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SIMPLE DESIGN OF DYE WATER FILTERING SYSTEM FOR CLEAN AND HEALTHY WATER QUALITY

Tony K. Timpua
Department of Environmental Health, Poltekkes Kemenkes Manado, Indonesia
tonytimpua@gmail.com

Jasman
Department of Environmental Health, Poltekkes Kemenkes Manado, Indonesia
jasman@gmail.com

Robinson Pianaung
Department of Environmental Health, Poltekkes Kemenkes Manado, Indonesia
robinson.pianaung@gmail.com

Deitje S. Pongoh
Department of Electrical Engineering, Politeknik Negeri Manado, Indonesia
pongohdeitje@gmail.com

Emma J. Pongoh
Department of Chemical Engineering, Universitas Negeri Manado, Indonesia
emma.pongoh@gmail.com

Syafaruddin
Department of Electrical Engineering, Universitas Hasanuddin, Indonesia
syafaruddin@unhas.ac.id

Abstract

Demand of clean and healthy water services in the community requires innovation of appropriate technology, for instance through the development of filtering to groundwater systems or to water wells with high turbidity levels in order to meet the water quality standards *based on health requirements. The proposed design of dye water filtering system utilizes simple filter media such as sand, gravel, active charcoal and palm fibers. The purpose of this study is to determine the ability of the dye water filtering system to reduce turbidity, contaminations of Ferrum (Fe) and Manganese (Mn) and total coliform bacteria. It is expected that the proposed design of dye water filtering system may produce clean and healthy water with good quality. The laboratory test results indicate that proposed design is effectively to reduce the turbidity level and the Fe concentration that contaminated in the water. Meanwhile, it still is necessary to increase the capability of filtering system by replacing the sand with smaller diameter in order to decrease the levels of Mn and adding disinfectant in order to minimize the concentrate of total coliform bacteria.*

Keywords

Dye Water Filtering, Filter Media, Turbidity, Contaminants of Fe and Mn, Coliform Bacteria

1. Introduction

According to World Bank data in 2013, only 20% of Indonesian population have good access to clean water services. Mostly, they are living in urban areas. This evidence is proved by *Jim Woodcock*, a water and sanitation consultant from the World Bank who presents research results that approximately 100,000 babies in Indonesia decease each year from diarrhea which the deadliest secondary diseases after the acute respiratory infections. The apparently main causes of this problem is the lack of access to clean water and sanitation. In parallel to the previous research, (Kurniawan, 2015) mentioned that one of the main obstacles in the provision of clean water in Indonesia is a limited supply of water. Most operation of clean water service companies relying on raw water from river flow. However, the flow discharge of important rivers is steadily declining, for instance Solo River dropped to 44.18 m^3/sec, Serayu River decreased to 45.76 m^3/s and Cisadane River reduced to 45.10 m^3/s.

One alternative water sources to meet the water needs of society in rural and urban areas are water wells, but the water quality of wells is still low. The health profile of Manado City in 2012 depicts that there were 11.8% of people using wells as a source of fresh water for domestic and drinking purposes (Tombokan, 2014). The physical conditions of wells are sometimes not eligible or properly constructed (Katiho et al., 2011). In this respect, the average turbidity level of the water wells is 87.5 mg of SiO_2/liter and the average contents of E. coli bacteria and Coliform are 6.8/100 ml and 518/100 ml, respectively (Harmayani et al., 2007). To overcome these problems, it is necessary to design filtration systems and to decrease the levels of contaminants such as bacteria, color, taste, smell and Ferrum (Fe) in order to meet the clean water standards.

According to (Suprihatin et al., 2013), the filtration design includes the mechanical or physical processes. The main effect of filtration is to maintain particles which have a larger size than the pore size of the filter. The deposition or adhesion of particles on filter media grains caused by the power mechanism of Van der Waal, electrochemical power (adsorption), chemical and biological reactions. Water filtrations process that has been widely known in the community are slow and rapid sand filters. Referring to (Chandra, 2007), the filter water immersion wells to reduce water turbidity is categorized as water treatment unit. The filtering system is commonly made of a series of PVC pipe with filter media of sand, gravel, charcoal and fibers that can be directly immersed in wells.

