Arsenic Removal Performance of Multi-GSF for Arsenic-Contaminated Groundwater in Bangladesh

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Abstract

In Bangladesh, many arsenic mitigations have been conducted these 25 years since the first detection of As-contamination of groundwater in 1993. Now, according to DPHE/JICA[1)] report, 19 million people do not have access to any safety water options (SWOs) yet, and also 4.6 million people are still living where As-contaminated ratio is more than 80% but safe water coverage is less than 20%. It is the worst As-contaminated areas. The Asia Arsenic Network (AAN)[2)] had the chance to study the situations of As-mitigation and construct SWOs in some of these worst areas. There were many highly As-contaminated tube wells with low Fe-concentrations. AIRP/GSF, used considerably in Bangladesh, can't be applied to these highly As-contaminated tube wells because that the iron concentration in tube well water is not so high as arsenic can be removed by the iron co-precipitation. In order to supply safe water in the highly As-contaminated areas, Multi-GSF[3)] has been developed by adding more tanks (iron tank and gravel tank) to the traditional GSF. This paper describes the arsenic-removal performance of Multi-GSF for highly As-contaminated groundwater.

Keywords: Arsenic, Groundwater, Arsenic removal, Bangladesh

1. INTRODUCTION

In Bangladesh, it is said that 19 million people do not have access to any safety water options yet, according to the DPHE/JICA report[1)], though 40 million people had no the access in those days of detection of As-contaminated groundwater. The DPHE/JICA report shows the situations of arsenic mitigation in detail, including that 4.6 million people are living where As-contaminated ratio is more than 80% and yet safe water coverage is less than 20%. It is the worst As-contaminated areas.

AAN2) had the chance to study the situations of As-mitigation and construct safety water options in the above-mentioned worst area, showing the following results: 1) a lot of tube wells were highly contaminated with arsenic (As>0.3mg/L), 2) the concentration of As and Fe did not show linear relation, and 3) many tube wells have high As-concentration with low Fe-concentration. These highly As-contaminated areas are, as we say, "the most difficult areas to obtain the safe water sources", which is left in Bangladesh unsettled.

On the other hand, the AIRP/GSF technology, developed by Univ. of Miyazaki (UOM) & AAN, has been working well in Bangladesh until now. AIRP/GSF is composed of 4 tanks of Inlet, Gravel, Sand and Storage. The arsenic is to be removed by the co-precipitation of iron, resolved in the groundwater, after aeration (So it is called generally as Arsenic Iron Removal Pant). In the AIRP, the aeration is caused at the Inlet tank and the co-precipitated

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material is to be settled in the gravel voids at the Gravel tank, and finally the tube well water is filtrated slowly at the Sand tank (So we originally named Grave Sand Filter). The As-removal ratio of AIRP/GSF is roughly 80% to 90%. In installation of AIRP/GSF, the value of 80% is used based on the safe side, and the arsenic-contaminated tube wells of As≦0.20mg/L is specifically selected. And also, the Fe-concentration of the tube well water is to satisfy the ratio of Fe/As>15 to remove arsenic by co-precipitation with iron.

Due to these conditions of As and Fe in AIRP/GSF, the technology is not effective to the above-mentioned "the most difficult areas to obtain the safe water sources". To solve this problem "Multi-GSF[3]", in which 2~3 tanks (iron tank and gravel tank) are added to the traditional GSF, has been developed these years. This paper describes the As-removal performance of the Multi-GSF which is applied to the highly As-contaminated tube well.

2. DEVELOPMENT OF MULTI-GSF

The traditional AIRP/GSF is mainly composed of Gravel tank and Sand tank. For the installation of GSF to As-contaminated tube well, we use the standards as shown in Table 1. But, there are the area where AIRP/GSF is not effective. There are many shallow tube wells with As≧0.3mg/L, moreover, with low Fe-concentration.

Table 1: Standards of GSF installation

Arsenic of groundwater<0.2mg/L
Fe/As>15 for low phosphate(0~1.0mg/L)
Fe/As>30 for high phosphate (1.0mg/L ~)

The principal idea of Multi-GSF is to install an Iron tank and another Gravel tank next to the 1st reservoir tank in Fig.1, in order to increase the iron concentration which is to be consumed in the 1st gravel tank and to remove again the arsenic which remains in the gravel tank through iron co-precipitation with arsenic.

2.1 Iron leaching and arsenic removal in the still standing test

From the fundamental tests: 1) iron leaching tests of iron materials in distilled water and 2) arsenic removal tests in the highly arsenic-contaminated groundwater of As=1.65mg/L, we selected a set of iron materials (Iron dust, Nail, Nut) and decided the ratio of iron material weight to water volume is to be 1kg to 10L.

