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ARSENIC REMOVAL FROM GROUNDWATER USING INDIGENOUS IRON AND MANGANESE OXDIZING BACTERIA

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ABSTRUCT

Groundwater often contains iron, manganese and arsenic originating from natural geological layer and/or mineral resources. We have applied biological iron and manganese removal system utilizing iron and manganese oxidizing bacteria (IRB) to arsenic removal. The conventional biological iron and manganese treatment by IRB colonizes indigenous IRB in groundwater on filter media by continuous percolation of groundwater. The IRB oxidizes dissolved ferrous iron and manganese ions to particulate form, which are subsequently deposited on the filter media or filtered out by the underlying filter media. In 2005, simultaneous removal of iron and arsenic was achieved in our pilot-scale test treating groundwater that contained arsenic, iron and manganese of geological origin. Removal of manganese, however, was low then. Biological oxidation of manganese reportedly occurs in the region shown in the pH-Eh diagram. The low redox potential of the raw water probably inhibited the oxidation and removal of manganese. In 2006, pre-aeration stage was placed before the biological reactor to facilitate the removal of manganese. Pre-aeration of the raw water was optimized based on the redox condition of the groundwater, which was characterized by analyses of redox-sensitive chemical species and electrochemical Eh measurements by platinum electrode.

KEYWORDS

Groundwater, Arsenic, IRB, Iron, Manganese

INTRODUCTION

Groundwater is generally a superior source of drinking-water compared to surface water because it contains less anthropogenic contaminants, therefore requiring lower cost for treatment. However, groundwater contains components originating from natural geological layers and/or mineral resources. Among these are iron, manganese and arsenic, all of which should be removed to meet drinking-water standards. Arsenic in particular is one of the most hazardous substances for human health, and the WHO has set the arsenic standard for drinking water at 0.01 mg/L.

Iron, manganese and arsenic in water can be removed by chemical oxidation followed by coagulation, sedimentation and sand filtration. However, this method is costly because of the chemicals needed for oxidation and coagulation and the disposal of the sludge produced. Development of a practical and economic method of arsenic removal which produces less sludge is needed for developing countries.

The purpose of this study is to develop a new method to remove arsenic using indigenous iron and manganese oxidizing bacteria (IRB) in groundwater. The conventional biological iron and manganese treatment with IRB colonizes indigenous IRB in groundwater on a filter media using a continuous percolation of groundwater, where dissolved ferrous iron and manganese are oxidized into particulate forms and are subsequently deposited on or filtered out by the filter media. We applied the IRB treatment to groundwater that contains arsenic as well as iron and manganese, and investigated the optimal conditions for the simultaneous removal of arsenic, iron and manganese.

MATERIALS AND METHODS

Pilot scale tests were conducted at wells in Kyoto, Japan and at drainage from a construction site in Hyogo, Japan. Fig-1 shows a schematic flow diagram for the test in Kyoto. Iron, manganese and arsenic concentrations in raw water from the pilot tests are shown in Table-1. Fig.-2 is a photograph of the pilot scale test in Kyoto.

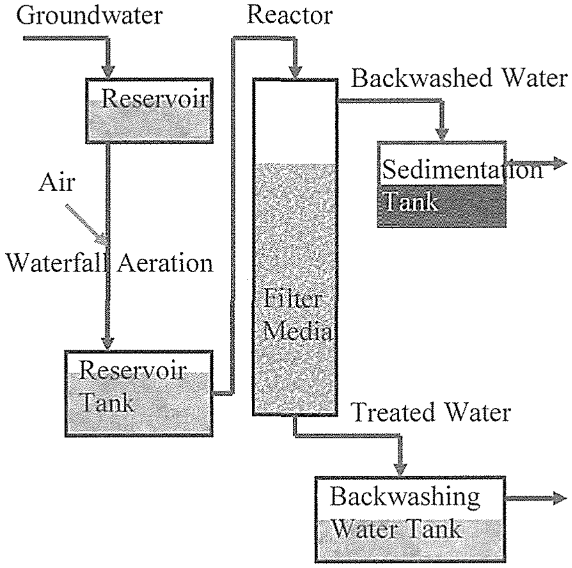

Fig.-1 Schematic view of the IRB pilot test in Kyoto

Table-1 Iron, Manganese and Arsenic Concentrations in Raw Water

Substances (unit)	Kyoto	Hyogo
Total Iron (mg/L)	2.1	7.6
Divalent Iron (mg/L)	2.0	Not Analyzed
Total Manganese (mg/L)	0.4	0.2
Total Arsenic (μg/L)	19.3	217.9

