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Effectiveness of Using a Combination of Media in a Multi-Stage Filter for Processing Cisadane River Water

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Abstract

Water filters are tools that are widely used to purify water so that the dirt contained in it is reduced. Limited clean water causes many people to use water from rivers. One of the rivers that is still often used by people for MCK (Bathing, Washing, Toilet) activities is the Cisadane River, Tangerang Regency. This study aims to determine the best composition in improving water quality pH, TDS, ammonia, and iron levels in a multi-stage filtration device. This study was conducted in January-March 2025. Testing of iron (Fe) levels was carried out at the Serang Regency Health Laboratory UPT. This study consists of three stages, namely filter tool design, tool testing, and water quality testing. The water quality measured is the physical and chemical parameters (pH, TDS, ammonia, and iron levels). The trial method used was a Completely Randomized Design with 2 treatments (combinations) of 3 replications, namely combination 1 (15 cm silica sand, 15 cm rubble, 15 cm activated carbon, 15 cm zeolite stone, 10 cm sponge) and combination 2 (20 cm silica sand, 10 cm rubble, 20 cm activated carbon, 10 cm zeolite stone, 10 cm sponge). Based on research data, it shows that the use of multilevel filtration devices with two different combinations can improve water quality pH, TDS, ammonia, and iron levels. The best treatment was obtained by combination 2 because it was able to reduce TDS, ammonia and iron levels by 73%, 100%, and 98% respectively and increase the pH value towards more neutral. All results of filtration water quality tests from both compositions were significant ($p > 0.5$), but both compositions still had a good effect in improving water quality.

Keywords : *Water filter, multi-stage filter, water quality, rubble, Cisadane River*

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1. Introduction

Water is an essential need in daily life, such as for drinking, cooking, bathing, and washing. However, the increase in the need for clean water is not comparable to its availability, especially in areas where water sources have been polluted by domestic waste (Nindito et al. 2024). Based on data from the Ministry of Environment (2014), around 75% of rivers in Indonesia, including the Cisadane River in Tangerang Regency, are severely polluted due to the lack of sanitation facilities and low public awareness of environmental cleanliness (Jiao Ding et al. 2015).

Although alternatives such as groundwater extraction or purchasing clean water are available, these options are considered expensive and impractical for low-income communities, so the use of polluted river water is still common. Sari (2019) stated that many

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filters available on the market are sold at quite expensive prices, and their operation and maintenance are relatively complicated. To overcome this problem, efforts need to be made to provide a household-scale water treatment system. One effective and economical solution to improve water quality is through the filtration method. Filtration is a method used in water treatment to produce clean water (Yaqin et al. 2020). According to Nasution (2021), filtration is divided into three types, namely physical, chemical, and biological. Physical filtration is a physical filtration or separation process based on particle size or other physical properties. Chemical filtration uses chemicals to bind or decompose pollutants. Biological filtration uses microorganisms to decompose organic materials or biological pollutants such as detergent residue, organic waste, and ammonia. Biological filtration is not only assisted by microorganisms such as bacteria, but also by other natural components that support the biological water cleaning process, namely aquatic plants such as water hyacinth to help absorb pollutants such as heavy metals. Porous media also help the biological filtration process because it is a place for microbes to live and grow to form biofilms such as rubble, gravel, and pumice. Effective filtration can be done using rubble media. Rubble media or coral fragments have a porous structure with calcium carbonate ($CaCO_3$) content which can absorb pollutants, stabilize pH, and improve water quality (Temarwut 2023). A combination of other media such as activated carbon, zeolite, and silica sand is also commonly used to reduce TDS levels, turbidity, odor, and heavy metals such as iron (Vegatama et al. 2020).

Water treatment in this study will be carried out using a multistage filtration method with three stages of filtration that applies a downflow system. This method is generally used to ensure that the filtered water is cleaner and free from contaminants. Previous research by Jamila (2017) showed that a multistage filtration system using silica sand and activated carbon media can significantly reduce pollutant levels and meet clean water standards with an effectiveness of reducing iron levels of up to 90%. Although not suitable for industrial or medical waste treatment that requires further processes such as coagulation or reverse osmosis, this system is ideal for use in treating household water with mild to moderate levels of pollution, such as river water or wells that are not yet suitable for consumption. This study aims to determine the combination of effective filter media heights in reducing TDS (Total Dissolved Solid), pH, iron, and ammonia levels in water, so that the resulting water meets the quality standards as clean water and is suitable for use.