The proposed design of filtering system in this research is the further development of dye water filtering system with the filter media of sand, gravel, charcoal, and fibers to reduce water turbidity designed by (Tombokan, 2014) and developed by (Timpua et al., 2015). The capability of dye water filtering system is claimed to reduce water turbidity level with the average percentage of 85.82%. The detail of proposed filter design is presented in the following sections.

2. Configuration of Proposed Design

Filtration is the process of filtering out the particles through physical, chemical and biological process through porous media. During the filtration process, the impurity substances in the filter media will be blocking the pores of the media so that the loss pressure would be binding. The filter media that is often used is sand, because it is easily found and economical. The other filter media rather than sand is an active carbon. Media in water filter system is functioning to strain the foreign particles that may be contained in water and to filter the water so that the dangerous substances and various other particles is separated from the water. Thus the water will be cleaner and healthier for meeting the daily use. The use of a water filter is one of the efforts in obtaining the clean and healthy water supplies. The dye water filtering system is proposed due to the existing of water source has still high levels of turbidity, odorless and tasteless, the characteristics of the water as it is not healthy and safe to be used or consumed.

The design of dye water filtering system which is shown in Figure 1 is made of 8" Polyvinyl chloride (PVC) as the main pipe with the filter media of 0.1-0.2 mm in diameter of sand, charcoal from coconut shell, palm fiber and a little gravel. Due to the use of relatively fine sand media, the proposed design is categorized as slow sand filter. Inside the main pipe, another PVC pipe of 3” in diameter is inserted as a storage space and clean water pumping.

