Treatment of brackish groundwater by zeolite filtration in Sumur Tua Wonocolo, Kedewan, Bojonegoro, East Java

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Abstract. Sumur Tua Wonocolo has typical groundwater quality i.e. the high total dissolved solid (TDS) and hardness concentration. This groundwater quality was caused by the dissolution of natural composition (napal) of its reservoir. Therefore, groundwater treatment in this area is needed. This study objected to analyze the performance of natural zeolite filter as one single treatment. The research method was fixed-bed filtration column. The performance of zeolite filter was analyzed by the effectiveness of those filters in reducing TDS and hardness. The natural zeolite was arranged in the columns with independent variable i.e. grain sizes of 0.1 cm, 0.3 cm, and 0.5 cm. Dependent variables in this experiment were zeolite type, filter media thickness (50 cm), and hydraulic loading rate (HLR) 0.33 m/h. The results showed that groundwater treatment by natural zeolite filter with grain size of 0.1 cm was able to reduce TDS and hardness concentration reaching 79.76% and 74.84% of effectiveness respectively. The smaller grain size of natural zeolite used, the better performance of that media in adsorbing dissolved ions proven by decreasing concentration of TDS and hardness. However, the higher the effectiveness of the media in reducing TDS concentration, the faster the media will reach the saturation phase.

1. Introduction
Exploitation of oil and gas has been done traditionally in Sumur Tua Wonocolo, Kedewan sub-district, Bojonegoro regency, East Java since 10 years ago. The oil exploitation activities in Sumur Tua Wonocolo affect the environment that visually can be seen by the black oily soil, contaminated river water, and polluted air. In addition, the groundwater quality in the area of Sumur Tua is not appropriate to be used as drinking water. This typical condition is caused by the nature itself that the groundwater derives from the sedimentary rock i.e. clay as the caprock of the oil reservoir in Sumur Tua Wonocolo. So, it can be inferred that the groundwater are not necessarily contaminated by the oil exploitation activities but naturally brackish by the dissolved ions exist in the natural rocks where the oil comes from.

Therefore, it is important to treat the groundwater to assure the water quality meets the drinking water regulation. Filtration process was assumed to be the best available technology in developing country such as Indonesia [1]. The selection of media in filter column will be the challenge that will be solved by this research as well as the operation mode of filtration process. Natural zeolite is one of media as the filter media for groundwater treatment. Natural zeolite was proposed to be used as the filter media since it was known as a very good adsorbent. Natural zeolite is a hydrated alumino silicate
compound with a major element consisting of alkaline and alkaline earth cations. Generally, zeolites have three main functions, as adsorbents, catalysts and ion exchange [8]. However, natural zeolite as a catalyst is finite due to its low purity and surface area. Therefore, natural zeolite as adsorbent is more generally used in the adsorption process and cation exchange capacity (ion exchange) [2,3, 4, 5].

2. Method
Research method applied in this research are sampling method and laboratory test method. The sampling method is done by taking samples of groundwater at several well points in research area which aims to proceed to the next method of laboratory analysis. In this study, the groundwater contains the high concentration of dissolved solid will be treated by natural zeolite as filter media through the filter column. The water quality parameters that will be observed are Total Dissolved Solid (TDS) and hardness.

The type of zeolite used as filter media in three columns is mordenite. The experiment was done on three column with different grain size of zeolite i.e. 0.1 cm, 0.3 cm, and 0.5 cm. At the bottom of the filter column is added by gravel as supporting media, so that small-sized zeolites do not pass when the water flow to the faucet which can lead to blockage. The configuration and design criteria of filter column can be seen in figure 1 and table 1.

