The results of the pilot plant study for arsenic removal

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Introduction

Contamination of potable ground water (well water) with arsenic is a large problem in Bangladesh and India. For removal of arsenic from the well water, various measures are positively examined mainly by UNICEF and WHO. We recently studied, jointly with Hokkaido University and Rajshahi University, a system iron ion and arsenic by sand filtration. This paper reports the results of running of a pilot plant using the well water in Chapi Nawabganj area, which was implemented as a part of this joint study.

Principal arsenic removing methods

Table 1 indicates principal arsenic removing methods. Arsenic removing methods can be roughly classified to coagulation and filtration method, adsorption method and membrane separation method. The adsorption method and membrane separation method are capable of removing the arsenic contained in the water to the order of several mg/l. However, these methods involve problems such as hard operation and high cost. The coagulation and filtration method, on the other hand, provides such merits that the equipment is simple and the cost is low, although the removing effect is rather low, and it is advantageous when well water of a large volume is treated.

Table 1. Principal Arsenic Removing Methods.

Principal arsenic removing methods

Methods	Coagulation & Filtration	Adsorption	Membrane Separation
Flow	Well water → Pre-treatment → Coagulation (Coagulant) → Sand filter → Treated water	Well water → Pre-treatment → Adsorption → Treated water	Well water → Pre-treatment → NF membrane → Treated water
Performance ■ Raw water	For low concentration (around 0.1 ~ 0.3 mg/L)	For high concentration (around 2 mg/L)	For high concentration (around 2mg/L)
■ Treated water	Less than 50 μg/L	Less than 10 μg/L	1 μg/L or less
Application	For large-scale facilities (10 ~ 2,000 m^3/d)	For small-scale facilities (~ 10 m^3/d)	For small-scale facilities (~ 10 m^3/d)
Maintenance	Resident operator ■ Chemical replenishment (once a week) ■ Sludge extraction (once a week) ■ Filter media back wash (once a day)	Patrol inspection ■ Adsorbing media replacement (once every 3 years) ■ Adsorbing media back wash (once a month)	Patrol inspection ■ Membrane replacement (once every 2 years) ■ Membrane wash (once a month)

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Basic principle of coagulation and filtration method

Iron ions are coexistent with arsenic in the well water. When these iron ions are oxidized and insoluble iron hydroxide is formed, arsenic is absorbed in iron hydroxide flocs and is removed from the water. Fig. 1 indicates a model diagram of the arsenic removing principle. Arsenic is located in the water in the forms of As (III) and As (V), and they are caught by the sand filter simultaneously with iron hydroxide flocs.

Pilot plant

Fig. 2 indicates the composition of the pilot plant used for experiments. Two sand filter columns of 200mm in diameter and 2,000mm in height are laid in tandem and each one of them is filled with manganese sand of height 1,000mm. Well water oxidized with air of chemical (NAClO) is continuously supplied to these sand filter columns, and arsenic is removed in the first stage and manganese is removed in the second stage.

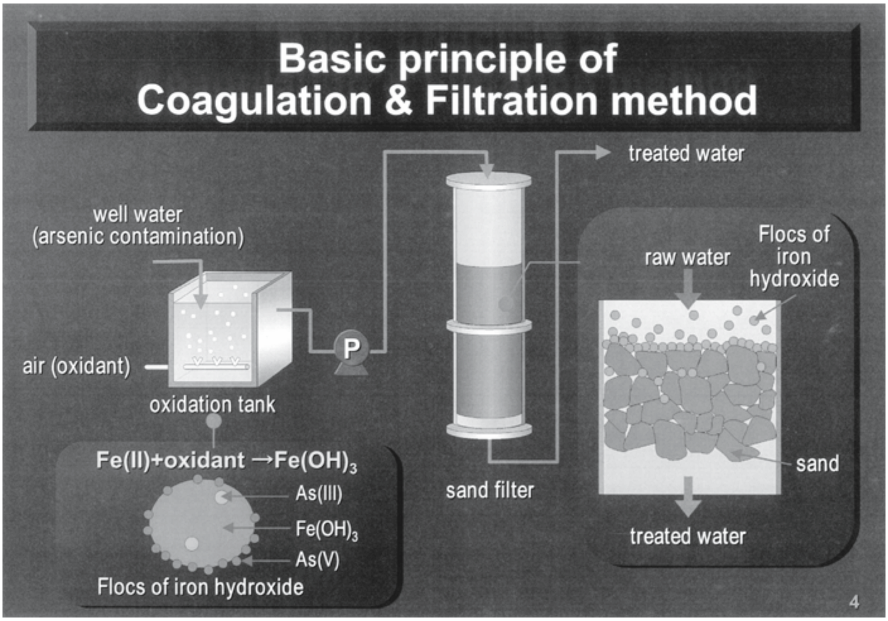

Fig. 1. Model diagram of the arsenic removing principle.

