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Open Access Journal of Waste Management & Xenobiotics
ISSN: 2640-2718

Arsenic Removal Using a Simple Oxidation Device

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Research Article

Volume 4 Issue 1

Received Date: February 12, 2021

Published Date: March 26, 2021

DOI: 10.23880/oajwx-16000158

Abstract

Arsenic exists widely in the environment, and a lot of arsenic pollution is found in the groundwater of South East Asia. In order to make arsenic free water, we made a simple device. The device is mainly composed of an iron containing oxidation tank, settling tank and sand filter. The arsenic in the water can be removed by iron oxidation which is caused by aeration. The device can remove about 98% of the arsenic in the water using less energy, and be maintenance free for a long period.

Keywords: Arsenic; Removal; Aeration; Iron, Water

Introduction

Arsenic is an one of the harmful elements, and is widely distributed in the environment [1]. It causes water pollution, especially groundwater [2-4] which is used as a domestic water source. In the countries of Southeast Asia, groundwater pollution causes serious arsenic poisoning. In order to solve the problem, arsenic removal methods are needed. Especially, in these countries, where small villages are dotted widely, simple and cost effective arsenic removal methods are longed for.

In order to remove arsenic, some methods, ①settling method [5] ②membrane method [6] ③adsorption method [7] are already introduced. However, the adsorption method needs expensive adsorbents and daily cleaning of the adsorbents. The membrane method can remove arsenic with high performance, but needs expensive equipment and trained maintenance workers. On the contrary, settling method are widely applied because of the simple handling and cost effectiveness. Usually, aluminum or iron compounds are used. Almost all arsenic in the ground waters is considered to be dissolved as a state of AsO_4^{3-} ion or AsO_3^{3-} ion. AsO_3^{3-} ion is easily oxidized to AsO_4^{3-} ion. AsO_4^{3-} ions react with Fe^{3+} ions, makes $FeAsO_4$ which has low solubility in the water [8]. In order to perform the arsenic removal, usually Iron compounds like $FeSO_4$, $FeCl_3$ are used. However, these compounds need significant amounts of reagents and daily maintenance, therefore lower cost and maintenance free devices are needed. The oxidation under the existence of iron metal is considered to be effective compared with the conventional methods which use $FeSO_4$ or $FeCl_3$. We made up a simple arsenic removal device which uses an iron plate, and investigated the performance for 5 months.

Method

Equipment of the Arsenic Removal

The device is composed of an aeration tank, sedimentation tank and sand filter (Figure 1), and the functions of each piece of equipment are mentioned as follows (Figure 2). The outline of the device is also shown in Table 1.

- **Aeration Tank:** The original water is let into the aeration tank in which the iron plate containing plastic net (shown in Figure 3) is installed. The water is maintained in an

aerobic state by the air pump, and the arsenic which is mainly in the state of AsO_4^{3-} ion, is mixed with the Fe^{3+} ion which is generated by the oxidation of the iron plate.

- **Sedimentation Tank:** The treated water from the aeration tank is let into the sedimentation tank, where the AsO_4^{3-} ion in the water reacts with Fe^{3+} ion, and forms particles of $FeAsO_4$. The particles of $FeAsO_4$ settles to the bottom.
- **Sand filter:** In order to remove the arsenic thoroughly, the particles of the formed $FeAsO_4$ are filtrated using sand (about 0.5mm diameter).

Equipment's	Volume (L)	Constitute material	Size, form
Original water tank	250	Polyethylene	650mm (d) x 860mm(H)
Aeration tank	900	Polyethylene	900mm x 900mm x 1250mm(H)
Sedimentation tank	170	Polyethylene	550mm (d) x 750mm x 500mm(H)
Sand filter	40	Polyethylene and sand	260mm x 370mm x 240mm(H)
Treated water tank	250	Polyethylene	650mm (d) x 860mm(H)
Feed pump	---	Cast iron	Flow rate: 40L/min, Power: 100W
Air pump	---	Cast iron	Flow volume: L/min, Power: 40W
Plastic net	---	Polyethylene	Filing rate: 70%
Iron plate	---	Iron	Road amount: 15kg

Table 1: The outline of the device.