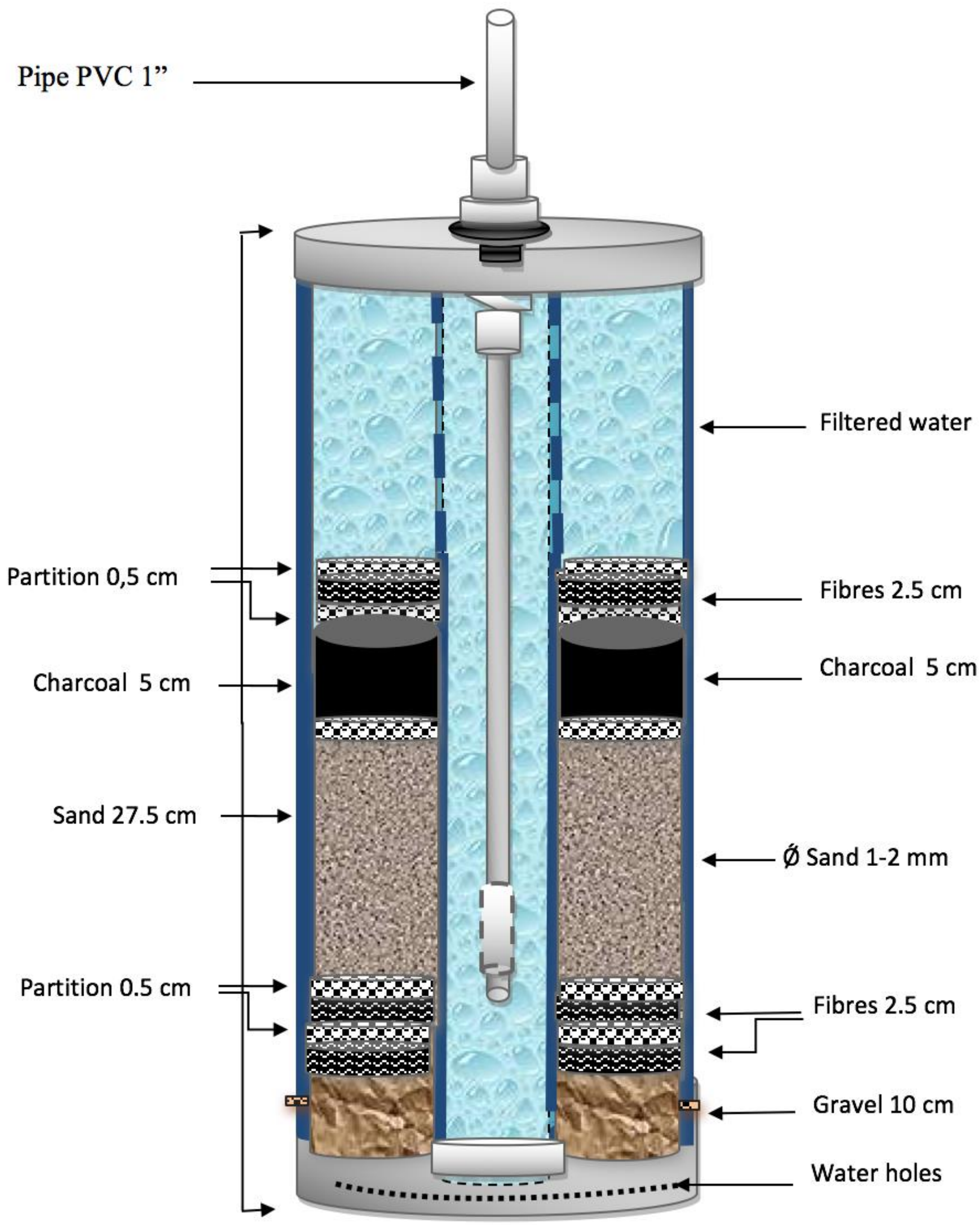

Figure 1: *Design of dye water filtering system*

In the application, the designed dye water filtering system immersed into the wells or infiltration wells, placed hanging inside the wells without reaching the bottom part as shown in Figure 2. The mechanism is then water will infiltrate into this dye filter slowly through a gap at the bottom part and come through the filter media of gravel, sand, fibers and coconut shell charcoal and finally entered the water storage space. The proposed filter has very small porosity and permeability, so that the organic particles including bacteria in the water will be retained on media to obtain clean water. The extraction of water from inside storage space utilizes a small water pump engine with a power of 75 Watts with the discharge flow capability of 12 liters/minute. Meanwhile, the operation of the pump suction resulted in increased in water infiltration from wells into the dye filter, so that the water storage space continues to be filled with clean water.