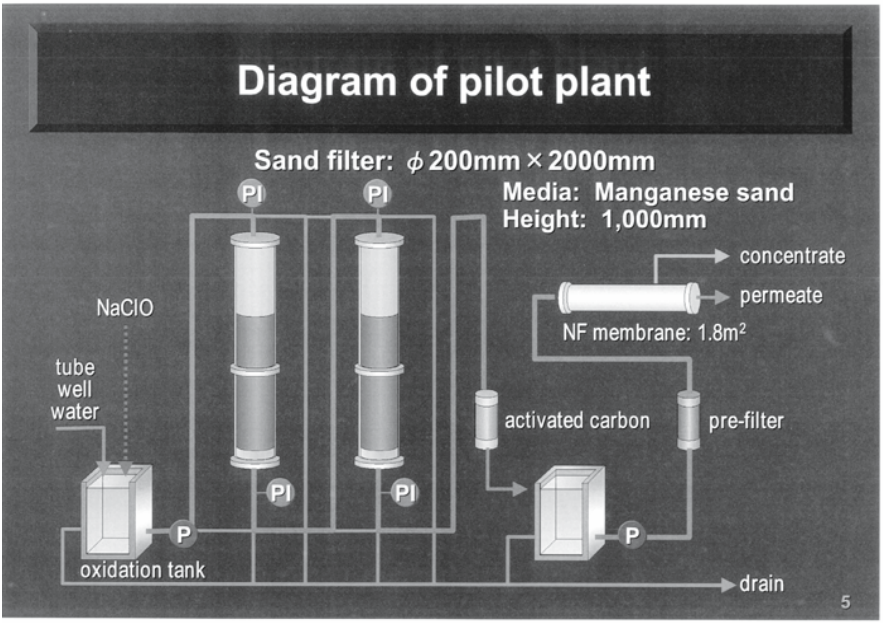

Fig. 2. Diagram of pilot plant for As removal From tube well water

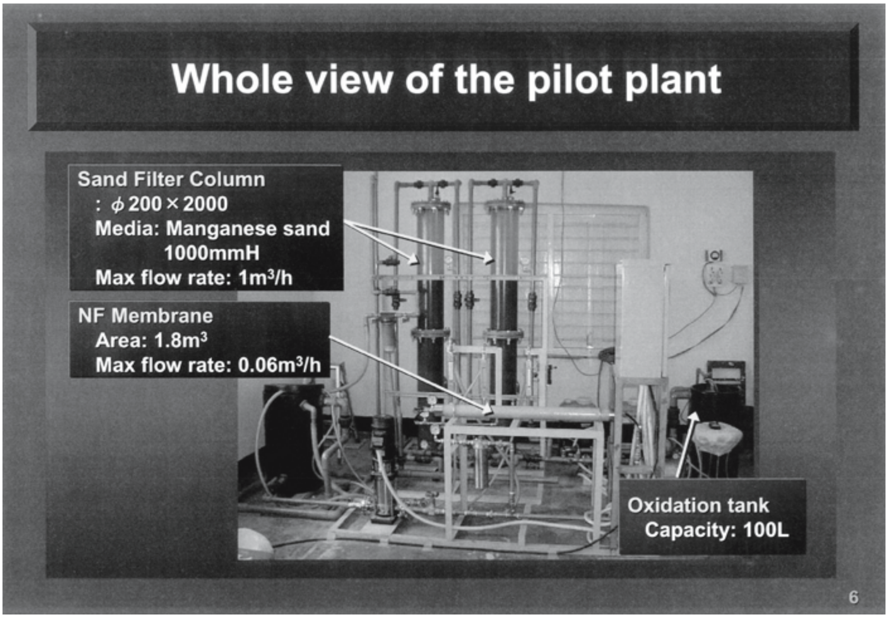

Fig. 3. Whole view of the pilot plant

Furthermore, a nano filtration (NF) membrane was provided for removing to a high degree the trace arsenic that outflows from sand filter columns. Fig. 3 indicates an external appearance of the pilot plant installed in BD Hall located in Chapai Nawabganj area. This pilot plant was installed in April 2001 and field tests at this pilot plant were conducted for about eight (8) months up to December 2001.

