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Design of Simple Water Treatment System for Cleaning Dirty Water in the Rural Area

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Abstract. The purpose of this study was to introduce our simple home-made water treatment system for solving the clean water supply problem in rural area. We designed a water system using several materials: activated sand, activated carbon, manganese, and zeolite. As a model, we investigated the water treatment system on two wells that placed in one of the rural area (far from the main city) in West Java, Indonesia. Experimental results showed that our designed water treatment system succeeded to purify dirty water and the properties and the chemical composition of the purified water is fit with the minimum standard requirement of clean water. Analysis and discussion about the way for the cleaning water process were also presented in the paper. Finally, since the wells are installed in the elementary school and the water is typically used for daily life activity for the neighbour people, this water system can be used for educational purposes and the school can become a center of life in this rural area.

1. Introduction

Water is one of the natural resources that are essential for human people and other living organisms. Water can be classified by clean water (consumable water) and dirty water (inconsumable water; further treatment is required prior to using). [1] Clean water is required for supporting people daily life and activity, such as drinking and cooking, bathroom uses, wash, and other purposes. Quality of clean water can support welfare and health for people [2]. On the contrary, bad water quality has a direct correlation to the health of users.

Nowadays, clean water supply becomes one of the main issues in the world, especially for developing country. With this shortage of clean water, people activity is disturbed; Further, this can give negative impact to the country in general.

In Indonesia, the definition of clean water is protected by government via The Indonesian Ministry of Health (IMH). IMH gives regulation for controlling definition of clean water in Peraturan Menteri Kesehatan R.I No: 416/MENKES/PER/IX/1990 Tanggal 3 September 1990. For this reason, consumable clean water in Indonesia is protected and strict. The process to purify water is a must. Otherwise, the clean water cannot be distributed. [3]

Many methods have been reported to treat and purify dirty water. One of the popular methods are combination of filter and physicochemical process system (namely filter system). [4] Although electrolysis is well-known as the best method to purify the water, the process is impractical for the



practical uses. [5] In short of the filter process, the water is through into the filter system. The filter system screens the larger component via hard screening, adsorption, and simple chemical reaction. To achieve this method, combination of filtering system, activated carbon, coagulant, and alum is typically used. In filtering system based on hard screening process, some cloths are typically used for filtering large floating or sinking component. [6] However, this is ineffective when the water containing colloidal component. For activated carbon, the process is basically used adsorption process for taking impurities, including organic compound. Typically, this activated carbon process is effective for eliminating odor in the water [1]. Then, in the case of coagulant, this step is typically used for water with high level of turbidity. Coagulant can be from either inorganic compound (e.g. aluminium salt and iron) or organic compound (e.g. polyacrylic amide and polyethylene imina) [7].

In Indonesia, mostly government usually fulfil the generation of clean water. However, for some cases in the rural area that is far from city, government has some difficulty in supplying clean water. Thus, the requirement for the facile process that can afford the production of clean water is required.

Here, the purpose of this study was to introduce our simple home-made water treatment system for solving the clean water supply problem in rural area. We designed a water system using several inexpensive materials: activated sand, activated carbon, manganese, and zeolite. As a model, we purified two wells that placed in one of the rural area (far from the main city) in West Java, Indonesia (see Figure 1). Experimental results showed that our designed water treatment system successfully purified the dirty water. The properties and the chemical composition of the purified water are fit with the minimum standard requirement for clean water. Analysis and discussion about how to clean and the main reason for the cleaning process were also presented in the paper.

2. Experimental method

2.1. Raw materials

The following raw materials were used: activated sand, activated carbon, manganese, and zeolite. All materials were purchased from commercially available product in Indonesia.

2.2. Object and location

For this water treatment, we selected one elementary school in Kebumen (7° SL and 109° EL) as the object. This school placed in one of the rural area that is far from the main city in West Java, Indonesia. Detailed information about this area is shown in Figure 1. In the school, we treated two wells; one is school's well (for student; namely Well 1) and the other is well that located near to the main office (for teacher; namely Well 2). Although both wells are near (about 200 m in distance), the characteristics of water are different.

2.3. Building conventional water treatment system

The water treatment system was constructed subsequently based on the following materials: activated sand, activated carbon, manganese, and zeolite (See Figure 2). Each material is compacted into a package. Each package has a diameter of 16 inch m and height of 40 cm. The package is set to form a filter system. To support the water treatment process, we used two 500-L containers and two pumps. Regarding the containers, containers were used for dirty and clean water. Then, pumps were used for supporting the flow into the container. Detailed information about the water treatment system is described in Figure 2.