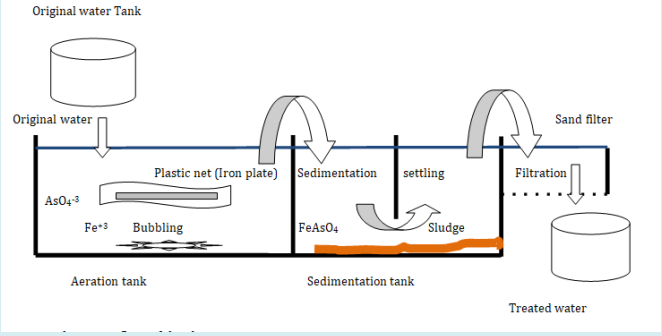

Figure 1: The water flow of the device.

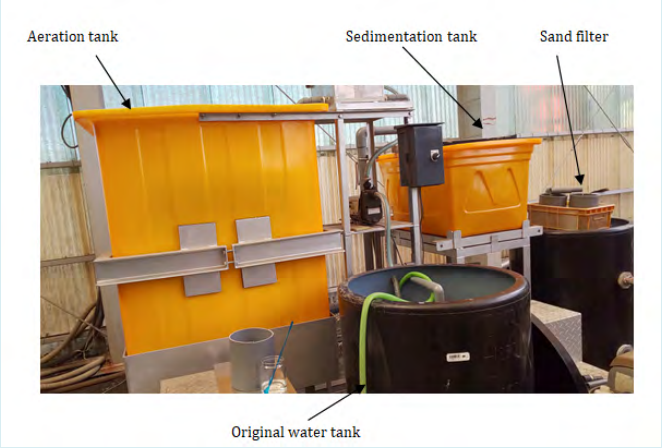

Figure 2: Outline of the device.

Figure 3: The photo of the Equipment.

Test Water (Original Water)

As the test water, the groundwater which contains un-detectable amounts of arsenic is used. To make the test water (arsenic concentration: about 0.2mg/L to 1mg/L), a small amount of the reagent of sodium arsenate was added to adjust the arsenic concentration.

Monitoring Parameter and Method

Parameters and analytical methods used in this survey are as follows.

- **pH:** Glass-electrode, EC: Platinum electrode, COD: Acidic Potassium permanganate method,
- **As:** Detector tube method was used. The method is a simple method for the arsenic analysis which is designed by Dr. Hori [9,10]. In this method, the arsenic in the

water is converted to AsH_3 (gas), and the AsH_3 can be measured using a detector tube instead of conventional analytical method (chemical color metric method or ICP-MS). Dissolved iron (D-Fe): Simple method (Kyouritsu Rika Co.Pack test).

Result and Discussion

The device is operated two days a week, from 1st Apr. to the middle of September (5 Month), using the original water mentioned above, with operation capacity; 50L/day. The results are shown as below

Water Quality

- **pH:** The pH value of the treated water became higher compared to the original water, however, it tends to be the same as the original water (Figure 4).

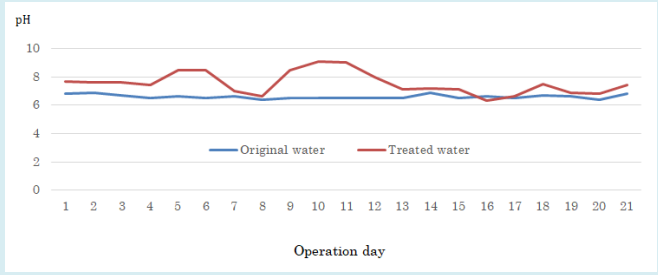

Figure 4: Transition of the pH of the treated water.

- **EC:** The EC value of the treated water became lower compared to the original water. It is considered to be due to the removal of the settling of the As ion or another dissolved salt components (Figure 5).