Results of experiments

Quality of well water

Fig. 4 indicates daily changes of the quality of the well water. The pH value varied in the range of 6.5 to 7.1 and the water temperature was in the vicinity of 30°C. The arsenic, iron and manganese content are in the range of 98 to 170 mg/l, 2,470 to 9,900 mg/l and 455 to 700mg/l, respectively. The arsenic removing performance of sand filtration is largely affected by the concentration ratio to the coexisting iron. Fig. 5 indicates typical arsenic removal in the cash where Fe/As ratio is varied. As the Fe/As ratio of the well water, which was the object of study of this time, was 20 to 45, we forecasted that the As concentration of the treated water produced by sand filtration is 30 to 40 mg/l (removal rate: 60 to 80%).

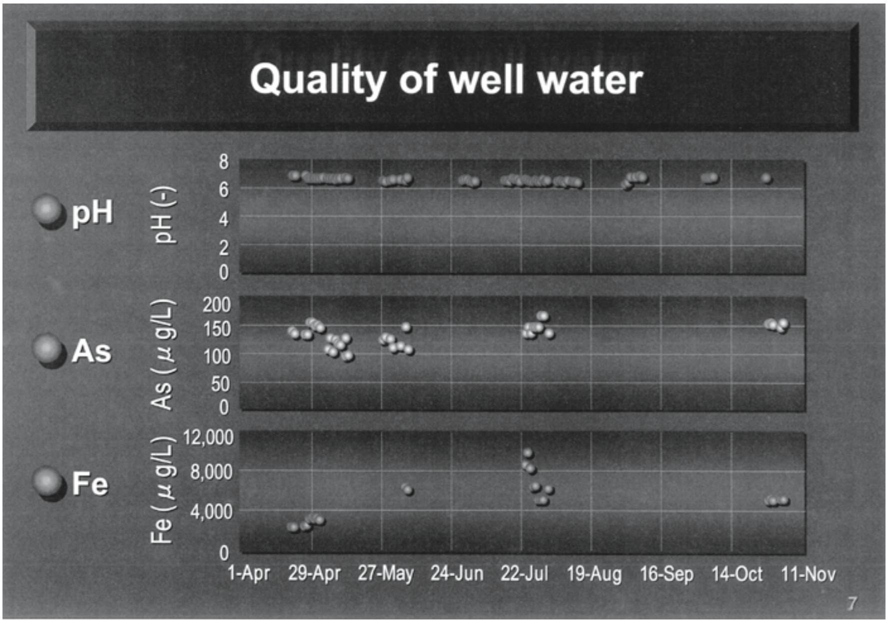

Fig. 4. Quality of well water.

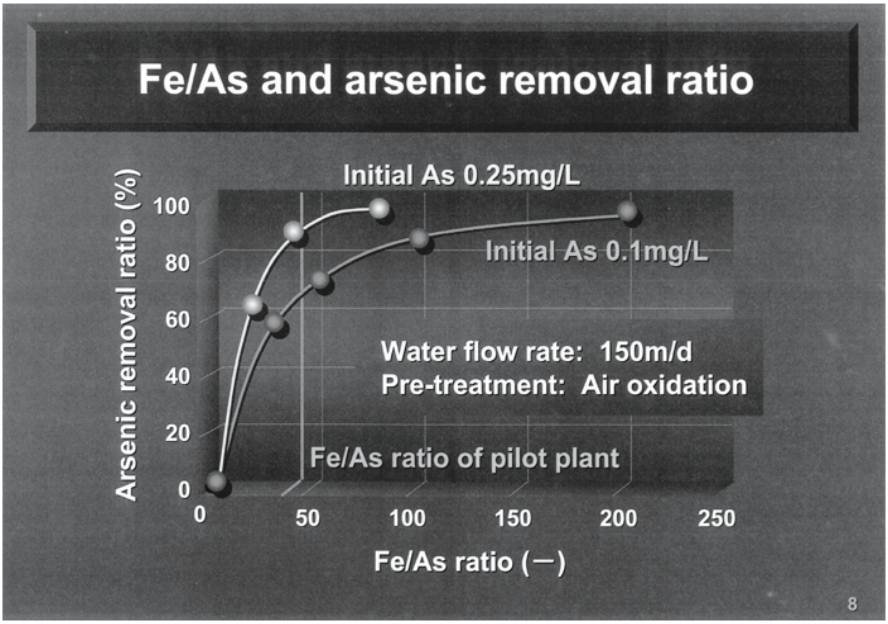

Fig. 5. Relationship between the Fe/As ratio and As removal rate.

