Journal of Engineering Science and Technology
Vol. 14, No. 4 (2019) 2090 - 2097

CONVENTIONAL FILTER FOR THE WATER TREATMENT SYSTEM IN RURAL AREA

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Abstract

Conventional filtering system for treating groundwater has been well-known and applied in the realistic condition. However, there is no information about the phenomena happening during water treatment. The purpose of this study was to investigate step by step process in the conventional filtering system for treating groundwater. The conventional filtering system used in this study was a combination of several commercially available materials, such as activated silica, natural sand, activated carbon obtained from carbonized coconut fibres, manganese, and natural zeolite. Groundwater in the rural area that is located near the agricultural area was used as a model. Since the raw water contains fertilizer components, this will be good as the model for describing most water condition in agricultural countries. Experimental results showed that the conventional water treatment system successfully purified the groundwater, and the physiochemical properties of the treated water are fit with the minimum standard requirement for clean water based on Indonesian regulation. Analysis and discussion in the step-by-step process during the treating groundwater were also presented in the paper. Finally, the present study would create a better understanding of the use of the water treatment system using the conventional filter in the realistic condition, especially for the agricultural area.

Keywords: Adsorption, Clean water, Conventional filter, Oxidation, Zeolite.

1. Introduction

Availability of clean water is one of the biggest issues especially in developing countries since this is required for supporting people's daily life and activity, including drinking and cooking, bathroom uses, wash, and other purposes [1]. Indeed, a shortage of clean water disturbs health and activity and even brings negative impacts to people and the community in the country in general.

Hidayat and Taufiq [2] proposed that most governments usually fulfil the need of clean water. For example, Indonesia has built one of the national companies to treat water for generating clean water. However, for some cases in the rural area, which is far from the city, the government has some difficulties in supplying clean water. Harris [3] explained that it resulted in creating the need for applying a facile water treatment system for affording the production of clean water.

The use of strategies for providing clean water that is massive and applicable is mandatory [4]. Many methods have been reported, which were applying techniques to treat and purify the available water, including sea [5], lake [6], river [7], groundwater [8], and dirty water. Some reports also showed the possibility in purifying wastewater [9] by various techniques (e.g., photocatalysis [10], adsorption [11], membrane [12], etc.), however, this cannot be not considered since most of the wastewater needs extra attention and purification system. Furthermore, for some cases, this type of water is only available in a specific industrial area. The most commonly applied techniques for the rural area are treating groundwater using a conventional filter. A conventional filter is the best for the large and massive water treatment process. The technique is done by introducing water into a certain filtering system to physically screen, adsorb, and sediment the larger component [4].

In the realistic condition in a rural area, prior to introducing to the filtering system, the groundwater is taken from well, putting into a container or a small lagoon to remove larger impurities that are floating and/or sinking in the water. To support the separation, an additional coagulant is sometimes done for assisting a simple chemical reaction to coagulate ions and enlarge impurities. Several types of commercial coagulants are available from either inorganic compound (e.g., aluminium salt and iron) or organic compound (e.g., polyacrylic amide and polyethene imina) [4]. From the container or lagoon, the groundwater has flowed into the filtering system. Then, the results of the filtering system are flowed and collected into other containers for further uses. In the conventional filter, the filter contains several types of well-known and available materials, including activated carbon, manganese, zeolite, activated sand, etc. The arrangement of the materials is also well-understood and passed down through generations.

Treating water using the conventional filtering system is not a new thing, however, there is no information in detail what kind of phenomena happening during the filtering system. This brings ideas for understanding the step-by-step process in the conventional filtering system for treating groundwater, which will be the main objective in this study. To support the discussion regarding detailed phenomena happening during the conventional filtering system, parameters relating to the types of adsorbents are investigated: Activated silica sand, activated carbon (obtained from carbonized coconut fibres), manganese, and natural zeolite. These adsorbents are typically used in the commercial uses and largely available in the local market but there is no information regarding the phenomena. As a model, the study used groundwater in the well in the rural area that is far from the main city in

Central Java, Indonesia. Based on studies by Permatasari et al. [13], the groundwater is also located near the agricultural area, containing more fertilizer components, in which, this will be a good model for describing most water condition in agricultural countries. Experimental results showed that the conventional water treatment system successfully purified the groundwater, in which, the properties and the chemical composition of the treated water are fit with the minimum standard requirement for clean water based on Indonesian regulation. Analysis and discussion in a step-by-step process happening during the treating groundwater were also presented in the paper.

2. Experimental Method

Groundwater was obtained from one of the elementary schools in Kebumen (7° SL and 109° EL), which is located in one of the rural areas in Central Java, Indonesia (see Fig. 1).