2.4. Characterizations

Several methods were used to analyse the composition of water, including

- (i) APHA-AWWA-WEF 2120-B-2012,
- (ii) APHA-AWWA-WEF 2340-C-2012
- (iii) APHA-AWWA-WEF 2540-B-2012,
- (iv) APHA-AWWA-WEF 3030-B-2012 / 3111-B-2012

- (v) APHA-AWWA-WEF 4500.CN-F-2012
- (vi) APHA-AWWA-WEF 4500.SO42--E-2012
- (vii) APHA-AWWA-WEF 5540.C-2012
- (viii) SNI 06-2480-1991
- (ix) SNI 06-6989.9-2004
- (x) SNI 06-6989.11-2004,
- (xi) SNI 6989.53:2004
- (xii) SNI 06-6989.29-2005
- (xiii) SNI 6989.19:2009

Detailed information about analysis used in this study is shown in Table 1.



Figure 1. Location of object for research. Figure (a) is the location of Kebumen in Indonesia. Dashed red area is the Central Java Province (the Kebumen placed in this province). Figure (b) is the high magnification of Central Java Map. Figure (c) is the location for object of the research (Madrasah Ibtidaiyah, Nurul Huda (Islamic school)). Figures (a) and (b) were adopted from <http://smartraveller.gov.au/Countries/asia/south-east/pages/indonesia.aspx> and <http://petakebumen.blogspot.co.uk/2015/05/peta-lokasi-kabupaten-kebumen-di.html>, respectively, retrieved on December 25, 2016.

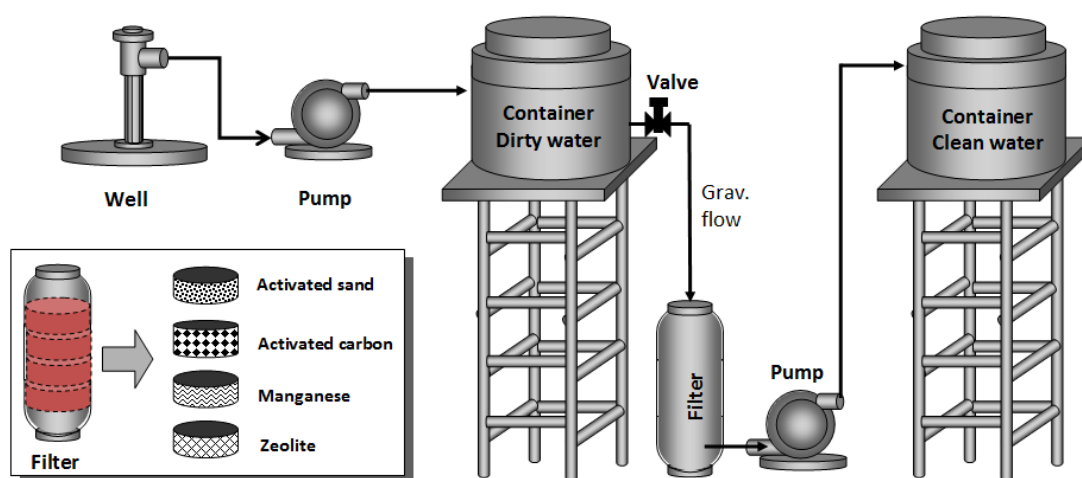


Figure 2. Illustration of the water treatment system. The panelled figure (in the left-bottom in the figure) is the description of filter system containing packages of activated sand, activated carbon, manganese, and zeolite.

Table 1. Analysis used for investigating the composition of water

<i>Parameter and composition</i>	<i>Method</i>
Colour	APHA-AWWA-WEF 2120-B-2012
Turbidity	APHA-AWWA-WEF 2130-B-2012
Dissolved Residue	APHA-AWWA-WEF 2540-B-2012
pH	SNI 06-6989.11-2004
Hardness	APHA-AWWA-WEF 2340-C-2012
Iron (Fe)	APHA-AWWA-WEF 3030-B-2012 / 3111-B-2012
Manganese (Mn)	APHA-AWWA-WEF 3030-B-2012 / 3111-B-2012
Cubrum (Cu)	APHA-AWWA-WEF 3030-B-2012 / 3111-B-2012
Zink (Zn)	APHA-AWWA-WEF 3030-B-2012 / 3111-B-2012
Crom VI (Cr ²⁺)	SNI 6989.53:2004
Cadmium (Cd)	APHA-AWWA-WEF 3030-B-2012 / 3111-B-2012
Plumbum (Pb)	APHA-AWWA-WEF 3030-B-2012 / 3111-B-2012
Fluoride (F)	SNI 06-6989.29-2005
Chloride (Cl)	SNI 6989.19:2009
Sulphate (SO ₄)	APHA-AWWA-WEF 4500.SO42--E-2012
Cyanide (CN)	APHA-AWWA-WEF 4500.CN-F-2012
Nitrate (NO ₃ -N)	SNI 06-2480-1991
Nitrite (NO ₂ -N)	SNI 06-6989.9-2004
Methylene blue	APHA-AWWA-WEF 5540.C-2012
Permanganate value	SNI 06-2506-1991

