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Studies of Improving Drinking Water Quality in the Kalurahan Banaran Kabupaten Kulon Progo Using Porous Concrete Filter

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Keywords:
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ABSTRACT

Some citizens of the Kalurahan Banaran Kabupaten Kulon Progo everyday use water that has an iron content (Fe) of 8.8 mg/L and a turbidity of 120 NTU, which is above the limit set by the Minister of Health's Regulation RI Number: 2 Tahun 2023 on the Quality Requirements of Drinking Water. To solve this problem, research has been conducted to reduce Fe and turbidity by using porous concrete filters. Three models of porous concrete A (porousity 0.42), B (porousity 0.44), and C (porousity 0.46), were used to filter water samples using two aerator diffusers at speeds of 3 L/h and 6 L/hour on each porous concrete filter. The results of the study showed that at an aeration rate of 3 L/hour, there had been a successive decrease in turbidity and Fe from 14.9 NTU to 1.38 NTU and 1.64 mg/L to 0.14 mg/L (filter A); 80 NTU to 0.5 NTU and 6.55 mg/L to 0.02 mg/L (filter B); 80 NTU to 0.1 NTU and 6.5 mg/L to 0 mg/L (filter C). For an aeration rate of 6 L/hour, there had been a successive decrease in turbidity and Fe from 80 NTU to 0.82 NTU and 6.55 mg/L to 0.05 mg/L (filter A); 89.8 NTU to 0.28 NTU, and 7.8 mg/L to 0.01 mg/L (filter B); 80 NTU to 0.28 NTU and 6,55 mg/L to 0 mg /L (filter C). The results show that the porous concrete filter can be considered an alternative to drinking water treatment in the Kalurahan Banaran Kabupaten Kulon Progo.

1. Introduction

Access to clean and safe drinking water is essential for the health and society [1]. In many rural areas, including Kalurahan Banaran Kabupaten Kulon Progo, drinking water quality is a concern due to the potential pollution from various sources. Contaminated water can cause water-borne diseases, posing significant risks to society.
One potential solution to improving drinking water quality is the use of concrete filters [2]. Concrete filters have been widely recognized as an effective and sustainable method for water treatment [3]. They are able to remove dirt, such as sediments, bacteria, and certain chemicals, producing cleaner and safer drinking water.

Located near the river Moor, it is potentially a waste landfill and increases the possibility of excess concentrations of iron (Fe) entering the settlement area, especially in wells that serve as a source of clean water for the population. As part of addressing this problem, the researchers intended to use concrete filters as a method of filtering iron. In this study, wells will be research samples, with several reference points selected as study samples. From the sampling results, wells with the highest Fe concentration will be used as raw water for experiments in this study. The researchers will use a porous concrete filter to assess the effectiveness of using concrete filters with an aerator diffuser as an initial pretreatment for iron filtration. Through this research, researchers hope to provide a solution to the problem of clean water so that it is worth consuming as drinking water for residents of the Kalurahan Banaran Kabupaten Kulon Progo.

Concrete filters are suitable for reducing iron levels in water for several reasons [4]. Concrete is known for its adsorption properties, especially for certain contaminants such as iron [5]. The porous structure of concrete allows it to effectively trap and hold the iron particles present in the water, thereby reducing their concentration. Concrete filters can facilitate chemical reactions that help remove iron [6]. The properties of the concrete base can drive iron oxidation (Fe2+) into iron (Fe3+), which is then deposited

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and trapped inside the filter [7]. This process helps remove dissolved iron from water. The concrete filter is durable, making it suitable for continuous filtration operations [8]. They can withstand the flow and pressure of water as well as degradation due to exposure to various environmental conditions. This durability ensures that the filter remains effective in reducing iron levels over a long period of time. Concrete is a relatively inexpensive material compared to other filtration media. Its wide availability and affordability make concrete filters a practical and cost-effective solution for communities, especially in rural areas with limited resources. Concrete filters require minimal maintenance [9].

