Study of Contact Time and Media Thickness on Rainwater Harvesting Technology Filtration at Tidar University

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Keywords:
Filtration,
Rainwater Harvesting,
Logistic Regression,
Thickness of Media,
Contact Time

ABSTRACT

Rainwater harvesting as an alternative raw water source can reduce water runoff. However, rainwater has been in contact with various pollutants in the air. In testing in Building 3, Faculty of Engineering, Tidar University, rainwater contained levels of E. Coli 8 CFU/100ml and Coliform 69 CFU/100ml which exceeded the quality standard of the Minister of Health Regulation No. 32 of 2017. This study aims to see the effect of media thickness and contact time on each mediA to improve rainwater quality using the Vertical Flow Roughing method. Up Flow filter flow with 3 filters containing zeolite gravel, activated carbon, and volcanic sand, with each having 3 different thickness variations, namely 60 cm, 70 cm, and 80 cm. The filter is operated for 18 minutes with sampling every 6 minutes. The results of logistic regression and log likelihood test showed that there was no significant effect on all filtration media in reducing the value of E. Coli and Coliform, but the highest efficiency occurred at 18 minutes with a thickness of 80 cm in each medium. In zeolite gravel filtration, the efficiency of reducing E. Coli and Coliform reaches 100%. In activated carbon filtration, the efficiency of E. Coli reduction was 100% and Coliform 51%. In volcanic sand filtration, the efficiency of E. Coli reduction is 100% and Coliform is 35%.

1. Introduction

Rainwater Harvesting (RWH) is a rainwater harvesting method that utilizes the roof of a building as a rainwater storage medium. Rainwater that falls on the roof of the building is channeled through pipes to then be collected and stored in a reservoir [1]. In the rainwater test in Building 3, Faculty of Engineering, Tidar University, the rainwater contained levels of E. Coli 8 CFU/100ml and Coliform 69 CFU/100ml which exceeded the quality standard of Minister of Health Regulation No. 32 of 2017. The research aims to see the effect of media thickness and time. contact on each medium to improve the quality of rainwater.

Coliforms are a group of bacteria that are used as indicators of microbial contamination of water quality, usually through feces whose conditions impair the quality of water, food and beverages. The Coliform group as a group of bacteria is characterized by rod-shaped, gram-negative, non-sporing, aerobic, and facultative anaerobic bacteria that ferment lactose to produce acid. Escherichia coli is one of the Coliform bacteria belonging to the Enterobacteriaceae family. Escherichia coli is a gram-negative, facultative anaerobic rod-shaped bacterium, does not form spores, and is a natural flora in the mammalian intestine [2]. E.coli is also known as hygiene and hygiene indicator bacteria, namely the presence of bacteria in food which indicates a low level of sanitation hygiene applied.

Based on the literature study, one of the water treatments that can be done to overcome these problems is the filtration process. Water that moves vertically or perpendicularly makes solid pollutants contained in the water able to settle at the bottom of the filtration. In the Up Flow vertical filter, it is supplied by water flowing at the bottom of the filter [3].

Filtering using an upflow system is believed to be more effective in reducing the occurrence of deadlocks on the media. In addition, it is easier to clean the media. The upstream filtration system does not require chemicals, can remove manganese, iron, as well as color and turbidity. The Up Flow filtration system can also remove organic pollutants and ammonia [4].

The thickness of the media and the time of filtration affect the water quality, it can be concluded that the thickness of the filter media has a large effect on the filtration discharge and reduces the value of the parameters contained in the water, the thicker the filter media, the smaller the value of the parameters contained in the water. slows down the filtration discharge, but the quality of the water produced is better [5].

2. Methods

Schematic of the research method for the study of contact time and media thickness on rainwater harvesting technology filtration at Tidar University is shown in Figure 1.