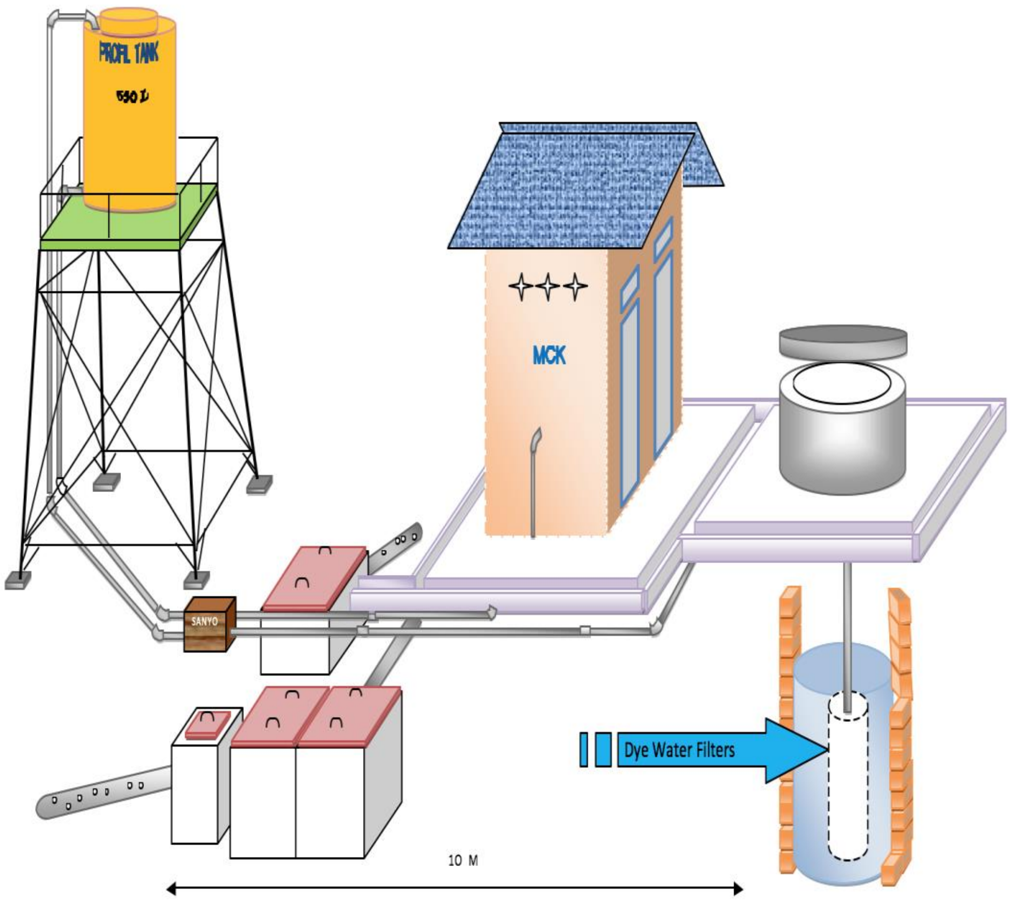

Figure 2: *The sanitary systems with proposed dye water filtering system*

The filtration system is necessary to decrease the levels of unsafe contaminants such as bacteria, color, taste, smell and Ferrum (Fe) in order to obtain clean water that meets the clean and healthy water standards. According to (Asmadi et al., 2011), the filtering process may be able to clean the water by passing the water through a porous medium. Particles or remnants of contaminants can be separated through the filtering process. Again, the filtering media that can be used is a layer of sand, gravel and anthracite. Another understanding of filtering is the process of separation between the solid and liquid colloids. The filtering process can be an initial process (primary treatment) or filtering from the previous process, for example the filtering from the coagulation results (Kusnaedi, 2010).

3. Parameters of Test Results

Groundwater can be contaminated with synthetic organic chemicals. These materials are generally in very low concentrations and not detected from the color, taste and smell. However, the contaminants may have high risk for health because they are toxic and carcinogenic. Normally, the groundwater does not contain any suspended solids; therefore it is not feculent and it does not require any processing stages with coagulation or flocculation. In this respect, it is important to measure the performance of proposed design dye water filtering system for groundwater sources. There are four testing parameters to evaluate the performance of designed dye water filter, such as turbidity, the contaminants of Ferrum (Fe) and Manganese (Mn) and total of coliform bacteria.

3.1 Water turbidity

Water turbidity might be influenced by the objects of fine suspended materials, such as mud, the presences of microorganisms and plankton and the color of water. The presence of plankton and microorganism can be considered as good turbidity. When turbidity is caused by plankton, the turbidity reflects the number of individuals microorganisms that float and always follow the motion of the water. Meanwhile, the turbidity due to suspension of colloidal soil or sludge, especially iron hydroxide is very dangerous for biota cultivation because it could stick to the gills that disturbing the respiratory systems of biota. If the gills are damage, it will be easily infected with a strain of protozoa and bacteria. Also, the lack of oxygen in body tissues often result in necrosis of heart tissue.

The testing results of water turbidity in Table 1 was taken from laboratory test on several samples in the conditions of before and after filtering. The results prior to the filtering indicates the fluctuation numbers where the highest turbidity level is 44.60 mg/liter and the lowest level is 17.76 mg/liter with an average water turbidity level before filtering is 25.3 mg /liter. After filtration with flow rate of 12 liters/minute, the flow of turbidity is 3.8 mg/liter with a percentage of 83.79% decline in turbidity.

Table 1: *Turbidity test results (Flow rate = 12 liter/minutes)*

No	Sample code	Turbidity (mg/liter)		Deviation (mg/liter)	Reduction (%)
		Before filtering	After filtering		
1	01	35.33	4	31.33	88
2	02	19.42	4.49	14.93	76.87
3	03	21.38	4.14	17.24	80.63
4	04	21.47	3.99	17.48	81.41
5	05	28.85	3.76	25.09	86.96
6	06	44.60	3.61	40.99	91.90
7	07	22.32	3.59	18.73	83.91
8	08	23.94	3.50	20.44	85.38
9	09	17.93	3.34	14.59	81.37
10	10	17.76	3.29	14.47	81.47
	Average	**25.3**	**3.8**	**21.5**	**83.79**

3.2 Contaminants of Ferrum (Fe) and Manganese (Mn)

Groundwater generally contain Ferrum (Fe) and Manganese (Mn) in high concentrations. Therefore, the groundwater usually requires softening stages of processing and aeration to precipitate the mineral. The pollution sources groundwater might be from industrial waste, landfill, mining, agricultural, residential waste and seawater intrusion (Suprihatin et al., 2013). According to (Said, 1999), the contaminants of Fe and Mn in water is usually dissolved in the form of compounds or salts bicarbonate, sulfate salts, hydroxides, and also in the form of colloidal or in a state to form the organic compounds. Thus, it requires processing methods in accordance with form of Fe and Mn compounds in the water to be treated.

