3-1.0
Chloride	250	250	150-600
Hardness (as $CaCO_3$)	100-500	-	200-500
Sulfate	250	250	400
Manganese	0.1	0.05	0.1
Fluoride	2.0	1.5	1.0
Nitrate	10	50	10
Arsenic	0.01	0.01	0.05
TDS	400-500	1000	1000

ARSENIC IN DRINKING WATER IN BANGLADESH AND RELATED PROBLEMS

DPHE in 1993 detected arsenic in groundwater at Barogharia of Chapai Nawabganj district (the western part of Bangladesh) following reports of extensive contamination of groundwater by arsenic in West Bengal, India. As per the latest statistics, out of 64 districts groundwater of 59 districts in Bangladesh contains arsenic. And out of these 59 districts worst affected parts of Bangladesh are the southern and the northeastern districts (DPHE/BGS, 1999). The access to safe drinking water in Bangladesh has declined by 17 percent in last three years due to the presence of arsenic in groundwater.

Arsenic is a cumulative substance, which slowly passes out of the body through the urine, hair, fingernails/toe nails, and skin. It takes around 8-14 years after starting to drink arsenic contaminated water for symptoms to appear. This period depends on the amount of arsenic ingested, the length of exposure and immunity level of the person. Symptoms of the initial stage of the disease are skin pigmentation, eye infections, trachea and cancer. Although arsenicosis, the disease caused by arsenic contamination, is not an infectious, contagious or hereditary, it creates social problems for the victims and their families.

ARSENIC REMOVAL TECHNOLOGIES BEING TRIED IN BANGLADESH

Technologies for removal of arsenic from drinking water already exist as incidences of arsenic contamination in groundwater have already been reported from various parts of the world. The removal technology usually relies on its very strong adsorption to iron and aluminum oxides, and if sufficient of these are added, the arsenic concentration can be reduced to a level as low as the standard set for Bangladesh.

Several technologies are currently being promoted for application in Bangladesh. They claim to be effective in removing arsenic from tubewell water. These are all new and in development stage. The effectiveness, viability and sustainability of the technologies under field conditions in Bangladesh are yet to be ascertained before their adoption and scale-up thereof. Some of the technologies so far tried both in laboratory and at field level are discussed below.

Auto-attenuation, which needs collection of groundwater from the wells and allowing it stand for a specific period of time, was tried in Rajshahi and Meherpur. Groundwater having high concentration of dissolved iron, is readily oxidized and forms ferric precipitates. The auto-oxidation of Fe^{2+} to Fe^{3+} generates favorable substrate with surface reactive sites for the adsorption of uncharged As(III) as well as anionic As(V) species. The test result showed that it needs further modifications for high-arsenic groundwater.

Nikolaidis et al. (1997) suggested a simple filter, which is a tube filled with sand and iron fillings (zero-valent iron) and is designed to fit in a well outlet. It can be an effective low–cost tool. $BaSO_4$ is to be added if not present in water. In the presence of $BaSO_4$, iron oxidizes and reacts with arsenic to form arsenopyrite that precipitates out and remains trapped in the filter. Laboratory experiments show 97% removal for initial arsenic concentration of 45 to 8600 µg/l.

Joshi and Chowdhury (1996) developed a home arsenic removal unit using iron-coated sand. The unit was able to produce 600 – 700 l of water at a flow rate of 6 l/h maintaining an arsenic concentration of 0.01 mg/l for an initial arsenic concentration of 1.0 mg/l.

Parknikar (1998) describes two types of metal-microbiological interactions that can be used for arsenic removal: i) microbial oxidation of As(III) to As(V) and its subsequent precipitation, and ii) bio-accumulation of arsenic by microbial biomass. The oxidation method can be operated in an immobilized reactor reservoir. A cheap source of organic substrate like sugarcane juice can be added along with iron fillings (Panikar, 1998). Iron fillings promote development of iron – oxidizing bacteria that oxidize iron at a rate 50×10^3 times faster than chemical oxidation of iron. Arsenic is then adsorbed on the ferric iron. Treated overflow of water typically contain arsenic < 0.05 mg/l for initial concentration up to 4.0 mg/l.

Lehimans et al. (1998) conducted pilot studies to adopt biological filtration for removal of As(III), the oxidation state where arsenic is the most delicate to treat. For concentration as high as 400 µg/l, upto 90% reduction was achieved. An initial level of 75 µg/l even allows a final concentration below 10 µg/l. In addition, complete iron removal was achieved. They conclude that under optimized pH, temperature and oxygenation condition and with a sufficient initial iron concentration, biological filtration allows simultaneous elimination of As(III) and iron.

SORAS is a simple method that uses irradiation of water with sunlight in PET or other UV transparent bottles to reduce arsenic level from drinking water (Wegelin et al., 2000). The process is developed by Swiss Federal Institute of Environmental Science and Technology, Switzerland and Swiss Agency for Development and Cooperation (SDC), Bangladesh. The method is based on photochemical oxidation of As (III) followed by precipitation or filtration of As (V) adsorbed on Fe (III) oxides. Field tests in Bangladesh show removal efficiency between 45-78% with an average of 67%. Concerning the Bangladesh guideline value of 50 µg/l, SORAS can treat raw water having an arsenic concentration below 100 – 150 µg/l.

