In-situ Removal of Arsenic - Experiences of DPHE-Danida Pilot Project

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Abstract

Two well-known methods of iron removal were tried to see their effectiveness in removing arsenic. One of these was in-situ sedimentation and the other was conventional iron removal technique. The analysis of the preliminary results revealed that both the methods are capable of bringing down arsenic level to Bangladesh standard when the raw water concentration is of the order of 0.1mg/l. The higher values could however, be reduced to halves of their originals. The former contamination level accounts for 50% of the total contaminated tubewells in most of the arsenic problem area. The promotion of these methods can bring a good range of coverage in arsenic mitigation in the country. The methods being chemical free are likely to be well accepted by the people. The methods may, however, be further improved for wider range of effectiveness and need to be field-tested for acceptability by the target group before mass scale promotion.

INTRODUCTION

The occurrence of arsenic in groundwater of Bangladesh is a major problem of the country. The contamination is of large scale and 8 years have passed since arsenic came into picture. Various organizations are still searching ways and means to address the problem. Treatment of arsenic contaminated water through appropriate technology is one of the options to mitigate arsenic problem. The latest but insignificant development with low-cost mitigation options demanded further investigations to identify immediate solution for the arsenic problem. With this end in view DPHE-Danida Arsenic Mitigation Pilot Project (AMPP) carried out action research on in-situ arsenic removal technology and on conventional iron-cum-arsenic removal technology (DPHE-Danida, 2000). For low concentrations of arsenic in the raw water the methods appeared to be promising and still having room for further improvement to broaden their spectrum. The process technology of in-situ removal and its experimental results would be presented here.

THE PROCESSES TECHNOLOGY

The prevalent occurrence of arsenic species in Bangladesh ground water are that of As(III) and As(V). There are significant differences in the chemical behaviours of these species during removal techniques. The literature on arsenic concludes from its removal behaviour that As(III) cannot be separated from water effectively as easy and complete as pentavalent, As(V) (Jekel,1994). So oxidation of arsenite to arsenate is considered a prerequisite for any treatment method to be efficient. Dissolved oxygen is preferred oxidant if a catalytic process is possible, otherwise oxidants like potassium permanganate can be selected (Jekel,1994). Precipitation of As^{5+} both by aluminium or ferric hydroxide is the method of arsenic removal, but dosing, filtration, and disposal of sludge are points of concern in operation.

<u>Oxidation of Arsenic(III)</u>

The redox reaction of the As(III) /As(V) system is described by the equation:

$$H_3AsO_4 + 2H^+ + 2e^- \longrightarrow H_3AsO_3 + H_2O$$
$$E_o = +0.56V$$

When Nernst formula is applied for the redox potential at pH 7, a value of +0.14V is calculated for the same concentration of the both forms. For a 99% oxidation of arsenic, however, +0.206V is necessary, indicating an easy oxidation of As(III), even by dissolved oxygen. However, the kinetics of a homogenous oxidation by O_2 is very slow (25-30% per 24hrs). As the effective removal of arsenic from water requires complete oxidation of As(III), special oxidation step is required to accelerate the oxidation process. There are number of means of oxidation, however, for drinking water treatment the residuals of oxidants, oxidation by-products, and the oxidation of other inorganic and organic constituents in water are to be checked very carefully.

IN-SITU SEDIMENTATION OF ARSENIC

The technology of in-situ removal has successfully been used for iron removal. The process technology is to allow oxygenated water to run back into the iron and arsenic contaminated aquifer through the same tubewell. This allows forming coating of iron hydroxide on sand grain around the strainer and while pumping again arsenic and iron reduces to acceptable limit. In case of ground water with low iron content, solution of ferric chloride/sulfate at low pH may be injected to achieve the same situation. Natural oxidation in the water phase of trivalent arsenic to pentavalent arsenic is a very slow process. Solid-liquid interfaces, however tend to catalyze most chemical reactions and likely the arsenic oxidation also. In the aquifer the solid-liquid interfaces are abundant and by introducing oxygen to the aquifer arsenite will be oxidized to arsenate. Arsenate is much less mobile than arsenite as it tend to co-precipitate out with metallic cations or to adsorb onto solid surfaces. Ferri-iron is known to facilitate the arsenic oxidation both by catalytic effects and by direct reaction. The aquifer, over time, is expected to be conditioned improving arsenic removal.

