# Rapid Assessment of Technologies for Arsenic Removal at the Household Level

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***Abstract***

*This paper reviews the results and conclusions from a DFID funded project 'Rapid Assessment of Household Level Arsenic Removal Technologies', carried out in association with the Bangladesh Arsenic Mitigation Water Supply Project. Nine technologies were assessed under this project. The project comprised two phases. Phase I sought to identify whether the nine technologies removed arsenic to below the Bangladesh Guideline Standard of 0.05 mg/L, under idealised field operating conditions. Phase II looked at arsenic removal under householder operation and considered the treatment of other water chemistry parameters, bacteriological contamination and the opinions of the householders who used the technologies. This paper considers the priorities in adoption of technologies, which are most effective in the treatment of groundwater and most acceptable to the potential users. It is argued that before a technology should be adopted it should be assessed against a given set of criteria (in the form of questions). These are: Does it work? Does it create any further chemical/biological problems? Is it acceptable to potential users? If not, why not? The issue of cost should only be brought into consideration if the technologies pass the preceding criteria. Five of the nine technologies (Alcan* *enhanced activated alumina, BUET activated alumina, Sono 3-kolshi, Stevens Institute technology and the Tetrahedron) comfortably passed the arsenic removal test. Two others (DPHE/Danida 2-bucket system and GARNET) passed the arsenic removal test under certain conditions and two (Ardash filter and passive sedimentation) failed the test. The performance of the seven that were further assessed was variable, with most requiring some modification to design or use or a change of attitudes to hygiene by the users. The main concerns, particularly for the lower cost technologies, related to apparently high levels of faecal contamination, low flow rates, the use of chemical reagents, long waiting times within the filtration process and the maintenance of the technologies.*

## INTRODUCTION

This paper seeks to present nine technologies which were assessed as part of a DFID funded 'Rapid Assessment of Household Level Arsenic Mitigation Technologies' carried out under the Bangladesh Arsenic Mitigation Water Supply Project (BAMWSP) between November 2000 and March 2001. The rapid assessment considered many different aspects relating to the use of the technologies, and this paper seeks to summarise these aspects in the context of assessing the problems and prospects of water treatment and its sustainability.

The project was carried out with the premise that treatment of arsenic contaminated water is only one of many mitigation measures available. Other measures include use of surface water sources, rainwater harvesting, hand-dug wells, deeper wells and community supplies from uncontaminated wells. However, in the short term, treatment is potentially the most effective solution. Some of the cheaper technologies are, indeed, presented as only a short-term crisis measure.

The sustainability of these technologies is not just a function of the inherent robustness of the technology and of the treatment process used, but a function of the infrastructure and support services provided in support of the users of the technologies. If a technology needs little in the way of spare parts or reagents, then it may be sustainable. However, the fact that a technology may need a constant supply of reagents and spare parts does not mean that it is unsustainable, so long as the support services for the technologies are local and effective.

The aim of this paper is twofold:

1. Illustrate the performance and acceptability of the nine technologies, and
2. Show key issues that need to be considered if a technology is to be considered as a realistic and sustainable solution to water supply in arsenic affected areas.

## TECHNOLOGIES

The nine technologies included in the rapid assessment are described in Table 1. Photographs of each are attached at the end of this paper. The treatment processes used included enhanced and regular activated alumina, resin columns, metallic iron and coagulation.

**Table 1 : The technologies included in rapid assessment**

| TECHNOLOGY | PROCESS |
|---|---|
| Alcan Enhanced Activated Alumina (AL) | Adsorption to enhanced activated alumina (AAFS-50) |
| Ardasha Filter (AR) | Passive sedimentation and adsorption to clay/carbonised organic matter candle |
| BUET Activated Alumina (BUET) | Oxidation, adsorption to sand filter and activated alumina |
| DPHE/Danida 2-bucket System (DPHE/DANIDA) | Oxidation, coagulation and adsorption through sand candle |
| GARNET Home-made Filter (GARNET) | Passive coagulation with iron (from brick chips) and adsorption to sand |
| Passive Sedimentation (PASSIVE SEDIM.) | Passive sedimentation |
| Sono 3-kolshi Method (SONO) | Passive coagulation with Fe and/or adsorption to sand matrix |
| Stevens Institute Method (STEVENS) | Enhanced coagulation and co-precipitation (ferrous suphate), filtration and adsorption to sand filter |
| Tetrahedron (TETRAHEDRON) | Ion exchange resin |

Photographs of Alcan enhanced activated alumina filter, BUET activated alumina filter, GARNET home-made filter, DPHE-Danida Bucket Treatment Unit, Steven's Institute of Technology, Tetrahedron ion exchange filter and Sono 3-Kolshi filter are shown in Figures 1 through 7.