In terms of Fe contaminant, the Ferrum is defined as a silvery-white metal, clay form and can be molded (Slamet, 1994). In nature, the Fe is found as hematite and the Fe may cause the drinking water of being taste, yellow color, deposition on the pipe wall, the growth of iron bacteria and turbidity. Basically, the Fe element is needed by the body in the formation of hemoglobin. The amount of Fe in the body is controlled in the absorption phase. The human body cannot excrete the Fe element. However, although the Fe is needed by the body, the large doses can damage the intestinal wall and the Fe dust can be accumulated within the alveoli and leads to reduce the lung function.

Table 2: *Contaminant of Ferrum (Fe) test results*
(Flow rate = 12 liter/minutes)

No	Sample code	Ferrum (mg/liter)		Deviation (mg/liter)	Reduction (%)
		Before filtering	After filtering		
1	01	0,7680	0,0190	0,7490	97,52
2	02	0,7374	0,0182	0,7192	97,53
3	03	0,9940	0,0249	0,9601	96,58
4	04	0,9710	0,0243	0,9467	97,49
5	05	0,8638	0,0215	0,8423	97,51
6	06	0,8025	0,0199	0,7826	97,52
7	07	0,9748	0,0244	0,9504	97,49
8	08	0,8982	0,0213	0,8348	97,51
9	09	0,3660	0,0197	0,7751	97,52
10	10	0,3621	0,0224	0,8758	97,50
	Average	**0.8660**	**0.0215**	**0.9366**	**97.42**

The testing results regarding the performance of designed dye water filtering system to the Fe contaminant is shown in Table 2. The results indicate from the laboratory test on several water sample where the contaminant of Fe before filtering have the highest level of 0.9940 mg/liter and the lowest level is 0.3621 mg/liter with the average of 0.8860 mg/liter. Meanwhile, there is significant decrease of Fe contaminant after filtering of 97.42% with the average of 0.0215 mg/liter.

Meanwhile, Manganese (Mn) is a reddish-gray metal. The poison of Manganese is often chronic as a result of inhalation of dust and metal vapor. The symptoms manifest after contaminated is in the form disturbances of nervous system, insomnia, weak legs and weak muscles of the face so that facial expressions became frozen and looked like a mask. When the poisoned exposure continues, it causes slowed speech and monotonous, hyper-reflection occurs, clonus and patella on heels and the patients may walk like people with Parkinson syndrome. The symptom of poisoned Manganese (Mn) does not cause symptoms of poisoning with vomiting and diarrhea. Manganese also cause problems purple-black color on the wall of the pipe.

Table 3: *Contaminant of Manganese (Mn) test results*
(Flow rate = 12 liter/minutes)

No	Sample code	Manganese (mg/liter)		Deviation (mg/liter)	Reduction (%)
		Before filtering	After filtering		
1	01	0.4223	0.0884	0.3339	79.06
2	02	0.4202	0.0880	0.3352	79.77
3	03	0.4490	0.0935	0.3335	74.27
4	04	0.4464	0.0930	0.3534	79.16
5	05	0.4307	0.0900	0.3407	79.10
6	06	0.4532	0.0943	0.3589	79.19
7	07	0.4683	0.0972	0.3711	79.24
8	08	0.4553	0.0947	0.3606	79.20
9	09	0.4558	0.0948	0.3610	79.20
10	10	0.4798	0.0994	0.3804	79.28
	Average	**0.4481**	**0.0923**	**0.3528**	**78.75**

The existence of Manganese in water samples as shown in Table 3 before filtering has the highest level of 0.4798 mg/liter and the lowest level is 0.4202 mg/liter with an average of 0.4481 mg/liter. After filtering, the Mn concentrate levels down to the average rate of 0.0923 mg/liter by means the percentage drop of Mn concentrate is 78.75%.