Considering the problem of iron levels and dryness in the drinking water used by the community in the countryside of Kalurahan Banaran Kabupaten Kulon Progo as well as the potential for the use of concrete filters, the researchers attempted to conduct research into the treatment of water by using a concrete filter that started the aeration using a diffuser. This research aims to determine the effectiveness of the use of concrete filters with preliminary pre-treatment using a diffuser aerator to improve the quality of drinking water in the Kalurahan Banaran Kabupaten Kulon Progo. The study will evaluate the performance of concrete filters in terms of improving the quality of drinking water in communities. These findings will provide valuable insights and recommendations for implementing concrete filters as a viable solution to improve the quality of drinking water in rural areas, thereby contributing to the overall well-being of society.

2. Method

The method of analysis is performed experimentally on a laboratory scale with tools that have been designed by the researchers. The study used 3 (three) variations of existing concrete filters that had been made in previous studies on the use of concrete filters, with three variations in grain size and one sand-cement composition operating at several variants of filtration rate [10]. The filter model is given in Table 1 and the concrete filter models A, B, and C from previous research in Figure 1.

Primary and secondary data were employed as the initial sources of information for this research. In order to assist the collection of primary data, secondary data is gathered from a variety of literary sources. Researchers collected primary data by conducting in-person interviews and testing water samples at four different sites throughout the Kalurahan Banaran Kabupaten Kulon Progo.

From the results of direct interviews with some citizens in the Kalurahan Banaran Kabupaten Kulon Progo, it was concluded that:

1. The people complained that the well water looked dirty and smelled.
2. The simple treatment that people can do today with sedimentation is by storing well water in the well and then being inhabited for 1 day for the water to be used the next day. In this way, the amount of water can be reduced.
3. Due to their distance from the PDAM pipeline network service, some residents choose not to subscribe to PDAM water.

Figure 1. Concrete filter models A, B, and C from previous research.

Table 1. Filter model

No.	Filter Model	Filter Composition	Porosity
1.	Model A	A concrete filter made of sand with a diameter of 0.424 – 0.85 mm	0.42
2.	Model B	A concrete filter made of sand with a diameter of 0.85 – 1.00 mm	0.44
3.	Model C	A concrete filter made of sand with a diameter of 1.00 – 2.00 mm	0.46

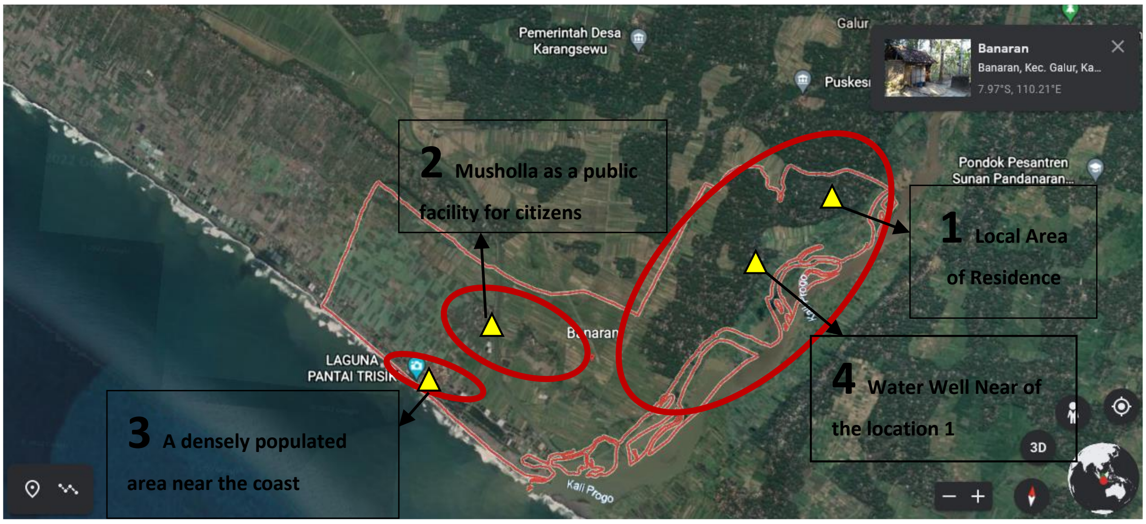


Figure 2. Location of sampling in Kalurahan Banaran Kabupaten Kulon Progo.

