

# Effect of Filter Media (Zeolite, Ferrolite, and Manganese Greensand) and Combination of Media on the Levels of Iron and Manganese in Borehole Water

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## Abstract

**Aim:** The presence of Fe and Mn content in water, apart from being able to interfere with health, also creates a metallic taste and odor of drinking water and causes a yellow color on the walls and clothes. Thus, it is necessary to use appropriate and effective technologies to lower the amounts of iron and manganese in water. The technology involves the use of Filtration Media for Iron (Fe) and Manganese (Mn) Content in Drilling Wells, including Zeolite, Ferolite, and Manganese Greensand. **Materials and Methods:** The first treatment was for control, and the second, third, fourth, and fifth treatments, each containing zeolite ferrolite, and Mn media and the combination of media, were for the filtration process and repeated four times. **Results:** The results showed that the use of zeolite, ferrolite, and Mn filter media and the combination of media was able to increase Fe level by 11.05%, 5.99%, 21.78%, and 40.98%, respectively. Meanwhile, the use of zeolite, ferrolite, and Mn and the combination of media was able to reduce Mn level by 35.58%, 44.97%, 48.30%, and 75.28%, respectively. **Conclusion:** It is not recommended to use zeolite, ferrolite, and Mn filter media for processing Fe in borehole water. Zeolite, ferrolite, and Mn filter media can be used to reduce Mn levels in the borehole water.

**Keywords:** Ferrolite, iron, manganese greensand, zeolite

## INTRODUCTION

Water is a very vital need for human life. Therefore, if the need is not fulfilled, it can have a big impact on health and social insecurity. The provision of clean water in Indonesia, especially on a large scale, is still concentrated in urban areas and is managed by the Regional Water Utility Company (PDAM). Areas that have not received clean water services from PDAM generally use ground water by means of dug wells or boreholes, river water, rainwater, spring water, and others.<sup>[1]</sup> Water is a potential source of disease transmission and includes harmful compounds.<sup>[2]</sup> 50%–80% of human body consists of fluids. The main and very vital use of water for life is as drinking water.

Groundwater can come into contact with various materials found in the earth, including iron (Fe) and manganese (Mn).<sup>[3]</sup> The Fe content in water is influenced by several factors, including the depth of water in the ground. The deeper the water is absorbed, the higher the solubility of Fe, the lower the pH of the water, the more presence of dissolved gases in the water (CO<sup>2</sup> and H<sup>2</sup>S).

Fe or Fe is one of the essential heavy metals, which in a certain amount is needed by living things. However, if Fe content exceeds the quality standard, it can have a negative impact on the environment and public health.<sup>[4]</sup> Water that contains Fe will cause a taste, a fishy metallic smell of the water, cause brown on white color on clothes, cause brown stains on the tub walls, and cause blockages in pipes. High levels of Fe in water consumed will affect the health of the human body, namely damage to the liver, kidneys, and nerves, and cause hemochromatosis.<sup>[3]</sup> The maximum permissible level of Fe in drinking water is 0.3 mg/l.<sup>[5]</sup>

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Mn is a reddish-gray metal. Water that contains excess Mn causes taste, color (brown/purple/black), and cloudiness. Relative Mn toxicity has been seen at low concentration. The permissible content of Mn in drinking water used for domestic purposes is below 0.4 mg/l.<sup>[5]</sup> Insoluble Mn types such as MnO<sub>2</sub>, Mn<sub>3</sub>O<sub>4</sub>, or MnCO<sub>3</sub> are formed at a rather high pH and aerobic condition, although the oxidation of Mn<sup>2+</sup> is relatively slow. In small amounts (<0.4 mg/l), Mn in water does not cause health problems, but is beneficial in maintaining brain and bone health, plays a role in hair and nail growth, and helps produce enzymes for the body's metabolism to convert carbohydrates and proteins and form the energy to be used. However, in large amounts (>0.5 mg/l), Mn in drinking water is neurotoxic. Nervous system symptoms, such as insomnia, weakness in the legs, and weak facial muscles that cause a frozen expression and a mask-like appearance of the face, may also manifest.<sup>[6]</sup>

Excess levels of Fe and Mn can be reduced by filtration. Filtration is a process of separating a solid from a fluid (liquid or gas), which carries it using a porous medium or other porous material to remove as much suspended fine solids and colloids as possible. Depending on the medium passed by the filtered fluid, filtration can not only lower the solid content but also the bacterial content, as well as the color, taste, smell, Fe, and Mn. Filter media generally have different sizes, shapes, and chemical compositions. The quality of the filter media is based on size, surface load, solid geometry, and surface catchment. The most commonly recognized filter media in water treatment are sand and anthracite.

