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Rainwater quality improvement model as an alternative source for drinking water in Mojoagung District, Jombang Regency

Galih M. Fatian [1]*, Hari Siswoyo [1], Riyanto Haribowo [1]

[1)] Water Resources Engineering Department, Universitas Brawijaya, Malang, 65145, Indonesia

*galihfatian@gmail.com

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Abstract. Water is a basic need for humans, yet often the quality and quantity become constrained, as happened in Mojoagung District, Jombang Regency. During the dry season, the potential for water reserves available for use is rainwater that has been stored. However, based on laboratory tests, the quality of the stored rainwater is below the quality standard due to its high $KMnO_4$ (Calium Permanganate) content. Hence we need a simple filter to improve the water quality. Researchers have conducted experiments with the filter composition of zeolite, activated charcoal, activated sand, sterile cotton, and aquarium filter. The results of the filtration process showed a significant decrease in potassium permanganate. The filtration results from the filter with the composition of zeolite, activated charcoal, activated sand, sterile cotton, and an aquarium filter sequentially 5 cm, 10 cm, 15 cm, 4 cm, and 2 cm succeeded in reducing potassium permanganate levels from 11.73 to an average of 2.12 mg. /l. Due to experimental activities, the best filter will be integrated with the rainwater harvesting system, which has been discussed with related social communities and stakeholders.

Keywords: Filtration, $KMnO_4$, Rainwater harvesting, Water

1. Introduction

It is estimated that more than 2 billion people per day are affected by water shortages [1]. Indonesia has more than 200 million of population, but 119 million do not have access to clean drinking water, while the need is estimated to increase to 15-35%/capita/per year [2]. The difficult condition of the community in accessing clean water is also a problem in Jombang Regency, especially during the dry season. At least six sub-districts in Jombang Regency have the potential to experience drought in the dry season in 2020. The six sub-districts are Wonosalam District, Mojoagung District, Bareng District, Bandarkedungmulyo District, Plandaan District, and Kabuh District [3].

Air Kita Foundation has been campaigning for the use of rainwater as drinking water since 2015. So far, the community has made initial observations using TDS and pH tests [4]. Based on the testing of the two parameters above, the test results were obtained where the value is still within the safe limit according to the Minister of Health Number 492/MENKES/PER/IV/2010 [5]. However, to state that the water is suitable for consumption, it is not only pH and TDS, but several parameters must be tested according to the standards of the Ministry of Health. For this reason, it is necessary to conduct further research related to the rainwater harvesting structure of Pemanenan Air Hujan (PAH) in Mojoagung District.

Meanwhile, based on previous research related to PAH, where there is rainwater that does not meet the 2010 Minister of Health [6 – 10], an effective PAH tool is needed to filter chemical pollutants in rainwater. Likewise, for the research case in the Mojoagung sub-district, if rainwater pollution occurs in Mojoagung, it is necessary to create an effective and efficient rainwater treatment model to make rainwater suitable as a source of raw water for drinking water.

2. Material and Methods

2.1. Location and Research Period

The research was conducted in Mojoagung District, Jombang Regency, which is located between 112°33'50.372"E and 7°58'8.089"L (Figure 1). The research starts from April 2021 to December 2021.