**Figure 1 : Alcan enhanced activated alumina filter**


Figure 2: BUET activated alumina filter


Figure 3: GARNET home-made filter


Figure 4 : DPHE-Danida Bucket Treatment Unit (BTU)


Figure 5: Steven's Institute of Technology


Figure 6: Tetrahedron Ion Exchange Resin Filter


Figure 7: Sono 3-Kolshi Filter

## METHODOLOGY

During Phase I, three replicates of each of the nine technologies were tested at twenty different wells (five in each of four areas of Bangladesh). Tests included arsenic, ferrous iron, total iron, total manganese, total aluminium, phosphate, nitrate, fluoride, chloride, sulphide, turbidity, redox, pH, conductivity, dissolved oxygen, sulphate and alkalinity. Technologies were operated by the field testing teams according to strict operating instructions and timing schedule.

During Phase II, three areas were used for the assessment (Satkhira, Iswardi and Hajiganj). In each area, twenty one wells were included in the assessment. At each well, three different technologies were used over a thirty day period. The same water chemistry tests were carried out as in Phase I but under normal operating conditions by the householders at each well. In addition, bacteriological testing of faecal coliforms was carried out. A social assessment was done with the householders to illicit their opinions of the technologies with regard to ease of operation and maintenance, flow rates, timeliness of water supply, quality of treated water (e.g. taste and smell).

## PRESENTATION OF RESULTS

This paper has used the results from the rapid assessment to put forward the idea that there is a process through which technologies should be evaluated, selections made and areas for improvement identified. This process requires answers to specific questions. If the answer to any of the questions for any of the technologies is clearly inadequate, then it is recommended that the technology should not be considered as a short/medium term solution to the arsenic problem. The key questions are seen as:

1. Does the technology reduce arsenic to below the Bangladesh Guideline Standard (0.05mg/L)?
2. Does the technology create any problems regarding major water chemistry parameters?
3. Does the technology create any bacteriological problems?
4. Is the technology acceptable to users?
5. If not, (a) Why not?
   (b) Are the reasons for unacceptability easy to address?
6. What is the cost/basis of cost of the technology?
7. What are the most appropriate financing options?

Each answer to each question for each technology, represents one box in Table 2. The darkness of the shading of each box represents the degree of concern relating to each answer for each technology.

When looking at the Table 3, the darkness of shading across the rows gives the degree of concern for each issue and the darkness of shading down each column gives the degree of concern for each technology.

**Table 2 : Degree of concern related to technologies under assessment**

| | |
|---|---|
| | No cause for concern |
| | Some cause for concern. Issues need rethinking. |
| | Significant cause for concern. Issues need addressing and design and/or operation modifications required |
| | Technology not acceptable on these grounds. Proceed no further |

## RESULTS

It is clear from the Table 3 that, overall, the most acceptable technologies are the Alcan, Tetrahedron, Sono and Stevens. It is also clear that arsenic removal and other water chemistry issues are, in many ways the least points of concern – the technologies do what they are designed to do on the whole.

The major issues relating to the prospects for the technologies and for sustainable use are the risk of bacteriological contamination and the acceptability of the technologies to prospective users. The main reasons why some technologies are not acceptable to the users are the amount of work needed to operate and maintain the technologies, the amount of time that they have to wait for water and the volumes of water that are available on a daily basis. These issues were highlighted in a rapid assessment. It is likely that they will become ever more a barrier to use in the longer term as householders become impatient with the volume of work and waiting times.

The amount of work required for, and the volumes of water produced by, the Alcan and Tetrahedron are considerably less than for the other technologies. However, they are considerably more expensive and this was a big barrier to acceptability.

**Table 3 : Relative performance of technologies**

| Question | Alcan | Ardasha | BUET | DPHE/ Danida | Garnet | Passive Sedim. | Sono | Stevens | Tetra Hedron |
|---|---|---|---|---|---|---|---|---|---|
| Does the technology reduce arsenic to below the Bangladesh Guideline Standard (0.05mg/L)? | Yes (100% samples) | **No (<5% samples\|** | Yes (99.5% samples) | **Yes (but only below groundwater As<0.12mg/L)** | **Yes (but only when operate exactly according to instructions 75% samples If not, then 43% samples** | **No (0% samples** | Yes (99% samples) | Yes (>90% samples) | Yes (>80% samples) |
| Does the technology create any problems regarding major water chemistry parameters? | No | – | No | **Yes – manganese and aluminium significantly increased to above Bangladesh Guideline Standards** | No | – | No | No | No |
| Does the technology create any bacteriological problems? | Some Temporary contamination at times. Slight design changes and instructions to users | – | **Yes Contamination in sand filter. Further research required.** | **Yes Contamination in sand filter. Further research required.** | **Yes Contamination in sand filter. Further research required.** | – | **Yes Contan nation i sand filter. Furthe researc require .** | **Very little Mainly from outlet pipe trailing on ground.** | No |