![Figure 1. Configuration of filter column](image)

| Specification                  | Filter Column A | Filter Column B | Filter Column C |
|-------------------------------|-----------------|-----------------|-----------------|
| **Filter column:**           |                 |                 |                 |
| Height                        | 120 cm          | 120 cm          | 120 cm          |
| Diameter                      | 8 cm            | 8 cm            | 8 cm            |
| **Filter media:**             |                 |                 |                 |
| Type of zeolite               | Mordenite       | Mordenite       | Mordenite       |
| Grain size                    | 0.1 cm          | 0.3 cm          | 0.5 cm          |
| Thickness of filter media     | 50 cm           | 50 cm           | 50 cm           |
| Thickness of supporting media (gravel) | 10 cm          | 10 cm           | 10 cm           |
| **Operation mode:**           |                 |                 |                 |
| Volume of sample water        | 2.5 liter       | 2.5 liter       | 2.5 liter       |
| Hydraulic loading rate (HLR)  | 0.33 m/h        | 0.33 m/h        | 0.33 m/h        |
The experiment was conducted in laboratory everyday in one week. The amount of sample used in this filter column was 2.5 liters for each time running. The hydraulic loading rate (HLR) was determined for each column i.e. 0.33 m/h. The water quality before and after the treatment were tested by portable toolkit to measure the TDS concentration.

3. Result and Discussion
Groundwater quality prior to filtration process was assessed based on 2 parameters i.e. TDS and hardness. These parameters were evaluated because the concentration of these parameters exceed the water quality standard allowed by Regulation of Republic of Indonesia Government No.82 Tahun 2011 on the Management of Water Quality and Water Pollution. For groundwater quality standard after processing will refer to the more detailed regulation that is Peraturan Menteri Kesehatan No.416/1990 on the Terms and Supervision of Drinking Water Quality.

According to Regulation of Republic of Indonesia Government No.82 Tahun 2011 on Water Quality Management and Water Pollution, the TDS concentration allowed for fresh water is 1000 mg/l. The amount of initial TDS in groundwater were 3832 mg/l of B1, 1300 mg/l of B2, and 1344 mg/l of B3. It can be concluded that the groundwater quality in Sumur Tua Wonocolo has higher concentration of TDS than that allowed by the regulation mentioned before. Not only TDS, but also the level of hardness was so high ranged between 1900 mg/l – 2600 mg/l that exceeded the water quality standard i.e. 500 mg/l. From the preliminary test of groundwater quality above, groundwater sample from B1 well which has the highest concentration of TDS and hardness.

| Day  | Initial Concentration of TDS (mg/l) | Filter 1 (Zeolit 0.1 cm) | Filter 2 (Zeolit 0.3 cm) | Filter 3 (Zeolit 0.5 cm) |
|------|-----------------------------------|--------------------------|--------------------------|--------------------------|
|      |                                   | 3832 mg/l                | 3832 mg/l                | 3832 mg/l                |
| Effectiveness (%) |                   |                          |                          |                          |
| Day 1 | 78,7                             | 77,66                    | 76,72                    |
| Day 2 | 79,2                             | 78,47                    | 77,66                    |
| Day 3 | 79,46                            | 78,62                    | 78,1                     |
| Day 4 | 78,86                            | 78,03                    | 78,39                    |
| Day 5 | 79,69                            | 77,61                    | 78,86                    |
| Day 6 | 77,34                            | 78,83                    | 79                       |
| Day 7 | 76,67                            | 77,64                    | 79,17                    |
| Average | 78,56                          | 78,12                    | 78,27                    |

*Based of test by portable TDS meter

The results of filtration performance of each column are shown in table 2. The average of effectiveness on three columns is relatively similar ranging from 78.12% to 78.56%. These results showed that there was no significant improvement of filter performance due to the grain size of zeolite used in this experiment. However, the filter with smaller grain size i.e. 0.1 cm had a better performance reaching 78.56% than those with bigger grain size in reducing the TDS concentration. Other authors also found that the grain size plays an important role in reducing the number of pollutants such as suspended solid and dissolved ions from the water [1, 6, 7]. The smaller grain size tends to have the higher removal efficiency of the media filter used in a column [1, 6, 7].

The graph shown in figure 2 describes the performance of three filter columns day by day. There are three lines represented each filter column. Filter column 1 with grain size 0.1 cm shows the highest effectiveness among other columns in early days. On the other hand, the filter performance in reducing TDS concentration drastically decreases in the last two days of experiment. Filter column 3 with grain size of 0.5 cm had the least effectiveness in reducing TDS in early days of experiment compared to the others. Differ from other filter, filter column 3 proved a better attainment on decreasing TDS among
other filter columns at the end of experiment. Additionally, not like other filter columns showed a fluctuate result, filter column 3 shows stable results of effectiveness in reducing TDS.

