Arsenic Knowledge and Action Network

ARSENIC REMOVAL TECHNOLOGIES - Short Note

Arsenic contamination in groundwater is widely acknowledged now as a public health issue of epidemic proportions and has spread across Asia especially in Bangladesh and large parts of India. West Bengal was one of the first stated to officially report the presence of arsenic in groundwater, while the first reported case of arsenicosis is also traced back to South 24 Parganas district, again in West Bengal.

With the scale of the problem being as high as it is in West Bengal, various technological options for treatment have been tried out over the last decade or so. The exercise for this team is to narrow down few best practices and identify contextual treatment solutions that could be implemented and promoted in collaboration with government departments. Here below is a brief of the mitigation and technology options available.

1.1 Mitigation approaches: Alternative sources of drinking water

Deep wells: These are defined as those wells which are completed entirely in sands beneath the Holocene/latest Pleistocene transgressive surface. If the wells are constructed so as to prevent leakage between the upper and lower aquifers, it is likely that they will be free of arsenic (and other undesirables) in future. It has been suggested that one should use deep wells for drinking and continue to use shallow wells for irrigation, lest the avail- ability of water from deep wells may cease. It has been suggested that ground water should be tested before installing a tube well in the locality. Apart from this, periodical testing of the water from tube wells is also recommended because arsenic concentrations in those wells could change over time.

Traditional dug wells (modernized as appropriate): They are recommended for more general use; on the other hand, the sanitary dug wells, have been shown to be arsenic free.

Treatment of surface water: This method is of use in places where perennial surface water in adequate quantity and of good quality is available. The available methods of treatment include slow-sand filter, pond-sand filter, pressure filtration followed by disinfection, small-scale conventional or prototype treatment plants, and conventional surface water treatment plants.

Rainwater harvesting: During the monsoon period, rainwater can be collected for drinking using several methods practiced in many parts of the world. This is of use in place where surface water source is limited and has to be combined with adequate storage tanks.

Table 1: Alternative sources of water supply

Sl No	Technology	Description	User friendliness	Sustainability	Approximate costs
1.	**Hand pump attached Water Treatment**	Water Treatment Filters with filter media are attached to the hand-pump	User friendly initially but later issues regarding disposal of the filter media and	Long term sustainability is questioned due to disposal of	

Sl No	Technology	Description	User friendliness	Sustainability	Approximate costs
	Plant		management arises. Operation & Maintenance at the community level may be a constraint.	filter media & proper management of the hand-pump.	
2.	**Rainwater Harvesting (Surface)**	Rooftop storage tank for collection of rainwater. Effective in areas of high rainfall.	User friendly with proper treatment. Intensive community involvement required.	Issues of treatment of the collected rain- water and maintaining the pH hinders sustainability.	Cost varies with building sizes, how-ever Rs. 2,000 to 30,000 for building of about 300 sq. m
3.	**Rainwater Harvesting (Ground)**	Ground storage tanks of collection of rainwater. Effective in areas of high rainfall.	User friendly with proper treatment. Intensive community involvement required.	Issues of treatment of the collected rain- water and maintaining the pH hinders sustainability.	Cost varies with building sizes, how-ever Rs. 2,000 to 30,000 for building of about 300 sq. m
4.	**Groundwater recharge**	Water from precipitation, natural streams, canals from large reservoirs etc., are used to recharge aquifers with depleted water levels.	Effective in areas with depleted groundwater levels.		
5.	**Water recycling**	Treatment of waste water and its further use for Non-drinking purposes.	Lack of community acceptance hinders user friendliness.	Sustainable only with effective treatment.	
6.	**Piped Water**	Treated surface	User friendly	Sustainable	Significant

Sl No	Technology	Description	User friendliness	Sustainability	Approximate costs
	Supply Scheme	water is distributed with a net- work of pipelines.		with proper management	investment has to be made.
7.	**River Bed Filtration**	Process of extracting groundwater from wells adjacent to a river, or from horizontal collector wells beneath a river bed or within the banks in order to induce filtration from the river.	Effective in areas where the quality of water in the river is not suitable for water supplies due to intermittent or chronic pollution.		
8.	**Sub-Surface Dams**	Dams built across seasonally flowing rivers or streams	User friendly as a small water supply scheme in arid and semi-arid regions.		

1.2 Techniques and Technologies for arsenic removal

The most commonly utilized technology for removal of arsenic is adsorption onto activated alumina with sedimentation and filtration. For removal of higher concentrations of arsenic a combination of coagulation-adsorption-precipitation is effective. For selection of a technology from among the successful technologies that can effectively remove arsenic, close attention needs to be paid to the treatment costs, operational complexity of the technology, acceptance of the technology by communities and disposal of arsenic bearing treatment residual/sludge. These technologies are used as short term arsenic remediation methods.

The following are the different techniques available for removal of Arsenic from drinking water.