2. Method

Time and Place of Research

This research was conducted during the period of January to March 2025. The entire research process was carried out at the Aquaculture Laboratory, Fisheries Science Study Program, Faculty of Agriculture, Sultan Ageng Tirtayasa University and Health Laboratory UPT, Serang Regency. Water sampling was carried out in the Cisadane River, Jl. Raya Cadas Baru, Sepatan District, Tangerang Regency, Banten.

Tools and materials

In this study, the tools used were saw, drill, brush, sieve (mesh 4), hammer, meter, waring, bucket, ammonia test kit, and stationery. The materials used in this study were 3 and ½ inch PVC pipes, elbows, caps, faucet sockets, ball valves, taps, rubber seals, pipe glue, silica sand (mesh 16), activated carbon (mesh 8), rubble (mesh 4), zeolite (mesh 6), sponges, tissues, sample bottles, and distilled water.

Research Procedures

1. Breaking up dead coral

The dead coral is first cleaned and crushed using a hammer, then filtered using a 4 mesh sieve to obtain a uniform size as a water filtration medium.

2. Prototype creation of a cascade filter

The prototype of the water filtration device in this study was developed based on a modification of the design proposed by Oriza et al. (2023). Three variations of the filter media combination were made with different thicknesses, but had a total media thickness of 70 cm at one level. The greater thickness of the fine filter media contributed to an increase in the

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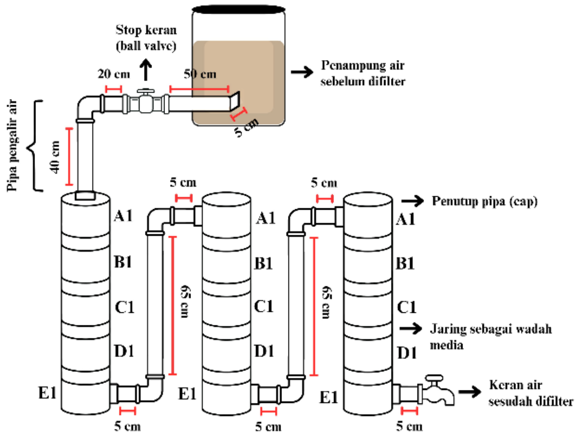
ability to absorb pollutants, as explained by Zharifah et al. (2024). The following is the design of a multi-level water filter designed in this study.

Combination 1

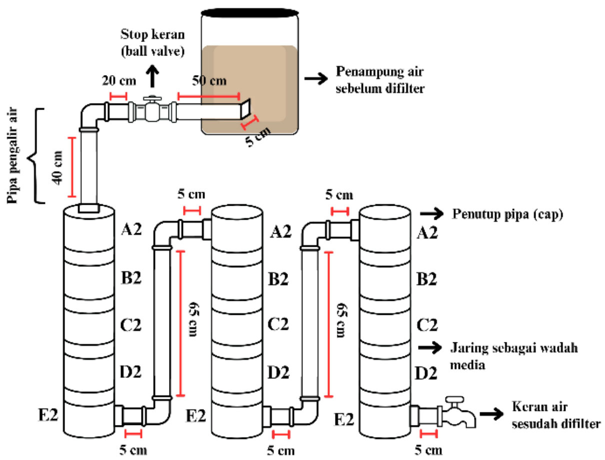


Information :

A1: Silica sand 15 cm
B1: Rubble 15 cm
C1: Activated carbon 15 cm
D1: Zeolite stone 15 cm
E1: Sponge 10 cm

Figure 1. Prototype of combination filter 1

Combination 2



Information :

A2: Silica sand 20 cm
B2: Rubble 10 cm
C2: Activated carbon 20 cm
D2: Zeolite stone 10 cm
E2: Sponge 10 cm

Figure 2. Prototype of combination filter 2

The steps of designing the water filter device in this study are starting from cutting 3 3-inch pipes with a length of 70 cm, then cutting 1 ½-inch pipe with a length of 20 cm, 1 50 cm, 1 5 cm, 7 and 1 40 cm. On the lower body of the bucket, the upper pipe cap, and the 3-inch pipe are perforated as water inlet and outlet. After that, fill the filter media in all 3-inch pipes using filter gauze for each media.