Some examples of effective filter media that are often used in water treatment in the community are silica sand, activated charcoal, zeolite, ferrolite, Mn greensand, and cation resin. Each of these filter media has different characteristics and benefits. Silica sand usually functions as a prefilter for water to be processed with the next filter; zeolite sand can increase oxygen levels, provide freshness in water, and absorb light lime in water; ferrolite functions to increase oxygen content and remove high levels of Fe, Mn, odor, and yellow color in water; and Mn greensand can remove Mn content and oily top layer in water.

Dug wells and boreholes are the means to provide clean water for every community in rural and urban areas. A dug well is a means of clean water that comes from a shallow soil layer. Apart from the soil layer, trace elements and contaminants that contaminate dug well water can come from seepage of waste and human waste.<sup>[7]</sup> Dug well as the source of clean water must meet good construction and location requirements. This is very necessary, so that the quality of dug well water can meet the requirements or be safe according to the predetermined rules.<sup>[8]</sup>

Furthermore, soil condition can also lead to less good quality of dug well water since water may contain high levels of dissolved Fe, Mn, and other chemical elements. People are unable to use this water to meet their daily needs such as drinking

water, bathing, or washing due to the large amount of Fe and Mn content in the water. Based on the background of these problems, the authors are interested in researching the effect of zeolite, ferrolite, and Mn greensand and the combination of media on Fe and Mn content in borehole water.

## MATERIALS AND METHODS

The subject in this study was artificial sample water. The use of artificial sample water in this study was due to concerns over fluctuations in the concentration of Fe and Mn in the drilled well water during the study period due to changes in weather factor. There were 25 samples involved. Each sample consisted of 5 types of filtration samples using zeolite, ferrolite, Mn greensand, combination of media, and control. A media combination is a combination of zeolite, ferrolite, and Mn greensand filtration media at the same time. The sample replication was performed 5 times, which aimed to obtain representative data.

The research steps were carried out by assembling the filtration installation as shown in Figure 1. Producing a sample solution by weighing 0.68 g of FeSO<sub>4</sub> and 0.27 g of MnSO<sub>4</sub> and dissolving them in 50 l of borehole water, and then figuring out the discharge used, which was 0.419 L/min. After that, the sample water was accommodated, the Fe and Mn content were measured before treatment, and then the running process was carried out. Initial control method without filtration media. In the second treatment, the sample flowed into the zeolite media. After that, the water is accommodated for Fe and Mn examinations. The third treatment was carried out for ferrolite media, the fourth treatment was for Mn greensand media, and the fifth treatment was for media combinations.

A measurement of Fe was carried out using the Indonesian National Standard Fe Test method SNI 6898.4–2009 and for Mn measurements, carried out using the Indonesian National Standard Mn Test Method SNI 6898.5–2009. The data were analyzed by using the one-way ANOVA test to observe the difference and it was followed by the least significant difference (LSD) test to compare the significance between each experimental group using SPSS version 22 software (IBM SPSS, New York, USA).<sup>[9]</sup>

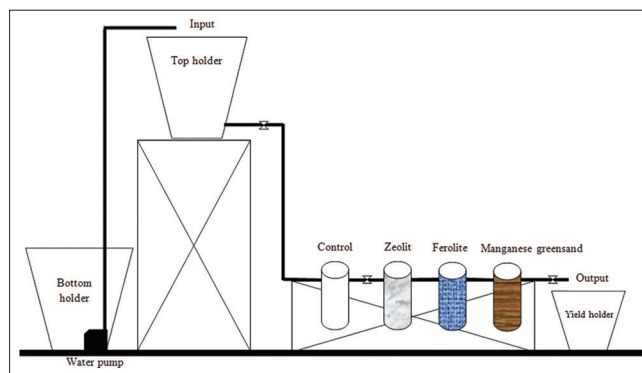


Figure 1: Research reactor

### Ethical clearance

Ethical approval for this study (No: LB.02.01/5312/2020) was provided by the Health Research Ethical Committee (KEPK) Politeknik Kesehatan Aceh, Indonesia, on 27 March 2020.

