Design and Performance of a Danida Designed Arsenic Removal Unit

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Abstract

The DPHE-Danida Urban Water & Sanitation Project has developed a proto-type filter to remove arsenic from ground water. The arsenic removal unit (ARU) is designed to be connected to a hand tube well (HTW) and can serve up to 25 families or 200 individuals.

The Project has installed two ARUs in Noakhali Pourashava on a pilot basis. The filters have only been in operation since beginning of March 1998, with average removal efficiency of 70 %. The results and observations presented in this paper, though promising, are very tentative It is likely that the ARU need more development and optimization to be feasible for further implementation.

Introduction

During recent years arsenic has been measured in the groundwater of various areas of Bangladesh. Moreover, people with arsenic related symptoms is increasingly observed in the country, thus adding one more serious calamity and creating a new major health concern in the country.

One way to mitigate the problem is to develop treatment methods which can remove arsenic from water abstracted from the large number of existing shallow-HTWs. Treatment methods which can be used at household level or at community / institutional level.

The method described in this paper is an arsenic removal unit (ARU) to be attached to a hand pump on a community / institutional level. During the design phase, special emphasis has been given to operation and maintenance considerations. The Project has tried to make a unit, which is easy to operate with low running cost, and where maintenance procedures are as easy and infrequent as possible.

Design and Methods

The design of the ARU is based on the following knowledge and experience:

- The fact that arsenic can be removed by co-participation with iron;
- experiences from existing Iron Removal Units (IRUs); and
- the fact that arsenic can be removed by traditionally water treatment processes (chemical addition / aeration / coagulation / flocculation / sedimentation / and filtration).

Furthermore emphasis has been put on the following:
- Simple design;
- simple operation and maintenance;
- low construction cost; and
- low running cost.

The ARU consist of one compact unit (app. 2x1 m in surface area and 1 m height). This unit is covered with a lid, so the users are not exposed to the details of the unit and to the fact that chemicals are added to the water. Water from a shallow well, is pumped by a Popular no: 6 hand-pump to one end of the ARU, and treated water is abstracted from a tap installed in the other end of the ARU.

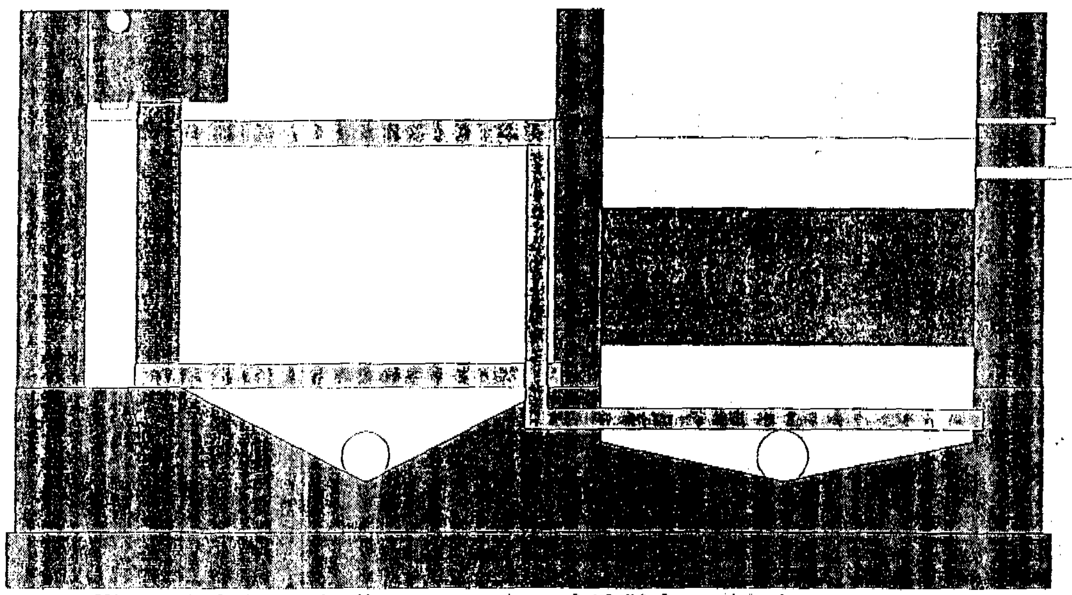

Figure 1. Schematically presentation of ARU from the site.