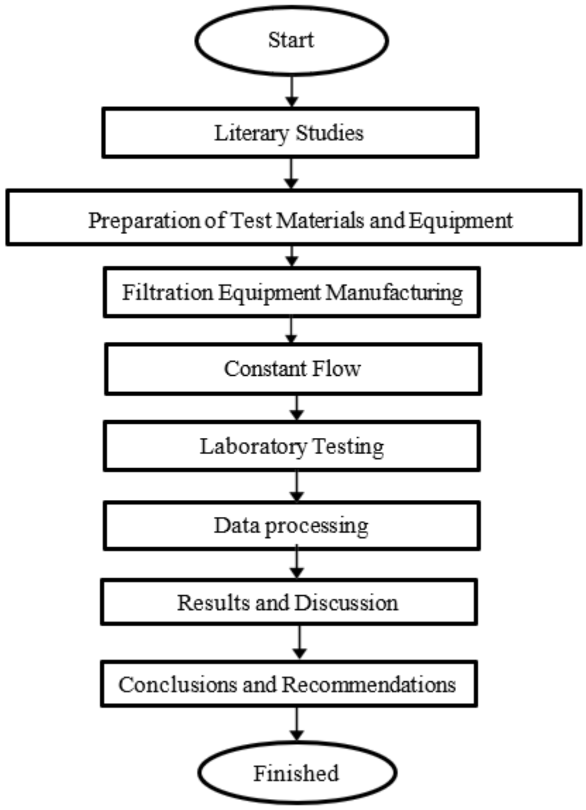


Figure 1. Research method scheme

In this study, media with a thickness of 80 cm, 70 cm, and 60 cm were used in each variation per medium and the contact time for each filter was 6 minutes, 12 minutes, and 18 minutes.

2.1. Tools and Materials

The filtration device is made using a 4” PVC pipe with a length of 1,2 meters. Then the materials needed are zeolite gravel, activated carbon, volcanic sand, and filter cotton. Details of the arrangement of the media layers in each filter are shown in Figure 2, Figure 3, dan Figure 4.

Sand has advantages as a filter medium because the particles are free, porous, degraded and homogeneous. Volcanic sand has the ability to filter dirt and small particles from the water because the grains of sand have pores that are small enough, so that larger particles can be retained.

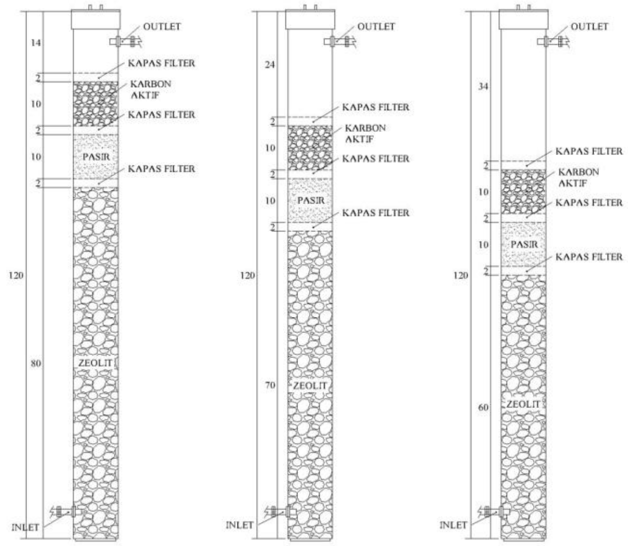


Figure 2. Zeolite gravel filtration variations

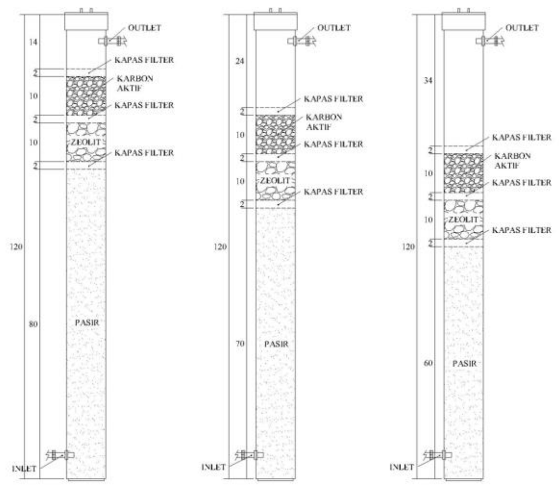


Figure 3. Vulcanic sand filtration variations

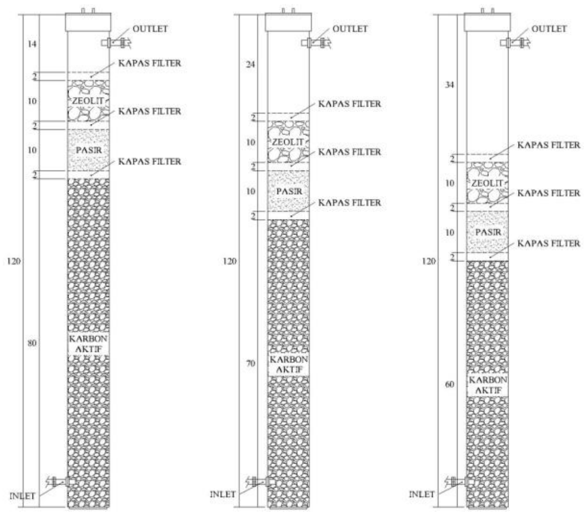


Figure 4. Activated carbon filtration variations

Volcanic sand has the same properties as silica sand > 60% which is able to reduce turbidity, manganese and iron. In addition, volcanic sand is easy to obtain and the price is relatively cheap [6].