Khair (1999) found Bijaypur clay from Mymensingh and processed cellulosic materials like delignified jute, bleached sawdust and pulped newspaper to be capable of adsorbing both As(III) and As(V) in solutions acidified with vinegar or hydrochloric acid. Iron (III) hydroxide–coated newspaper pulp in lab-scale adsorption filters coagulated arsenic. The material showed potential for use in small-scale home treatment units. Workable exposure length, flow rate and extractant volume demonstrated arsenic removal at least or even below 0.050 mg/l. The sludge was regenerated by sodium hydroxide elution.

Laterite has been tested as an adsorbent and proved to be a promising low–cost remedial technique to safeguard drinking water (Larsson et al., 1999). Laterite is vesicular clayey residuum occurring abundantly in the tropical regions. Adsorption experiments showed that the removal efficiency varied between 50 and 90% for 5 g of added laterite per 100 ml water under an equilibrium period of 20 minutes (Larsson et al., 1999). Modification of laterite by treating with 0.01 M HNO_3 increased the adsorption capacity of laterite due to an increased specific surface area (Larsson et al., 1999).

Chatterjee et al. (1999) patented a filter and tablet system to remove arsenic from water. The tablet contains Fe^{3+} salts, an oxidizing agent and activated charcoal. The filter was made by using fly ash, clay, charcoal etc. The system is made up of two jars. For 20 liter of water, using one tablet, 95 – 100% removal of arsenic was achieved.

Adsorbing Colloid Flotation (ACF) with ferric hydroxide as the co-precipitant, anionic surfactant sodium dodecyl sulfate (SDS) as the collector and nitrogen micro-bubbles has been shown to be effective in removing arsenic from low concentration of arsenic aqueous solution. When pH is in the range of 4 – 5, 99.5% arsenic removal efficiency can be achieved.

The Bucket Treatment Unit was developed by DPHE-Danida and is being under the Arsenic Mitigation Pilot Project. This project was launched in Lakshpur and Chaumuhini Pourashavas in the coastal region of Bangladesh. The system can treat any kind of tubewell water, regardless of the arsenic concentration, and to an arsenic level below Bangladesh's standard of 0.05 mg/l.

BCSIR (1999) has developed a low cost arsenic filter. The technology consists of adding a floc forming composition to the arsenic contaminated water followed by stirring and settling. The chemicals are composed of iron oxide, alum, activated charcoal and calcium carbonate, which are to be mixed in definite proportions, homogenized and micronized. After settling the water is passed through a filter bed composed of sand and some iron bearing minerals of definite particle size range, which are to be activated by suitable chemical and heat treatment. The dose of the floc forming composition depends on the extent of arsenic contamination. Water containing upto 2.7 ppm arsenic could be purified below safe limit set by WHO.

Project Earth Industries, USA, developed a arsenic removal unit which is used with a hand pump tube-well. The Unit was tested at Sonargaon, Naraynganj, where groundwater arsenic concentration is very high. The principal component of the Arsenic Removal Unit consists of an adsorption media. The removal mechanism involves adsorption of arsenic onto the media surface as tubewell water flows through it. Along with arsenic a number of other anions and cations (including iron) also get adsorbed on it.

Shin Nihon co. Ltd. of Japan developed a house holds arsenic removal unit, which is a cylindrical container made of plastic and fitted with a tap close to the bottom for outflow. The container is filled with READ-F adsorbent resin. The inlet of the tap is fitted with a screen to block the entry of the resin into the tap. The adsorbent is always kept under water to retain its effectiveness. This is an effective system in removing arsenic from drinking water containing a low level of iron.

Coolmart Water Purifier, Korea, developed another purification unit, which consists of a series of beds containing activated carbon, silver-activated carbon, bio-mineral sand, zeolite and silica sand through which water passes. A laboratory tests of the system shows that around 25 litres of water containing 300 ppb of arsenic and 0.1mg/l of iron could be treated by the purifier satisfying the Bangladesh drinking water standard for arsenic.

Allergy Environmental Research and Skin Care Institute (AARSCI), Integrated Quality and Environmental Management (IQM) etc. have developed simple cost effective filters. AARSCI used indigenous materials such as coconut coir, coconut shells and husk, along with small amount of alum to prepare the filter bed. IQM prepared the filtering bed using the clay pots, sunlight, air, iron, sand or ferrous salts and alum. Another filter developed by US company called Arsen: X filter, which has been tested successfully in the Sadar thana of Kishoreganj. This filter not only removed arsenic, but also reduced other contaminants including fluoride and lead and it can be safely land-filled or recycled as non hazardous material. 100 percent removal of arsenic from water is accompanied by a unique bonding of arsenic into molecular structure of the filter and therefore, it does not disassociate.

Tetrahedron has developed a filter medium based on anionic resin. The filter has already been tested successfully. They claimed that the bed can easily be regenerated using Sodium Chloride solution, which is available in our country and the filter can be used for ten years.

CONCLUSIONS

To save millions of people from arsenic poisoning it is important to detect the arsenic concentration in groundwater and also to provide a suitable, user friendly and cost effective arsenic removal process for the rural people of Bangladesh. Unfortunately, the very first step towards prevention and arsenic testing is in great chaos. The instruments are expensive and require skilled person to operate. There is no licensing authority to supervise the testing procedure in Bangladesh. At present, very few laboratories can provide reliable result. On the other hand removal technologies so far tried for the rural people have potential but not tested thoroughly for adoption. Most of the rural people are illiterate. They developed the habit of drinking hand tubewells water during the last 30 years. So any change in their behavioral needs more friendly approach and technology.

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