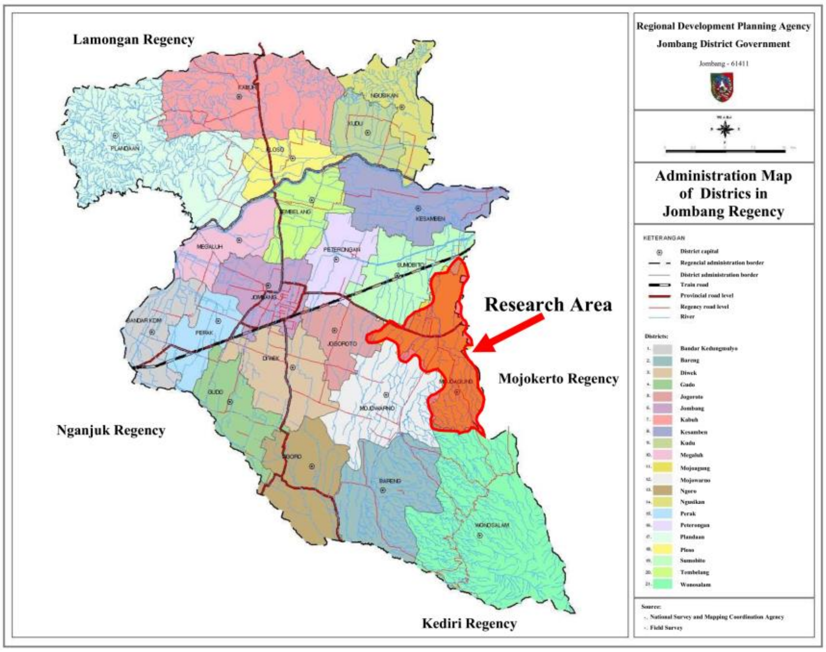

Figure 1. Mojoagung districts map [11]

2.2. Tools and Materials

The equipment used in the research phase of the correlation between rainwater quantity and quality includes a bucket to hold rainwater directly. Siemen Digital Conductivity Tester is used to measure Electrical Conductivity (DHL); a thermometer is used to measure water temperature. A pH meter is used to measure the pH value in rainwater caught directly in the bucket. Sterile jerry cans to collect rainwater samples directly to be taken to the health laboratory in the Jombang area. The material studied at this research stage is rain taken directly.

The equipment used in the effectiveness of the filter's research phase includes a two-inch PVC pipe used for modeling tools. A tube made of mica with a two-inch diameter is used as a container for placing the filter composition. The filter uses zeolite material, activated sand, activated carbon, an aquarium filter, and sterile cotton. The material used for the test material is rainwater stored for four years. Then, a sterile bottle brings the filtered water sample to the laboratory.

While the equipment is used in the design research stage, a compatible laptop is to be installed with the AutoCad 2018 program to design the application of filters in the field. Next, use the Excel 2010 program to Compile the total cost of applying the filter.

2.3. Data Collection

The data in this research are divided into primary and secondary data with the following details:

1. Primary data
   1) Rainwater sample

   The first collection was in April 2021 at the Mojoagung and Penanggalan Barat BMKG stations for two rainy days with four samples. The second collection of stored water was in four locations with four samples.

2) Quality of sample
   They were obtained from laboratory test results on all collected samples and filtration results.
3) Interviews
   Results of interviews and deliberation with the community and related stakeholders.
4) Hydrological data
   Daily rainfall data from Mojoagung and Penanggalan Barat BMKG stations.

2. Secondary data
   Literature studies that are directly related to research.

2.4. Research Stages

This research is divided into several stages as follows:

a) Analysis of the relationship between daily rainfall and rainwater quality
   The rainwater quality data obtained were compared with the daily rainfall intensity on the day of sampling. This analysis results in the relationship between the quality of the rainwater that falls and its intensity on the same days. The flowchart for this step is shown in Figure 2.
b) Determining the filter variation
   The composition of the filter is determined after the pollutants are known from the results of laboratory analysis of rainwater and reservoir water. This stage is described in Figure 3.
c) Rainwater Filtering Process
   After the filter composition used in the experiment has been determined, the next step is to conduct water filtration experiments with various combinations of compositions. This filtering process is shown in Figure 4.
d) PAH building planning process
   The last stage for this research is PAH planning to integrate with the chosen rainwater filter. The planning and integration process is described in Figure 5.

All samples of the filtration experiment results were sent to the laboratory to investigate which filter effectiveness was the best. After obtaining the best filter for filtering water, the last step is to integrate the filter with the PAH building, which has been designed as a result of consultation with the community and related stakeholders.