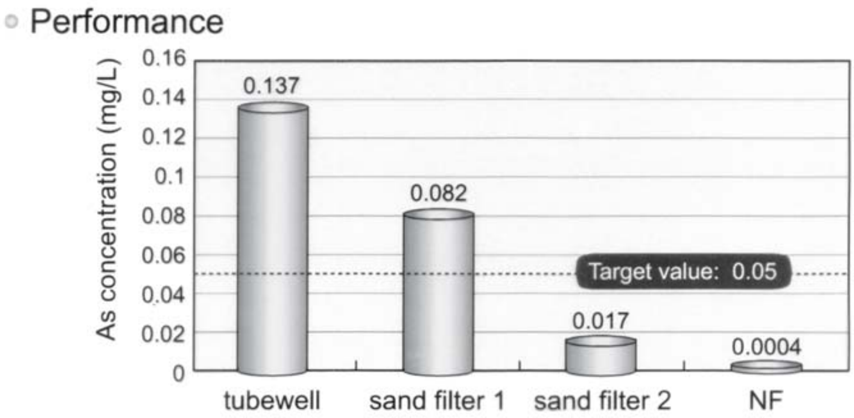

Fig. 6. The arsenic removal performance of pilot plant.

Arsenic removing effect of the pilot plant

We examined basic characteristics of each unit during the initial stage of running of the pilot plant. We then evaluated the arsenic removing performance under the optimum running conditions. Fig. 6 indicates the results of this evaluation. The arsenic concentration (0.136 mg/l) of the well water. which is the raw water, was reduced to 0.44mg/l after passage through sand filter column 1. The arsenic removal rate is 68% in this case, and it is less than .05 mg/l, which is the arsenic concentration advocated by WHO. That is, it is possible to remove arsenic and iron simultaneously in the sand filtration process, if the iron contained in the raw water is converted to iron hydroxide flocs by aeration in the oxidizing tank.

The NF equipment was installed with the objective to highly remove the arsenic which is left after sand filter columns. We confirmed that arsenic can be removed stable to 0.4mg/lor less by NF treatment. Although this separation equipment is of excellent arsenic removing performance, it provides the demerit of high cost, we position it as equipment for public facilities such hospitals and schools.

Optimum water feed rate to sand filter columns

The arsenic removing effect of sand filter columns is largely affected by the method for oxidation in the preceding stage and also by the flow rate of water (LV) passing through sand filter columns. Therefore, we examined the arsenic removing performance in the case where aeration is performed in the oxidizing tank and in the case where oxidizing agent (NACIO) is injected to the oxidizing tank. The LV was varied in the range of 150 to 350m/d.