DESIGN AND INSTALLATION

A cylindrical tank with effective capacity of 500 litres was designed attached to tubewell with provision of wash out and returning the pumped water to the tubewell again. (Figure 1) The tank could be filled up to the required level with water from the TW by manually or using an electric pump. A contact aerator was designed to aerate the water during filling the tank. An arrangement was made to allow back flow of aerated water to the tube well through a pipe located 15-cm above the bottom of the tank to avoid iron flocs settled in the tank to flow back to the aquifer and clog the screen. The pipe was fitted with a gate valve and connected to the tube well pipe with a tee. There was an outlet at the bottom of the tank for wash out iron sludge. Necessary controlling valves, fittings and cover to the tank were provided for sanitary protection of whole setup including the tubewell. The cost of each setup could be accommodated within Tk. 2000 except the pumping unit. Manual operation of the unit was possible. Three such setups were installed in Maijdee area attached to shallow tubewells (screen depth 10-12m) having arsenic concentration of 0.11 mg /l, 0.52 mg /l and 1.27 mg /l respectively. The iron concentrations of the respective tubewells were 1.02mg/l, 2.35mg/l and 1.04mg/l.

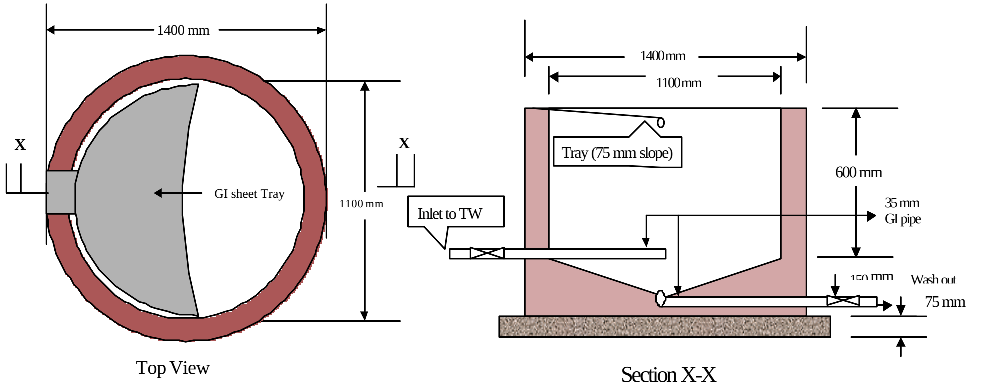

Figure 1 : Feed Water Tank

OPERATION AND MONITORING

The operation of all the units were planned in such a way that every day at 6:00PM 500 litres of aerated water was allowed to flow back to the aquifer of each tubewell. The tubewells were left undisturbed for 12 hrs. Next day morning from 6:00AM water was pumped and samples were taken at every 500 litres of water pumped till 3000 litres of water was pumped. The samples were sent to the laboratory and tested for arsenic and iron. The process was continued for 1 month for all the installations and then monitoring was done once in a day at 5:00PM.after normal use of the tubewell and continued for another month.