Install the inch pipe that has been filled with filter media according to the order shown in the picture separated by a net on each media. Install the pipe cap (cap) on the water filter containing the filter media that has been arranged, then connect it with a 65 cm pipe using an elbow that points upwards. The top of the 65 cm pipe is reconnected with an elbow that points to the left to be connected with a 5 cm pipe that enters the second filter that has been drilled into three levels. Connect the 3 inch pipe with the 5 cm pipe to the tap as a path for the filtered water.

Connect the 3 inch pipe to the ½ inch pipe with a length of 5 cm, 50 cm, 20 cm, and 40 cm using an elbow and ball valve as a water supply pipe that will enter the filter. Attach the water supply pipe to the bucket hole. The design scheme of the water filter tool can be seen in Figure 3.

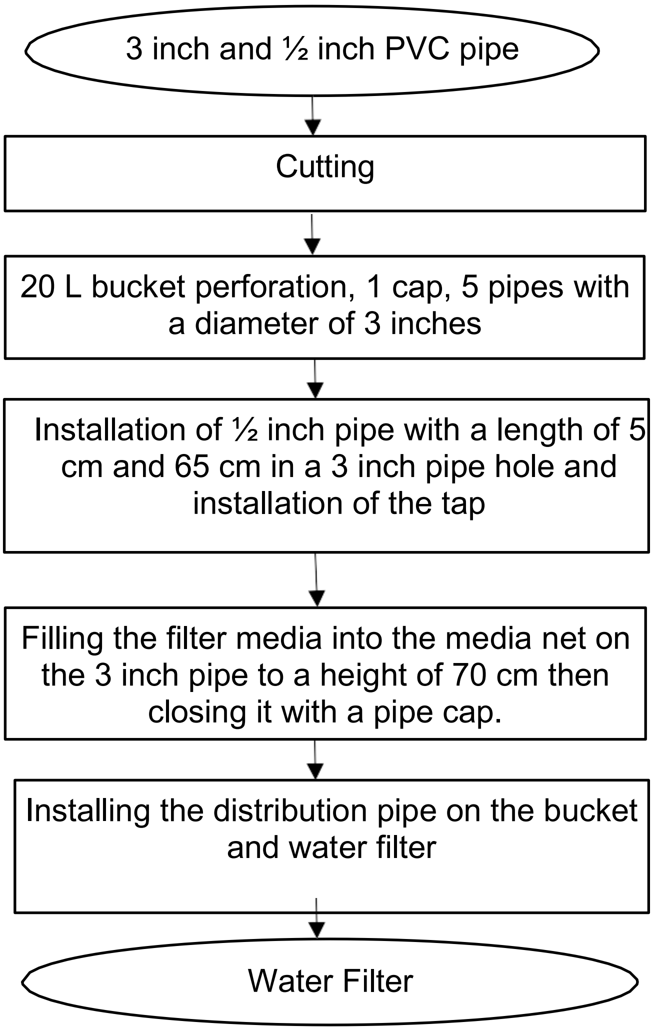


Figure 3. Multilevel filter design flow diagram

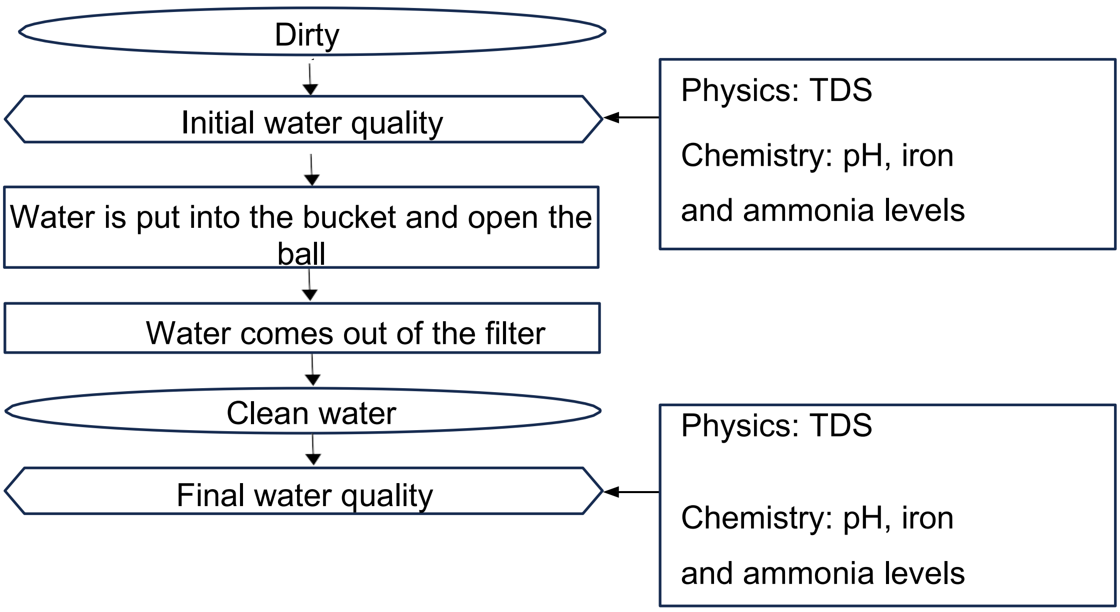
3. Cascading filter test

The prototype water filter that has been installed will then be tested. This water filter test will use 2 combinations of tiered filtration, namely:

1. Combination 1: Silica sand 15 cm – rubble 15 cm – activated carbon 15 cm – zeolite stone 15 cm – sponge 10 cm
2. Combination 2: Silica sand 20 cm – rubble 10 cm – activated carbon 20 cm – zeolite stone 10 cm – sponge 10 cm

The water sample to be tested using the water filter tool came from the Cisadane River, Tangerang Regency, Banten. The water sample used in 1 trial was 15 liters for each combination of media thickness. The water filter tool trial used a Completely Randomized Design (CRD) of 2 treatments and 3 replications. The following is a flow diagram of the multilevel filter trial.

Figure 4. Flow diagram of the multistage filter test



4. Water quality measurement