Activated carbon or Granular Activated Carbon (GAC) is free carbon and has an inner surface, so it has good adsorption properties. Activated carbon is able to remove organic content from water and also reduces unpleasant odors, colors and tastes. Activated carbon has a very strong adsorption capacity due to its high adsorption pore volume. A study showed that activated carbon filtration systems using granular activated carbon were more effective at removing chlorine, bad odors, and microorganisms. The activated carbon filter design must ensure that the filter is deep/thick enough so that contaminants will be absorbed into the activated carbon system during the filtration process [7].

2.2. Sampling and Tool Running

The process of running the filtration device starts from collecting rainwater from the roof of the building in an artificial pond measuring 1 m x 2 m x 0.5 m. After being accommodated, the pond is placed in Building 3, Faculty of Engineering, Tidar University for 26 days from April 29, 2022 – May 24, 2022. Rainwater can be filtered and operated by connecting an auxiliary pump from the holding pond with a hose to the inlet of the filtering device. After the water enters the filter, the filtering process begins and the water exits through the filter outlet, then enters a 250 ml glass bottle for laboratory testing conducted at the Center for Environmental Health and Disease Control Engineering (BBTKLPP), Yogyakarta. Sampling was carried out on Tuesday, May 24, 2022 starting at 05.35 WIB on filter 1 and its multiples until all filters were completed up to 11.04 WIB.

2.3. Data processing

The stages in data processing are carried out with the following steps:

(1) Calculation of Filtration Output Discharge
If the flow rate and water flow rate increase, the filtration effectiveness will decrease. In a study conducted by Solihin (2009) discharge also affects the saturation of activated carbon, a discharge that is too large carries large amounts of pollutants, so that the filter becomes saturated faster. Calculating debit is calculated by equation (1) [8].

$$Q = \frac{V}{t} \tag{1}$$

where Q is the flow rate, V is the volume of the water holding container per unit liter, and t is the time it takes the water to fill the container per unit second.

(2) Filter Efficiency
The results of the filtration are analyzed in the laboratory to determine the efficiency of the decrease that occurs in the E. Coli and Coliform parameters, after the results are known, the efficiency can be sought by comparing the influent and effluent and expressed in percent. Efficiency calculation:

$$Efficiency = \frac{C_{in} - C_{out}}{Cin} \times 100\% \tag{2}$$

where Cout is the Yield after filtration and Cin is the Yield before filtration.

(3) Logistics Regression
In this study, a logistic regression model was used to determine the effect of decreasing E. Coli and Coliform with operating time and media thickness for each filtration with SPSS application. Binary logistic regression is a common linear model used for binomial regression and is widely used as a modeling analysis tool when the response variable (Y) is binary. The term binary refers to the use of two-digit categories, 0 and 1, in place of the two categories of response variables. Hypothesis testing is carried out simultaneously to determine whether the independent variables used simultaneously affect the dependent variable. In the binary logistic regression model, the likelihood comparison test is used to test the parameters simultaneously.

3. Results

3.1 Rainwater Test Results Before Filtration

The results of the rainwater testing before filtering are shown in Table 1.

Table 1. Laboratory test results before filtration process

No	Parameter	Unit	Maximum Rate	Test results
1	E.Coli	CFU/100ml	0	8
2	Coliform	CFU/100ml	50	69

Based on Table 1, it can be seen that the quality of the biological parameters of rainwater in the environment of Building 3, Faculty of Engineering, Tidar University, has not met the quality standards of the Regulation of the Minister of Health of the Republic of Indonesia Number 32 of 2017. Parameters that do not meet these quality standards include E. Coli bacteria reaching 8 CFU/100ml and Coliform reached 69 CFU/100ml. The water quality problem needs to be addressed immediately by treating the water by filtering using a filter media that can remove E. Coli and Coliform bacteria, namely with activated carbon, zeolite gravel and volcanic sand. Filtration in this study uses three types of filter variations that have different thicknesses.

3.2 Calculation of Filtration Discharge of Each Filter

Discharge is measured by calculating the time it takes to completely fill a liter water tank. Repeat 3 times and find the average. The results of the discharge measurement are shown in Figure 5.