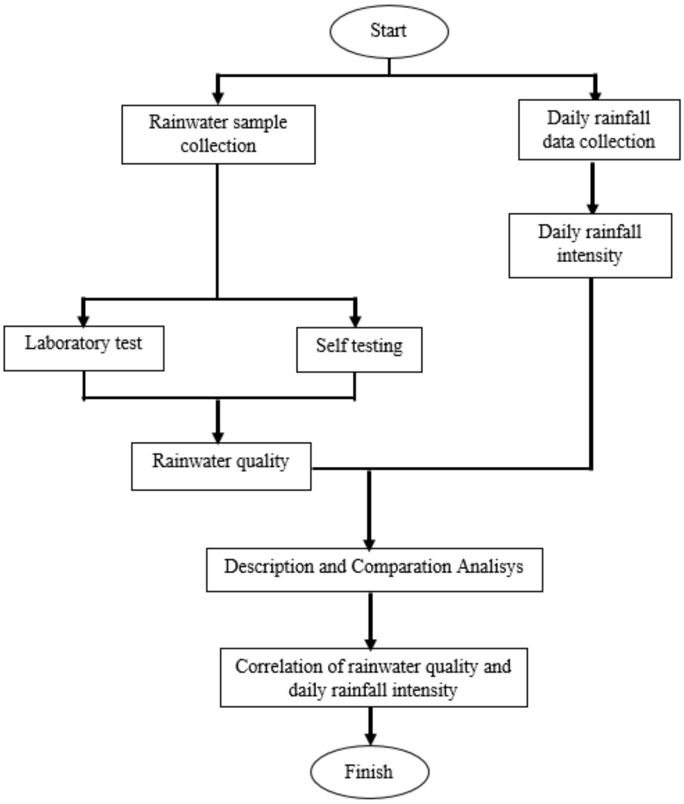

Figure 2. Analysis of the relationship between daily rainfall and rainwater quality