## RESULTS

### Iron parameter

Changes in Fe parameters after going through the process of zeolite filter media, Mn greensand, and combinations with each repetition and the average value of changes can be seen in the in the Figure 2.

The mean Fe for the control group without filtering media was 0.952 mg/l, for zeolite medium it was 1.363 mg/l, for ferrolite medium it was 1.300 mg/l, for manganese greensand medium it was 1.494 mg/l, and for the combination of filter media it was 1.730 mg/l. The highest increase in Fe was obtained with the use of combination of filter media of 1.730 mg/l.

The research data were first tested for the level of normality of the data with the Levene statistic test before performing the ANOVA test, and the result was 0.184, indicating that the data were considered normal. See the one-way ANOVA study Table 1 below to evaluate how different filter media types affect the levels of Fe in borehole water.

There was a significant difference ( $P = 0.000$ ) between each treatment of the filter media on the level of Fe in borehole water. The *post hoc* test using the LSD test concluded that there were significant differences between each filter media treatment group and the other treatment groups ( $P < 0.05$ ), except between zeolite and ferrolite filter media groups, zeolite and Mn filter media groups, ferrolite and Mn filter media groups, as well as Mn and combination of filter media groups ( $P > 0.05$ ).

### Manganese parameter

Changes in Mn parameters after going through the process of zeolite filter media, Mn greensand, and combinations with each repetition and the average value of changes are shown in Figure 3.

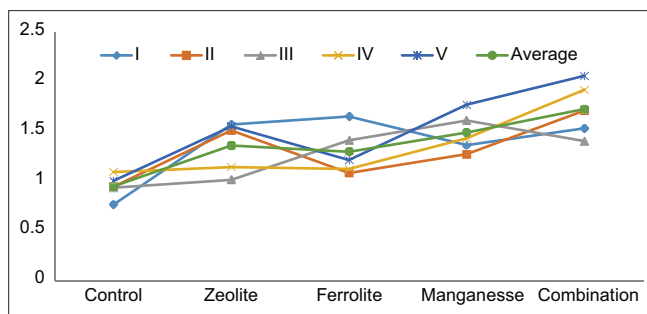


Figure 2: Increase in the level of Fe (mg/l) through various filter media and replication

The mean Mn for the control group without filtering media was 5.448 mg/l, for zeolite medium it was 3.440 mg/l, for ferrolite medium it was 2.939 mg/l, for manganese greensand medium it was 2.761 mg/l, and for the combination of filter media it was 1.320 mg/l. The highest reduction in Mn was obtained with the use of combination of filter media of 1.320 mg/l.

The one-way ANOVA analysis Table 2 below shows the impact of different types of filter media on the 1 level of Mn in borehole water.

There was a significant difference ( $P = 0.000$ ) between each treatment of the filter media on the level of Mn in borehole water. The *post hoc* test concluded that there were significant differences between each filter media treatment group and the other treatment groups ( $P < 0.05$ ), except between zeolite and ferrolite filter media groups, zeolite and Mn filter media groups, ferrolite and zeolite, as well as ferrolite and Mn ( $P > 0.05$ ).

Table 1: Result of ANOVA test on the effect of filter media (zeolite, ferrolite, manganese greensand) and combination of media on the level of iron in borehole well water

Variable	Mean±SD	95% CI	P
Control	0.952±0.121	0.802-1.102	0.000
Zeolit	1.363±0.261	1.039-1.686	
Ferrolite	1.301±0.235	1.008-1.593	
Manganese	1.494±0.200	1.245-1.743	
Combination	1.730±0.270	1.394-2.065	

SD: Standard deviation, CI: Confidence interval

Table 2: Result of ANOVA test on the effect of filter media (zeolite, ferrolite, manganese greensand) and combination of media on the level of manganese in borehole well water

Variable	Mean±SD	95% CI	P
Control	5.448±0.172	5.235-5.661	0.000
Zeolit	3.44±1.083	2.095-4.785	
Ferrolite	2.939±0.1691	2.729-3.149	
Manganese	2.761±0.905	1.638-3.884	
Kombinasi	1.320±0.231	1.033-1.607	