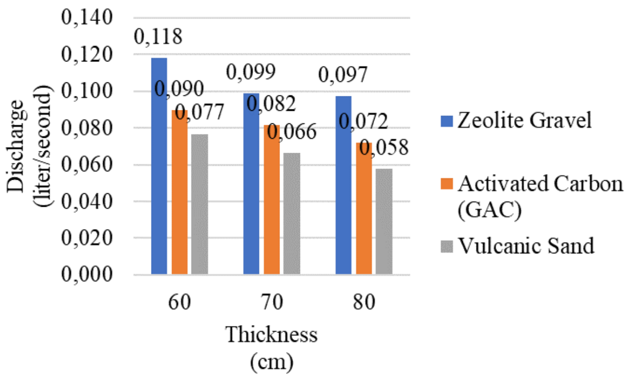


Figure 5. Discharge Data of Each Filter

Based on Figure 5, it is known that the fastest discharge is found in a filtration device using zeolite gravel with a thickness of 60cm, which is 0.118 liters/second. The filter with the smallest discharge is a filtration device using volcanic sand with a thickness of 80 cm, which is 0.058 liter/second. The filter with volcanic sand has a smaller discharge because the grain size of the media is finer and denser and has a high density, while the filter with zeolite gravel has a media size with larger grains so that the density is looser and has holes that cause water to escape more quickly. easy. Water is easier to pass through the filter media with holes and gaps so that when it flows, the time needed for filtration is shorter.

3.3 Laboratory Test Results After Filtration Process

The results of the initial test of rainwater that has been accommodated in an artificial pond in Building 3, Faculty of Engineering, Tidar University, were carried out in the laboratory of the Center for Environmental Health and Disease Control Engineering (BBTKLPP), Yogyakarta. These results are used to determine the initial state of rainwater before conducting research. E. Coli bacteria and the amount of Coliform in water can be known so that research can be done on the water. The results of testing water quality parameters are shown in Table 2.

Table 2 describes the results of laboratory tests on water quality parameters which include E. Coli and Coliform bacteria. These results are based on filtering that has been carried out on rainwater in Building 3, Faculty of Engineering, Tidar University. The filter was operated with running water for 6 minutes, 12 minutes and 18 minutes then samples were taken each time they were observed. It can be seen that the levels of E. Coli experienced a very significant decrease using a filter with 80 cm thick zeolite gravel with a contact time of 6 minutes 18 minutes, so that the value of E. Coli met the quality standard. Regulation of the Minister of Health of the Republic of Indonesia Number 32 of 2017. The content of E. Coli and Coliform filters still exceeds the required quality standards and there is a TNTC (Too Many Too Count) statement which means that the results of the water test can no longer be calculated using a tool, because the maximum colony limit per group is 300.

The condition of the water source at the time of sampling was in poor condition due to several factors. Factors that can affect water conditions in this study are air, storage time, water contact, and rain conditions. Air and storage time can affect the proliferation of bacteria found in water, this can also be caused by water contact with animals such as birds, mosquitoes, and flies that can carry bacteria from outside. Rainy conditions also affect water quality, because when acid rain or conditions after the volcano erupts, initially it can carry pollutants and other polluted gases, thus affecting the substances contained in rainwater.

4. Discussion

4.1 Efficiency Analysis of Rainwater Quality Parameter Reduction

Efficiency calculation is carried out by determining the initial value concentration and final value concentration of the E. Coli & Coliform parameter by subtracting the concentration of the test parameter substance before filtration by the concentration of the test parameter after filtration and then dividing it by the concentration of the test parameter before filtration and used as a percent. The efficiency of decreasing the parameter is calculated for each filter. The calculation of the efficiency of decreasing the parameter value is carried out to determine the effectiveness of the filtration at each thickness and operating time. The results of the efficiency analysis are shown in Table 3.

Table 2. Rainwater test results after filtration

Media Filtration	Media Thickness (Cm)	Contact Time (Minutes)	E. Coli			Coliform		
			Contact Time (CFU/100ml)	Test Results (CFU/100ml)	M/ TM	Maximum Rate (CFU/100ml)	Test results (CFU/100ml)	M/ TM
Zeolite Gravel	80	6	0	4	TM	50	52	TM
		12	0	0	M	50	8	M
		18	0	0	M	50	0	M
	70	6	0	6	TM	50	23	M
		12	0	0	M	50	20	M
		18	0	0	M	50	4	M
	60	6	0	7	TM	50	67	TM
		12	0	3	TM	50	24	M
		18	0	2	TM	50	6	M
Activated Carbon (GAC)	80	6	0	10	TM	50	TNTC	TM
		12	0	8	TM	50	TNTC	TM
		18	0	0	M	50	34	M
	70	6	0	30	TM	50	TNTC	TM
		12	0	23	TM	50	TNTC	TM
		18	0	12	TM	50	TNTC	TM
	60	6	0	34	TM	50	TNTC	TM
		12	0	24	TM	50	TNTC	TM
		18	0	0	M	50	39	M
Vulcanic Sand	80	6	0	35	TM	50	TNTC	TM
		12	0	29	TM	50	TNTC	TM
		18	0	0	M	50	45	M
	70	6	0	42	TM	50	TNTC	TM
		12	0	35	TM	50	TNTC	TM
		18	0	10	TM	50	TNTC	TM
	60	6	0	44	TM	50	TNTC	TM
		12	0	37	TM	50	TNTC	TM
		18	0	0	M	50	49	M