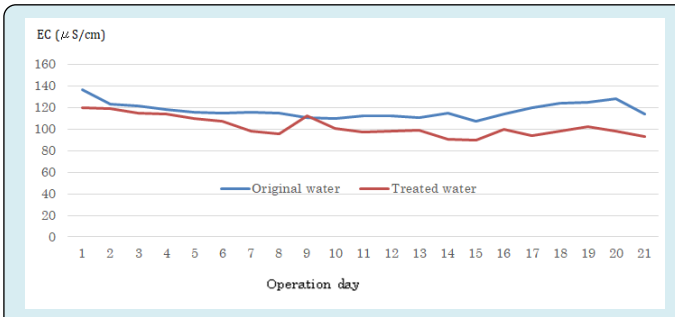

Figure 5: Transition of the EC of the treated water.

- **COD:** The COD of the original water and the treated water were almost the same, and it is considered that the arsenic removal did not influence the COD of the treated water (Table 2).

Day of the operation	2nd Sep. 2020	9th Sep. 2020
Original water	<0.5 mg/L	<0.5 mg/L
Treated water	<0.5 mg/L	<0.5 mg/L

Table 2: COD of the original water and the treated water Dissolved iron: Apparent solution of the iron to the treated water, was not found.

Transition of the Arsenic Concentration

The arsenic concentration of the treated water tended to become lower compared to the original water by the removal of the arsenic ion. Arsenic concentration of the treated water reached under 0.01mg/L (Figure 6)

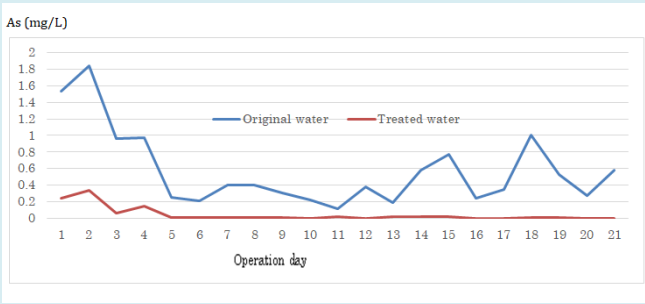

Figure 6: Transition of the arsenic concentration of the treated water.

Transition of the Arsenic Removal Rate

The transition of the arsenic removal rate is shown in Figure 7, and the Arsenic removal rate tends to higher with the operation days, and finally reached 98%. The improvement of the removal rate is considered to be due to the increase of the concentration of the Fe^{3+} ion through the acceleration of the oxidation.

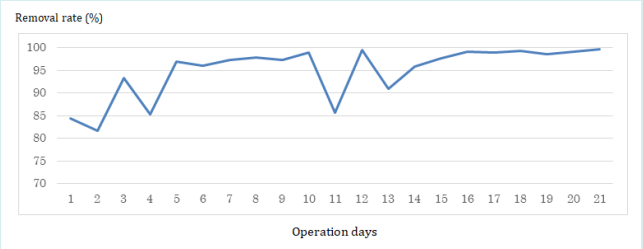

Figure 7: Transition of the arsenic removal rate.

Conclusion

We have investigated a simple device for arsenic removal, for 5 months using the test water which contained an arsenic concentration of 0.2 mg/L to 1mg/L. Almost all of the arsenic

in the test water was removed, and the removal rate reached almost 98%. The device can also decrease the value of the EC, and the elution of the iron into the treated water, was not found. We consider that the device has this important point as follows.

- Arsenic removal can be maintained long term.
- The device needs no chemical reagents or troublesome operations except for the small power supply which can be operated using a solar panel.
- The device can be used long term with minimum maintenance.
- The device is small and simple, therefore it can be carried many place and also operated by people with minimal skill.
- The device can be used with the many kinds of water quality.
- It should be noted, however, the device generate small amounts of iron sludge which has the possibility of containing arsenic which is removed from water. This sludge has to be carefully controlled by following the environmental laws.

Acknowledgement

The authors wish to Dr. Eric Bray (Professor of Yokkaichi University) for his advice on making the article.

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