Explanation:
Location 1: Local area of residence
Location 2: Musholla, as a public facility for citizens,
Location 3: A densely populated area near the coast,
Location 4: Water well near of the location 1 (primary sampling location).

Other primary data was obtained from water sample testing at four different locations in the Kalurahan Banaran Kabupaten Kulon Progo. The initial sampling location shown in Figure 2 and the results of water sample testing can be seen in Table 2.

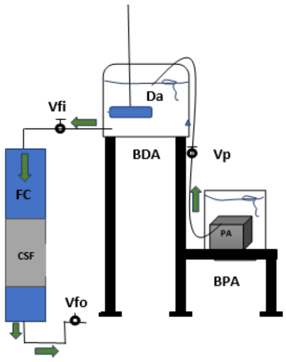
Table 2. Initial results of water sample testing in Kalurahan Banaran Kabupaten Kulon Progo

Parameters	Limits	Samples from location-			
		1	2	3	4
1. TDS (mg/L)	500	233	408	210	278
2. Fe (mg/L)	0.3	0.21	0.02	0.01	**8.8**
3. Mn (mg/L)	0.4	**0.4**	*Trace*	0.1	**2**
4. $KMnO_4$ (mg/L)	10	1.11	**11.27**	0.43	2.55
5. Turbidity (NTU)	5	2.62	1.69	0.29	**120**

If the well water at points 1 and 4 that is located in the location of the residential area of the citizen experiences a surplus of quality on the parameters of Mn, Fe, and turbidity, then the researchers will use the water well in the resident area as raw water in this research experiment.

This research method includes the analysis of the iron (Fe) concentration and the level of turbidity of the well water at the location of point 1 before and after pretreatment using a diffuser aerator, followed by filtration through a concrete filter. According to the Minister of Health's Regulation RI Number: 2 Tahun 2023, the maximum allowable Fe is 0.3 mg/L while for turbidity is 5 NTU.

The research was conducted through 24 experiments with 3 variations of the filter media, 1 variation of the discharge, and 2 variations in the aerator diffuser speed. The study was conducted in the morning for six hours. Start by taking a sample of water from one of the point 1 wells in the Banaran Kalurahan Kabupaten Kulon Progo about 50 liters using gallons already cleaned and dried. The water collection from the wells is done by the first collection to rinse the gallon, and the cover is then discarded and filled again until the gallon is filled. The filtration process begins by preparing the filter installation (Figure 3), cleaning the water pump tank and the aerator diffuser tank, and then filling them with a water sample. In this study, the filter column had a total volume of 4.1 liters. Once the water flow target is reached, the initial experiment can start by activating the aerator diffuser and opening the water pump valve and filter outlet valve according to the experimental setting. Samples are taken at 0', 15', 30, and 60'. Each test consists of 5 samples (Figure 4 and Figure 5), including 1 sample of raw water and 4 samples of outlet water taken from the filtration outlet every specified minute, and then immediately performed Fe and turbidity levels testing. After the test process is completed, the water pump is turned off, and the water inside the filter is drained and cleaned. The water pump tank and diffuser aerator tank were also empty and backwash for testing the next day.



Explanation:
BPA : Water Pump Bucket
PA : Submersible Water Pump (Capacity 2000 L/hour)
Vp : Pump Valve
BDA : Diffuser Aerator Bucket
Vfo : Outlet Filter Valve
Vfi : Inlet Filter Valve
DA: Diffuser Aerator (Capacity 3L/hour and 6 L/hour)
FC : Filter Column
CSF: Concrete Filter

Figure 3. Sketch of equipment filtration installation

Figure 4. Water sampling process for primary testing.

Figure 5. Water samples for primary testing.