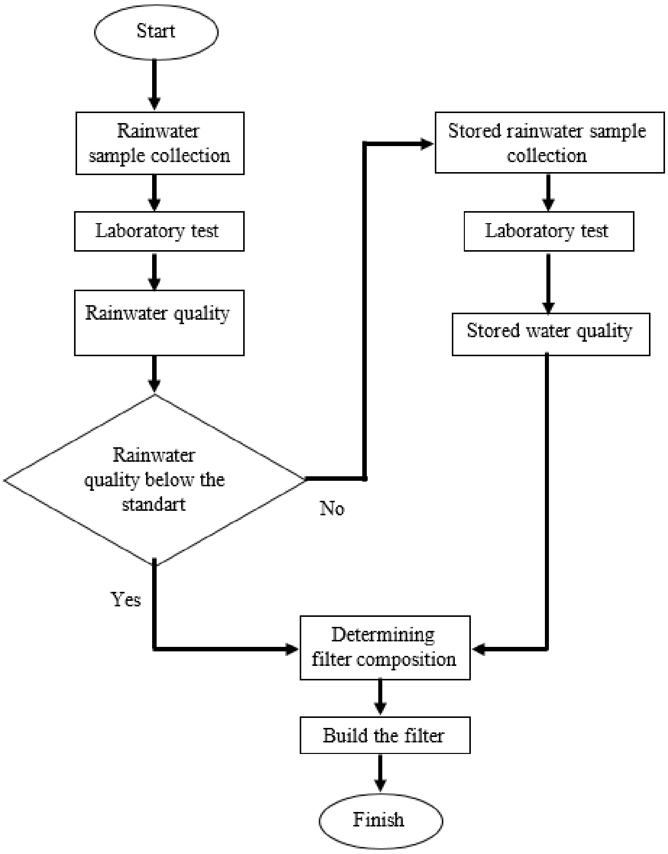

Figure 3. Determining the process of filter variations

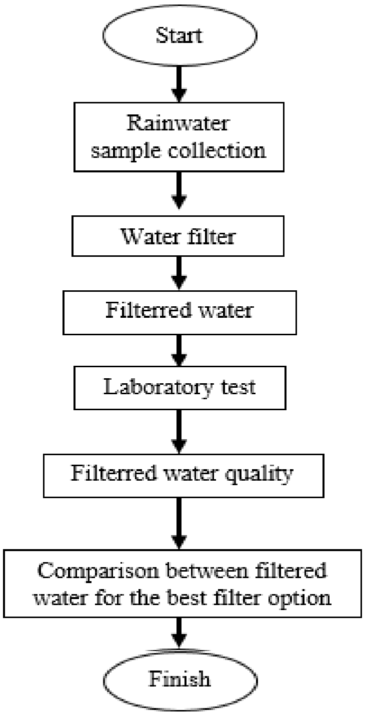

Figure 4. Rainwater filtering process

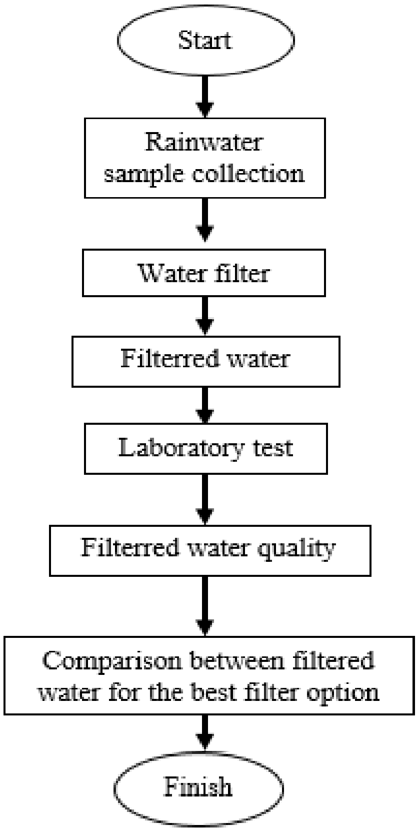

Figure 5. PAH planning process

3. Results and Discussion

3.1. Rainwater Quality and Quantity

The first sampling in April 2021 had quality self-test results and daily rainfall data presented in Table 1 and Table 2. At the same time, samples with codes MJG 1, MJG 2, PNG 1, and PNG 2 water quality laboratory test results by Jombang Regional Health Laboratory are shown in Table 3.

Table 1. Mojoagung water quality and daily rainfall data

Date	Rainwater quality			Daily rainfall (mm)
	pH	TDS (mg/l)	Temperature (°C)	
08 April 2021	6.43	10.4	30.56	10
09 April 2021	6.75	19.2	25.8	-
10 April 2021	5.78	26	28.42	-
13 April 2021	4.75	15.8	26.2	-
15 April 2021	4.72	26	26.46	-

Table 2. Penanggalan Barat water quality and daily rainfall data

Date	Rainwater quality			Daily rainfall (mm)
	pH	TDS (mg/l)	Temperature (°C)	
08 April 2021	5.28	15.2	27.66	14
09 April 2021	6.82	22.8	24.3	-
10 April 2021	5.55	42.2	26.92	-
13 April 2021	4.43	16.4	23.48	-
15 April 2021	4.26	13.8	24.08	4

Tables 1 and 2 indicate that there is no relationship between daily rain thickness and rainwater quality due to several things, because of the following possible reasons:

1. Rainwater quality at the research site did not experience significant changes based on the self-test results in Tables 1 and 2.
2. The rainfall at the rain gauge station is not recorded because the intensity is too small.

Based on the test results at the health laboratory in the Jombang area shown in Table 3, rainwater was found to have a quality that met the standard of raw water, so it did not require a filtration process. But in reality, the rainwater that falls in the Mojoagung area is not used directly by the community but is accommodated for use during the dry season when water supplies are reduced.
This storage period is suspected to cause changes in the characteristics of rainwater and cause a decrease in water quality. Therefore, the research was developed by conducting the second stage of sampling to ensure the condition of the quality of rainwater that is accommodated by the community.

This second sampling stage must be carried out during the dry season when water supply conditions are very lacking, namely in October 2021. This stage survey collects four samples in each rainwater reservoir scattered in the research location. The storage period and the water quality test for each sample are presented in Tables 4 and 5.