Explanation: M = Memenuhi
TM = Tidak Memenuhi

In the zeolite gravel filter there is an efficient reduction for both parameters, namely at 80 cm media thickness with a contact time of 18 minutes with 100% efficiency. The highest Coliform reduction occurred at operating time 18 at a thickness of 80 cm with 100% efficiency. In the activated carbon filter there was an efficient decrease for the E. Coli parameter, namely at a media thickness of 80 cm with a contact time of 18 minutes with an efficiency of 100%. As for the Coliform parameter, there was no decrease and there was a very high spike or an uncountable increase (TNTC). There was no efficient reduction in the volcanic sand filter for E. Coli and Coliform parameters. This can be caused by several influencing factors, namely filtration media, long water storage time, and pollution from the surrounding air.

4.2 Logistics Regression Analysis

Logistic regression analysis was conducted to determine the effect of decreasing E. Coli with operating time and media thickness at each filtration by making a graph to explain each treatment and it can be seen how much one variable can explain the other variables. The data collected includes two variables, namely X1 = media thickness (cm), X2 = contact time (minutes), and Y = the success of the filter meeting the PerMenKes standard with the assumption (1 = Meets, 0 = Does not Meet). The graph of the relationship between the decline of E. Coli with operating times of 6 minutes, 12 minutes, and 18 minutes on a filtration device using zeolite gravel, activated carbon, and volcanic sand is shown in Figures 6 to 11.

Table 3. Results of Analysis Efficiency Decreasing Parameter Value of E. Coli and Coliform.

Media Filtration	Media Thickness (Cm)	Contact Time (Minutes)	E. Coli			Coliform		
			Initial Concentration (CFU/100ml)	Final Concentration (CFU/100ml)	Decreasing Efficiency (%)	Initial Concentration (CFU/100ml)	Final Concentration (CFU/100ml)	Decreasing Efficiency (%)
Zeolite Gravel	80	0	8	8	0%	69	69	0%
		6	8	4	50%	69	52	25%
		12	8	0	100%	69	8	88%
		18	8	0	100%	69	0	100%
	70	0	8	8	0%	69	69	0%
		6	8	6	25%	69	23	67%
		12	8	0	100%	69	20	71%
		18	8	0	100%	69	4	94%
	60	0	8	8	0%	69	69	0%
		6	8	7	13%	69	67	3%
		12	8	3	63%	69	24	65%
		18	8	2	75%	69	6	91%
Activated Carbon (GAC)	80	0	8	8	0%	69	69	0%
		6	8	10	-25%	69	TNTC	TNTC
		12	8	8	0%	69	TNTC	TNTC
		18	8	0	100%	69	34	51%
	70	0	8	8	0%	69	69	0%
		6	8	30	-275%	69	TNTC	TNTC
		12	8	23	-188%	69	TNTC	TNTC
		18	8	12	-50%	69	TNTC	TNTC
	60	0	8	8	0%	69	69	0%
		6	8	34	-325%	69	TNTC	TNTC
		12	8	24	-200%	69	TNTC	TNTC
		18	8	0	100%	69	39	43%
Vulcanic Sand	80	0	8	8	0%	69	69	0%
		6	8	35	-338%	69	TNTC	TNTC
		12	8	29	-263%	69	TNTC	TNTC
		18	8	0	100%	69	45	35%
	70	0	8	8	0%	69	69	0%
		6	8	42	-425%	69	TNTC	TNTC
		12	8	35	-338%	69	TNTC	TNTC
		18	8	10	-25%	69	TNTC	TNTC
	60	0	8	8	0%	69	69	0%
		6	8	44	-450%	69	TNTC	TNTC
		12	8	37	-363%	69	TNTC	TNTC
		18	8	0	100%	69	49	29%