SD: Standard deviation, CI: Confidence interval

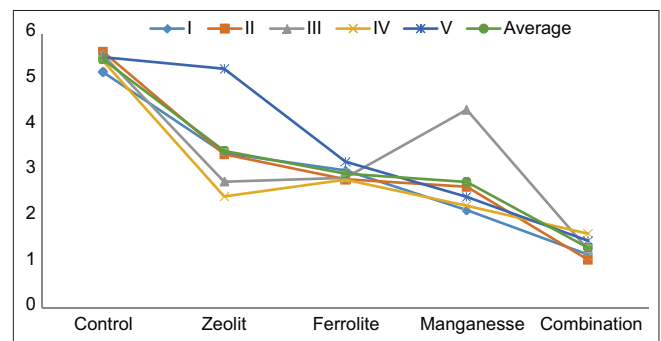


Figure 3: Graph of the decrease in the level of Mn (mg/l) through various filter media

## DISCUSSION

Fe is a common trace element which presents in almost all groundwater, while Mn is only present in a few places, but its existence is usually together with Fe. Groundwater generally has a relatively low dissolved oxygen concentration, which leads to anaerobic state. This condition causes the concentration of Fe and Mn in the form of insoluble minerals ( $\text{Fe}^{3+}$  and  $\text{Mn}^{4+}$ ) to be reduced to dissolved Fe and Mn in the form of  $\text{Fe}^{2+}$  and  $\text{Mn}^{2+}$  ions. The Fe concentration in groundwater varies widely from 0.01 mg/l to  $\pm 25$  mg/l, while the Mn concentration in groundwater is generally  $<1.0$  mg/l.<sup>[10]</sup>

There are several principles in the process of removing Fe and Mn contents, namely, by ion exchange, oxidation, coagulation, filter media, and biological process. In fact, chemical oxidation process is commonly used in water supply system, namely, increasing the level of oxidation by an oxidizer with the aim of changing the form of dissolved Fe and Mn to insoluble Fe and Mn (sediment) which are then proceed with the sedimentation and/or filtration process.<sup>[11]</sup>

### Iron parameter

The study findings revealed that the use of various filter media (zeolite, ferrolite, and Mn) could not reduce Fe content in the sample water. The use of filter media is one method of eliminating dissolved Fe in water that is rarely used since it requires a longer hydraulic retention time so that water treatment is not efficient. A study conducted by Abdur Rahman in Jakarta concluded that the optimum condition for removing Fe was 30 min for contact time and 2 mL/minute for the filtration rate. In such condition, zeolite reduced Fe by 55% in groundwater containing 3.6 mg/L Fe. Unfortunately, this optimum condition only produced a water discharge of 2.88 L/day. Quantitatively, with a filtration rate of 2 mL/min, up to 2.5 h of contact time, Fe could only be reduced to 1.12 mg/L (quality standard: 1.0 mg/L),<sup>[12]</sup> whereas this study used a discharge of up to 1.12 mg/L with 500 ml/min so that the hydraulic retention time with the filter media was very short.

Effective Fe reduction can be done by integrated processing between aeration and slow sand filtering media so that it can reduce Fe content in water up to 85%.<sup>[13]</sup> The reduction of pollutants in the water can also be increased by the contact time between the water and the filtration media.<sup>[14]</sup> Aeration or the process of making contact between water and air either naturally or by mechanical design to increase dissolved oxygen levels in water is a very effective Fe reduction method that can be applied at this time since it is not merely able to reduce Fe up to 100% but also can increase the redox potential up to 2 mV.<sup>[15]</sup>

Another effort is to increase dissolved Fe removal in groundwater using an aerator diffuser, increasing air flow and increasing the length of aeration time to meet the predetermined quality standard.<sup>[16]</sup> In general, Fe in water can be in the dissolved form of  $\text{Fe}^{2+}$  (ferrous) or  $\text{Fe}^{3+}$  (ferric), suspended as colloidal grains (diameter of  $<1$   $\mu\text{m}$ ) or larger, such as  $\text{Fe}_2\text{O}_3$ , FeO, FeOOH, Fe (OH)<sub>3</sub> etc., and is combined

with organic substances or inorganic solids such as clay. Ferrous ions can be oxidized to ferric ions which are not homogeneously dissolved in water by contacting water with air to increase the dissolved oxygen content.