   Water quality parameters such as pH, TDS, iron content, and ammonia measured refer to the Regulation of the Minister of Health of the Republic of Indonesia Number 32 of 2017 concerning Environmental Health Quality Standards and Water Health Requirements for Hygiene Sanitation Needs, Swimming Pools, Solus Per Aqua, and Public Baths, with quality standards respectively of 6.5-8.5 mg/L, 1000 mg/L, 1 mg/L, and 1 mg/L. Water quality parameters were measured ex situ at the Aquaculture Laboratory, Fisheries Science Study Program, Faculty of Agriculture, Sultan Ageng Tirtayasa University and the Serang Regency Health Laboratory UPT.

Data analysis

1. Independent-Samples T Test
   The Independent-Samples T test is used to compare the means of two unrelated groups.
2. Tool effectiveness
   The measured water quality will be calculated to determine the effectiveness of using a water filter on the parameters tested, using the formula referred to by Rattu et al. (2022).

$$E = \frac{S0 - S}{S0} \times 100$$

Information:
E : Eftool activity
S0 : Levelbefore
S : Levelafter

3. Results and Discussion

Cascading Filters

Water filtration is a way to filter dirty water to make it clean by passing it through several layers of filtering materials. These materials can be silica sand, dead coral (rubble), activated carbon, zeolite, and sponge. Each of course has a special function, where sand can filter mud and large dirt, rubble helps stabilize pH, activated carbon absorbs odors and chemicals, zeolite binds metals such as iron and ammonia, and sponges prevent fine dirt from coming out. All of

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these materials are arranged from top to bottom so that the flowing water can be filtered gradually and the results will be more optimal if using multi-level filtration (Lubis et al. 2020). This method is suitable for use at home because the materials are easy to find, effective, and do not require electricity. The final result of the water filter design can be seen in Figure 5 as follows.

