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The Effect of Media Variation in Simple Filtration Systems on the Physical Quality of Clean Water Post-Flooding

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ABSTRACT

Flooding is one of the most common disasters in Indonesia and often causes deterioration in clean water quality, particularly through increased turbidity, color, and suspended solids. One alternative for improving post-flood water quality is the use of simple filtration systems with different filter media combinations. This study aimed to analyze the effect of filtration media variations on the physical quality of post-flood water. An experimental study using a Completely Randomized Design (CRD) was conducted with four treatments and three replications. Water samples were collected from flood-affected areas in Padang City, West Sumatra, Indonesia. The treatments consisted of P0 (control), P1 (sand and gravel), P2 (sand, gravel, and activated carbon), and P3 (sand, gravel, activated carbon, and zeolite). The observed parameters included turbidity, color, and Total Suspended Solids (TSS). Data were analyzed using One-Way Analysis of Variance (ANOVA) at a 95% confidence level. The results showed that variations in filtration media significantly affected turbidity, color, and TSS ($p < 0.05$). Descriptively, treatment P3 showed the lowest mean values of turbidity (7.8 NTU), color (11.7 TCU), and TSS (12.0 mg/L) among all treatments. However, because no post hoc analysis was performed, these findings should not be interpreted as evidence that P3 was statistically superior to the other treatment combinations. The values obtained in P3 met the applicable water quality standards for all observed physical parameters. It can be concluded that variations in filtration media significantly influence the physical quality of post-flood water, and a filtration system combining sand, gravel, activated carbon, and zeolite has potential as an appropriate technology for post-disaster clean water provision.

Keywords: *Post-Flood Water, Simple Filtration, Turbidity, Total Suspended Solids, Environmental Health*

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INTRODUCTION

Floods are one of the most common hydrometeorological disasters in Indonesia and have a wide-ranging impact on social, economic, and public health aspects. Data from the National Disaster Management Agency show that floods continue to account for the majority of disasters in Indonesia each year and often result in damage to infrastructure, including clean water supply systems. This situation makes it difficult for communities to access safe water for daily needs, thereby increasing the risk of waterborne diseases.

Clean water is a basic necessity that plays a vital role in supporting people's lives and health. The availability of water that meets health standards is a key indicator in efforts to improve public health. According to the World Health Organization (2022), access to safe drinking water and clean water is a key component in the prevention of infectious diseases as well as the achievement of the Sustainable Development Goals (SDGs). Water that does not meet quality standards can serve as a medium for the transmission of various diseases such as diarrhea, cholera, dysentery, and other infectious diseases that remain public health issues in many developing countries (WHO 2022).

From a regulatory perspective, the public's right to safe water is enshrined in Law No. 17 of 2019 on Water Resources, which states that every citizen has the right to access water to meet their basic daily needs. Additionally, water quality for hygiene and sanitation purposes is regulated by Regulation of the Minister of Health of the Republic of Indonesia No. 2 of 2023 on the Implementing Regulations of Government Regulation No. 66 of 2014 on Environmental Health, which stipulates that water used by the public must meet physical, chemical, biological, and radioactivity requirements in accordance with health standards.

One of the primary issues arising after flooding is the deterioration of water's physical quality. Flood-contaminated water typically exhibits increased turbidity, changes in color and odor, as well as high levels of total suspended solids (TSS). High turbidity indicates a large number of suspended particles in the water and can serve as a refuge for pathogenic microorganisms, thereby reducing the effectiveness of the disinfection process (WHO 2022). Therefore, improving the physical quality of water is an important first step before the water is used by the public.

Although various water treatment technologies have been developed, post-disaster emergency situations require methods that are simple, inexpensive, and easy for communities to implement. One widely used method is a simple filtration system that employs a combination of media such as sand, gravel, activated carbon, and zeolite. These media work through physical filtration, sedimentation, and adsorption mechanisms to reduce the content of suspended particles and contaminants in water (Tiwari et al. 2021).