Groundwater from several wells was mixed in a reservoir, and was subjected to waterfall aeration with a single drop of approximately one meter in height. The concentration of dissolved oxygen was increased from 0.7±0.5 (mg/L) in the raw water to 3.5±0.9 (mg/L) in the reservoir tank (data from FY2006). The aerated water was fed to the reactor filled with cylindrical plastic filter media on which IRB propagated. The IRB then oxidizes dissolved ferrous iron and manganese, and transform them into particulate forms, which are deposited on or filtered out by the filter media.

Simultaneous removal of the arsenic occurred through the physicochemical sorption on the bacterial floc (consisting of ca. 35% of iron, 50% of oxygen, less than 3% of phosphorus, manganese, carbon, silicate, and calcium, and less than 1 % of hydrogen, sulfur and nitrogen) deposited on the filter media. Periodical backwashing of the reactor was conducted to avoid localized lumping of the filter media and to distribute the active biomass evenly over the reactor height.

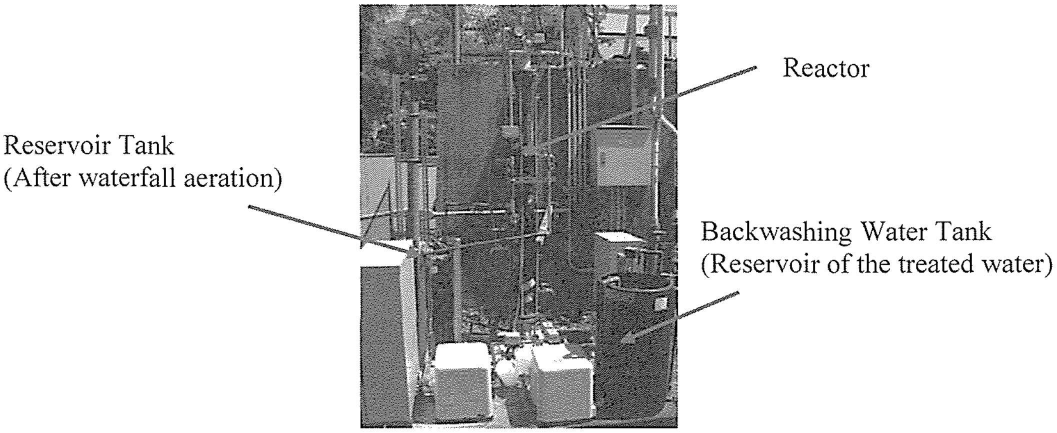

Fig.-2 Pilot Scale Test in Kyoto, Japan

RESULTS AND DISCUSSION

Table-2 shows the removal at the Kyoto test in FY 2005. In 2005, simultaneous removal of iron and arsenic was achieved in the pilot scale test while the removal of manganese was low. Biological oxidation of manganese reportedly occurs in a certain region in the pH-Eh diagram, and requires higher Eh than required for that of iron. The low redox potential of the raw water was considered to have hindered the oxidation and removal of manganese.

Table-2 Removal at Kyoto Test Site in FY2005

Substances	Removal (%)
Total Iron	76.1 ± 12.0
Divalent Iron	89.6 ± 9.9
Total Manganese	0.8 ± 9.4
Total Arsenic	66.5 ± 9.2

Table-3 shows the removal at the Kyoto test site in 2006. In 2006, the pre-aeration stage was placed before the reactor to facilitate the removal of manganese. Concentration of dissolved oxygen was increased from 1.4 ± 0.3mg/L (in raw water in 2005) to 3.5± 0.9mg/L (in aerated water in 2006). Pre-aeration of the raw water was optimized based on the redox condition of the groundwater, which was characterized by analyses of redox-sensitive chemical species and electrochemical Eh measurements using a platinum electrode. As a result, more than 80 % of iron, manganese, and arsenic was removed from the raw water in the 2006 pilot scale test. The removal of manganese was decreased when we deliberately reduced the pre-aeration rate on the 67th day after the reactor was started. The observed pH-Eh values after the aeration, however, did not fall within the region required for biological oxidation of manganese when manganese removal was achieved. It is possible that the propagation of manganese oxidizing bacteria or fungi was promoted by the elevated level of dissolved oxygen. The results also suggest that pH-Eh values in the vicinity of manganese oxidizing microbes may be different from those in the bulk water.

