



Investigation on the long-term storage and fate of arsenic obtained as a treatment residual: A case study



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H I G H L I G H T S

- A simple method for containment of arsenic in the treatment residual was developed.
- Leaching of arsenic from sludge was not significant under aerobic storage condition.
- The containment of arsenic laden waste was effective under field conditions.

A R T I C L E I N F O

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In several places in India, activated alumina is used for effective removal of arsenic from contaminated ground water used for drinking purposes. Once exhausted, activated alumina is regenerated and reused for number of cycles. Regeneration of activated alumina generates treatment residuals containing arsenic, disposal of which needs care so as to avoid further pollution of the neighbouring environment. In the present study, a suitable stabilization and disposal method for the treatment residuals inside a well aerated coarse sand filter bed has been developed. Standard leaching tests carried out with the stabilized treatment residual indicated that the leaching of arsenic from the stabilized treatment residual was minimum, and was within the regulatory limit. Water quality data of all the wells located within 100 m from the sand filter were monitored for nearly four years and no adverse impact of disposal of arsenic-laden treatment residuals in the sand filter was observed.

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1. Introduction

Natural arsenic contamination in groundwater in South and South-East Asian countries including India and Bangladesh is considered to be one of the most serious public health problems in the recent past. The use of groundwater for drinking purposes in these regions is favoured by its easy availability and microbial safety as opposed to unsafe nature of surface water which is often contaminated due to prevalent poor hygiene and sanitation practices. The occurrence of dangerous level of arsenic in groundwater used for drinking puts upwards of 100 million people at risk of developing arsenic-related health hazards in the Gangetic Delta regions

alone. The consequence of drinking of arsenic-contaminated water over a long period of time causes severe damages to the human body and often becomes fatal [1]. Many argue that switching over to surface water-based water treatment and supply system provides a long-term and stable solution to the problem. However, in India, due to unregulated agricultural and industrial wastewater discharges surface water is likely to get contaminated also by pesticides and fertilizer residues and other toxic metals and chemicals. This may delay the wide-scale implementation of surface water-based water supply systems as the water treatment in such a case becomes rather complex and expensive. Thus, in order to save lives before a changeover to surface water based treatment and distribution system is made possible, it is imperative to build arsenic removal systems on an urgent basis. Several arsenic removal technologies have been developed over the last two decades; some of them have gained wide-scale application in the field. A significant proportion of the technologies use adsorption

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onto metal hydroxide or hybrid materials using metal hydroxides, the metals being iron, aluminum, titanium, etc. Whether it is adsorption or co-precipitation, all the treatment techniques produce treatment residuals, at varying amounts, containing arsenic in various concentrations. Treatment of water for drinking is important; of equal importance is the ecologically safe management of the treatment residuals which, for a sustainable future, should not leach dangerous proportion of arsenic back in the environment. Central Pollution Control Board of India [2] restricted random disposal of hazardous waste and commented that care should be taken during the disposal of hazardous wastes so that it does not further pollute air, water and soil and does not cause any harm to human beings and habitat in the surroundings. United States Environmental Protection Agency (USEPA) found that bulk liquids and semisolid wastes could be stored in a landfill under certain controlled conditions with a secure liner and a system for the collection and removal of leachate [2–4]. It is further mentioned that a solid waste is considered to be hazardous and toxic if it leaches arsenic at concentrations beyond 1 mg/L, when subjected to toxicity characteristics leaching procedure (TCLP) test method proposed by USEPA as per SW 846, Method 1311. A variety of reactions may take place during the storage of a treatment residual which influence the speciation and mobility of inorganic contaminant(s); such reactions include acid/base interactions, precipitation/dissolution, oxidation/reduction, sorption or ion exchange.

Since 1997, more than 150 community-scale arsenic removal units have been installed in the villages of West Bengal, a state of India neighbouring Bangladesh. The treatment units along with ancillaries and protocols were developed jointly by Bengal Engineering and Science University (BESU), India in collaboration with Lehigh University, USA. The project has been implemented by BESU with the financial help mostly supported by Water For People, Denver, USA. The treatment units mostly used activated alumina (AA), and in a few cases used either hybrid anion exchange (HAIX) resin [5] or a combination of both as adsorbents for arsenic removal. The technology is unique in its characteristics because of its ecologically sustainable practices that include regeneration and reuse of the adsorbent media over multiple cycles.