Figure 5. Cascading filter

The multilevel water filtration system shown in Figure 5 is the result of designing a water filter with gravity flow through several vertical filtration stages. Water from the reservoir flows into tubes containing different filter media, such as silica sand, dead coral (rubble), activated carbon, zeolite, and sponges, which are arranged sequentially. This system does not require additional pumps or power sources, making it more energy efficient and environmentally friendly. The filtration results show an increase in water clarity, indicating that the device is working effectively. This is in line with the findings of Santoso (2020) who stated that the multilevel filtration system can improve water quality because each stage has a specific function in removing contaminants. The results of observations on the parameters of Total Dissolved Solid (TDS), pH, iron, and ammonia show that this filter can be used to improve the quality of test water from the Cisadane River.

Total Dissolved Solid **(TDS)**

*Total Dissolved Solid*is a measure of the total amount of solids dissolved in water, both from organic and inorganic materials. These dissolved substances can be minerals, salts, metals, cations, and anions that dissolve in water. Based on the standards of WHO (World Health Organization) and the Indonesian Minister of Health Regulation No. 32 of 2017, the maximum limit of TDS in drinking water is around 500 mg/L. This means that if the TDS level is below this limit, it is generally still safe to consume.

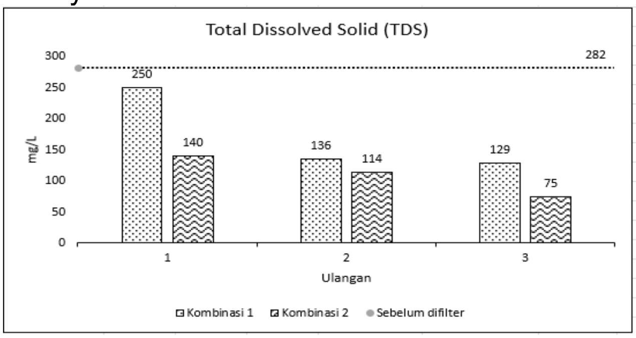

Figure 6. TDS value of multistage filtration test results

The results of the study showed that the pH value in water decreased significantly after going through the filtration process using two combinations of filter media in three repetitions (Figure 6). The TDS level of Cisadane River water before filtration was 282 mg/L. After filtration, the TDS value became very low from all combinations, namely with a TDS value of

75 mg/L in combination 2 repetition 3. The decrease in TDS proves the effectiveness of the multi-stage filtration device in filtering dissolved solids such as minerals, salts, and small organic materials. According to Putra (2021), the addition of a layer of 16 mesh silica sand in combination 2 as much as 5 cm in each tube has been proven to be able to reduce TDS levels in water. According to Shafira (2023), the use of silica sand as a filter medium can significantly reduce TDS levels because its tight pore structure allows the retention of small dissolved particles. The TDS value of the research results is far below the standard quality limit of 1,000 mg/L according to Permenkes No. 32 of 2017, so that the filtered water is safe to use.

Based on the calculation of the effectiveness of the tool, both combinations showed good effectiveness in reducing TDS levels in water. The effectiveness of reducing TDS in filter combination 1 ranged from 11–54%, with an increase after several uses. Combination 2 showed higher and more consistent effectiveness, reaching up to 73% in the third repetition. The increase in effectiveness from the first to the third repetition indicates that the filter media in this combination is more effective in absorbing or filtering dissolved solids (TDS). According to Suhartawan et al., (2023), effectiveness above 50% is considered very good in a household filtration-based clean water treatment system.

Table 1. Results of the independent-samples t test for Total Dissolved Solid (TDS)

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
TDS	Equal variances assumed	3,207	,148	1,424	4	,227	62,000	43,530	-58,860	182,860
	Equal variances not assumed			1,424	2,880	,253	62,000	43,530	-79,843	203,843

Source: (Results of researcher data processing, 2025)

Based on the study, the combination of filters effectively reduces TDS levels. Descriptively, Combination 2 is more effective in reducing TDS, but based on the Independent-Samples T Test statistical test p = 0.227 (p > 0.05), the difference between the two combinations is not significant. This means that although there are variations in the results, the difference in effectiveness between the two combinations cannot be directly linked to the difference in the type of filter media used.

