ALKIMIA : Jurnal Ilmu Kimia dan Terapan

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# Reduction of Fe Levels in Groundwater Using Aeration-Filtration Method with Tray Aerator System

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**Abstract**. The presence of high iron (Fe) content in water consumption is a major factor that causes health and aesthetic problems. Its amount in water samples can be reduced by combining the aeration and filtration methods of water treatment. The aeration method basically involves making direct contact between air and water, which is usually done by adding both together. Subsequently, the filtration method uses porous media like sand, gravel, and activated charcoal to filter water. This research compares the effectiveness of aeration, filtration, and combined aeration-filtration methods of water treatment. For the aeration method, a form of trays aerator arranged in 6 levels with a distance of 20cm is used along with a varied contact time duration of 1, 3, and 5 hours. In addition, quartz sand, activated carbon, palm fiber, and coral were used as the media for the filtration method. The results obtained as the % value of iron (Fe) removal were varied at a contact time of 1, 3, and 5 hours for both the aeration and combined aeration-filtration method, and 46.95; 78.2; 82.48; 72.32; 81.71; 87.24; and 70.44 for the filtration method shows the working effectiveness of the tools. The combination of aeration with filtration provides maximum results when compared to using aeration or filtration methods.

**Keywords** : aeration, filtration, Fe removal, water treatment

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## Introduction

Water is an essential requirement of life. All living things on earth basically depend on water, and a total of 33% of the world's source is from groundwater [1—3]. However, in Indonesia, most people depend on the groundwater obtained from well as their primary source of clean water. This source was chosen because of its cheap manufacturing processes [4]. Furthermore, it has several disadvantages when compared with other water sources. One of the main problems is high concentration of mineral substances, such as iron (Fe) and manganese (Mn). Fe and Mn generally present together in groundwater but the presence of Fe is greater concentration than Mn [5, 6]. Iron and manganese in high concentration is still one of common problem from groundwater [3].

High concentration of Fe and Mn in groundwater is due to factors such as the oxidation-reduction reactions that occur naturally, microbiological activities from certain microorganisms, and anthropogenic activities like the disposal of iron and steel [6—8]. The contamination of Fe and Mn can also caused by pipe and storage tanks, pumps components, and well casing [9]. Consequently, its presence is the leading cause of several problems, which includes the corrosion of pipes, the presence of yellow spots in wells and other domestic appliances, and health problems.

The higher concentration of iron may lead certain bacteria grow in water distribution pipes because the surface pipes are the most suitable habitat for some bacteria. Increasing these bacteria into high population can clog pumps and drainage pipes resulting the flow rate of water in pipe line is reduced. These bacteria also have a strong iron odor, unpleasant taste, and very bright orange color [2,8].

The presence of high concentration of iron in water may also cause serious problem in human health. Consumption of iron contaminated water continiuously may result a condition called iron overload that may lead to hemochromatosis [7,8]. However, to reduce the amount of Fe in groundwater sources, it is necessary to develop a technology that will be used by the community, and according to the government's quality standards. Several treatment methods to remove iron from groundwater have been studied, including physical, chemical, physicochemical, and biological processes [3,10]. One efficient way to achieve this is to combine the aeration and filtration methods of water treatment [11]. This is because the instruments are practical and easy to operate.

Aeration is one way to maintain water quality standards for various purposes [12]. The aeration method of treating water basically involves making direct contact between air and water by adding both together. There are two main principles in aerators work: (1) aeration by splashing water into the air and (2) aeration by bubbling air into the water [13]. Aerator have been a common choice for groundwater treatment throughout the 20th century [14]. The filtration methods involve the use of porous media to remove suspended particles from a solution [11].

## Experimental

### *Materials and tools*

The tools used in this study include the Atomic Absorption Spectroscopy (AAS), pH meter, aerator pump, water pump, PVC pipe, storage tub, tray, faucet, and hose. The materials used were samples of well water taken from the Dumai—Riau area, $HNO_3$ (Merck), sand, activated carbon, and coral. A sketch of this research tool is shown in **Figure 1.**