1.1. The treatment unit and its performance

Fig. 1A is a schematic of the treatment unit along with the important reactions taking place inside the unit whereas Fig. 1B shows a photograph of the treatment unit. The units do not require any electricity, addition of chemicals or pH adjustment for their daily operation. The community scale arsenic removal unit essentially is a gravity-type flow-through stainless steel column consisting about 100 L of adsorbent. Groundwater in this area (West Bengal) predominately contains dissolved iron in ferrous form [Fe(II)] in concentrations ranging from 1 to 3200 $\mu\text{g/L}$ [6]. The top part of the column is so designed with a spray head, splash plate and vent pipe that it promotes the oxidation of dissolved ferrous iron by atmospheric oxygen resulting in the formation of precipitates of hydrated Fe(III) oxide particles. Freshly precipitated hydrated Fe(III) oxide (HFO) particle surfaces have surface functional groups of FeOH_2^+ and FeOH at circum-neutral pH. They can selectively bind both arsenites or As(III) and arsenates or As(V) through formation of bidentate and/or monodentate inner-sphere complexes where Fe(III), a transition metal, serves as electron-pair acceptor or Lewis acid [7–9]. The arsenic-rich ferric hydroxide particles get trapped on the adsorbent bed at the bottom portion of the column. Arsenic remaining in the partially-treated water is removed by the adsorbent bed, which comprises of either activated alumina or HAIX resins as adsorbent. The mechanism of arsenic removal in the treatment units has been detailed elsewhere [10].

Backwashing of the column on every other day helps to maintain the necessary flow rate through the column by driving out the precipitated HFO particles that tend to clog the bed. The arsenic-laden HFO particles in the waste backwash water are trapped on top of a coarse sand filter provided in the same premises [11].

Depending on the arsenic and iron concentration in the raw water, on an average the arsenic removal units produce about 1,000,000 L or 10,000 bed volumes of treated water before the concentration of arsenic in the treated water exceeds the maximum contaminant level (MCL). Once the arsenic concentration in the treated water exceeds the MCL, the adsorbent media is

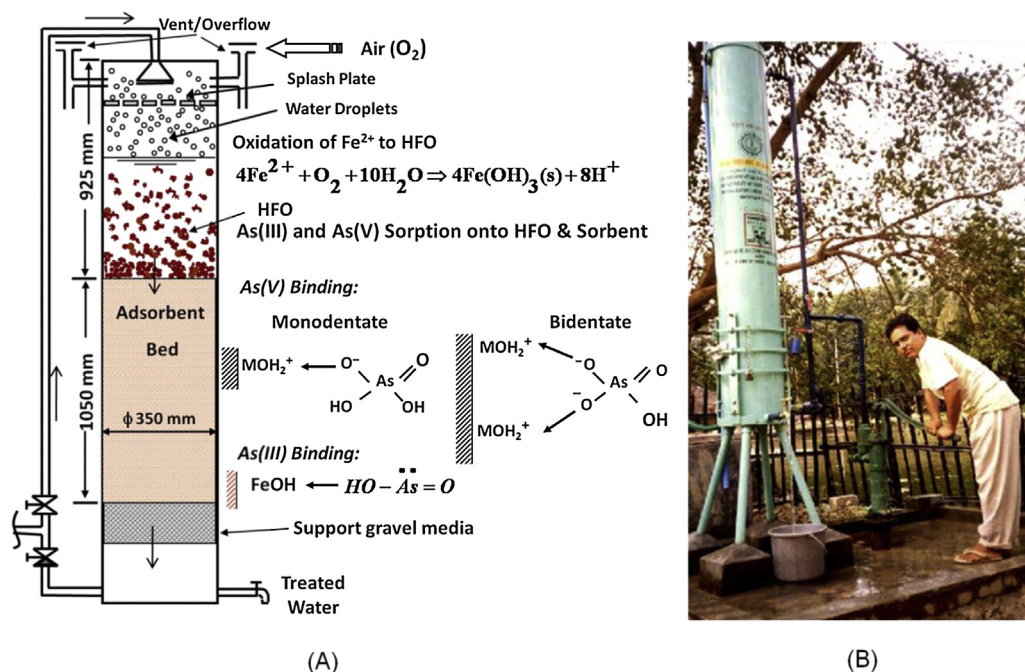


Fig. 1. (A) Schematic of an arsenic removal unit alongwith major reactions taking place during water treatment and (B) photograph of an arsenic removal unit in West Bengal, India.

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