Degree of Acidity (pH)

pH is a measure of the acidity or alkalinity of a solution expressed on a scale of 0-14, where pH 7 is neutral, below 7 is acidic, and above 7 is alkaline (Effendi, 2015). If the pH of water is too acidic or too alkaline, it can be dangerous for humans, animals, and plants, and can damage pipes or metal tools.

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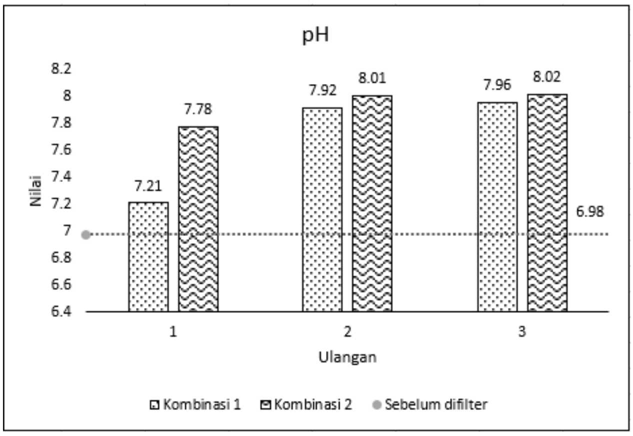

Figure 7. pH value of the results of the multistage filtration test

Based on the research results, it is known that the pH value of the Cisadane River water before the filtration process was at 6.98, which is included in the neutral category but tends to be slightly acidic. After going through the filtration process with a multi-stage filtration system, there was an increase in the pH value in combination 1 and combination 2 which can be seen in Figure 7. In combination 1, the pH value increased to 7.21, while in combination 2, the pH value increased even higher to 8.02. This shows that the filtration system used is able to stabilize and increase the pH of the water, so that it is more in accordance with the water quality standards based on the Regulation of the Minister of Health of the Republic of Indonesia Number 32 of 2017, namely 6.5-8.5. This increase in pH is partly due to the presence of a layer of rubble with a mesh size of 4 in this multi-stage filtration process. Based on the research results, reducing rubble from 15 cm to 10 cm can increase pH. Rubble functions as a base layer of the filter that not only filters coarse particles, but also helps stabilize the pH of the water by neutralizing acidic compounds. The porous physical structure of rubble helps maintain flow stability and increases the effectiveness of the media above it, such as silica sand, which also plays a role in increasing the pH of the water after the filtration process (Sutrisno, 2019).

Table 2. Results of the independent-samples t test for pH

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
pH	Equal variances assumed	6,538	,063	-,938	4	,401	-,24000	,25591	-,95051	,47051
	Equal variances not assumed			-,938	2,410	,433	-,24000	,25591	-1.17976	,69976

Source: (Results of researcher data processing, 2025)

Based on the results of the Independent-Samples T Test, it shows that the pH values of the two filter combinations are not significantly different, with a p value = 0.401 ($p > 0.05$). This means that although combination 2 looks better at increasing pH descriptively, the difference is not strong enough to be considered a real effect of the difference in filters. According to Khoiriah and Stighfarrinata (2023), an increase in pH can occur due to air bubbles when water flows through the filter media. These bubbles cause collisions between water molecules, which trigger ionic reactions and increase H ions.$^{+}$, so that the pH of the water rises.

Iron (Fe)

Iron (Fe) is a metal element that is often found in groundwater, especially in areas with high mineral content. If the levels exceed the threshold, iron can affect color, taste, and pose potential health risks if consumed in the long term. Based on the Regulation of the Minister of Health of the Republic of Indonesia No. 32 of 2017, the maximum concentration of Fe allowed in clean water is 1 mg/L.