### *Research Procedures*

The initial stage of the research mainly involved the assembling of tools. The process consists of a filter cube and an aerator tray system that has been equipped with holes and has 6 levels each at a distance of 20 cm. Subsequent to this stage, an aeration process is performed at a varied time of 1, 3, and 5 hours by flowing the prepared samples of raw water to the trays using an aerator pump. The water produced in this process is made to flow into a filtration tub that has been filled with media in the form of quartz sand, activated carbon, and coral. In addition, the pH meter and AAS were used to measure the pH value and iron (Fe) content of the water obtained from the aeration-filtration process in the laboratory. The results gotten was then compared to the government's quality standards through the Indonesian Health Minister Regulation No 32 of 2017 [15]. The determination of the % Fe removal was calculated using the formula below:

$$\% \, Removal = \frac{Initial\ Fe - Final\ Fe}{Initial\ Fe} \, x\ 100\ \%$$

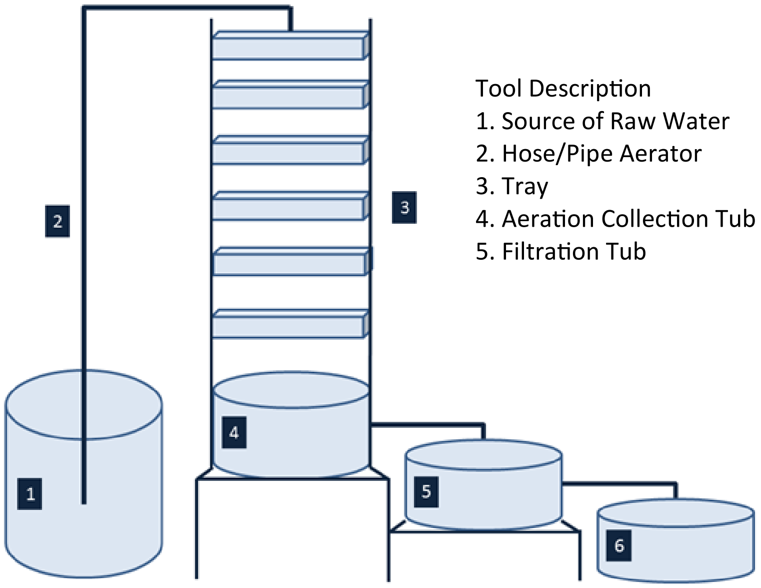


**Figure 1.** Aeration-Filtration Tool Scheme

## Results and Discussion

Based on the data from previous research [16], the water that used by the community in Dumai, especially in Dumai Timur contained high concentration of iron. Physical properties of water are not in accordance with quality standard by Regulation of the Ministry of Health of the Republic of Indonesia.

Measurement of pH samples. pH of water is very important measurement concerning water quality. pH value is one of the significant factors that cause a high amount of iron in water consumption, and it decreases with an increase in the iron concentration. However, water with a pH value below 6.5 is acidic and will dissolve iron, which causes corrosion [2]. Iron at this pH value is usually in the form of $Fe^{2+}$ and $Fe^{3+}$. The $Fe^{3+}$ form is insoluble and will settle in the water, thus giving it a characteristic smell, color, and taste. In the range of pH 5.5 to 8.2 with 6.5 being the optimum level, iron bacteria can grow and may form large masses of an orange-brown slime [2]. Iron bacteria in water do not cause health problems, but they can reduce well yields by clogging screens and pipes (**Figure 2**).

Furthermore, the water samples in the untreated condition usually have a smelly and yellowish appearance due to its acidic pH value of 6.1. This value does not conform to the government's quality standards, which ranges from 6.5 to 8.5. After the aeration-filtration process, which involves 5 hours of aeration treatment followed by filtration, the pH value of the water then increased to 8.4. These values can be seen in **Table 1.**

**Figure 2.** Water Color of the Sample

The factors responsible for increasing the pH value of water during the aeration process are dissolved oxygen (DO), water, and $CO_2$. During the filtration process, the primary factor responsible for the changes in the pH value of water is the carbon's cation content, which causes contact between the activated carbon and the water samples [17].

### *Measurement of dissolved oxygen (DO)*

Dissolved oxygen is an important variable that regulates post-aeration water treatment systems. DO refers to the mass of oxygen contained in water. DO concentrations are important indicators of water quality in terrestrial or aquatic environments. Aerators increase DO levels in water bodies, thereby increasing the oxygen transfer rate and simultaneously providing water circulation preventing stratification in water bodies [12].

**Table 1**. The pH value of water before and after passing through aeration and filtration

| Treatment | Quality Standards | Measurement results |
|---|---|---|
| Without treatment | | 6.1 |
| Aeration for 1 hour | | 7.0 |
| Aeration for 3 hours | | 7.0 |
| Aeration for 5 hours | | 7.3 |
| Aeration for 1 hour + Filtration | 6.5—8.5 | 7.8 |
| Aeration for 3 hour + Filtration | | 8.3 |
| Aeration for 5 hour + Filtration | | 8.4 |
| Filtration | | 8.0 |

The primary purpose of the aeration process is to maximize the contact between water and air to increase oxygen levels. Furthermore, the longer the contact time, the more dissolved oxygen in water. **Table 2** shows the increase in dissolved oxygen (DO) value in water before and after going through the aeration-filtration process. It also shows that the value of DO increases with the length of aeration time.