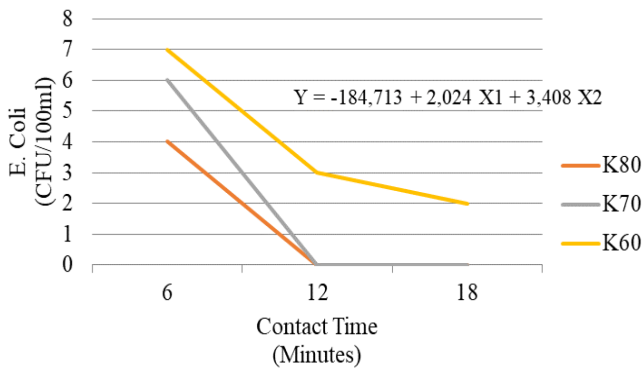


Figure 6. Relationship of Effect of Contact Time and Thickness of E. Coli on Zeolite Gravel Filtration

Figure 6 explains the results of the regression Y = -184.713+2.045X1+3.408X2, the constant value is negative, meaning that if there is no increase in media thickness and contact time, there will be no decrease in the value of E.coli. Variables X1 and X2 are positive, which means that every time there is an increase in media thickness and contact time, there is a possibility of a decrease in the value of E. Coli, but there is no significant effect between media thickness. and contact time with the value of E. Coli. The insignificant result is explained by the significance value of the variables in the equation, the value is greater than a or > 0.05 so the result is not significant.

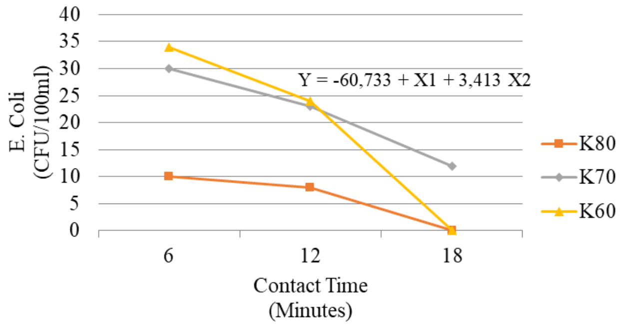


Figure 7. Relationship of Effect of Contact Time and Thickness of E. Coli on Activated Carbon Filtration

Figure 7 explains the results of the regression Y = -60,733+X1+3.413X2, the constant value is negative, which means that if there is no increase in media thickness and contact time, there will be no decrease in the value of E. coli. Variables X1 and X2 are positive, which means that every time there is an increase in media thickness and contact time, there is a possibility of a decrease in the value of E. Coli, but there is no significant effect between media thickness. and contact time with the value of E. Coli. Insignificant results are explained by the significance value of the variables in the equation, the value is greater than a or > 0.05 so the results are not significant.

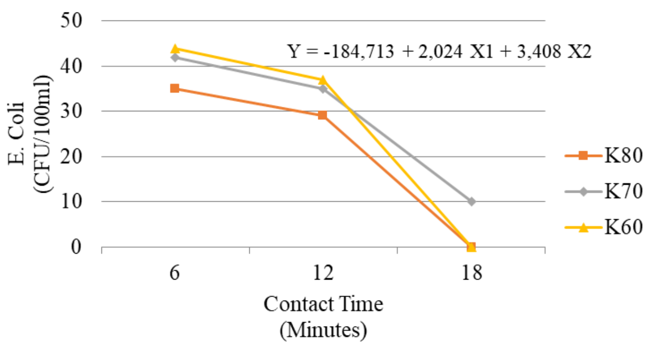


Figure 8. The Relationship of the Effect of Contact Time and Thickness on E. Coli in Vulcanic Sand Filtration

Figure 8 explains the results of the regression Y = -184.713+2.045X1+3.408X2. The constant value is negative, which means that if there is no increase in media thickness and contact time, there will be no decrease in the value of E.coli. Variables X1 and X2 are positive, which means that every time there is an increase in media thickness and contact time, there is a possibility of a decrease in the value of E. Coli, but there is no significant effect between media thickness. and contact time with the value of E. Coli. Insignificant results are explained by the significance value of the variables in the equation, the value is greater than a or > 0.05 so the results are not significant.