The aeration process allows the oxidation process of the elemental compounds of Fe in the ferrous form ( $\text{Fe}^{2+}$ ) to become the ferric form ( $\text{Fe}^{3+}$ ). Due to the tendency of divalent ferrous compounds to dissolve in water, these substances must be changed into a ferric state (trivalent) in order to be filtered on the filter medium. Water-soluble divalent Fe hydroxide of Fe ( $\text{HCO}_3$ )<sub>2</sub> is subjected to oxidation through the aeration unit in order for a reaction (ion) to take place and produce Fe(OH)<sub>3</sub>. According to the oxidation reaction, every 1 mg/l of  $\text{Fe}^{2+}$  will produce 1.913 mg/l Fe precipitate.<sup>[17]</sup>

The use of filter media is a further treatment that can be applied to significantly reduce Fe content in water after aeration treatment. The use of partial filter media will result in ineffective processing outcome since Fe is a compound that cannot be physically separated easily without going through the oxidation process.

### Manganese parameter

Regarding the test of Mn parameter, the study findings revealed a decrease in Mn through the use of various filter media (zeolite, ferrolite, and Mn) of 35.58%, 44.97%, 48.30%, and 75.28%, respectively. The first element in the VIIB metal group, Mn is a silvery gray metal with an atomic mass of 54.94 g/mol, an atomic number 25, a specific gravity of 7.43 g/cm, and valences of 2, 4, and 7. (other than 1, 3, 5, and 6). In nature, Mn is rarely found in the elemental state. In general, it is found in a compound state with various valences. In relation to water quality, Mn compound varies depending on the degree of acidity (pH) of water. Changes in Fe and Mn compounds in nature are based on pH condition. Therefore, in water treatment system, Mn compounds with a higher valence are insoluble in water so they can be easily separated physically.<sup>[11]</sup>

The decrease in Mn levels in the filtering process occurs by the process of water seeping and passing through the filter media so that it will be accumulated and collected on the filter surface along the depth of the media in which it passes.<sup>[6]</sup> The phylum will be formed on the surface of the filter media used, which serves as a catalyst for the oxidation process. The grain of the filter media will be covered with metal oxides, or in such a case, it is called "contact filtration" using filter media such as Mn, zeolite and ferrolite.<sup>[18]</sup>

According to a study done in Yogyakarta, without prior oxidation, the mean decrease in Mn after filtering with a resin filter was 92.32%, with a zeolite filter it was 57.11%, with an activated carbon filter it was 73.49%, and with parallel filters it was  $>98.90\%$ .<sup>[19]</sup> Thus, the use of filter media in reducing Mn could be concluded to be effective even without aeration treatment, in contrast to water-soluble Fe compounds. This could be due to the adsorption ability of Fe (II) and Mn (II)

which can vary substantially, but generally it increases with higher pH.<sup>[20]</sup>

Mn naturally forms in surface and groundwater sources, particularly when the oxidation state is low. Typically, Mn in water dissolves compounds such as bicarbonate salts, sulfate salts, hydroxides, colloids, or in a condition mixed with organic compounds. As a result, the treatment procedure needs to be modified to account for the compound's form in the treated water. One of the Mn processing methods is the filtration technique. The process of physically, chemically, and biologically separating or filtering particles through porous media is known as filtration.<sup>[19]</sup>

Contact filtration is carried out by flowing raw water containing Mn into a filter medium which contains  $\text{MnO}_2 \cdot n\text{H}_2\text{O}$ . As long as it flows through the medium, the Mn contained in the raw water will be oxidized to form  $\text{Mn}_2\text{O}_3$  which will be filtered out by the media. During the filtration process, there is also an ion exchange process with the filtration media. Since the dissolved Mn in the form of cations is varied with  $\text{Mn}^{2+}$ , the ion exchange process can be used to remove Mn from water. In this process, monovalent cation, Na or  $\text{H}^+$ , is usually released from the cationic ion exchanger when Mn is selectively released. If there is an oxidation process during ion exchange, it will slow down the reduction process of Mn with ion exchange.<sup>[21]</sup>

## CONCLUSION

Based on statistical test, there was an effect of zeolite, ferrolite, and Mn and combination of filter media on the levels of Fe and Mn in borehole water. The filter media could increase the Fe content in borehole water up to 40% on combined filter media but reduced the Mn content in borehole water up to 75% on combined filter media. It is not recommended to use zeolite, ferrolite, and Mn filtration media for the treatment of Fe parameters in borehole water. Zeolite, ferrolite, and Mn filtration media can be used to reduce Mn levels in drilled well water without having to go through the aeration process.