Table 3. Rainwater quality laboratory test

Parameters	Unit	Maximum content (LD)	Sample Code MJG 1	MJG 2	PNG 1	PNG 2
I. Parameters directly related to health						
a. Chemical an-organik						
1 Nitrite (as NO_{2-})	mg/l	1,0	< LD	< LD	< LD	< LD
2 Nitrate (as NO_{3-})	mg/l	10	1,2	1,7	1,3	1,0
3 Fluorida (F)	mg/l	1,5	0,17	0,24	0,22	0,22
II. Parameters that are not directly related to health						
a. Physical parameters						
1 Smells	#	No Smell	No Smell	No Smell	No Smell	No Smell
2 Total Dissolved Solid (TDS	mg/l	1000	1,8	20,5	18,9	17,0
3 Turbidity	NTU Scale	5	1,74	3,9	1,53	3,05
4 Taste	#	No taste	No taste	No taste	No taste	No taste
5 Temperature	^oC	± 30 ^oC	22,8 ^oC	23,8 ^oC	23,8 ^oC	24,1 ^oC
b. Chemical parameters						
1 Ferrum	mg/l	1,0	0,11	0,32	0,08	0,17
2 Hardness	mg/l	500	25	15	15	12
3 Chloride	mg/l	600	3,97	4,96	3,97	3,4
4 Manganese	mg/l	0,5	< LD	< LD	< LD	< LD
5 pH	#	8,5	7,18	7,19	7,22	6,99
6 Residual chlorine	mg/l	0,2	0,06	< LD	< LD	< LD
7 $KMnO_4$	mg/l	10,0	3,03	2,42	2,12	1,51

Table 4. Storage periods of each sample

Sample Code	Sample collection	Storage time
Sample 1	June – August 2021	± 4 months
Sample 2	October – December 2020	± 12 months
Sample 3	June – August 2020	± 16 months
Sample 4	Rainy season 2017	± 4 years

From Table 5, it can be seen that some do not meet the quality standards, which are;
1. Turbidity
2. Potassium Permanganate ($KMnO_4$)
3. Total Coliform
4. And pH

Of the four parameters that do not meet water quality standards, the levels of Potassium Permanganate ($KMnO_4$) and total coliform are very prominent, indicating that the longer the storage period, the higher the value of these two indicators. For this reason, it is necessary to design a filter device that can reduce the character content of raw water that has been described in general and the content of Potassium Permanganate ($KMnO_4$) in particular. The next step of the research is the stage of the filtration process.

Table 5. Stored rainwater quality test results

Parameters	Unit	Maximum content (LD)	Sample Code			
			Sample 1	Sample 2	Sample 3	Sample 4
I. Parameters directly related to health						
a. Chemical an-organik						
1 Nitrite (as NO_{2-})	mg/l	1,0	0.03	0.02	0.03	0.02
2 Nitrate (as NO_{3-})	mg/l	10	-	-	-	-
3 Fluorida (F)	mg/l	1,5	0.18	0.18	0.17	0.15
II. Parameters that are not directly related to health						
a. Physical parameters						
1 Smells	#	No Smell	No Smell	No Smell	No Smell	No Smell
2 Total Dissolved Solid (TDS)	mg/l	1000	94.2	88.3	91.2	83.4
3 Turbidity	NTU Scale	5	2.13	2.52	7.73	0.85
4 Taste	#	No taste	No taste	No taste	No taste	No taste
5 Temperature	^oC	± 30 ^oC	29.4	29.8	29.1	29.1
b. Chemical parameters						
1 Ferrum	mg/l	1,0	0.05	0.05	0.05	0.05
2 Hardness	mg/l	500	75	55	59	69
3 Chloride	mg/l	600	7.4	6.9	5.9	7.9
4 Manganese	mg/l	0,5	0.035	0.032	0.221	0.015
5 pH	#	8,5	8.71	8.41	8.14	7.74
6 Residual chlorine	mg/l	0,2	0.07	0.05	0.14	0.05
7 $KMnO_4$	mg/l	10,0	8.6	9.5	11.37	11.5
III. Microbiology Parameter						
1 Total of Coliform	MPN/ 100 ml	0	23	33	33	46

3.2. Filtration Modeling

From the literature that has been stated, no research has been found that discusses the effectiveness of using zeolite filters, activated charcoal, and activated sand to reduce $KMnO_4$ levels. However, these materials indicate being able to reduce $KMnO_4$ levels through the adsorption process [12].

Then the choice of materials for the composition of the water filter in the experiment to be carried out is as follows:

a. Zeolite diameter 3 mm

b. Activated carbon 3 mm

c. Activated sand 1 mm

The filter effectiveness experiment was carried out using ten variations of the filter. Each filter produced two samples (a total of 20), which were then checked for quality in the laboratory. Variations in the composition of each filter and their filtration results are presented in Tables 6 and 7.