3. Result

3.1 Measuring of Filtration Outlet Flow Rate

The total variation of the experiment in this study was 24 experiments, consisting of 3 variations of the filter media, 2 variations in the flow rate, and 2 variations in the diffuser aerator rate. To obtain the planned filter outflow rate, simultanly or continuous water flow is achieved by adjusting the water pump valve opening and filter output valve. The measurement of the outflow flow of the filtration is done by holding the outflow water on the meter glass for 5 seconds, and then the volume observation is performed on the meter glass. By comparing the volume of water collected and the time of collection, the outflow rate of filtration is determined in liters per hour. The calculation process was carried out over three experiments, and the average was taken as the final result.

On the measurement data, the opening of the filter outlet valve with a discharge of 3 liters per hour is achieved when the valve is opened at 18.5 degrees. As for the measurement data of the opening of the water pump valve to ensure simultaneous flow at a discharge of 3 liters per hour, a 32 degrees opening was obtained. It should be noted that these valve openings can vary in each experiment. Therefore, before starting the experiment, the drainage is measured according to the planned valve opening, and adjustments can be made if necessary.

3.2 Iron and Turbidity Testing

The measurement of the iron consentration and turbidity in this study was done from inlet and outlet samples. Sampling was carried out at minutes 0', 15', 30, and 60', resulting in a total of 6 inlet and 24 outlet samples. The iron content value of the inlet and outlet water samples is obtained from the readings on the spectrophotometer, measured in mg/L, while the turbidity value is obtained from the reading on the turbidimeter, measured in NTU (Nephelometric Turbidity Units). The results of measurements of iron levels and turbidity on filtering inlets and outlets can be seen in Table 3 and Table 4.

These iron particles are successfully eliminated by concrete filters using both mechanical and physical methods [11]. The porous concrete construction of the filter catches and retains the suspended particles as water flows past it, lowering turbidity [12]. According to the decline in the values in table, the loss of turbidity increases with the length of the filtration process. Iron content can be decreased using concrete filters in a number of ways. First, iron particles can adhere to the surface of concrete due to its porous nature. In order to remove iron ions from the water, the filter medium may also contain chemicals that can chemically attach to them. The decrease in iron content seen in the table is a result of a mix of physical and chemical processes. The aeration process plays an important role in water treatment. Aeration puts oxygen into the water, which promotes the oxidation of certain contaminants, including iron [13]. When water is exposed to oxygen, the dissolved iron (Fe2+) can be converted into iron (Fe3+), which forms insoluble particles that can be trapped and effectively removed by the filter [14]. The longer the duration of aeration, the higher the level of oxidation and subsequent iron elimination, which leads to a significant decrease in iron content. Variations in filtration parameters, such as flow rate and aeration rate, can affect the efficiency of the filtration process. Higher flow rates can result in reduced contact times between water and filter media, potentially leading to lower discharge rates. Similarly, the speed of aeration affects the rate of oxidation and subsequent elimination of iron. These factors explain the variation observed in the table between different filtration conditions.

The Measurement of Iron Concentration and Turbidity at the Inlet and Outlet of the Filtration with a Flow Rate of 3 L/hour and Aeration rate of 6 L/hour shows that the iron value (Fe) and turbidity sizable range of decrease. This is a result of the sedimentation process that occurs during aeration inside the diffuser tank of the aerator as minute particles are filtered through the concrete filter. Small particles gather into clumps and settle inside the aerator diffuser tank as a result of the diffuser aerator's constant oxygen spraying treatment, which triggers the sedimentation process.

Table 3. The measurement of iron concentration and turbidity at the inlet and outlet of the filtration with a flow rate of 3 l/hour and aeration rate of 3 l/hour

Samples	Filter Model	Aeration Rate (L/hour)	Minut es-	Turbidity (NTU)	Fe (mg/L)	Efficiency Removal of Turbidity (%)	Efficiency Removal of Fe (%)
Raw water 1				14.9	1.64		
1	A	3	0	2.8	0.26	81.2	84.1
2	A	3	15	1.65	0.16	88.9	90.2
3	A	3	30	1.38	0.16	90.7	90.2
4	A	3	60	1.48	0.14	90.1	91.5
Raw water 2				80	6.55		
5	B	3	0	13.2	1.01	83.5	84.6
6	B	3	15	2.31	0.16	97.1	97.6
7	B	3	30	0.5	0.02	99.4	99.7
8	B	3	60	0.59	0.03	99.3	99.5
Raw water 2				80	6.55		
9	C	3	0	0.52	0.01	99.4	99.8
10	C	3	15	0.26	0.01	99.7	99.8
11	C	3	30	0.22	0	99.7	100.0
12	C	3	60	0.11	0.01	99.9	99.8