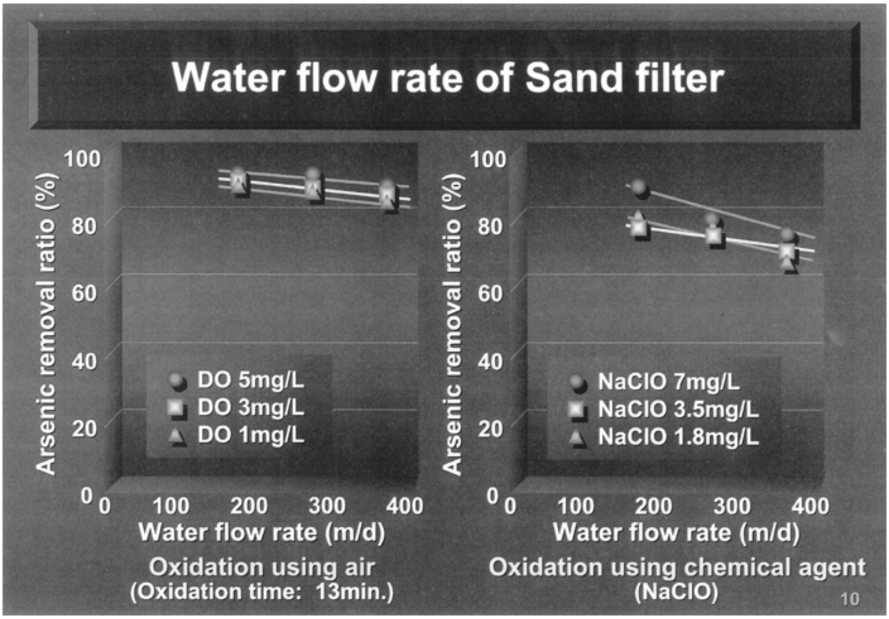

Fig. 7(a). Relationship between water flow rate and as removal ratio under aeration.

Fig. 7(b). Relationship between water flow rare and as removal ratio injection of oxidizing agent (NaCIO)

Fig. 7 (a) indicates the arsenic removing characteristics in case of aeration and Fig. 7(b) indicates the same in case of injection of oxidizing agent. Aeration was implemented with dissolved oxygen concentration used as the index, 1, 3 and 5 mg/l. When filtration was executed under the condition of LV 150 to 350 m/d after aeration (aeration time 13 minutes), although the arsenic removal rate drops to a certain extent as LV increases, arsenic removing effect of 80% or higher was obtained under any condition. On the contrary, the arsenic removing performance was of such a trend that it dropped accompanying increase of LV in case of injection of oxidizing agent. Furthermore, the removal rate was also low compared to the case of aeration.

We estimate that the reasons why the arsenic removing performance is low in case of injection of oxidizing agent are that the oxidizing agent is consumed for carbonate and manganese in the well water and that the oxidizing agent autolyzes in sand filter columns.

From the results stated above, we determined that aeration is more effective for converting iron contained in the water to iron hydroxide and obtained the outlook to be able to secure arsenic removal rate 80% under high speed filtering condition of LV 350 m/d.

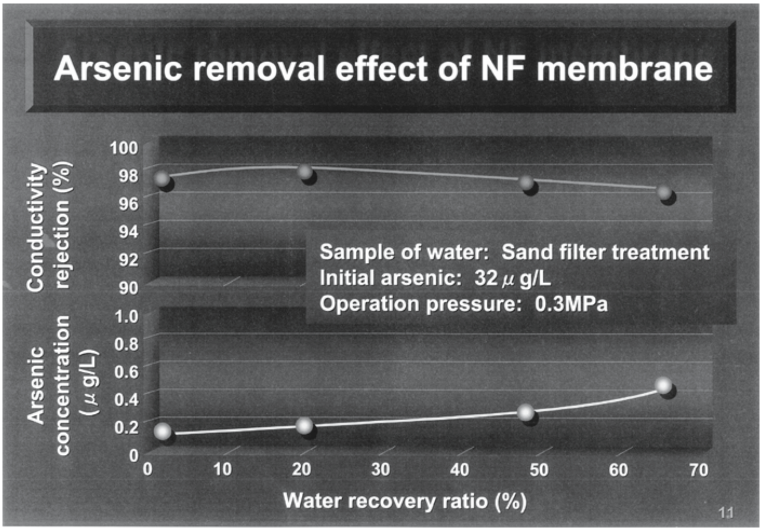

Fig. 8. Relationship between the water recovery rate and As concentration of permeated water.

Arsenic removing characteristics of NF membrane

We examined the arsenic removing performance using NF membrane with sand filtration treated water as the object. Fig 8 indicates typical results. This figure indicates the water recovery rate of the NF membrane and arsenic concentration of the filtered water. The arsenic concentration of the membrane permeated water was 0.05 mg/l or less even at water recovery rate of 60% and we were able to verify excellent arsenic removing performance of the NF equipment.

Conclusion

We installed a pilot plant in BD Hall located in Chapai Nawabganj area and checked the arsenic removing performance using actual well water. As the result to these experiments we were able to clarify the plant running conditions to reduce the arsenic content in the water to 0.05mg/l or less, which is the level advocated by WHO. with a system that combines an oxidizing tank with sand filter columns. Furthermore, we were able to secure potable water with almost on arsenic content as a result of addition of NF Separation equipment in the post stage. We intend to promote putting into practical use of purifying equipment for well water contaminated with arsenic in the future based on the results of these experiments. This type of plant can be installed for community based for getting arsenic free water at a very low cost.