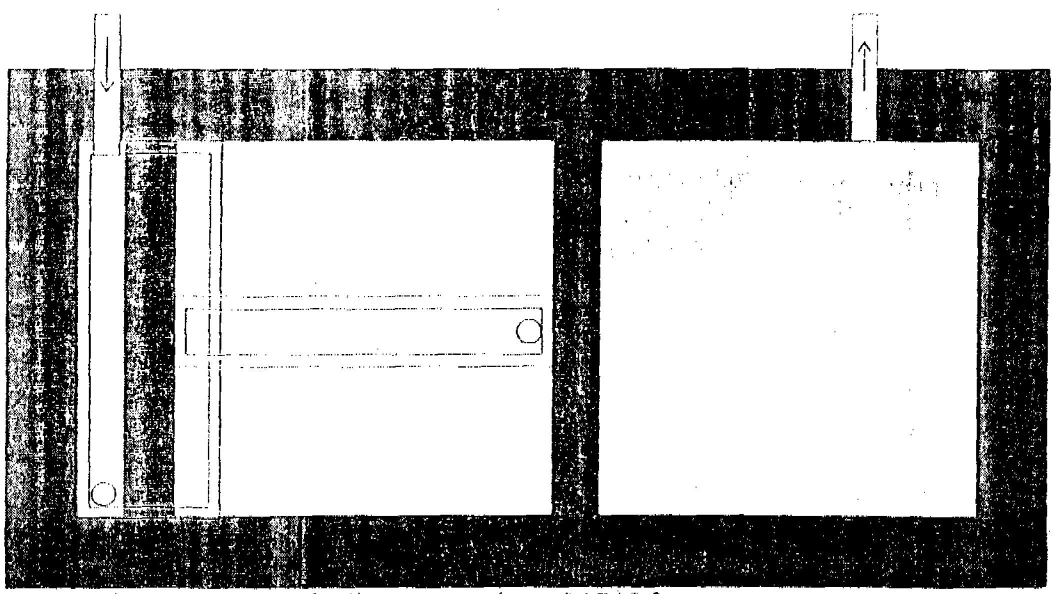

Figure 2 Schematically presentation of ARU from top.

The ARU comprises of four compartments (figure 1&2):

1) A compartment where the raw water is pumped into, and where chemical addition, rapid mixing and aeration take place is in fact sub-divided into 5 compartments (figure 3):
   a) Buffer chamber to control chemical addition (on-off system);
   b) mixing chamber;
   c) aeration channel;
   d) aeration chamber;
   e) chemical stock solution chamber.
2) A narrow chamber in the concrete structure for flocculation. The chamber is installed with vertical baffles to direct the water flow, and has a hydraulic retention time of app. 15 minutes (figure 2).
3) An up-flow vertical sedimentation tank with a surface loading of 1100 L/h/m^2, based on 75 % of full time maximum pumping capacity of the hand-pump. The water is distributed in the lower part of the chamber through a perforated 1.5" PVC pipe.
4) An up-flow gravel filter with a surface loading similar to the sedimentation tank. The gravel size is 15-25 mm.

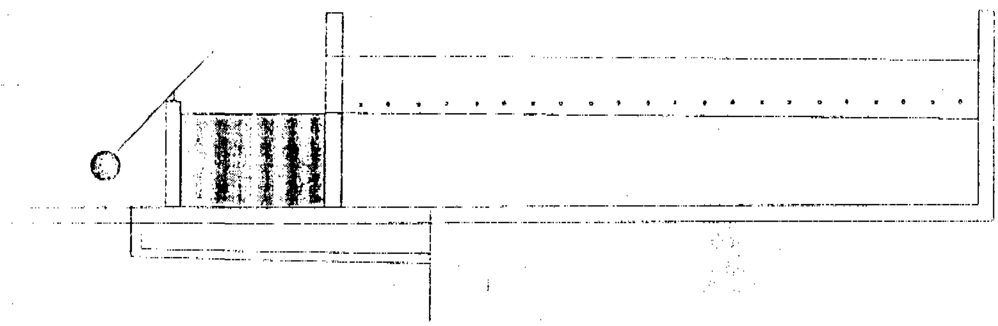

Figure 3. Chemical addition and aeration chamber.

Compartment 1 for chemical addition, aeration and stock solution, is build as one unit by fiberglass. Chemical addition is controlled by a mechanism with a float floating in the buffer chamber. When water is pumped into the system the buffer chamber will be filled with water and the float will go up, bringing the chemical addition pipe down in the mixing chamber and starting dosing. When pumping stops, the water will drain out of the buffer chamber through a hole in the bottom, lowering the float and stopping the chemical dosing. This gives an on-off dosing system, with dosing on when the ARU is used, and off when the ARU is not used. The amount of chemicals added is not proportional to the pumping speed. With this mechanism the control and consumption of chemicals added to the water is much higher than in a continuous addition system.

The construction price of an ARU is approximately 12 – 15.000,- taka, depending on the type of cover supplied. The construction is fairly easy. The main problems is to carefully administer the small pressure head available, which shall be shared between the four compartment, and to have the first compartment for chemical addition made in a proper way.

Operation & Maintenance

As the ARUs have only been in operation for a few weeks, the filter run period and the frequency of refilling chemical stock solution have not been established yet. It is anticipated, however, that the sedimentation and the filter chambers need to be back-washed on a monthly basis, while the chemical chamber must be re-filled on a weekly basis. Furthermore, the chemical dosing mechanism, though working without adjustment after a month of operation, need to be tested and monitored over a long period

If alum is added to the raw water as flocculant with a dose of 2-300 mg-alum/L, and the ARU is supplying drinking and cooking water to 25 families (15 L/c/d), the operational cost for purchasing alum will be in the range of 10 taka per family per month.