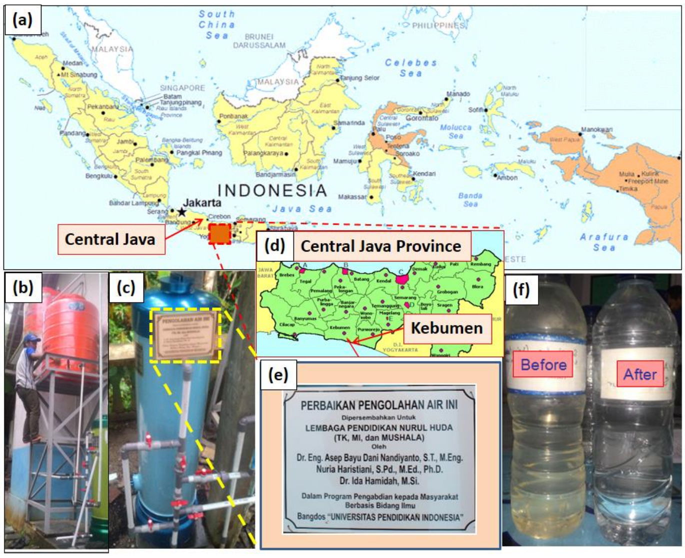

Fig. 1. Location of groundwater object in this study in Indonesian map: (a) to (c) With apparatus setting up, (d) Detailed location for ground water in Kebumen, Central Java, Indonesia, (e) Photograph image of information regarding fund. (f) Samples before and after purification [4].

The groundwater was purified using the conventional filter with a length and a diameter of 200 and 30 cm, respectively. The main idea in this study was to investigate parameters relating to the types of adsorbents, in which, this can be used to understand detailed phenomena during the conventional filtering system. The raw adsorbents are activated silica sand, activated carbon, manganese, and zeolite. Each material was compacted into a package with a diameter of 30 cm and a height of 40 cm (about 1 kg). The filter shell (where the materials are inserted) and water containers are made from polypropylene. To comprehend the step-by-step phenomena during the water treatment system, we investigated the flow of water when introduced into each filter component. All materials were purchased from PT. Ady Water, Indonesia and washed with clean water for about 1 hour (flow of cleaning water of 1 L/min) prior to using. The flow of groundwater into the filtering system was fixed at 1 L/min. To support the water treatment process, two 500-L water containers, a 100-L intermediate water container, and two pumps were used. The first 500-L water container is to put groundwater and flowed using a pump. Then, the water flows into the filtering system. To ensure the cleaning process of water, the flow of groundwater was set using a gravitational force and fixed at about 1 L/min using a simple valve. The product of the filtered water is then collected into a smaller container), in which, this small container is set with the pump to flow the clean water to the second 500-L water container. The clean water can be obtained from the second 500-L water container. Detailed information about the present water treatment system using the conventional filter is shown in Fig. 2. To support the analysis, several methods were used, which is presented in Table 1.

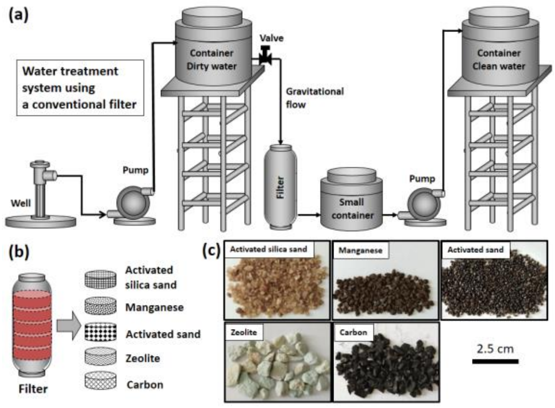

Fig. 2. (a) Illustration of water treatment system, (b) Filter system containing packages of activated sand, manganese, activated sand, zeolite and activated carbon and (c) Photograph images of adsorbents used in filter.

Table 1. Standard analysis for composition of water [4].

Parameter and composition	Method
Color	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
Cuprum (Cu)	APHA-AWWA-WEF 3030-B-2012 / 3111-B-2012
Zinc (Zn)	APHA-AWWA-WEF 3030-B-2012 / 3111-B-2012
Chrome (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.SO_4^{2-}-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 and Discussion

The constructed conventional filter is designed for purifying water from well in the Central Java area (see Fig. 1(a), and the detailed map for the location is shown in Fig. 1(d). In short, the well as the water source is relatively dirty, while the community and people who are near the well have no alternative way for using the water directly to support their lives and activities. The main reason for the unsuitable water is due to the leak and pollution of farming area and highly land erosion, making the water to have high turbidity. To support the filtration process, container (Fig. 1(b) that was set before the filtration system (Fig. 1(c) was used. The optimum condition for the filtration process can change the water into clean water, which can be observed from physical appearance (Fig. 1(e)).