***Measurement of Fe***

According to the Indonesia Minister of Health Regulation No. 32 of 2017, the maximum allowable level of Fe in water is 1.0 mg/L. This implies that water is unsafe to drink or use if it has a higher Fe content. The water sample used in this research has a Fe content of 5.6672 mg/L, which is far beyond the government's quality standard.

**Table 2.** DO value of the water before and after passing aeration and filtration

| Treatment | Measurement results |
|---|---|
| Without treatment | 7.28 |
| Aeration for 1 hour | 7.88 |
| Aeration for 3 hours | 7.88 |
| Aeration for 5 hours | 8.47 |
| Aeration for 1 hour + Filtration | 8.27 |
| Aeration for 3 hour + Filtration | 8.47 |
| Aeration for 5 hour + Filtration | 8.47 |
| Filtration | 8.27 |

In addition, the Fe value obtained after 5 hours of aeration treatment is 0.9931 mg/L, while 0.7231 mg/L was obtained for the combined aeration-filtration treatment process. These values conform to the government's quality standards. Consequently, the contact between air and water to produce $Fe(OH)_3$ deposits is responsible for the decrease in the Fe level of the aeration tray system [17]. This reaction is as shown below:

$$4Fe^{2+} + O_2 + 10H_2O \rightarrow 4Fe(OH)_3 + 8H^+$$

After the aeration stage, there is a decrease in the amount of Fe in water obtained. This makes it easier to work on the aerated water in the filtration process, and the $Fe^{3+}$ present is filtered through the filtration media.

In **Table 3** shows the Fe content of water before and after the aeration filtration process as a whole. The % removal of Fe obtained in the aeration process alone was 82.48%, while the filtration alone was 70.44%. However, the highest % removal of Fe was obtained after the aeration process, which lasted for 5 hours, and 87.24% removal was achieved after the combined aeration-filtration process.

**Table 3.** Fe content of water before and after passing through aeration and filtration

| Treatment | Unit | Quality Standards | Measurement results |
|---|---|---|---|
| Without treatment | | | 5.6672 |
| Aeration for 1 hour | | | 3.0065 |
| Aeration for 3 hours | | | 1.2356 |
| Aeration for 5 hours | | | 0.9931 |
| Aeration for 1 hour + Filtration | mg/L | Max. 1.0 | 1.5686 |
| Aeration for 3 hour + Filtration | | | 1.0365 |
| Aeration for 5 hour + Filtration | | | 0.7231 |
| Filtrati on | | | 1.6750 |

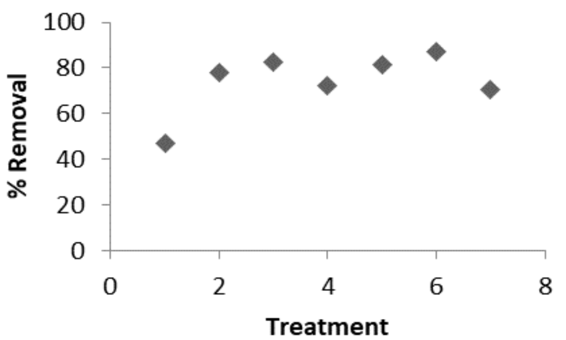


**Figure 3**. The Efficiency of Reducing Fe Value After Passing Aeration and Filtration Process ((1) Aeration for 1 h, (2) Aeration for 3 h, (3) Aeration for 5 h, (4) Aeration for 1 h + filtration, (5) Aeration for 3 h + filtration, (6) Aeration for 5 h + filtration, (7) Filtration)

The success of the aeration process depends on the value of temperature, oxygen saturation, water characteristics and water turbulence. The tray aerator method is effective in reducing Fe levels because it has a larger contact area between water and oxygen. The number of trays also provides a longer contact time so that Fe can be oxidized by $O_2$. The addition of contact media such as activated carbon to the filtration process can provide a high efficiency of Fe reduction. This is in line with what was stated [16], there was a more significant reduction in Fe in the filtration process using activated carbon media because in the filtration process there was a further process of deposition and separation of pollutants from aeration, resulting in a more optimal reduction in Fe levels.

## Conclusion

In the aeration process, the efficiency of iron (Fe) removal is affected by the length of the aeration contact time. The longer the time, the better the results obtained. However, the combination of aeration with filtration provides maximum results when compared to using aeration alone or filtration methods alone. In addition, further research needs to be carried out to determine the effects of the treatment methods on the efficiency of iron (Fe) removal by increasing the contact time and comparing the distance between the trays.

## Acknowledgements

The author The authors are grateful to the Directorate of Research and Community Service, the Ministry of Research and Technology for the financial assistance provided in this research process. Furthermore, the authors are also grateful to the Research and Community Service Institute (LPPM) of the Islamic University of Riau for providing moral support in the implementation of this research.

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