ARTICLE IN PRESS
STOTEN-21755; No of Pages 11
Science of the Total Environment xxx (2017) xxx–xxx
Contents lists available at ScienceDirect
Science of the Total Environment
journal homepage: www.elsevier.com/locate/scitotenv

A socio-economic study along with impact assessment for laterite based technology demonstration for arsenic mitigation

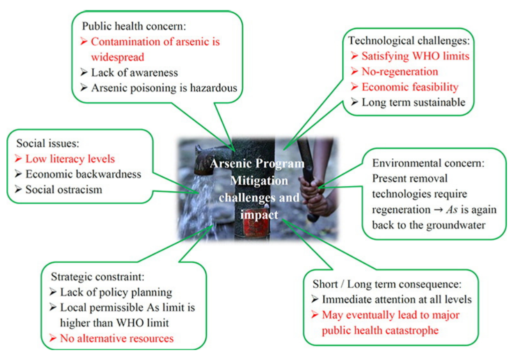
Sourav Mondal, Anirban Roy, Raka Mukherjee, Mrinmoy Mondal, Sankha Karmakar, Somak Chatterjee, Munmun Mukherjee, Saikat Bhattacharjee, Sirshendu De *

Department of Chemical Engineering, Indian Institute of Technology Kharagpur, Kharagpur 721302, India

HIGHLIGHTS

- Technology demonstration of the low cost activated laterite based arsenic filter.
- The filter does not require any regeneration and backwashing during its lifetime.
- Cost of the filtered water is less than 0.2 USD/m^3.
- The spent adsorbent does not leach on disposal and meets environmental limits.Arsenic free safe drinking water is provided to more than 5000 people at present.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 23 November 2016
Received in revised form 23 December 2016
Accepted 7 January 2017
Available online xxxx

Editor: Simon Pollard

Keywords:
Arsenic
Laterite
Community filter
Domestic filter
Adsorption
Social impact

ABSTRACT

Arsenic contamination mitigation technologies have been adsorption-based, but the most widely-used and traditionally available adsorbents suffered inherent limitations, including cost infeasibility and problems associated with regeneration and disposal of the spent adsorbent. The present technology is based on indigenously developed activated laterite prepared from the naturally and abundantly available material, and can hence easily be scaled up for community usage and large scale implementation. The total arsenic removal capacity is 32.5 mg/g, which is the highest among all naturally occurring arsenic adsorbents. A major issue in earlier adsorbents was that during regeneration, the adsorbed arsenic would be released back into the environment (leaching), and would eventually contaminate the groundwater again. But the adsorbent in this filter does not require regeneration during its five-year lifespan and does not leach upon disposal.

An attempt is made to test and demonstrate the practical implementation of the technology – its effectiveness and viability in three community (primary schools - one in Malda and two in north 24 Parganas, West Bengal, India) and 20 household filters, catering to over 5000 people in different areas of West Bengal exposed to high arsenic contamination of groundwater (ranging from 0.05 to 0.5 mg/l). The work also focuses on the social impact of the real life technological solution on the lives on the affected people in the worst hit arsenic affected communities, perhaps the greatest public health risk emergency of the decade.

* Corresponding author.
E-mail addresses: souravmondal2008@gmail.com (S. Mondal), anirbanroy.ju@gmail.com (A. Roy), rakamukherjee10@gmail.com (R. Mukherjee), mrinmoy.hit@gmail.com (M. Mondal), sankha999@gmail.com (S. Karmakar), chatterjeesomak1988@gmail.com (S. Chatterjee), mukherjee.munmun@gmail.com (M. Mukherjee), saikat12144@gmail.com (S. Bhattacharjee), sde@che.iitkgp.ernet.in (S. De).

http://dx.doi.org/10.1016/j.scitotenv.2017.01.042
0048-9697/© 2017 Elsevier B.V. All rights reserved.

Please cite this article as: Mondal, S., et al., A socio-economic study along with impact assessment for laterite based technology demonstration for arsenic mitigation, Sci Total Environ (2017), http://dx.doi.org/10.1016/j.scitotenv.2017.01.042

1. Introduction

Arsenic is a documented human carcinogen present in drinking water and poses the greatest threat to public health. Severe health effects have been observed in populations drinking arsenic-rich water over long periods in countries including Bangladesh (Yokota et al., 2001), Mexico (Del Razo et al., 1990), Vietnam (Berg et al., 2001), Western United States (Welch et al., 1988), Taiwan (Chen et al., 1994), India (Chakraborti et al., 2003), Canada (Wang and Mulligan, 2006) and 95 other countries (Murcott, 2012). More than 300 million people worldwide and over 170 million people in India and Bangladesh are exposed to the risk of arsenic contamination (Murcott, 2012). The situation in India and Bangladesh, described by WHO as "the largest mass poisoning of a population in history". It is generally agreed that the arsenic contamination of groundwater is of geological origin and derives from the geological strata underlying Bangladesh. The most commonly manifested disease so far is keratosis because of chronic arsenic poisoning from drinking water and over the next decade, skin and internal cancers are likely to become the principal human health concern arising from arsenic contamination. Around 90% of this population lives in rural areas and often do not have access to safe drinking water. Moreover, the arsenic affected regions are mostly under developed, inaccessible, low literacy and income levels making the situation grave. The arsenic concentration in the contaminated regions is reported to be over 10–100 times over the allowable WHO limit in drinking water (Smith et al., 2000). The problem is likely to aggravate as ground water resource depletes and there is no feasible and alternate socio-economic-environmentally sustainable solution available.