Table 7 is a recapitulation of laboratory tests by LABKESDA Jombang on the quality of the filtration experiment results from all 20 samples of filters with codes A to J1. Table 7 shows how the effectiveness and efficiency of each filter. It can be seen that the lowest KMnO4 results were found in samples H1 and I with a value of 1.24 mg, respectively. Meanwhile, the lowest turbidity value is in sample H with a value of 13.62 NTU. The graph of the filtration results for the KMnO4 content is more clearly depicted in Figure 6, while the results of the turbidity value are shown in Figure 7.

Table 6. Experiment filter variations

	Filter code	Compositions	Thickness (cm)		Filter code	Compositions	Thickness (cm)
		Zeolite	5			Zeolite	15
1	Filter A	Activated charcoal	5			Activated charcoal	5
		Activated sand	5	7	Filter G	Activated sand	5
		Zeolite	5			Sterile cotton filter	4
2	Filter B	Activated charcoal	5			Aquarium filter	2
		Activated sand	10			Zeolite	5
		Zeolite	5			Activated charcoal	10
3	Filter C	Activated charcoal	5	8	Filter H	Activated sand	15
		Activated sand	15			Sterile cotton filter	4
		Zeolite	5			Aquarium filter	2
4	Filter D	Activated charcoal	10			Zeolite	5
		Activated sand	5			Activated charcoal	15
		Zeolite	5	9	Filter I	Activated sand	10
5	Filter E	Activated charcoal	15			Sterile cotton filter	4
		Activated sand	5			Aquarium filter	2
		Zeolite	10			Zeolite	10
		Activated charcoal	5			Activated charcoal	10
6	Filter F	Activated sand	5	10	Filter J	Activated sand	10
		Sterile cotton filter	4			Sterile cotton filter	4
		Aquarium filter	2			Aquarium filter	2

Table 7. Filterred stored water quality

	Sample	$KMnO_4$ (mg/l)	Turbidity (NTU)		Sample	$KMnO_4$ (mg/l)	Turbidity (NTU)
1	A	17.96	93.1	11	F	4.02	81.3
2	A1	13.32	233	12	F1	4.02	76.1
3	B	18.58	91.1	13	G	6.19	64.1
4	B1	11.15	290	14	G1	5.88	49.1
5	C	13.01	87.3	15	H	3.4	13.62
6	C1	4.33	271	16	H1	1.24	17.03
7	D	20.75	98.5	17	I	1.24	15.71
8	D1	13.32	115	18	I1	8.98	20.3
9	E	18.27	71.5	19	J	8.67	16.23
10	E1	8.67	78.1	20	J1	4.33	22.5

Figure 6 and Figure 7 show the filtration results for all filters. As seen in the table and figure, the filter that can reduce the best KMnO4, which was originally valued at 11.5 mg/l to an average of 2.32 ((3.4 + 1.24)/2) mg/l is filter H which has an average turbidity value of 15.325 ((13.62) +17.03)/2) mg/l. The composition of filter H is zeolite, activated charcoal, activated sand, and sterile cotton; aquarium filters are 5 cm, 10 cm, 15 cm, 4 cm, and 2 cm, respectively. The filter height will be incorporated into the Rainwater Harvesting (PAH) building scheme.