Detailed illustration of the filter system shown in Figs. 1(b) and (c) is shown in Figs. 2(a) and (b), respectively. In short, the system was started by pumping out water from well (Fig. 2(a)). Then, the pumped water was stored into a container, in which, the container is equipped with a vertical filter system. Due to the gravitational force, the water is flown into the filter. The filtered water is pumped into the clean water container for further purposes. The main idea for the filtering system is to absorb or hold unwanted components from the dirty water (Fig. 2(b)). Thus, the filtering system must contain several materials as the adsorbents. In short, the filtration was packed with five layers, in which, the first layer located on the top layer is filled with activated silica. Following the silica, the second layer was filled by manganese. The third and fourth layers were active sand and zeolite, respectively. The final layer was carbon. The physical appearance of solid materials packed in the filter is shown in Fig. 2(c). The shapes of the activated silica sand, manganese, activated sand, zeolite, and carbon are, respectively, brown powder with sizes about 2 mm; coffee bean-liked particles with sizes of about 3 mm; greyish black powder with sizes of about 1.5 mm; ocean blue stone with sizes of around 10 mm; and black particles with sizes of about 4 mm.

Table 2 explains the analysis results of water treatment using several adsorbents, namely silica, manganese, activated sand, zeolite, and carbon. To clarify the results from the filtration process, we marked with a superscript of up (^{up}) and down (^{down}) to inform the increases and decreases in the value compared with the initial groundwater. To confirm the quality of the product, the minimum threshold for the clean water was also presented, based on the Indonesian Ministry of Health No: 416/MENKES/PER/IX/1990 Tanggal 3 September 1990.

The results showed that the main problem in the initial groundwater is the turbidity, manganese (7 times threshold), and nitrite (3 times threshold). Then, by applying adsorbents, it gave a significant impact on cleaning the water, shown by decreases in water turbidity, manganese ion, and nitrite content. The process also allowed increases in the pH of the water. This is comparable with the high release of the nitrite ions that is the main reason for bringing acidity. Then, when we used a combination of adsorbent system, we obtained further decreases in the contaminants, followed by increases in the pH solution. This informs that the combination of adsorbents has better performances to clean water. The results also confirmed that the conventional water treatment system is successfully purified the groundwater, making the physicochemical properties of the purified water to be fit with the minimum standard requirements for clean water for daily activity based on

Indonesian regulation. However, the water is still not suitable for being used as drinking water, informing the need for further purification to be consumable directly.

The process also allowed increases in the nitrate content. This is probably due to the existence of reaction of nitrite into nitrate, confirming the involvement of oxidation in addition to the adsorption process in the present conventional water treatment. The fundamental reason for the occurrence of oxidation is because of the existence of air contact during the filtration system. The filtration system contains a high volume of the void from the spaces between the packed adsorbents. Since the adsorbents are in large particle forms with sizes of more than 1 mm, the more void space can be obtained. This is the main reason why the use of nanoparticles is not effective although they have a surface area that is active for the adsorption process. Packed nanoparticles have less void space, *H* results in the decreases in the possibility of the oxidation process.

The existence of the oxidation also confirms the other possible reactions. For example, the reduction of some dissolved cations, such as manganese and iron. Thus, the dissolved anions can be converted into its oxidized forms, such as manganese oxide and iron oxide that formed as coagulates (not dissolved in water).

Experimental results showed that to get excellent filtration process, the adsorbents must be packed in a specific sequence. Based on the result, we can conclude that the adsorbents must be placed in the following manner: silica, manganese, sand, zeolite, and carbon. Different sequences will create failure in obtaining optimum filtration. However, different sequences will be investigated in our future work. Detailed explanations based on the above analyses in Table 2 are shown in the following:

- The best quality of clean water can be obtained when five types of adsorbents are put in specific sequences. If one of the adsorbents is removed, the quality of the clean water can be decreased.
- Silica, sand, and zeolite can increase sulphate-like anion. These three types of adsorbents cannot be placed at the end of the process. Otherwise, some releasing anions will be created in the final water product.
- Silica is relatively the cheapest adsorbent. Silica is also effective to adsorb turbidity and suspended solids. However, silica can increase the colour in the water, which is because it might be broken and dispersed in water. Thus, silica cannot be placed at the bottom of the filtration. However, since silica is inexpensive and easily change, this material can be put in the top of the filtration. Thus, silica can take most of the large particulates. Silica also acts for preparing more aeration process.
- Carbon is the most effective adsorbent. However, carbon is relatively expensive. Thus, it must be placed at the bottom of the process. Putting the carbon in the top of the filtration is not effective since it can make carbon to work hard and decreases its lifetime.
- Manganese is effective to adsorb several anions. However, manganese is less active than carbon. Manganese has active sites to make oxidation. Thus, it can be placed prior to zeolite to minimize the number of anions that can disturb the zeolite reaction as well as lead the first oxidation (decreasing the work of zeolite). 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).