The WHO permissible level of arsenic in drinking water is 10 μg/l, which is also accepted by regulatory agencies of the European Union, EPA, Canada and other countries. However, many developing nations set the permissible level of 50 μg/l due to lack of sampling programs, funding and administrative infrastructure to enforce lower standards effectively resulting in masking an extensive exposure of a large population and the associated health risks (Henke, 2009).

In recent years, adsorption is gaining importance due to process simplicity, volume of waste and ease of waste disposal. Adsorbents like, hydrous ferric oxide, granular ferric hydroxide, etc., can remove both As(III) and As(V) ions from aqueous solution (Deschamps et al., 2005). However, most of these oxides are available only in fine powder or generated in situ as gel or suspension in aqueous solution and therefore, are inconvenient for large-scale practical application causing difficulties in separation of solid and liquid. The iron oxides, thus generated are unsuitable as filter medium due to their low hydraulic permeability. The widely used (commercially available) arsenic adsorbent is activated alumina (AA), but is expensive and requires frequent regeneration. During regeneration, the adsorbed arsenic in the adsorbent is again released into the environment and subsequently contaminates the ground water. Further, AA is much less effective to As(III) species, which is predominant in contaminated groundwater in India and Bangladesh. The maintenance of the available technologies is crucial and requires skilled man power and technical knowledge. A comparison of the different available technologies is presented in the supplementary Table S1. Six states along the Indo-Gangetic plains (in India) are affected by arsenic, impacting more than 100 million lives. Nine out of the twenty districts in West Bengal (WB) are at risk to arsenic contamination. More than 70 million people live in arsenic affected regions in WB alone. In remote areas of the affected regions, there is no electricity, making it more challenging for any water filter to work. The government efforts are to bore deep tubewells and put the extracted water into public distribution. However, this initiative diminishes the limited water reserve underground.

The indigenously developed ultra-low cost activated laterite based arsenic filter provides an alternative solution to arsenic mitigation (Maiti et al., 2009; Maiti et al., 2013; De and Maiti, 2011; Mondal et al., 2013). The adsorbent does not require regeneration during its lifetime of five years and has about three times higher arsenic adsorption capacity than AA (Maiti et al., 2010a). As a result, the maintenance of the filter based on this technology is negligible. There is no leaching into the environment from the spent adsorbent satisfying TCLP protocol (Maiti et al., 2010b). The key features of the filter are:

(i) Arsenic removal capacity is 32.5 mg/g, the highest among all naturally occurring adsorbents.
(ii) Arsenic concentration of filtrate is always within the WHO drinking water permissible limit of 10 μg/l, independent of the ground water concentration.
(iii) Extremely long life of the filters, at least five years.
(iv) No power requirement for the household filter.
(v) Removal of arsenic (below 10 μg/l), iron (below 0.3 mg/l) and bacteriological contamination (more than 98%) together in a single unit.
(vi) Upon exhaustion of the filter, the filter medium can be safely disposed without any risk of leaching and further contamination.
(vii) Cost of the treated water is less than 0.35 USD/m^3.

The technology has been approved by the Department of Science & Technology (DST), Govt. India and Arsenic Task Force, Govt. of West Bengal. The filter performance has been successfully demonstrated in field at community and household level with collaboration from UNICEF and DST, Govt. India. The technology is also featured by the DST (Govt. India) as one of the promising solution for remediation of arsenic contamination (http://dst.gov.in/Arsenic_Compendium.pdf).

The field implementation of the developed filter provides arsenic, iron and coliform free safe water to the people in the affected habitat covering a population of 5000 people. The present innovation has remarkable effect on improvement of the health, lifestyle and living conditions in the context of the socio-economic issues of the rural people. It may be noted that the health problems associated with consuming arsenic contaminated water results in social taboos in India. Populations in the affected villages are ostracized and face difficulties in marriages, discrimination of access to various activities including education and other resources. Therefore, these burning social aspects are expected to be improved in the long term due to the impact of present work. Since, the filter does not require any power, the areas with no or limited electrical supply is most benefitted. Since, the adsorbent preparation technology is based on the availability of natural laterite as the primary raw material which is abundant in the rural (affected) areas, commercial exploitation as a source of employment to the locals is a viable option in the long term.

2. Field studies

2.1. Site location and level of contamination of the selected regions

The developed filters have been deployed in the field to study the impact on the health and social well-being of the end users, both in the household and community. Total 20 household filters have been installed so far in various districts as described in Table 1. Typically, the household filters have an output capacity of 100–120 l/day of safe drinking water, sufficient to the needs of a family of 5–6 members. The physical dimension of the domestic filter is 50″ (height) × 15″ (diameter) as shown in the household images presented in Fig. S1a (refer to supplementary information). The filter bed consists of different layer of materials including bacteriostatic activated carbon, charcoal, fine granular sand, activated laterite and raw laterite.

Three community filters have been installed in the primary schools of the affected communities (refer to Fig. S1b of the supplementary section) and their locations are mentioned in Table 1. The primary schools are chosen to prioritize the need to provide safe drinking water to the children at risk, particularly where there is no safe alternate resource. Moreover, the sense of ownership and security of the installed filters