

A Study of Arsenic Treatment Technologies and Leaching Characteristics of Arsenic Contaminated Sludge

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Abstract

The arsenic crisis of Bangladesh has led to massive concerted efforts of NGOs and donor agencies in mitigating the disaster. Most of the focus has been on awareness building and the development and distribution of arsenic removal treatment systems. The disposal of arsenic concentrated sludge generated from the treatment process is one issue that has received little attention from the sponsors of the technologies and the users. This study was aimed at determining whether the present sludge disposal methods are safe and arsenic does not return to contaminate the environment. The present research investigated 15 NGO-led arsenic mitigation projects in 11 districts. Qualitative data were collected from interviews with villagers and NGOs, while soil and sludge samples were collected from the field sites. Samples were analysed at the BUET Environmental Laboratory and a toxicity characteristic leaching test was conducted to determine the quantity of mobile arsenic in the sludge samples. This study has concluded that the arsenic treatment units rendered the majority of the arsenic into a stable and non-mobile phase. No hazardous leachate was identified from the sludge produced from these units. Therefore, present arsenic-sludge disposal methods appear to be safe and not to contribute to recontamination of the environment. It is hoped that this study will lay the groundwork for informed public debate on arsenic treatment technologies and more particularly on long-term consequences of sludge disposal methods.

COMPARISON OF DIFFERENT TYPES OF ARSENIC TREATMENT UNITS AND TREATMENT ALTERNATIVES

A comparison of the different types of arsenic treatment units in operation and treatment alternatives is provided in Table 1. The cost of each unit, treatment capacity, maintenance requirements and acceptability by users are compared. All the units, except the iron removal unit, have comparable and sufficient arsenic removal capabilities (greater than 90% arsenic removal). The possibility of arsenic leaching from the sludge/waste generated from the treatment processes is dependent on the type of removal mechanism and the ultimate sludge disposal method. These issues are covered in the next section.

Table 1: Comparison of different types of arsenic treatment units and treatment alternatives

Type of Unit	Removal Mechanism	Daily Capacity	Cost (Taka)	Complaints by Users
3-Pitcher Filter	Adsorption by iron chips and sand	25-40 L One Family	250-300	Clogging of pitcher
Chari Filter	Adsorption by iron chips and sand	25-40 L One Family	300-400	No complaints
Tubewell Sand Filter	Adsorption by iron chips and sand	20 Families	5,000	No complaints
3-Pitcher Brick Filter	Adsorption by brick and sand	25-40 L One Family	300	No complaints
Bucket Treatment Unit (BTU)	Oxidation and coagulation followed by settling	20 L One Family	300-400	Leaking of buckets, Lack of chemical
Fill and Draw	Same as BTU	20 Families or 1 School	10,000	No complaints
HYBRID	Coagulation with lime and alum, followed by settling	25 L One Family	550	No complaints
SIDKO	Adsorption by granular $\text{Fe}(\text{OH})_3$	200 Families	2,00,000	Too expensive and difficult Maintenance
Iron Removal Plant	Aeration, sedimentation and rapid filtration	10 Families	8,000	Partial removal of arsenic only

SLUDGE DISPOSAL METHODS

An evaluation of sludge disposal methods was undertaken to determine whether the present methods lead to recontamination of the environment. Results of leaching test of sludge or soil samples would indicate whether the arsenic is bound to the adsorbent material or whether it leaches back into the environment. It was decided that direct observation of disposal practices in the field would be necessary. Both quantitative and qualitative data were collected during field visits. The method for obtaining data and the testing procedure followed are summarised below.

Methodology and Testing

At the start of each field visit an interview took place with the NGO project coordinators. During this interview data were collected about the project size, extent of problem, number of units in place, and removal methods for each unit. Questions were also asked about the sludge disposal methods suggested by the NGO to the users.

Visits were then made to the users and further questions were asked. The interviews with the users provided information about the method of use, ease of use of the unit and the maintenance of the unit. Information regarding location, frequency and method of sludge disposal were also collected. It was found, except for a few exceptions, that the users followed the method of disposal suggested by the NGOs. This information was used to determine whether a sludge sample should be collected for analysis.