Table 4. The measurement of iron concentration and turbidity at the inlet and outlet of the filtration with a flow rate of 3 l/hour and aeration rate of 6 l/hour

Samples	Filter Model	Aeration Rate (L/hour)	Minutes-	Turbidit y (NTU)	Fe (mg/L)	Efficiency Removal of Turbidity (%)	Efficiency Removal of Fe (%)
Raw water 1				80	6.55		
13	A	6	0	8.88	0.58	88.9	91.1
14	A	6	15	1.46	0.1	98.2	98.5
15	A	6	30	0.82	0.05	99.0	99.2
16	A	6	60	0.93	0.06	98.8	99.1
Raw water 2				89.8	7.8		
17	B	6	0	0.67	0.04	99.3	99.5
18	B	6	15	0.3	0.01	99.7	99.9
19	B	6	30	0.28	0.02	99.7	99.7
20	B	6	60	1.01	0.06	98.9	99.2
Raw water 2				80	6.55		
21	C	6	0	0.72	0.03	99.1	99.5
22	C	6	15	0.28	0.01	99.7	99.8
23	C	6	30	0.28	0	99.7	100.0
24	C	6	60	0.29	0.02	99.6	99.7

3.2 Measured Iron Content and Turbidity at Inlet and Outlet

The results of the iron concentration and turbidity readings can be seen in Figure 6 to Figure 11. From Figure 6, Figure 7, and Figure 8 it can be observed that during the experiment, the Fe and turbidity results showed a directional relationship, where both remained stable for up to 30 minutes. However, on the Concrete Filter model C, after 30 minutes, there is a decrease in removal. This indicates that the filter begins to become saturated due to the greater use and porosity of the filter, allowing more particles to pass through it. If the filter is to be used again, it must be cleaned first.

Figures 9, Figure 10, and Figure 11 show that during the experiment, the data for Iron Concentration and turbidity also demonstrated a directional relationship, which remained constant for up to 15 minutes. On the Concrete Filters Model B and C, there is a decrease in separation after 30 minutes. This shows that as the filter is used more frequently and grows more porous, it becomes saturated, allowing more particles to flow through.

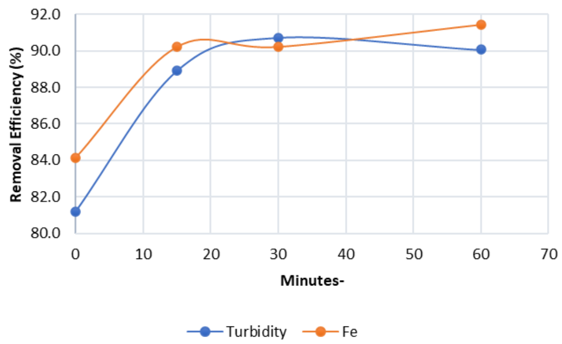


Figure 6. Removal efficiency of fe and turbidity using concrete filter a aerasi 3 L/hours

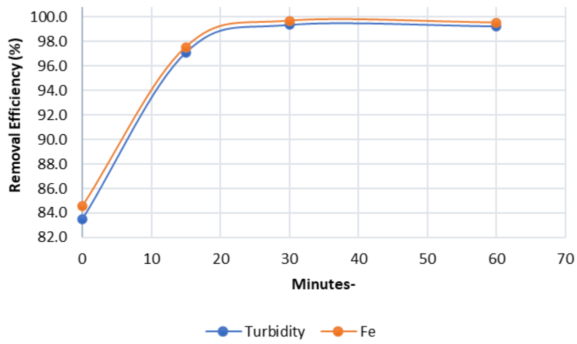


Figure 7. Removal Efficiency of Fe and Turbidity using Concrete Filter B Aerasi 3L/hours