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## Conflicts of interest

There are no conflicts of interest.

## REFERENCES

- Said NI. Making filters to remove iron and manganese in water. Direktorat Teknologi Lingkungan Badan Pengkajian dan Penerapan Teknologi. Jakarta Pusat; 2011.
- Fitriani F. Effect of Concentration and Duration of Immersion of Coconut Shell Active Charcoal on Fe Levels and Peat Water pH. University of Lampung Mangkurat; 2009.
- Sasadara SC, Mahawati E, Hartini E. The Effectiveness of Water Purifiers in Reducing Iron (Fe) Levels Based on Variations in Residence Time in Dug Well Water, Thesis Dian Nuswantoro University. Universitas Dian Nuswantoro; 2013.
- Joko T, Rachmawati S. Variation addition of adsorption media on tray aerator of the level of iron (Fe) of shallow groundw. Jurnal Kesehatan 2016;15:1-5.
- Kementerian Kesehatan Republik Indonesia. Permenkes No. 492 Tahun 2010. Jakarta: Kementerian Kesehatan Republik Indonesia; 2010.
- Febriana L, Ayuna A. A ceramic filter was used to study the decreasing levels of iron (Fe) and manganese (Mn) in ground water. J Teknol 2015;7:35-44.
- Zulfikar Z, Putri R, Aditama W. Correlation between the pollution risk of wells and the presence of *Escherichia coli* bacteria at Daroy Kameu Village Darul Imarah subdistrict Aceh Besar district in 2017. Hig J Kesehat Lingkung 2019;5:22-31.
- Tangkilisan SL, Joseph WB, Sumampouw OJ. Relationship between construction factors, dug well distance from pollution sources, and total coliform of ded well water in Motto Kelurahan, Lembah Utara District. Kesmas; 2018;7:4.
- Dahlan MS. Statistics for Medicine and Health. 4<sup>th</sup> ed. Jakarta: Salemba Medika; 2016.
- Pakasi FG. The effectiveness of the up flow sand filter in reducing iron (Fe) and manganese (Mn) in raw water. J Kesehatan Lingkungan. 2014; 4:1.
- Said NI. Methods of removing iron and manganese from the domestic drinking water supply. Jurnal Air Indonesia 2011;1:3.
- Rahman A, Hartono B. Ground water filtration with natural zeolite to lower iron and manganese levels. Makara Kesehatan 2004;8:1-6.
- Pacini VA, Maria Ingallinella A, Sanguinetti G. Removal of iron and manganese using biological roughing up flow filtration technology. Water Res 2005;39:4463-75.
- Zulfikar Z, Nasrullah N, Kartini K, Aditama W. Effect of hydraulic retention time on the levels of biochemical oxygen demand and total suspended solid with simple integrated treatment as an alternative to meet the household needs for clean water. Open Access Maced J Med Sci 2022;10:6-11.
- Cheng LH, Xiong ZZ, Cai S, Li DW, Xu XH. Aeration-manganese sand filter-ultrafiltration to remove iron and manganese from water: Oxidation effect and fouling behavior of manganese sand coated film. J Water Process Eng 2020;38:101621.
- Batara K, Zaman B, Oktiawan W. Effect of Air Discharge and Aeration Time on Iron and Manganese Reduction Efficiency Using Diffuser Aerator in Groundwater. Diponegoro University; 2017.
- Ayu D, Mirwan M. Fe and Mn decrease in well water using multiple tray Aerator Pyramid. ENVIRONUS 2020;1:28-35.
- Barloková D, Ilavský J. Removal of iron and manganese from water using filtration by natural materials. Polish J Environ Stud 2010;19:1117-22.
- Yeni Yuliani YY, Lilik Hendrarini LH, Haryono H. Manganese in Dig Well Water Reduces With Media Filter Variations to Reduce Manganese in Dig Well Water. Poltekkes Kemenkes Yogyakarta; 2019.
- Vries D, Bertelkamp C, Kegel FS, Hof B, Dusseldorp J, Bruins JH, *et al.* Iron and manganese removal: Recent advances in modelling treatment efficiency by rapid sand filtration. Water Res 2017;109:35-45.
- Tobiason JE, Bazilio A, Goodwill J, Mai X, Nguyen C. Manganese removal from drinking water sources. Curr Pollut Rep 2016;2:168-77.