A sample of the sludge or left-over residuals was collected from each type of unit at least once and from each NGO. The location and methodology of collecting the sample varied depending on the situation. Ideally, the collection method should have remained the same but differences in disposal methods, lack of available sludge and sludge collection systems made the sampling procedure vary. There were four types of sampling methods; (I) collecting the absorbent media from the treatment unit, (II) collecting the absorbent media from the disposal site, (III) collecting the material on which the sludge was disposed (in the case of liquid sludge), (IV) collecting absorbent media from a sludge storage system. In all cases, a predominately solid phase sample of approximately 100g was collected into a plastic-sampling jar with a scoop or by hand. No sample preservation techniques were used when transporting samples from the field to the laboratory. The time between sample collection and sample testing averaged about one week. During this time samples remained in storage containers.

The types of materials collected by sampling method I was sand, brick, and iron chips. These were collected directly from the units primarily because there

had not been any recent disposal of material or the location of disposal was too arbitrary to be precise. Sampling method II was used when the location of disposed adsorbent media (usually sand) could be found. This sampling procedure provides the best opportunity to examine of whether there is leaching of the arsenic out of the adsorbent media into the ground. Sampling procedure III is similar to procedure II except that it was used when a liquid sludge had been disposed of. Cow-dung and soil samples, on which the liquid sludge was poured onto, were collected. A leaching test of these samples would indicate whether the liquid sludge binds to the cowdung/soil particles or leaches into the environment. In two cases, NGOs had developed a sludge collection system. The sludge was collected in pitchers or buckets and stored for further remediation. To date the NGOs have not developed a remediation process although credit should be given to them for taking steps to control indiscriminate sludge disposal. Sampling procedure IV collected the saturated sand from 3-pitcher unit from the spent pitchers in these storage areas.

The leaching test that was determined to be appropriate for this project was the Toxicity Characteristic Leaching Procedure (TCLP, USEPA method 1311). The TCLP is designed to determine the mobility of both organic and inorganic analytes present in liquid, solid and multi-phase wastes (USEPA, 1992). The Bangladesh University of Engineering and Technology (BUET) Environmental Engineering Laboratory was contracted to perform the leaching tests. Three initial samples were tested at a private laboratory, Intronic Technology Centre (ITC). However, BUET was chosen to perform the rest of the tests because of its good reputation and better laboratory facilities.

Typically, the TCLP test removes the mobile component of any analyte present in the solid phase. The solid phase sample is extracted with an amount of extraction fluid equal to 20 times the weight of the solid phase. The extraction fluid employed is a function of the alkalinity of the solid phase of the waste (USEPA, 1992). The resultant extract from the TCLP test is the leachate. This leachate was analysed by atomic absorption spectrophotometer. The lower detection limit for this test is 0.001 mg/L. The reported concentration of arsenic in the leachate is precise to $\pm 10\%$.

RESULTS AND DISCUSSION

The results from the TCLP tests are presented in Table 2. The type of material tested, the arsenic concentration in the leachate, the sampling procedure, treatment unit of origin and the sponsoring agencies are also indicated in the table. The types of adsorbent media tested have been grouped together for better comparison.

Table 2: Results of TCLP tests performed on sludge/soil generated from arsenic removal units

Sample No.	Sample Type	Arsenic Concentration in TCLP Extraction Fluid (mg/L)	Sampling Procedure	Arsenic Treatment Unit	Name of the sponsoring agencies and Location
1	Iron Chips	<0.001	I	TWSF	DCH, Pabna
2	Iron Chips	<0.001	I	Chari Filter	DCH, Pabna
3	Sand	0.002	I	TWSF	DCH, Pabna
4	Sand	0.001	I	Chari Filter	DCH, Pabna
5	Sand	0.002	II	Pitcher Filter	AFV, Rajshahi
6	Sand	<0.001	I	Chari Filter	DCH, Pabna
7	Coarse Sand	<0.001	IV	Pitcher Filter	BRAC, Jhikargachha
8	Fine Sand	0.003	IV	Pitcher Filter	BRAC, Jhikargachha
9	Brick	0.005	I	Brick Pitcher Filter	Grameen, Kachua
10	Cow Dung	0.002	III	BTU	NGOForum, Manikganj
11	Soil	0.006	III	BTU	VERC, Nawabganj
12	Soil	0.012	III	Fill & Draw	Danida, Majidi
13	Cow Dung	0.007	III	BTU	Danida, Majidi
14	Soil	0.003	III	BTU	NGO Forum, Sylhet
15	Cowdung	0.001	III	Hybrid Filter	Hybrid, Singair
16	Soil	0.013	III	Brick Pitcher Filter (Wash Water)	Grameen, Kachua
17	Soil	0.043	III	Alum Settling	MCC, Majidi
18*	Sand& Iron	<0.001	I	Pitcher Filter	BRAC, Sonargaon
19*	Sand	<0.001	I	Safi Filter	BRAC, Sonargaon
20*	Sand	<0.001	II	Pitcher Filter	BRAC, Sonargaon