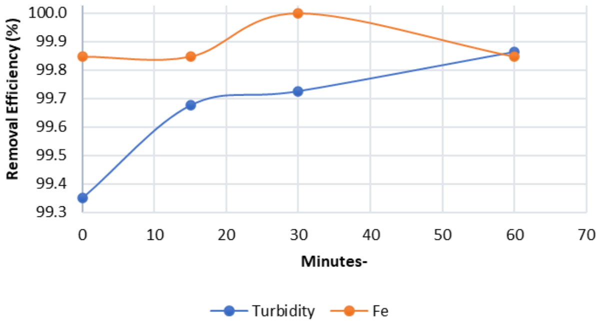


Figure 8. Removal efficiency of fe and turbidity using concrete filter C aerasi 3L/hours

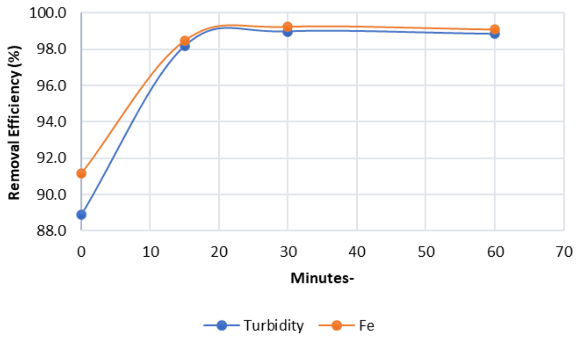


Figure 9. Removal efficiency of fe and turbidity using concrete filter a aerasi 6 L/hours

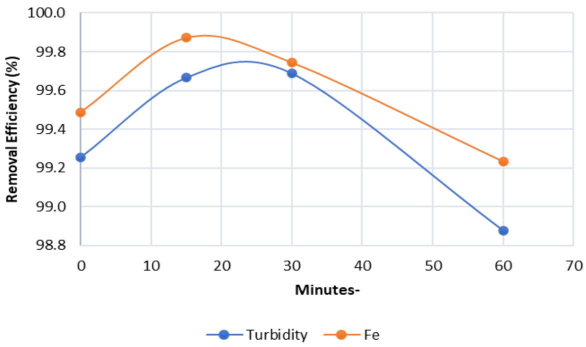


Figure 10. Removal efficiency of fe and turbidity using concrete filter b aerasi 6 L/hours

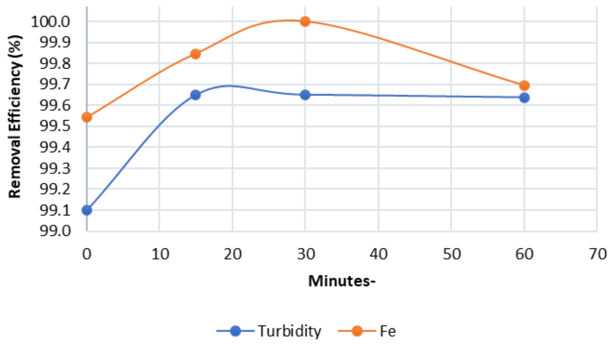


Figure 11. Removal efficiency of fe and turbidity using concrete filter c aerasi 6 L/hours

There is an anomaly in the result of the C-model concrete filter, where the iron filtering results can reach the best score of 100%, whereas the C filter model has the highest porosity. This is possible because the filter is so dirty that the pores of the filter shrink, resulting in good filtering efficiency.

3.4 Results of Fe and Turbidity Test

The quality of drinking water that has been treated with concrete filters is associated with the Minister of Health's Regulation RI Number: 2 Tahun 2023. The iron and turbidity value on inlet and outlet filter with aeration 3 L/hour can be seen in Table 5 while Table 6 show the turbidity value with aeration 6 L/hour.