3. Results

Figure 3a shows the constructed water treatment in the school. The appearance of main constructed filter system is shown in Figure 3b, whereas the information about the result from water system is shown in Figure 3c. We also added information from our sponsor in the water treatment system (shown in Figure 3d).

As shown Figure 3a, the water system was equipped with two 500-L containers, in which this volume can be used enough for daily activity for students and teachers, as well as people living in that area. The successful water treatment system was also revealed in Figure 3c, where the initial turbid water was changed into clean, clear, and transparent water.

To ensure the effectiveness of our water treatment system, we analysed the condition and chemical composition in the water before and after the water treatment process (shown in Table 2 and 3). Table 2 is the information regarding well 1, whereas Table 3 is for well 2.

Table 2 shows analysis of water condition in well 1 before and after the water treatment process. To clarify the main problems in the water, we make bold and italic font for the component in the table that exceed the minimum threshold for the clean water. The main problems in well 1 are the turbidity and the manganese component.



Figure 3. Appearance of water treatment system. Figure (a) is photograph image of total water treatment system. Figure (b) is the photograph image of the filter system. Figure (c) is the samples before and after the purification method. Figure (d) is the photograph image of the information regarding the fund

In the initial condition, the water turbidity is high, reaching 76 NTU. This turbidity is also followed by the odor (metal-like odor). This value cannot be accepted since the quality standard for turbidity based on regulation must be less than 25 NTU. Since turbidity is usually caused by the existence of colloidal, an organic substance, microorganisms, mud, clay, and the some floating component (Valentina et al., 2013), simple hard screening process is ineffective. Additional chemical treatment to coagulate, flocculate, and precipitate is required. Other component that is unacceptable is Manganese component, reaching 3.53 mg/L, which is seven times higher than the standard value. In addition, manganese is also dissolve in water, making simple hard screening process to be incompatible.

As shown in this figure, the quality of water increased after the water treatment process. All values are less than the minimum threshold requirement for clean water.

Table 3 is the test result analysis of water in well 2. Similar to Table 2, we also compared the analysis results of water before and after the water treatment process. The result showed that the main problem in well 2 is the concentration of nitrite which exceeds the minimum threshold for the clean water (see bold and italic font in the table). However, after water treatment, we found that the concentration of nitrite decrease greatly.

Table 2. Test result for water condition before and after the water treatment

<i>Parameter</i>	<i>Unit</i>	<i>Test Result</i>		<i>Quality Standards*</i>
		<i>Before additional water treatment</i>	<i>After additional water treatment</i>	
Colour	PtCo Unit	1.8	4.0	50
<i>Turbidity</i>	<i>NTU</i>	<i>76</i>	<i>3.0</i>	<i>25</i>
Dissolved Residue	mg/L	514	361	1500
pH	-	6.8	8.1	6.5 – 9
Hardness	mg/L CaCO ₃	276	146	500
Iron (Fe)	mg/L	< 0.012	< 0.012	1.0
<i>Manganese (Mn)</i>	<i>mg/L</i>	<i>3.53</i>	<i>0.624</i>	<i>0.5</i>
Cuprum (Cu)	mg/L	< 0.012	< 0.012	-
Zinc (Zn)	mg/L	0.004	< 0.004	15
Chrome VI (Cr ²⁺)	mg/L	< 0.004	< 0.004	0.05
Cadmium (Cd)	mg/L	0.001	< 0.001	0.005
Plumb (Pb)	mg/L	< 0.009	0.020	0.05
Fluoride (F)	mg/L	< 0.06	0.638	1.5
Chloride (Cl)	mg/L	85.7	60.5	600
Sulphate (SO ₄)	mg/L	10.9	1.2	400
Cyanide (CN)	mg/L	< 0.003	< 0.003	0.1
Nitrate (NO ₃ -N)	mg/L	1.67	0.38	10
Nitrite (NO ₂ -N)	mg/L	3.38	0.007	1.0
Metylene blue	mg/L	< 0.02	< 0.02	0.5
Permanganate value	mg/L KMnO ₄	8.1	5.5	10.0