*Note: These samples were tested at Intronic Technology Centre

It was observed that in almost all cases arsenic leaching was observed, although the concentration in the TCLP extraction fluid was very small. The highest leachate concentration observed was 0.043 mg/L. This was from an “alum settling method” developed by MCC. On the other hand, iron chips from the “Chari” and “tubewell sand filter” indicated almost no leaching at all.

Additionally the total arsenic contents of some randomly selected soil/sludge samples have been determined and are presented in Table 3 along with the concentration of arsenic in TCLP extraction fluid. From Table 3, it can be inferred that leaching rate is independent of arsenic content in the original residual.

Table 3 : Comparison of total arsenic concentration in sludge/soil samples & corresponding arsenic concentration in the TCLP extraction fluid

Sample No.	Sample Type	Arsenic Content in Dry Solids (mg/Kg dry wt.)	Arsenic Concentration in TCLP Extraction Fluid (mg/L)	Sampling Procedure	Arsenic Treatment Unit
2	Iron Chips	7.09	<0.001	I	Chari Filter
4	Sand	6.55	0.001	I	Chari Filter
7	Coarse Sand	1.63	<0.001	IV	Pitcher Filter
8	Fine Sand	3.44	0.003	IV	Pitcher Filter
9	Brick	15.16	0.005	I	Brick Pitcher Filter
12	Soil	14.46	0.012	III	Fill and Draw
14	Soil	12.62	0.003	III	BTU
16	Soil	8.50	0.013	III	Brick Pitcher Filter (Wash Water)

These initial results give the impression that leaching of arsenic from sludge/soil generated from arsenic removal processes is not a major problem. A USEPA criterion for leachate concentrations was used to make a comparison of the level of toxicity of these samples. According to the criteria, if arsenic concentration in the extraction fluid exceeds 5 mg/L, the waste is considered as a “hazardous waste”. It is observed that the leachate concentrations of all the samples are over 100 times less than the USEPA hazardous waste criteria, and according to this criteria none of the samples can be classed as “hazardous”. No comparable criterion exists in Bangladesh.

However, the leachate concentrations are all well below the drinking water criteria of 0.05 mg/L. It should also be noted that further dilution may occur after leaching of arsenic from sludge/soil, further reducing the arsenic concentration in the leachate. With these arguments in mind, it is safe to assume that no dangerous level of arsenic leaching is occurring from the sludge from

various treatment processes in use. The arsenic being removed from the drinking water remains in a stable and non-mobile form in the sludge.

As to the specific methods of disposal that are characteristic to each treatment type, it can be noted that there appears to be no significant difference between the different disposal methods. The alum settling method developed by MCC had a leachate concentration that was significantly higher than all other samples. There are a few possible explanations. The first is that there might not have been sufficient oxidation of arsenite into arsenate prior to settling. The arsenite are more likely to be mobile and leach out of the soil sample. Another explanation could be possible experimental error. However, it should be noted that even a leachate concentration in the order of 0.05 mg/L is still 100 times less than the hazardous waste criteria and is still within drinking water criteria.

CONCLUSIONS

Field observations and interviews with the sponsoring agencies, particularly NGOs, and beneficiaries of arsenic treatment units have indicated that there is much promising and fruitful work being done to tackle the overwhelming arsenic contamination problem. Many arsenic awareness programs and mitigation projects are in operation and are being expanded by local and international NGOs. It is important to note that the success of many small-scale projects (less than 20 units) has shown a good potential for expansion. Equally important is the observation that even large scale projects (over 1000 units) have had similar successes and have not been hampered by the bureaucracy that often characterises these projects. All the treatment units in operation successfully reduce high levels of arsenic in tubewell water below the 0.05mg/L drinking water standard.