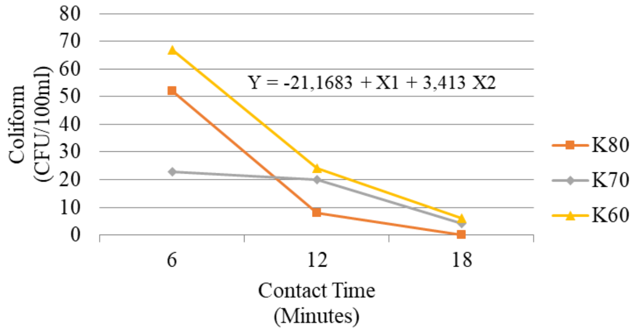


Figure 9. The Relationship of the Effect of Contact Time and Thickness on Coliforms in Zeolite Gravel Filtration

Figure 9 describes the regression results Y=-21,168+X1+3,413X2, where the constant value is negative, which means that if there is no increase in media thickness and contact time, there will be no decrease in the value of Coliform. Variables X1 and X2 are positive, which means that every time there is an increase in media thickness and contact time, there is a possibility of a decrease in the value of Coliform, but there is no significant effect between media thickness. and contact time with the value of Coliform. Insignificant results are explained by the significance value of the variables in the equation, the value is greater than a or > 0.05 so the results are not significant.

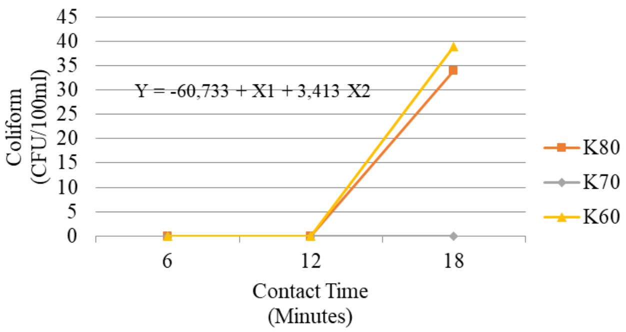


Figure 10. The Relationship of the Effect of Contact Time and Thickness on Coliforms in Activated Carbon Filtration

Figure 10 explains the results of the regression Y=-60,733+X1+3.413X2, where the constant value is negative, which means that if there is no increase in media thickness and contact time, there is no decrease in Coliform value. Variables X1 and X2 have positive values, which means that every time there is an increase in media thickness and contact time, there is a possibility that the Coliform value will decrease, but there is no significant effect between media thickness and contact time. with coliform values. Insignificant results are explained by the significance value of the variables in the equation, the value is greater than a or > 0.05 so the results are not significant.

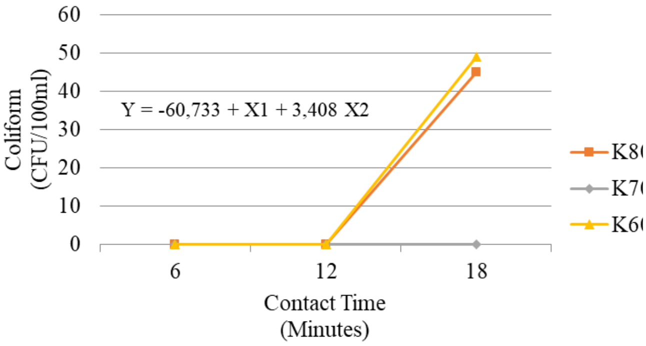


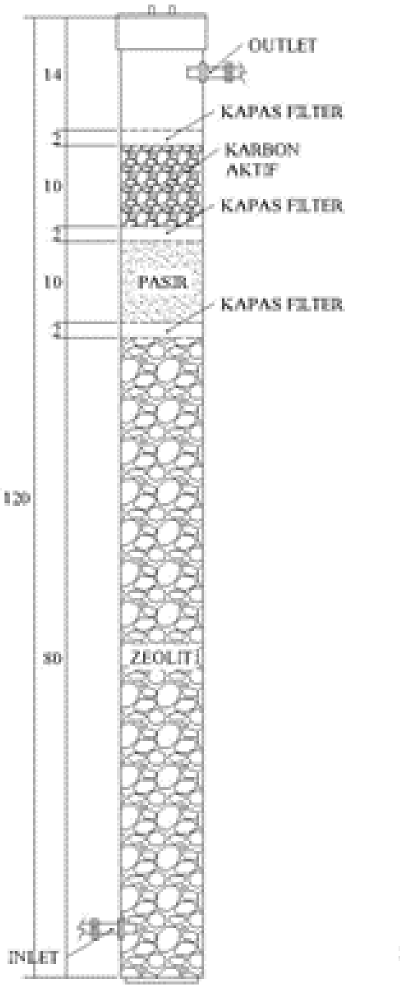
Figure 11. The Relationship of the Effect of Contact Time and Thickness on Coliforms in Vulcanic Sand Filtration

Figure 11 explains the regression results that the constant value is negative, which means that if there is no increase in media thickness and contact time, there is no decrease in Coliform value. Variable X has a positive value, which means that every time there is an increase in media thickness and contact time, there is a possibility that the Coliform value will decrease, but there is no significant effect between media thickness and contact time with the media. Coliform value because the significance value of the variables in the equation is greater than a. or > 0.05.