2.2 Performance of Multi-GSF for highly As-contaminated groundwater

We installed a prototype of Multi-GSF at the same groundwater of As=1.65mg/L mentioned above. Fig.1 shows the schematic diagram for highly As-contaminated groundwater (As≧1.0mg/L), composed of a raw water tank, 2 iron tanks, 2 gravel tanks and a sand tank. The SP1~SP6 are sampling points.

The size of each tank is 500L in volume, roughly 95cm in height and 90cm in diameter. The weight of a set of iron material in the each iron tank is 30kg, which was decided by the conditions that the water volume in the tank is 300L and the ratio of iron weight to water volume is 1/10 as mentioned

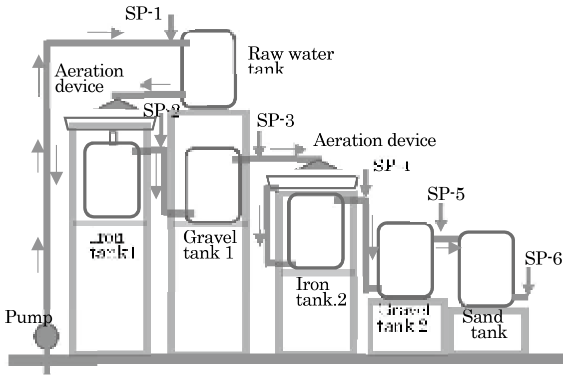

Fig.1 Schematic diagram of prototype Multi-GSF for high As-contaminated groundwater (As≧1.0mg/L)

before. The depth of iron layer and gravel layer are roughly 8cm and 50cm, respectively.

The water velocity in tanks is 0.5m/h, which has been decided for the iron co-precipitation with arsenic at the gravel tank in the traditional GSF. It is controlled here by keeping the flow rate in tanks at 5L/min. The cubic velocity, CV, at iron layer and gravel layer, is about 7 and 1.0, respectively. The concentration of arsenic and iron were changed higher than those in the above-mentioned fundamental test, showing roughly As=1.9mg/L and Fe=7.5mg/L.

The concentrations of Fe & As are shown in Fig.2 under such test procedure as 1) we flowed the tube well water for 10 hours with flow rate of 5L/min (9:00~19:00) and 2) next day, samples are three times collected at each point of SP-1~SP-6 during 8:30~8:45 with flow rate of 5L/min.

From Fig.5 we can see good As-removal as follows:

1) Iron tank 1 (SP-1~SP-2): The high As-concentration of raw water, As=1.7~2.0mg/L, decrease largely to 0.3~0.5mg/L through the iron tank 1. The iron concentration, Fe=7.5mg/L, increase a little than those of raw water. The Fe-concentration in the iron tank increases by leaching from iron materials and is simultaneously consumed by co-precipitation with arsenic.

2) Gravel tank 1 (SP-2~SP-3): At the SP-2 the ratio of Fe/As ≒20, which satisfies the Fe/As condition of Table1.

The As-concentration of 0.3~0.5mg/L is, however, higher than the As-concentration in Table 1. So, the As-removal in the Gravel tank 1 is not so large compared with the large decrease of iron concentration.

3) Iron tank 2 (SP-3~SP-4): The iron concentration increases up to about 6mg/L with As-decrease of 0.3~0.5mg/L to 0.06~0.07mg/L. Fe/As=100 at SP-4 is so much enough to remove the low arsenic concentration of 0.06~0.07mg/L.

4) Gravel tank 2 (SP-4~SP-5): The iron concentration decrease 6mg/L to about 1mg/L with As-decrease to 0.03~0.05mg/L which is under the drinking standard of 0.05mg/L in Bangladesh.

5) Sand tank (SP-5~SP-6): The concentration of As & Iron become zero at SP-6.

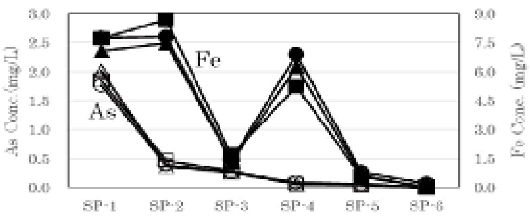

Fig.2 Removal of As & Fe of Multi-GSF Prototype For high As-contaminated tube well

2.3 Prototype of Multi-GSF for medium As-concentrated groundwater

We installed a Multi-GSF for tube well with medium level of As-contamination in Alampur village, Meherpur district, where As-concentration of groundwater is about 0.50mg/L.