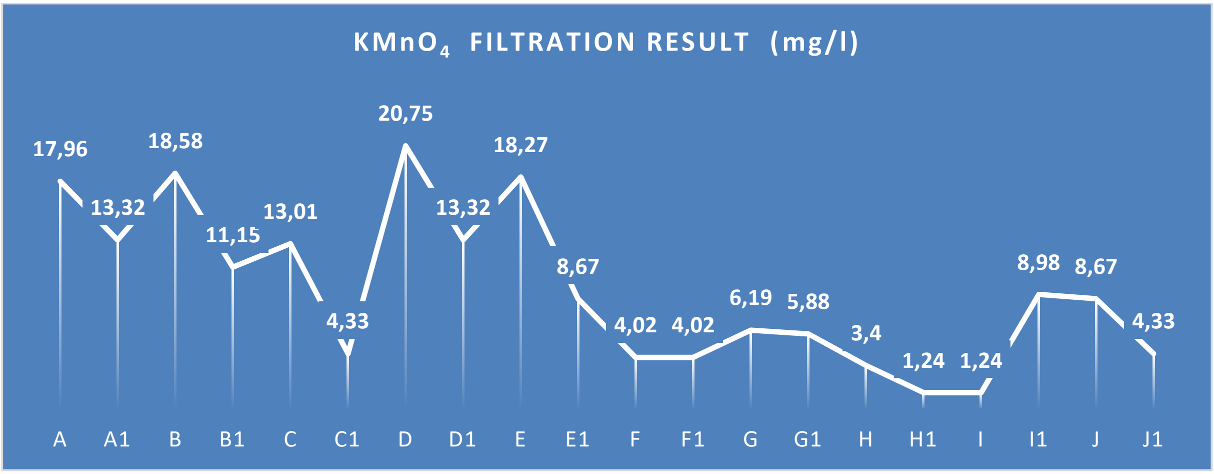

Figure 6. Filtered result of $KMnO_4$ contain

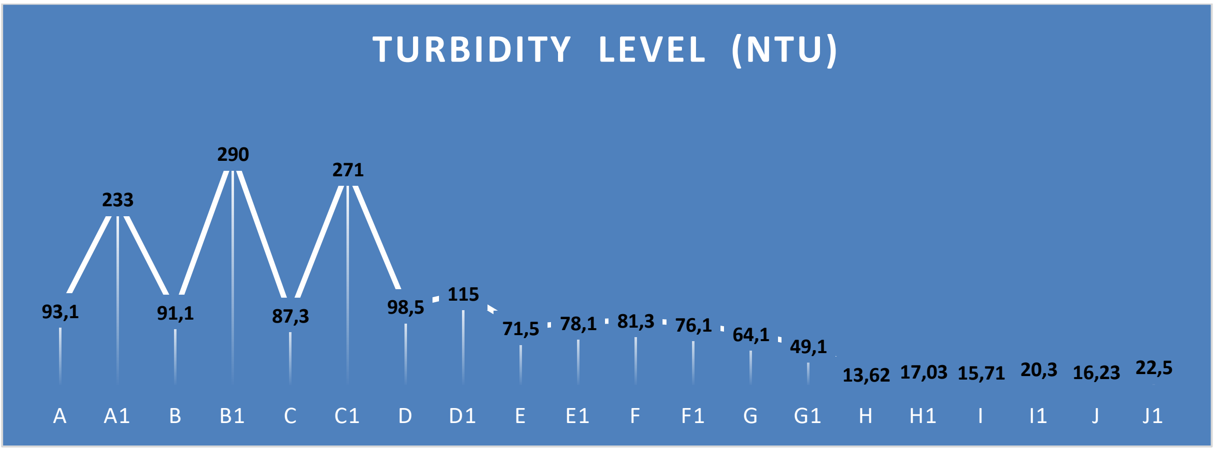

Figure 7. Turbidity level of filtered water

3.3. PAH Building Planning

After getting which filter is the best (filter H), the next step is to integrate the filter into a rainwater harvesting (PAH) building scheme based on literature studies and consultations with the community and related stakeholders.

The rainwater harvesting process starts from the rainwater that falls on the roof of the house and flows through gutters to the storage reservoir and is stored. When needed to be used, water from the reservoir is channeled to the filter installed in the PAH installation and then to the outlet. The type of water filter used is the slow flow type. Determination of the type of slow water filter is due to several advantages, including::

1. Simple and relatively easy to implement even by ordinary people;
2. No chemical additives
3. Low operating and maintenance costs;
4. Operation and maintenance, such as washing the filtration material, is relatively easy.

4. Conclusion

The results of this research are as follows:

1. The quantity of rainwater that fell directly at the study site at the time of the study was very small, with a range of 0-14 mm. This was due to the entry of the dry season. The quality of rainwater that fell directly at the study site at the study time met the standard water standards according to the

Minister of Health Regulation No. 492/MENKES/PER/IV/2010.

2. An effective filter model to improve rainwater quality ($KMnO_4$) at the research site is a filter model using a slow-flow filter scheme with a composition, aquarium filter, sterile cotton, zeolite, activated charcoal, and activated sand. For comparison, the best composition of zeolite, activated charcoal, and activated sand is 1:2:3.

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