- Adsorption on different media
- Bioremediation and In- situ remediation
- Coagulation-flocculation- Sedimentation-filtration (Co- precipitation)
- Ion exchange
- Iron coated sand
- Low pressure Nanofiltration
- Oxidation of Arsenic (III)
- Passive sedimentation
- Reverse Osmosis and electro dialysis
- Solar oxidation

Table 2: Technologies for removal of arsenic from water

Major oxidation/precipitation processes	**Advantages**	**Disadvantages**
Air oxidation (Dug wells, ponds, in-situ oxidation)	Relatively simple, low-cost but slow process; in-situ arsenic removal; also oxidizes other inorganic and organic constituents in water	Mainly removes arsenic (V) and accelerate the oxidation process. Partial removal of arsenic slow process. High alkalinity and presence of iron in the tube wells water increase arsenic removal by storage.
Chemical oxidation- (Utilizing oxidizing chemicals such as NaOCl or $KMnO_4$ / Ozone)	Oxidises other impurities and kills microbes, relatively simple and rapid process; minimum residual mass.	Efficient control of the pH and oxidation step is needed. Preliminary analysis of the water is required. Requires controlled environment.
Solar oxidation Precipitation of Fe(III)-Oxides with Adsorbed As(V) (SOAS method)	Simple process of UV radiation on plastic bottles. Removes iron and microbial contamination from water.	Only reduces level of arsenic in water. Can reduce water with arsenic level 100 - 150 m g/L to half level. Not applicable in regions where As. Conc is higher than 150 m g/L. Arsenic removal efficiency is between 45 - 78 % and averages 67 %.
Major Coagulation and Filtration technologies	**Advantages**	**Disadvantages**
Oxidation-Floculation-sedimentation- filtration (eg. AIIH&PH domestic Arsenic removal system, SOES- filter tablet system)	Low cost filtering system. Can be used at community and household level	Level of removal of arsenic is depended on a balanced dosing of chemicals. Difference can cause changes in taste of water and also ineffective removal of arsenic. Hardness and salinity of water will influence the process.
Coagulation and filtration (All India Hygiene and Public Health (AIIH&PH) technolog/ The Bucket Treatment Unit (BTU) and the Stevens Institute Technology/Arsiron Nilogon)	Durable powder chemicals are available; relatively low capital cost and simple in operation; effective over a wider range of pH. Can be done at household and community level.	Sludge removal; pre-oxidation may be required. Requires small level of training at local level on proper utilization. There may be health implications of excess manganese in water.
Iron coagulation	Common chemicals are available; more efficient than alum coagulation on weight basis.	Medium removal of As(III); sedimentation and filtration needed.

Lime coagulation (quick lime, CaO, or hydrated lime, Ca(OH)2	Chemicals are available commercially. It is better used as a pretreatment option, lime softening before alum or iron coagulation.	Readjustment of pH is required. Lime coagulation has low arsenic removal about 40-70%.
Sorption filtration Technologies	**Advantages**	**Disadvantages**
Activated alumina (e.g: Oxide India (Catalysts) Pvt. Ltd. /BE college model/ PHED technology/School of Fundamental Research (SFR) technology/ Pal Trockner – AdsorpAs® technology/ RPM technology/ UNICEF -GoWB model of domestic filter/ AMAL filter)	Relatively known and commercially available. Removes arsenic by way of adsorption. Several technology variation patients are available for it.	Needs replacement after four to five years. Regeneration of Alumina requires grassroots level service centers which turns out to be a major challenge. Also each technologies' sludge removal option needs to be seriously considered.
Ion-exchange (Water Systems International (WSI) technology)	Provides high quality safe drinking water.	High investments, expensive and requires dedication to operation and maintenance. Requires close monitoring of resin and replacement is expensive as well
Membrane Processes: (Microfiltration (MF), utrafiltration (UF), nano-filtration (NF), reverse osmosis (RO) and electrodialysis reversal (EDR))	Provides high quality safe drinking water	High investments, expensive and requires dedication to operation and maintenance. Requires close monitoring of membranes. Discharge of the concentrate can be a problem. Water loss associated with concentrate stream membrane fouling and flux decline
Other New technologies	**Advantages**	**Disadvantages**
Arsenic Removal Using Bottom Ash' (ARUBA)	Simple chemistry, Low cost around 38-40 Rupees/ $m^{3.}$ Effective removal of Arsenic	Gaining access to the ARUBA substrate, Requires handling, storage, transportation from facility increases the cost. Requires establishment of centralized manufacturing unit of ARUBA substrate. Requires arsenic sludge disposal.
Electro Chemical Arsenic Remediation (ECAR)	Low cost said to be 40-60 Rupees/$m^{3.}$ Removal of arsenic from concentrations of 266 µg/L to < 5 µg/L. Presented as community scale micro-utility business model.	Requires electricity for functioning. Trained maintenance required. Purified water has some level of turbidity. Cost to collect stabilize arsenic laden sludge still unknown. Process of converting sludge to other safer forms still under trial.

AMRIT – Arsenic and Metal Removal through Indian Technology	Low cost, removes arsenic and other impurities as well. Experimented in field sites in W. Bengal	New technology, the field level utilization and effectiveness is still in the process of analysis.

1.3 Emerging methods

Besides the methods mentioned in table several new methods have been developed or in the process of being developed. They include:

- Green sand filtration
- Coagulation assisted Microfiltration
- In situ (sub-surface) arsenic immobilization
- Enhanced coagulation (aka electrocoagulation, electroflotation)
- Biological arsenic removal
- Phytoremediation
- Electrokinetic treatment
- IOCS (iron oxide coated sand)
- Memstill®
- Water Pyramid
- Solar Dew Collector
- AMRIT – Arsenic and Metal Removal through Indian Technology

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