Table-3 Removal at Kyoto Test Site in FY 2006

Substances (unit)	Conc. of Raw Water	Removals (%)
Total Iron (mg/L)	2.1 ± 0.4	94.9 ± 6.6
Divalent Iron (mg/L)	2.0 ± 0.4	98.5 ± 1.2
Total Manganese (mg/L)	0.4 ± 0.1	85.6 ± 22.6
Total Arsenic (μg/L)	19.3 ± 8.6	73.1 ± 15.6

We also investigated the relationship between percolation rate and removal(Table-4). Removal of iron and arsenic was greater than 70 % during the percolation rates from 150 to 600 m/day. Removal of iron and arsenic in the Hyogo test was lower than in the Kyoto test, and manganese removal did not occur in the Hyogo test because manganese oxidizing bacteria did not propagate due to the intermittent operation of the biological reactor. This was confirmed by the lack of Mn(IV) in backwashed sludge from Hyogo.

Table-4 Relationship between Filtration Rate and Removal (%) in 2006

Percolation Rate	Total Iron	Total Manganese	Total Arsenic
150 m/day^{*1}	96.2 ± 3.8	87.5 ± 23.7	71.0 ± 16.3
300 m/day^{*1}	97.9 ± 0.2	80.7 ± 26.3	89.3
500 m/day^{*2}	74.5 ± 40.6	-69.8 ± 106.3	58.9 ± 16.1
600 m/day^{*1}	97.9	72.1	75.7

^{*1} Results of Kyoto Test ^{*2} Results of Hyogo Test

Fig.-3 shows the correlation between removal of arsenic and arsenic concentration of raw water in the Kyoto and Hyogo tests. According to the Hyogo test, the removal changed little over the wide range of raw water arsenic concentration. But the Kyoto test indicates that the removal changed significantly when coupled with a slight change in the raw water arsenic concentration. The low removal rate occurred in the late fall to winter period when the arsenic concentrations were higher due to the change of the well tested, and also when the backwashing was conducted less frequently, due to clogging of the conducting pipes. It is possible that parameters other than arsenic concentrations, e.g. maintenance of the reactor and water temperature, also affected the arsenic removal.

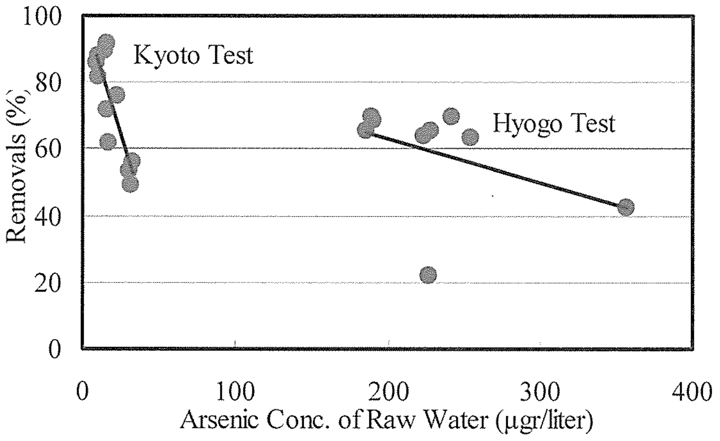

Fig.-3 Relationship between Removals and Raw Water Conc. of Arsenic

CONCLUSIONS

Simultaneous removal of iron, manganese and arsenic was achieved using the IRB system at a filtration rate of 150 m/day to 600 m/day. Iron removal in particular was high and stable. High concentrations of arsenic were also removed in the Hyogo test.

The test in Kyoto will be continued to confirm the removal of iron, manganese and arsenic with a scaled-up reactor, and to further clarify the parameters pertinent to the removal of arsenic and manganese.

This method seems to suit small and medium sized local governments and developing countries which have financial difficulties in maintaining large-scale drinking water plants. The goal after completing the pilot study is to make a guideline for construction and operation of practical IRB systems.

REFERENCES

Y. Fujikawa, D. Yoneda, A. Minami, H. Yashima, K. Tonokai, S. Tani, M. Fukui, T. Hamasaki, M. Sugahara, XANES analysis of the mechanisms of arsenic removal in biological iron and manganese treatment unit. Chinese Journal of Geochemistry, 25, 113 (2006).