3.3 Total of coliform bacteria

Coliform bacteria is a class of intestinal bacteria which lives in the human digestive tract. Coliform bacteria are indicators of the presence of other pathogenic bacteria. More precisely, fecal coliform bacteria is an indicator of contamination of pathogenic bacteria. The characteristics of coliform bacteria are aerobic or facultative anaerobes, categorized into gram-negative bacteria, no-form spores and it produces ferment lactose to produce acid and gas at a temperature of 35-37°C. Examples of coliform bacteria include Escherichia coli, Salmonella, Citrobacteria, Enterobacteria, Clebsiella.

Determination of fecal coliform as indicators of pollution due to the number of colonies certainly has positively correlated with the presence of pathogenic bacteria. In addition, the detection of coliform is much cheaper, faster, and simpler than detecting other pathogenic bacteria. Examples of coliform bacteria are Escherichia coli and Enterobacteria aerogenes. Therefore, the coliform is an indicator of water quality by means the less the content of coliform, the better the water quality (Nengsih, 2010). The laboratory test results regarding the total coliform content in Table 4 indicate that the total coliform before filtering is an average of 2140/100 ml. After filtering, the average 1194/100 ml with the percentage reduction of 47.64%.

Table 4: *Total coliform bacteria contaminant test results*
(Flow rate = 12 liter/minutes)

No	Sample code	Total coliform (per 100 ml)		Deviation (per 100 ml)	Reduction (%)
		Before filtering	After filtering		
1	01	>2400	>2400	0	0
2	02	>2400	>2400	0	0
3	03	>2400	1100	1300	54.17
4	04	>2400	1100	1300	54.17
5	05	>2400	1100	1300	54.17
6	06	>2400	1100	1300	54.17
7	07	>2400	1100	1300	54.17
8	08	>2400	1100	1300	54.17
9	09	1100	460	640	58.18
10	10	1100	75	1025	93.18
	Average	**2140**	**1194**	**947**	**47.64**

4. Discussions

Turbidity is an optical effect that occurs when the ray beam forming suspended material in the water. Water turbidity can be caused by the presence of organic and inorganic materials, such as sludge and effluent from a certain surface that causes river water to become feculent. Laboratory test results in Table 1 with flow rate (Q) = 12 liter/min shows the levels of turbidity before filtering exceeds the limit, i.e 25.3 Nephelometric Turbidity Unit (NTU). After filtration, the NTU value within the limits specified in the Regulation of Ministry of Health of Indonesia which is 3.8 with the percentage decline of turbidity is 83.79%. The results can be claimed to fulfill the objective criteria that the proposed design of dye water filtering system can reduce effectively the turbidity of more than 80%.

The previous results by (Timpua et al., 2015) about the modification of the dye filter wells, it demonstrates effectively for lowering the turbidity of 92.59%. The percentage of decrease in the level of turbidity is higher due to the diameter of the sand is smaller (1 mm) and the suspension would be separated with water because the suspension cannot pass through the pores of the filter media. As results, the turbidity level decreases as the value of the turbidity increases with the number of particles or suspension contained in the water.

Water which high turbidity is difficult be processed into a clean water source. The another difficulty is during the filtering process. The water with high turbidity will be ineffectively disinfected, i.e the process of removing unexpected microbial content. Turbidity levels are affected by water pH where turbidity in drinking water generally has been alleviated in such a way that the water becomes clear and clean. According to (Timpua et al., 2015), the turbidity in the raw water is caused by the presence of dissolved organic matter and the activity of bacteria in the water with NTU, otherwise by the scale of Silica (SiO_2). Appropriate turbidity according to the water quality standards in the regulation of Ministry of Health of Indonesia is the maximum of 5 NTU for drinking water and 25 NTU for clean water.

Regarding to the Ferrum (Fe) contamination, the iron is a natural element that can be found in soil and rocks. The iron and Manganese can be attributed to the weathering of rocks and minerals. With low alkalinity, the Fe levels may reach 10 mg/liter and it is usually found in water wells, lake and reservoir. The laboratory test results shows a decrease of 97.42% of Fe content after filtration by means the Fe contamination before and after filtration are 0.8660 mg/liter and 0.0215 mg/liter, respectively. The results indicate that the proposed dye water filtering is effectively lowering the Fe content in the water. The previous study presented that the concentration of iron (Fe) in water that is utilized as clean water after filtering process has an average rate of decrease down flow and top flow are 0.2007 mg/liter (91.15%) and 0.1189 mg/liter (93.39%), respectively.