**Table 3 : Relative performance of technologies ( Contd. )**

| Question | Alcan | Ardasha | BUET | DPHE/ Danida | Garnet | Passive Sedim. | Sono | Stevens | Tetra Hedron |
|---|---|---|---|---|---|---|---|---|---|
| Is the technology acceptable to users? If not, (a) Why not? (b) Are the reasons for unacceptability easy to address? | Yes (1st favourite) Only concern is cost. | – | **No (7th avourite Too tall and unstable ifficult t use. Redesig equired** | **Fairly acceptable (3rd favourite) Bothersome use (reagents), waiting times. Maybe reconsider reagents.** | **No (6th favourite) Slow flow rates (not enough As free water), heavy. Further research on materials/ design.** | – | Yes (2nd favourite) Main concerns difficult to move and slow flow rates. | **Fairly acceptabl (5th favourite) Main concerns are cleaning frequency taste, nee for additiona reagents.** | Fairly **cceptabl (4th avourite Main concerns are taste mell and cost** |
| What are the volumes of water produced in 12 hours? | >3600 litres Enough for >100 families | – | 50 litres Enough for 1.5 families | 43 litres Enough for 1 family | **13 litres Not enough for 1family** | – | 40 litres Enough for 1 family | 169 litres Enough for 5 families | 624 Enough for >20 families |

## DISCUSSION

The rapid assessment illustrated that there are many different ways to successfully approach arsenic removal from groundwater at a household level. However, it also showed that arsenic removal is just one small element in the production of a successful and acceptable technology.

Many would argue that, given that the technologies are mainly designed to be a short/medium solution, bacteriological contamination is potentially a far more serious and immediate hazard to health than drinking untreated water. There are recommendations made for each of the technologies where there are problems with bacteriological contamination. These principally concern regular cleaning with hypochlorite to minimise contamination and a hygiene educationprogramme as part of the distribution of technologies. This adds further stages to the water treatment process and potentially further reduces acceptability of the technologies to users.

In most cases, the process has been proven to be effective in the removal of arsenic and it is problems in the design of the technology to accommodate that process which has caused a reduction in acceptability. The more expensive technologies have gone for a much higher specification which has reduced the number of inconveniences to users and increased the performance in terms of volumes of water available.

There is some room for a trade off between cost and performance. However, lower cost should not be made the priority if it results in a technology which is unacceptable to users, does not produce sufficient water and which may deliver water of a lower quality and containing faecal coliforms. The Stevens is a good example of a lower cost technology that does perform well on all water quality issues (including microbiology) but needs some refinement to make it more acceptable to users, particularly with regard to cleaning. The Sono is highly acceptable and affordable, but the issue of contamination needs close scrutiny before mass production. It is believed that a smaller, less expensive version of the Alcan has been produced and is currently being evaluated. This is an example of where modifications to design to address the points of concern have been made.

The cost of water supply for these technologies has not been finally determined. The capital costs have been identified, but the regularity of replacement (following break through) has not yet been finally identified. This is important in the calculation of costs over a period of time and defining average costs per litre of water in the short to medium term.

The cost issue is one that varies in importance depending upon the financing arrangements that are proposed. For example, if the financing arrangements are for market sector, private purchase, then whether or not the more expensive units (in terms of capital costs) are the cheapest in terms of cost per litre is immaterial. The vast majority of potential individual households will be unable to afford the capital costs. A group of households could potentially afford it if community supply was an acceptable option to users.

However, if some form of subsidy or public provision of technologies was the proposed arrangement, then the issue of cost is potentially a less crucial issue in terms of purchasing power. Value for money, rather than affordability, becomes more important.

## CONCLUSIONS AND RECOMMENDATIONS

There are a variety of processes which have been developed and which do remove arsenic. However, how these processes are packaged, in terms of engineering, can have a big influence on the treatment of other water quality parameters (both chemistry and microbiology) and on the acceptability of the technologies to potential users.

In many cases, refinements are needed to the technologies. This is not surprising as these technologies were among the first to be developed at this scale to address the groundwater arsenic problem. The important first step is to be sure that they remove arsenic. Once this has been proven, then it essentially a question of 'market testing' to identify ergonomic and other concerns of the users and to modify design to address these concerns. This rapid assessment was part of this on-going process of refinement and the process needs to be continued, particularly in relation to:

- reducing the risk of bacteriological contamination,
- increasing the acceptability of the technologies to users.

The issue of cost should not be a constraining factor until the process for introduction of these technologies, and associated financing arrangements, has been identified.