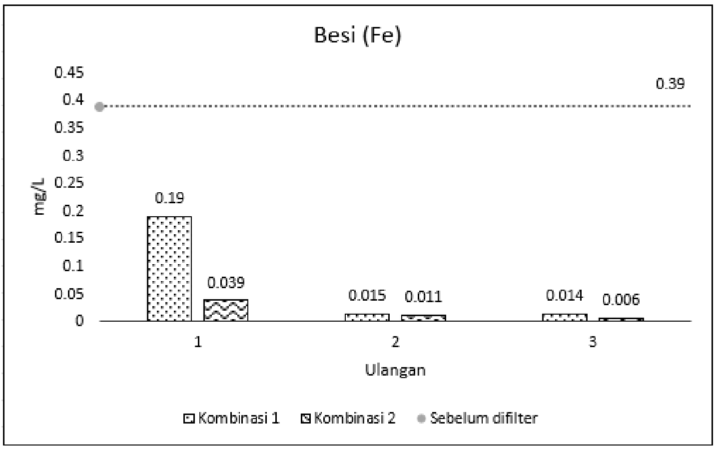

Figure 8. Iron content from multistage filtration test results

Based on the research data, it shows a decrease in iron (Fe) levels in water after the filtration process using two combinations of filter media in three repetitions, as shown in Figure 8. The initial Fe level of 0.39 mg/L was significantly reduced by both combinations. Combination 1 reduced Fe levels to 0.19; 0.015; and 0.014 mg/L, while combination 2 showed lower results, namely 0.039; 0.011; and 0.006 mg/L. This study shows that both media combinations are effective in reducing iron levels, but combination 2 has a higher effectiveness.

The results of the calculation of the effectiveness of the tool showed that both combinations of filter media were able to reduce iron (Fe) levels effectively. In the first repetition, combination 1 reduced iron levels by 51%, while combination 2 showed higher effectiveness with a reduction reaching 90%. Filtration effectiveness increased in the second and third repetitions, where combination 1 reached 96% effectiveness, and combination 2 increased to 98%. This study indicates that combination 2 has more optimal performance from the beginning of use, while combination 1 takes time to reach maximum performance. This means that the filter media in combination 2 is more effective in eliminating iron from water.

The difference in effectiveness between the two combinations of filter media is due to the proportion of zeolite used, where zeolite is known to be effective in reducing heavy metal levels through ion exchange and adsorption mechanisms (Bhatia, 2017). This study shows that modifying the media composition by reducing zeolite by 5 cm and adding 5 cm of silica sand can still reduce heavy metal levels. Zeolite has a microporous structure and a large surface area, so it is able to absorb metal ions such as $Fe^{2+}$and Fe^{3+}effectively. This effectiveness is also reinforced by the findings of Widiastuti et al. (2011) which proves that zeolite can increase the effectiveness of reducing heavy metals such as iron and manganese in water.

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Table 3. Results of the independent-samples t test for iron levels

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Iron	Equal variances assumed	10,543	,031	,915	4	,412	,054333	,059395	-,110574	,219241
	Equal variances not assumed			,915	2,123	,452	,054333	,059395	-,187533	,296200

Source: (Results of researcher data processing, 2025)

Based on the research results, both combinations of filter media were proven to be able to reduce iron (Fe) levels to below the maximum limit set. Although combination 2 resulted in a lower reduction in Fe levels compared to combination 1, the results of the Independent-Samples T Test statistical test showed a value of p = 0.412 (p > 0.05), which means that the difference was not statistically significant. This means that although there are variations in the results, the difference in effectiveness between the two combinations cannot be directly linked to the differences in the types of filter media used.

Ammonia (NH3)

Ammonia (NH_3) is a nitrogen compound derived from the decomposition of organic materials, domestic waste, and agricultural activities, and is often detected in water. This compound needs to be monitored because in high concentrations it is toxic to aquatic organisms and has the potential to harm human health. This is stated in the Regulation of the Minister of Health of the Republic of Indonesia No. 32 of 2017, the level of ammonia in drinking water must not exceed 0.5 mg/L.