Locations

Two ARUs have been installed in Noakhali Pourashava. One, in the Danida Guesthouse where the Project have good control of the use, and easy access for monitoring. The other is built in Sonapur, in the southern part of Noakhali Pourashava.

Sampling & analysis

Raw water, water leaving the sedimentation tank and finished water has been sampled once or twice per week from both ARUs. One L of polythene bottles was used after thoroughly being washed with the sample water and added 4 ml of concentrated hydrochloric acid for preservation. The samples were analyzed for total inorganic arsenic.

The arsenic concentrations were measured using the silver diethyldithiocarbamate method described in the Standard Methods /1995/. The method was slightly modified by changing the U shaped absorber tube into a diffuser blowing the produced arsine directly into an absorber tube suitable for direct portable spectrophotometric measurement.

The Hack DR/2010 portable spectrophotometer was used for both iron and arsenic measurements.

Results

Arsenic removal efficiency of ARU. The two ARUs installed have been in operation for nearly one month with the addition of 100-150 mg-alum/L.

Samples from raw water, water after the sedimentation tank and water after the filter tank, were sampled five times during the 2nd and 3rd weeks of operation, and analyzed for total inorganic arsenic.

The results are listed in table 1 together with the removal efficiency and the average concentrations over the five sampling days.

Table 1. The concentration of arsenic, measured as total inorganic arsenic in the raw water, in water after sedimentation and in finished water. The table also show the fraction removed and the averages and standard deviations over five sampling days.

Sonapur		After			
Date	Raw water Mg/L	Sediment mg/L	Removed %	Finished mg/L	Removed %
9-Mar	0.136	0.072	47	0.052	62
11-Mar	0.118	0.065	45	0.040	66
12-Mar	0.139	0.069	50	0.034	76
16-Mar	0.135	0.075	44	0.043	68
18-Mar	0.132	0.056	58	0.037	72
Average	0.132	0.067	49	0.041	69
St.-Dev.	0.008	0.007	5	0.007	5

Guest house		After			
Date	Raw water Mg/L	Sediment mg/L	Removed %	Finished mg/L	Removed %
9-Mar	0.174	0.083	52	0.053	70
11-Mar	0.147	0.058	61	0.045	69
12-Mar	0.160	0.054	66	0.043	73
16-Mar	0.162	0.054	67	0.041	75
18-Mar	0.172	0.070	59	0.049	72
Average	0.163	0.064	61	0.046	72
St.-Dev.	0.011	0.013	6	0.005	2

Operation & Maintenance. It is to early to report on any possibly complications in terms of O&M. It was observed, however, that the chemical dosing mechanism on both ARUs were still working without any adjustment after a month of operation. Furthermore, one of the ARUs was back-washed after one month of operation. It seems that all sludge from both the sedimentation tank and the filter tank were washed out during this operation.

Discussion

To remove arsenic from water is technically not a difficult task. There are, however, limited experiences from de-arsination in rural and semi-rural areas of developing countries.

De-arsination technologies can be categorized into the following three groups:
- Coagulation / co-precipitation techniques
- Sorption techniques
- Membrane techniques.

Taken from below, the following comments can be given to the different categories of technologies.
- Membrane techniques are generally costly both in investment and in running; the techniques need close supervision; and are often high-tech solutions, which are not appropriate in rural areas of developing countries.
- The sorption technique normally implies filtering the water through an activated filter media. Activated filter materials have limited capacity of adsorbing arsenic,

and thus need to be changed or regenerated at certain intervals. To make this operational, though, a monitoring system must be established.

- The Coagulation / co-precipitation techniques have problems with sludge handling. These techniques like alum and ferri coagulation and co-precipitation, however are cheap in investment and running, and do not need constant monitoring of removal efficiency.

The two ARUs installed in Noakhali Pourashava have been in operation for a one-month period with addition of alum to a concentration of 100-150 mg/L. No other chemicals were added to the water. The removal efficiencies were approximately 70 %, bringing the arsenic concentration down below Bangladesh Standard.

70 % removal, however, is not sufficient, if higher concentrations of arsenic are found in the raw water. Moreover, 70 % removal has previous been reported from co-precipitation with naturally occurring iron, and thus the results does not clearly prove the efficiency of the unit, and the addition of alum.

The O&M observations, however, are promising and the removal efficiency is expected to be improved by further development and optimization. The effects of the following parameters are planned to be examined and optimized by the Project in the near future, and before implementing more ARUs.

- Sizes of different chambers;
- control unit in dosing system;
- dosing amount;
- $FeCl_3$ as coagulant;
- addition of second chemical like lime or bleaching powder.

References

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