*Based on Indonesian Ministry of Health No: 416/MENKES/PER/IX/1990 Tanggal 3 September 1990

Table 3. Test result for water condition before and after the water treatment

<i>Parameter</i>	<i>Unit</i>	<i>Test Result</i>		<i>Quality Standards*</i>
		<i>Before additional water treatment</i>	<i>After additional water treatment</i>	
Colour	PtCo Unit	0,3	1.9	50
Turbidity	NTU	3,5	3.4	25
Dissolved Residue	mg/L	276	204	1500
pH	-	6,7	8.1	6,5 – 9
Hardness	mg/L CaCO ₃	172	142	500
Iron (Fe)	mg/L	< 0,012	< 0.0012	1,0
Manganese (Mn)	mg/L	< 0,006	0.010	0,5
Cuprum (Cu)	mg/L	< 0,012	< 0.012	-
Zinc (Zn)	mg/L	< 0,004	< 0.004	15
Chrome VI (Cr ²⁺)	mg/L	< 0,004	< 0.004	0,05
Cadmium (Cd)	mg/L	0,001	< 0.001	0,005
Plumb (Pb)	mg/L	< 0,009	< 0.009	0,05
Fluoride (F)	mg/L	0,581	< 0.06	1,5
Chloride (Cl)	mg/L	32,0	15.9	600
Sulphate (SO ₄)	mg/L	13,4	10.9	400
Cyanide (CN)	mg/L	< 0,003	< 0.003	0,1
Nitrate (NO ₃ -N)	mg/L	3,29	0.70	10
Nitrite (NO₂-N)	mg/L	1,19	0.0020	1,0
Birumetilen	mg/L	< 0,02	< 0.02	0,5
Permanganate value	mg/L KMnO ₄	3,9	2.6	10,0

*Based on Indonesian Ministry of Health No: 416/MENKES/PER/IX/1990 Tanggal 3 September 1990

4. Discussion

We found that although the wells are relatively near (about 200 meters in distance), the chemical compositions of both wells are different. In the case of well 2, the well is near to the rice field, making the water in the well 2 to have more nitrite compound. This nitrite compound is from the fertilizer leaching. Regarding well 1, the well is far from the rice field. The existence of high content of manganese compound in well 1 is from their originated diatoms/rock in the well surrounding.

The successful present water treatment system is due to the effectiveness of our method in removing several impurities, specifically, turbidity (in well 1), mangan (in well 1), and nitrite compound (in well 2). In general, the main component in the water filter system can be described in the following:

1. The activated sand was used for giving the surface area for making further contact for aeration process (between dirty water with air (oxygen)). This process is required for increasing dissolved oxygen (DO), as well as supporting the oxidation phenomena for dissolved inorganic ions (such as Fe²⁺ and Mn²⁺) and low molecular weight of organic compound.
2. The activated carbon was used for adsorbing the organic component, in which this organic component is the main reason for the existence of odor in the water. However, since the activated

carbon is utilized the adsorption process, the change of the activated carbon must be done after several times.

3. The manganese compound was used due to its catalytic activity for making oxidation process. Specifically, this catalyst is used for converting Fe^{2+} and Mn^{2+} ions (that are dissolved in water) into Fe^{3+} and Mn^{3+} (that are precipitated and insoluble in water). Since the precipitated components are generated every time, the backwash process must be done after several times of process for removing them from the catalyst and avoiding the blockage of the water flow in the filter system.
4. The zeolite compound was used for decreasing the hardness (Ca^{2+} and Mg^{2+} ions). However, in both wells, water has no problem with the hardness. As shown in Tables 2 and 3, hardness decreased down to about 140 mg/L.

5. Conclusion

We have successfully introduced our simple home-made water treatment system for solving the clean water supply problem in rural area. We designed a water system using several materials: activated sand, activated carbon, manganese, and zeolite. Experimental results showed that our designed water treatment system succeeded to purify dirty water. The properties and the chemical composition of the purified water are fit with the minimum standard requirement for clean water. Finally, since the wells are installed in the elementary school and the water is typically used for daily life activity for the neighbour people, this water system can be used for educational purposes and the school can become a center of life in this rural area.

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