- Zeolite is one of the most active materials since it can act as a catalyst for making reduction and oxidation reaction. However, to make a longer lifetime of the zeolite, some adsorbents must be placed prior to the zeolite. Zeolite is also effective to reduce the hardness (Ca^{2+} and Mg^{2+} ions). That is why the lowest hardness can be obtained after contacted with zeolite.

Table 2. The analysis result of water treatment by several adsorbents.

Parameter	Unit	Initial sample	Treatment						Sample
			Silica	Mn	Sand	Zeolite	Carbon	Comb.[1]	
Physical properties									
Turbidity	NTU	76	2.2^{down}	2.96^{down}	0.62^{down}	7.29^{down}	2.94^{down}	3.0	25
Color	PtCo	1.8	5.5^{up}	1.0^{down}	1.5^{down}	1.2^{down}	1.6^{down}	1.6	50
Dissolved residue	mg/L	514	364^{down}	369^{down}	365^{down}	405^{down}	351^{down}	361^{down}	1500
Chemical properties									
Iron (Fe)	mg/L	<0.012	<0.012	<0.012	<0.012	<0.012	<0.012	<0.012	1.0
Detergent	mg/L	0.163	0.153^{down}	0.090^{down}	0.138^{down}	0.171^{up}	0.135^{down}	0.135^{down}	-
Fluoride (F)	mg/L	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	1.5
Cadmium (Cd)	mg/L	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.001^{down}	0.005
Hardness ($CaCO_3$)	mg/L	276	149^{down}	153^{down}	141^{down}	129^{down}	153^{down}	146^{down}	500
Chloride (Cl)	mg/L	85.7	66^{down}	70^{down}	72^{down}	68^{down}	70^{down}	60.5^{down}	600
Chrome (Cr^{2+})	mg/L	<0.021	<0.021	<0.021	<0.021	<0.021	<0.021	<0.004^{down}	0.05
Manganese **(Mn)**	mg/L	3.53	0.106^{down}	0.143^{down}	0.140^{down}	0.140^{down}	<0.006^{down}	<0.006^{down}	0.5
Nitrate (NO_3-N)	mg/L	1.67	3.15^{up}	3.09^{up}	2.58^{up}	3.29^{up}	3.27^{up}	0.38^{down}	10
Nitrite (NO_2-N)	mg/L	3.38	<0.001^{down}	0.003^{down}	0.008^{down}	0.062^{down}	0.074^{down}	0.007^{down}	1.0
Permanganate value ($KMnO_4$)	mg/L	8.1	6.10^{down}	3.66^{down}	3.65^{down}	4.26^{down}	7.33^{down}	5.5^{down}	10.0
pH	-	6.8	7.86^{up}	7.82^{up}	7.67^{up}	7.83^{up}	7.88^{up}	8.1^{up}	6.5 - 9
Zinc (Zn)	mg/L	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	15
Sulphate (SO_4)	mg/L	10.9	23.2^{up}	10.2^{down}	15.5^{up}	12.6^{up}	7.1^{down}	1.2^{down}	400
Cyanide (CN)	mg/L	<0.003	<0.003	0.003^{up}	<0.003	<0.003	<0.003	<0.003	0.1
Cubrum (Cu)	mg/L	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013	<0.012^{down}	-
Plumbum (Pb)	mg/L	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	0.020^{down}	0.05

Note: 1. Comb. = combination of silica, manganese, sand, zeolite, carbon, 2. Based on Indonesian Ministry of Health No:416 /MENKES/PER/IX/1990 Tanggal 3 September 1990, superscripts of "up" and "down" are to inform the value compared with the initial sample.

4. Conclusions

Understanding the step-by-step process in the conventional filtering system for treating groundwater has been discussed. Experimental results showed that the conventional water treatment system successfully purified the groundwater, in which, the properties and the chemical composition of the treated water are fit with the minimum standard requirements for clean water for daily activity based on Indonesian regulation. However, for being used for drinking water, further purification must be added. Analysis and discussion in a step-by-step process happening during the treating groundwater were also presented in the paper. Finally, the present study would create a better understanding of the use of the water treatment system using a conventional filter in the realistic condition, especially for the agricultural area.

Acknowledgements

We acknowledged "Program Pengabdian kepada Masyarakat Berbasis Bidang Ilmu (PKM Bidang Ilmu)" from Bangdos, Universitas Pendidikan Indonesia for its support in funding our study.

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