RESULTS AND DISCUSSION

Water quality test results showed that the arsenic concentrations in the following day reduced to more than 50% in all the cases and remained so till 2500 litres of water was pumped. Then the arsenic level gradually increased to its original level. Although it was expected that over time with the continuation of the process the aquifer be conditioned and the removal efficiency would be increased but no such changes could be traced during the monitoring period. The modalities of the results are presented graphically in Figure 2. The oxygen level of the aerated water could be raised to 5mg/l with the present design of the contact aerator. Arsenic species (As^{3+} and As^{5+}) of the raw water and treated water were measured but the results so far obtained were inconsistent. As a result the effectiveness of oxidation of As^{3+} to As^{5+} in the solid liquid interface could not be ascertained fully. The reduction of the arsenic level up to 50% indicated that the adsorption/co-precipitation mechanism was active in the processes and this could be made efficient further through enhanced aeration of the feed water. In all cases the iron concentration was reduced to minimum level.

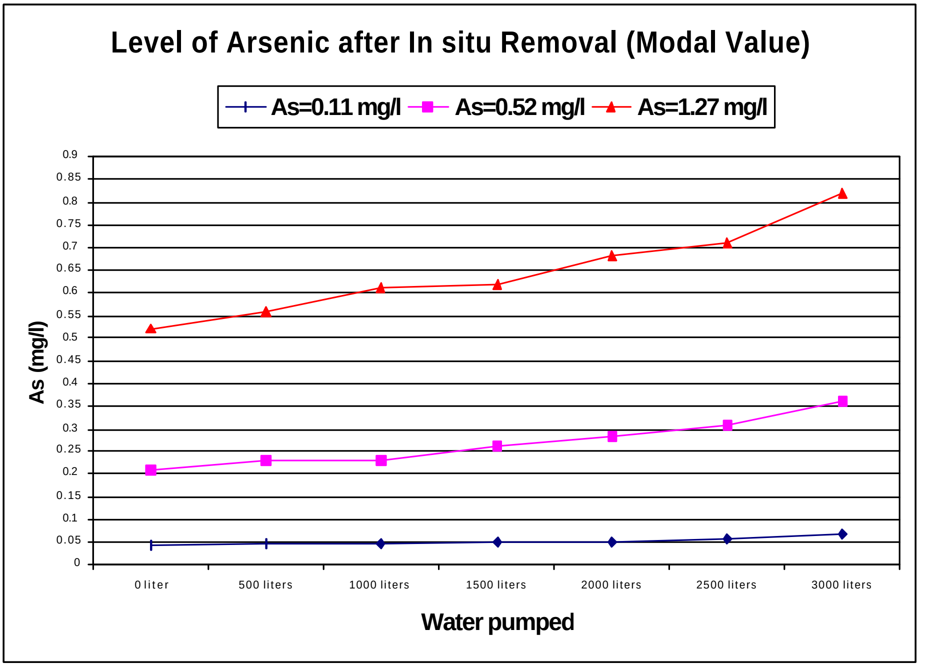

Figure 2 : Arsenic Treatment Efficiency with Different Concentrations of Raw Water

RECOMMENDATION

In order to increase the efficiency of the process in removing arsenic the experiments can be repeated giving extra care to the following points:

- Oxygen level of the feed water is to be increased with sprinkler type aerator;
- Precise measurement of arsenic species of both raw water and treated water;
- Monitoring of oxygen level of feed water and pumped water;
- To increase iron content of the raw water to 10 times higher than arsenic;
- Prolong test of the process to see conditioning of aquifer if any.

CONCLUSIONS

The analysis of the preliminary results revealed that the method is not promising for higher concentration of arsenic but capable of bringing down arsenic level to Bangladesh standard when the raw water concentration is of the order of 0.1mg/l. The values higher than this could however, be reduced to halves of their originals. The contamination level of 0.1mg/l accounts for 50% of the total contaminated tubewells in most of the arsenic problem area. As such the promotion of the method can bring a good range of coverage in arsenic mitigation in the country. The method being chemical free is likely to be accepted by the people. There is, however, scope for further improvement of the method for wider range of effectiveness and the option needs to be field-tested for acceptability by the target group before mass scale promotion.

REFERENCES

DPHE-Danida (2000) Arsenic Mitigation Pilot Project, Bangladesh, Quarterly Progress Reports, September 1999, December 1999, February 2000.

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