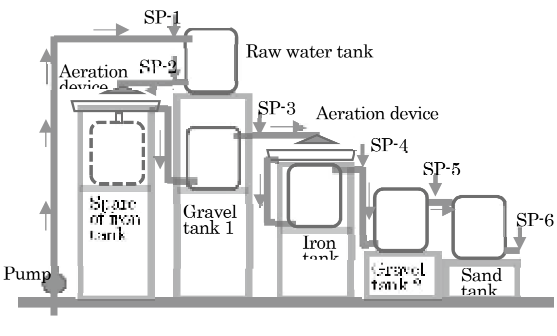

Fig.3 Schematic diagram of Multi-GSF prototype for medium As-contaminated groundwater (As=0.5mg/L)

As the As-concentration is much lower than tube well water in the 2.2, the iron tank 1 was not used here, shown as the spare of iron tank in Fig.3. More, the sample point of SP-2 is different from one in Fig.4. And, the followings are different. That is, a) size of tank is smaller than those in Fig.1, such as 200L in volume, 61cm in height and 72cm in diameter , b) so, the flow rate is smaller as Q=3L/min, decided to keep water velocity as 0.5m/h in the tanks as mentioned before, and c) iron weight is 16kg, decided from the conditions that the water volume in the Iron tank is about 160L and the ratio of iron weight to water volume is to be 1/10 mentioned before.

From Fig.4, the behavior of As-removal & Fe-leaching, measured 3 times September 2017, is mentioned as follows.

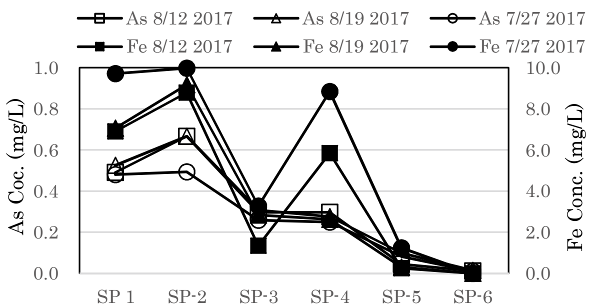

Fig.4 Behavior of As & Fe for Medium As-contaminated groundwater in Meherpur

1) Raw water tank (SP-1~SP-2): The concentration of arsenic and iron increase at SP-2, which means the happening of co-precipitated material of Fe with As at the bottom of raw water tank.

2) Gravel tank 1 (SP-2~SP-3): The Arsenic is removed to the half concentration of raw water (As=0.2~0.3mg/L). The iron decreases to the concentration less than the half concentration of raw water (Fe=1.0~3.5mg/L). As the value of Fe/As is less than 10 at SP-3, the additional Fe concentration, through the iron tank, is to be need.

3) Iron tank (SP-3~SP-4): The iron concentration increases in the ● & ■ data, but decreases in ▲ data. It may be considered the leaching of iron materials was not good for the ▲ data, which was measured after one week of ■ data and after three weeks of ● data. We are now checking the causes of the phenomenon. The As-concentration is not changed, showing no co-precipitation of Fe with As.

4) Gravel tank (SP-4~SP-5): The value of Fe/As at SP-4 is 20~30 for ● & ○ and ■ & □ data, and so As-removal is good and the As-concentration at SP-5 become both low (0.04~0.08 mg/L). But, regarding ▲ & △ data, the Fe/As value is under 10 at SP-4 and As-concentration is high at SP-5 (0.1mg/L). It shows the data of ▲ & △ is not applicable to the Standards of GSF application as shown in

Table 1. The arsenic is, however, well removed.

5) Sand tank (SP-5~SP-6): The concentration of arsenic & iron both decrease to zero.

The above performance data show that the prototype Multi-GSF can remove perfectly arsenic from As-contaminated groundwater with medium level. There was, however, a case of less Fe-leaching at the iron tank which may be caused from the rust of iron materials. Or, the co-precipitated materials of iron with arsenic, which is often generated in the Iron tank, may disturb the iron leaching. The problem will be solved by the establishment of the maintenance system of the Multi-GSF.

3. CONCLUSION

The prototype Multi-GSF was developed for high As-contamination (As>1.0mg/L) and medium As-contamination (As=0.5mg/L), supplying the As-free treated water.

The iron tank in Multi-GSF, added to the traditional GSF to increase iron concentration, shows good performance at the initial stage of the Multi-GSF operation, but after 3 weeks of the operation the iron leaching became not so large. This may be caused from the rust of iron materials in the iron tank. Or, the co-precipitated materials of iron with arsenic, which is often generated in the iron tank, may disturb the iron leaching. The problem will be solved by the establishment of the maintenance system of the Multi-GSF

We will install the Multi-GSF to the other highly As-contaminated areas with the maintenance system hereafter.

4. REFERENCES

1) DPHE/JICA (2010), "Situation Analysis of Arsenic Mitigation 2009".

2) Asia Arsenic Network (2015), "Increase access to arsenic-safe water by rehabilitation of arsenic contaminated tube wells in Sunamganj and Meherpur Districts".

3) Hiroshi Yokota, Yasunori Yano, Shigeki Tomomatsu, Sachie Tsushima, Shamim Uddin, Abu Shamim Khan and Sayed Sunny (2015), "Highly Arsenic-contaminated Areas in Bangladesh and Development of Multi Gravel Sand Filter", Proc. of 4th International Arsenic Symposium in Miyazaki 2015, pp16-19