Figure 2. Graphic of the Effectiveness of Natural Zeolite Filters Against TDS Decrease

The effectiveness in reducing TDS in filter column 1 increased slowly from the 1st day with 78.7% of effectiveness to the 5th day of experiment reaching the maximum value of 79.69% effectiveness. After the 5th day, filter capability began to decline touching 76.67% of effectiveness in the end of experiment. This can be happened because the zeolite was getting saturated in adsorbing dissolved ions so that once this zeolite material reaches maximum effectiveness, its adsorption capacity decreases by treatment time. It also occurred in filter column 2 which showed the improvement of good enough effectiveness until the 6th day of experiment. The effectiveness of TDS reduction filter column 2 was smaller than that of the filter column 1 but the time of getting saturation point in the filter column 2 (6th day) was longer than the filter column 1 (5th day). In the filter column 3, the effectiveness of TDS reduction continued to increase very well without any declines until the end of experiment. In addition, the behavior of filter column 3 showed better than that of filter column 2 since the trend of charts of filter column 3 that still continues to increase reaching the effectiveness of 79.17%.

This fact can be influenced by the wider surface area on filter column 1 so that allowed a better adsorption capacity of its material represented by the highest percent of effectiveness in reducing TDS concentration. This high effectiveness of filter column 1 caused a relatively short time in getting saturated compared to other filter columns. On the other hand, filter column 3 had a slowly decrease of TDS concentration due to a smaller surface area of its media filter, so that produced a longer time of its media to get saturated. It was indication that zeolite media in filter column 3 with grain size of 0.5 cm was not saturated yet in adsorbing the dissolved ions. Additionally, filter column 3 proved that the grain size of 0.5 cm would be a promising filter media characteristic that can be used in reducing dissolved solid from the raw water. Other author who used zeolite filter with grain size of 0.1 cm to 0.3 cm found that this range of grain size was able to remove ammonia up to 95%, turbidity up to 95%, Total Coliforms near to 100%, and chemical oxygen demand reaching 40% [6].

At the end of the experiment, the results of water that has been processed with natural zeolite filter has been tested in certified laboratory (Balai PIPBPJK) in Yogyakarta with the results that can be seen in table 3.
Based on the table 3, it can be seen that the filtration method with natural zeolite material that was conducted in the experiment could effectively reduce the content of TDS and hardness met the water quality standard especially for TDS up to less than 1000 mg/l. Even though the outlet concentration of hardness was still slightly above the quality standard allowed by Indonesian regulation, the reduction of hardness concentration was quite significant ranging between 72.66% and 74.84%. However, according to the results gain by this experiment, the groundwater in this area can be safely used for daily needs such as washing, taking showers, cleaning, and flushing the toilet. To be used as drinking water, this groundwater needs further treatment to reduce the hardness both temporary hardness and permanent hardness in the groundwater. The temporary hardness can be removed by boiling the water or adding lime. The permanent hardness can be removed by adding chemicals or ion exchange (resin, activated carbon).

4. Conclusion
The results of three filter columns with zeolite material (mordenite type) grain size of 0.1 cm, 0.3 cm, and 0.5 cm with HLR 0.33 m/h were good in reducing high levels of TDS in the range of 78.12% - 78.56% and hardness in the range of 72.66% and 74.84%. The media in filter column 3 was deemed as a promising media to reduce the high concentration of TDS due to 78% of effectiveness in reducing TDS, the steady results in the effluent, and the longer time for the filter to get saturated. The TDS concentration in the outlet met the water quality standard regulation (PERMENKES No.416/1990). On the other hand, the hardness concentration did not meet the water quality standard that still slightly above the maximum quality standard allowed by PERMENKES No.416/1990. There was no significant difference of effectiveness in reducing TDS and hardness by three different grain sizes of natural zeolite.

5. References
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