Table 5. Iron and turbidity value on inlet and outlet filter (aeration 3L/hour)

Sample	Filter model	aeration (L/hour)	Minutes-	Turbidity (NTU)	Fe (mg/L)
Raw water 1				14.9	1.64
1	A	3	0	2.8	0.26
2	A	3	15	1.65	0.16
3	A	3	30	1.38	0.16
4	A	3	60	1.48	0.14
Raw water 2				80	6.55
9	B	3	0	13.2	1.01
10	B	3	15	2.31	0.16
11	B	3	30	0.5	0.02
12	B	3	60	0.59	0.03
Raw water 2				80	6.55
17	C	3	0	0.52	0.01
18	C	3	15	0.26	0.01
19	C	3	30	0.22	0
20	C	3	60	0.11	0.01

Table 6. Iron and Turbidity Value on Inlet and Outlet Filter (Aeration 6 L/ hour)

Sample	Filter model	aeration (L/hour)	Minutes-	Turbidity (NTU)	Fe (mg/L)
Raw water 1				80	6.55
5	A	6	0	8.88	0.58
6	A	6	15	1.46	0.1
7	A	6	30	0.82	0.05
8	A	6	60	0.93	0.06
Raw water 2				89.8	7.8
13	B	6	0	0.67	0.04
14	B	6	15	0.3	0.01
15	B	6	30	0.28	0.02
16	B	6	60	1.01	0.06
Raw water 2				80	6.55
21	C	6	0	0.72	0.03
22	C	6	15	0.28	0.01
23	C	6	30	0.28	0
24	C	6	60	0.29	0.02

At the maximum filtering result, the turbidity parameter uses a filter model A of 1.38 NTU, a filter model B of 0.5 NTU, and a filter model C of 0.1 NTU. For the maximum filtering outcome of the Fe parameter, filter model A was 0.14 mg/L, filter model B was 0.03 mg/L, and filter model C was 0. When associated with the Minister of Health's Regulation RI Number: 2 Tahun 2023, where the maximum turbidity rate is 5 NTU and Fe is 0.3 mg/L, the filtration result using a concrete filter with preliminary pretreatment using an aerator diffuser of 3 L/hour has been met. The table also found that the greater the porosity in the filter model, the greater the reduction, but the time it takes to obtain the maximum filtration is shorter, so that the model of the filter with the larger porosities is faster saturated and at the next filtration time is no longer able to reduce to the maximum.

This also occurs at the maximum filtration result using the initial pre-treatment diffuser aerator 6 L/hour turbidity parameter using filter models A of 0.82 NTU, B of 0.28 NTU, and C of 0.29 NTU. For the maximum filtering result of the Fe parameter, filter model A was 0.05 mg/L, filter model B was 0.01 mg/L, and filter model C was 0 mg/L. When associated with the Minister of Health's Regulation RI Number: 2 Tahun 2023, where the maximum turbidity rate is 5 NTU and Fe is 0.3 mg/L, the filtration result using a concrete filter with preliminary pretreatment using a 6 L/hour aerator diffuser has been met. The table also found that the greater the porosity in the filter model, the greater the reduction, but the time it takes to obtain the maximum filtration is shorter, so that the model of the filter with the larger porosities is faster saturated and at the next filtration time is no longer able to reduce to the maximum.

4. Conclusion

The results of the study showed that at an aeration rate of 3 L/hour, there had been a successive decrease in turbidity and Fe from 14.9 NTU to 1.38 NTU and 1.64 mg/L to 0.14 mg/L (filter A); 80 NTU to 0.5 NTU and 6.55 mg/L to 0.02 mg/L (filter B); 80 NTU to 0.1 NTU and 6.5 mg/L to 0 mg/L (filter C). For an aeration rate of 6 L/hour, there had been a successive decrease in turbidity and Fe from 80 NTU to 0.82 NTU and 6.55 mg/L to 0.05 mg/L (filter A); 89.8 NTU to 0.28 NTU, and 7.8 mg/L to 0.01 mg/L (filter B); 80 NTU to 0.28 NTU and 6,55 mg/L to 0 mg /L (filter C).

Thus, porous concrete filter can be considered an alternative to drinking water treatment according to the requirements set out in the Minister of Health's Regulation RI Number: 2 Tahun 2023 on Monitoring Requirements and Quality of Drinking Water) in Kalurahan Banaran Kabupaten Kulon Progo.

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