Figures 6 to Figure 11 explain that the formed logistic regression model is getting better. The picture also shows that the value of the constant is negative which means that if there is no increase in media thickness and contact time, there will be no decrease in the value of E. Coli & Coliform. The value of the variables X1 & X2 is positive, which means that every time there is an increase in media thickness and contact time, there is a possibility that there will be a decrease in the value of E. Coli & Coliform, but there is no significant effect between media thickness and contact time with the value of E. Coli & Coliform because the value the significance of the variables in the equation is greater than a or > 0.05.

4.3 Application Design Filters in the Field

From the test results and efficiency that have been discussed, the most efficient filter is filtration using zeolite gravel with a thickness of 80 cm so that in field applications the filter using zeolite gravel with the addition of activated carbon and volcanic sand can be used. The filter design is shown in Figure 12.



.**Figure 12.** Filtration Design

4.4 Filtration applications in the field

The application of filtration in the field is seen from the need for rainwater that has been filtered with the volume requirement of water in the water tank, which is 4 m^3 or 4000 liters per day as a non-domestic standard reserve water source for sanitation purposes. The process of distributing rainwater starts from when rainwater from the roof falls through the water channel to the distribution pipe to the 2000 liter water tank with a gravity system, after the rainwater is accommodated the filtering process can be carried out. After the rainwater is filtered, the water is stored in a 4000 liter capacity water tank which can then be channeled into the bathroom or for other sanitation purposes. The scheme of applying the filter is shown in Figure 13.

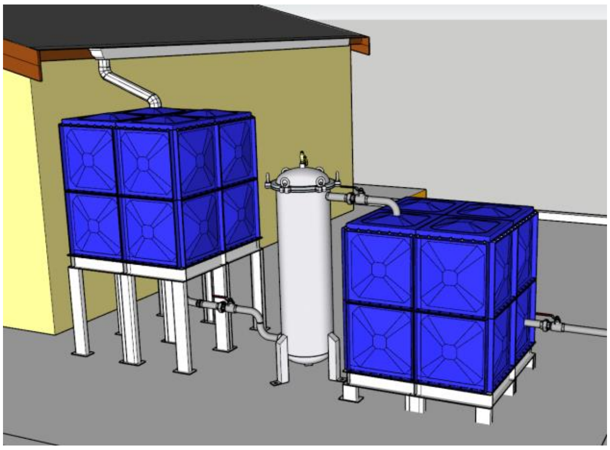


Figure 13. Schematic of Application of Filters in the Field

The filtration unit was carried out according to the plan, namely one tube-shaped filter containing 80 cm thick zeolite gravel media, 10 cm thick activated carbon, and 10 cm thick volcanic sand. Although the zeolite file filter is able to reduce the bacterial content in rainwater, it is still recommended to add other water treatments for more optimal results.

5. Conclusions and suggestions

After conducting research, analysis and discussion, the following conclusions can be drawn:

1. The results of laboratory testing of rainwater in Building 3, Faculty of Engineering, Tidar University, have levels of E. Coli bacteria of 8 CFU/100ml and Coliform bacteria levels of 69 CFU/100ml. These results exceed the quality standards of the Regulation of the Minister of Health of the Republic of Indonesia Number 32 of 2017.
2. The filtration process using the filtration method with 80 cm thick zeolite gravel filter media, 10 cm volcanic sand, and 10 cm activated carbon with a contact time of 18 minutes can overcome clean water quality problems in the form of E.coli removal. Coli and Coliform bacteria in rainwater are effective with the highest efficiency of 100%, and in accordance with the quality standards of the Regulation of the Minister of Health of the Republic of Indonesia Number 32 of 2017.
3. The results of the regression analysis showed that there was no significant effect between media thickness and contact time with decreasing the value of E. Coli and Coliform in all filtrations in reducing the value of E. Coli and Colifom parameters.
4. The most optimal filter used to improve water quality is 80 cm thick zeolite gravel filtration media, 10 cm volcanic sand, and 10 cm activated carbon with a filter installation installed after rainwater is drained using pipes or gutters from the roof of the building.

In this study, suggestions that can be used as improvements in further research are:

1. It is recommended that rainwater or water that is to be filtered and treated is not stored for too long because it can cause more bacterial growth, so that the value of the content of biological parameters increases.
2. It is possible to add variations in the size of the media gradation and the thickness of the media to get more optimal results.
3. Addition of water treatment can be done to get water results that can be used more optimally.
4. Can be done by providing more varied operating times so that efficiency and optimal results can be known

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