According to (Taufan, 2016), the Ferrum (Fe) contents in water has common properties, for instance inlaid with organic substances or inorganic solids, such as clay; suspended as colloidal grains (diameter < 1 μm) or greater as Fe_2O_3, FeO, $Fe(OH)_3$ and so on; dissolved as Fe^{2+} (ferrous) or Fe^{3+} (ferric). Dispersion of Fe content in the water can be obtained higher when water filtration is combined with aeration process that enables the reaction between oxygen with Ferrum. The results of this chemical reaction is the Fe will be deposited in water that will be easily filtered through the filter pores.

In terms of Manganese (Mn) contaminant, the ability of the proposed dye water filtering system to reduce the Mn content is high enough but it has not reached the set objective criteria of 80%. Based on the laboratory test results, the average Manganese content before filtration is 0.4481 mg/liter and after filtering the average content 0.0923 mg/liter with a decline percentage of 78.75%. This effort is said to be ineffective because the percentage has not reached 80%. According to (Said, 2016), the iron and Manganese in the water are in the compound states with organic substances. The most often effort to eliminate the iron or manganese in water is by oxidation and solids separation. In this respect, the Manganese is harder than iron because the level of manganese oxidation rate is lower than the iron oxidation.

The existence of Manganese (Mn) in water exists in the form of suspended and dissolved materials. In fresh water, it contains one to several thousand micrograms of Manganese per liter. Even the ground water often contains dissolved Manganese (Mn) in high concentration. High Manganese levels normally found in industrial areas. Reduction of high levels contaminant is needed in groundwater where the concentration tends very high in some lakes and reservoirs. According to (Taufan, 2016), the presence of Manganese in drinking water can affect the human health. The concentration that exceeds 0.15 mg/liter can cause unpleasant taste and stains on plumbing equipment and clothing. When Manganese compounds through oxidation, the Manganese will precipitate. Even the concentration of 0.02 mg/liter, the Manganese will form a black coating on the pipe. It can also cause interference with the growth of organism. High Manganese concentration causes problems of smell, taste and turbidity in water distribution.

The last laboratory test result is to determine the contaminants of coliform bacteria. This type of bacteria is classified as intestinal bacteria that lives in the human digestive tract. Coliform bacteria are indicators of the presence of other pathogenic bacteria and contaminated bacterial pathogens. Determination of fecal coliform as indicators of pollution due to the number of colonies certainly positively correlated with the presence of pathogenic bacteria. Nonetheless, the detection of coliform bacteria is much cheaper, faster and simpler than detecting other pathogenic bacteria. Examples of coliform bacteria are Escherichia coli and Enterobacteria aerogenes. For these reasons, the coliform bacteria is an indicator of water quality. The less the content of coliform, the better the water quality.

The laboratory test results regarding the total coliform content indicates that the average contaminants are 2140/100 ml before filtering and 1194/100 ml after filtering with the percentage decline of 47.64%. It is due to the maximum limit capability of detection tools which only reached 2400 most probable number (MPN). Therefore, if the number of coliform over 2400 MPN, the measurement result just indicate > 2400 MPN. The low decline of coliform bacteria content after filtering can be also caused by the inoptimal formation of biofilm. In addition, the gradation of media filter size is still quite large (2 mm) which results of leakage the coliform bacteria contents (Ati, 2016).

5. Conclusion

Simple design of dye water filtering system in water wells has been presented to provide solution for clean and healthy water service in the community. The proposed design utilizes filtering media of sand, gravel, active charcoal and palm fibers which are easily found in markets.

The laboratory test results indicate that proposed design is effectively to reduce the turbidity level and the Ferrum (Fe) concentration that contaminated in the water in order to meet the healthy water standard requirements. Nevertheless, it is still necessary to increase the capability of dye water filtering system by replacing the sand with smaller diameter in order to descend the levels of Manganese (Mn) and adding disinfectant in order to minimize the concentrate of total coliform bacteria.

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