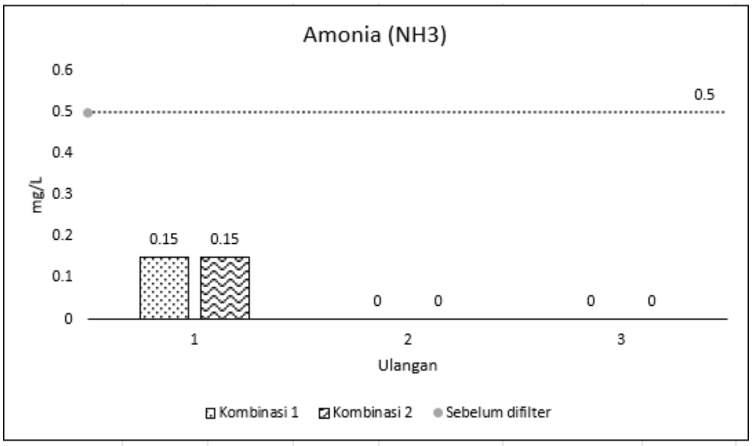

Figure 9. Ammonia levels from multistage filtration tests

The results of the study showed that the concentration of ammonia (NH_3) in water experienced a significant decrease after going through the filtration process using two combinations of filter media in three repetitions (Figure 9). Before filtration, the ammonia level was recorded at 0.5 mg/L. After filtration, there was a sharp decrease to 0.15 mg/L in the first repetition, and reached 0 mg/L in the second and third repetitions for both media combinations. This decrease indicates the high effectiveness of the filtration system in removing ammonia. Activated carbon and silica sand play an important role in this process through the adsorption mechanism of ammonium ions (NH_4^+). The addition of 5 cm of activated carbon and silica sand each increased the filter's ability to reduce ammonia levels, in line with the findings of Widiastuti et al. (2011) which stated that activated carbon is effective in absorbing ammonium ions through its pore structure and surface charge.

Based on the calculation of the effectiveness of the tool, both combinations of filter media showed very good effectiveness in reducing ammonia levels (NH_3) in water, especially in the second and third repetitions with an effectiveness reaching 100%. In the first repetition, both combinations only succeeded in reducing the levels of $NH_3$by 70%, which is likely due to the filter not being optimal. In the second and third repetitions, both combinations 1 and 2 showed a decrease in ammonia of up to 100%, meaning that all ammonia was successfully removed from the water. This shows that both filtration systems have a high ability to filter ammonia after the filter works optimally. Media such as zeolite, activated carbon, and silica sand play a role in absorbing NH ions.$_4^+$effectively (Kurniawan et al. 2010). Based on the Regulation of the Minister of Health of the Republic of Indonesia No. 32 of 2017, the safe limit for ammonia content in clean water is 0.5 mg/L. The results of 100% effectiveness provide evidence that the filtered water in this study meets the standards for clean water quality and is safe for use in household activities and supports fish farming activities.

Table 4. Results of the independent-samples t test for ammonia levels
Source: (Results of researcher data processing, 2025)

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Ammonia	Equal variances assumed	,000	1,000	,000	4	1,000	,00000	,07071	-,19632	,19632
	Equal variances not assumed			,000	4,000	1,000	,00000	,07071	-,19632	,19632

Based on the results of the Independent-Samples T Test on ammonia levels, a p value of 1,000 ($p > 0.05$) was obtained, indicating that there was no significant difference between the combination of filter media 1 and 2 in reducing ammonia levels. This means that even though there are variations in the thickness of silica sand and zeolite, these differences do not have a significant effect on the effectiveness of reducing ammonia in water.

4. Conclusions

Based on the research that has been conducted, it can be concluded that the use of a multi-level water filter with two different media combinations, namely silica sand, rubble (dead coral), activated carbon, zeolite stone, and sponge, is effective in filtering river water to make it cleaner. Both combinations showed good effectiveness, but combination 2 with a thickness of 20 cm silica sand, 10 cm rubble, 20 cm activated carbon, 10 cm zeolite stone, and 10 cm sponge, was superior compared to combination 1 which had a more even media thickness. Combination 2 succeeded in reducing the levels of TDS ammonia and iron by 73% 100%, and 98% respectively and increasing the pH of the water towards a more neutral direction. Although statistically the difference between the two combinations was significant, the results of the study showed that the water filtered with combination 2 looked clearer and cleaner. Overall, both filters worked well and can be selected based on needs, whether prioritizing water quality (combination 2) or filtration speed (combination 1). Both of these combinations have met the standards for clean water in accordance with the Regulation of the Minister of Health of the Republic of Indonesia No. 32 of 2017, which regulates water quality standards for sanitation hygiene activities.

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