Sand is a commonly used filtration medium because it is capable of retaining small particles through a mechanical filtration process. Gravel serves as a support medium while also filtering out larger particles. Activated carbon has a high adsorption capacity for organic compounds and color-causing substances in water, while zeolite is known for its effective ion exchange and adsorption capabilities in improving water quality (Mishra et al. 2021). The combination of these various media is believed to enhance filtration efficiency compared to using a single type of media alone.

Previous research has shown that the use of different filtration media yields varying levels of effectiveness in improving water quality. A study by Nurhady, Ramlan, and Suparmin (2022) reported that the use of filtration media was able to significantly reduce turbidity levels and improve the physical quality of water. Another study by Puspa (2022) showed that the addition of zeolite in a filtration system can enhance the removal of color and turbidity from water through adsorption and ion exchange mechanisms. Meanwhile, an international study conducted by Tiwari et al. (2021) indicates that natural media such as sand, activated carbon, and zeolite are effective for household-scale water treatment, particularly in emergency situations and areas with limited water treatment infrastructure. Various recent studies indicate that a combination of natural filtration media such as sand, activated carbon, and zeolite can improve the efficiency of removing physical water parameters through filtration, adsorption, and ion exchange mechanisms. The use of this media combination has proven effective in reducing turbidity, color, and suspended solids in surface water and post-disaster water (Sarkar et al., 2022).

Nevertheless, studies on the effects of varying combinations of simple filtration media on the physical quality of water after flooding remain relatively limited, particularly at the household level where such systems can be easily implemented by the community. Previous studies generally focused on evaluating the effectiveness of one or two types of filtration media, such as sand, activated carbon, or zeolite, in improving water quality. However, limited research has compared different combinations of filtration media in a stepwise manner to determine their relative effectiveness in treating post-flood water. Therefore, this study was conducted to analyze the effects of varying filtration media in simple filtration systems on the physical quality of clean water after flooding, based on the parameters of turbidity, color, and Total Suspended Solids (TSS). By comparing four filtration configurations (P0, P1, P2, and P3) consisting of different combinations of sand, gravel, activated carbon, and zeolite, this study provides a more comprehensive evaluation of the contribution of each media combination to the reduction of turbidity, color, and TSS in post-flood water. The results of this study are expected to serve as a basis for the development of simple water treatment technologies that are effective, inexpensive, and easy for the community to apply in post-flood conditions.

METHODS

This study is an experimental quantitative study using a completely randomized design (CRD) aimed at determining the effect of variations in filtration media in a simple filtration system on the physical quality of post-flood water. The study was conducted in November 2025 in Padang City, West Sumatra Province. The research samples consisted of post-flood water collected from floodwaters in flood-affected areas of Padang City. Water samples were collected from three flood-affected locations representing different residential areas in Padang City. Sampling was conducted within 24–48 hours after the flood event at three sampling points for each location. Samples were collected at a depth of approximately 20–30 cm below the water surface using sterile polyethylene containers to avoid surface debris contamination. Each sample was transported to the laboratory in a cooled container at a temperature of approximately 4°C and analyzed within 24 hours after collection to maintain sample integrity and prevent changes in water quality characteristics prior to testing.

The study employed four filtration treatments: P0 (control without filtration), P1 (filtration using sand and gravel media), P2 (filtration using sand, gravel, and activated carbon media), and P3 (filtration using sand, gravel, activated carbon, and zeolite media). Each treatment was repeated three times, resulting in 12 experimental units. Three replications were considered sufficient to evaluate the consistency of treatment effects while maintaining feasibility within the available time, laboratory resources, and research budget. In addition, the number of replications was adjusted to the availability of post-flood water samples and laboratory testing capacity during the study period. The filtration media were arranged in a simple filtration column with the same media thickness for each treatment to maintain consistency.

The filtration media comprising silica sand, gravel, activated carbon, and zeolite were washed and dried before use to remove impurities that could affect the research results. The sample water was then passed through the filtration system by gravity, and the filtrate was collected for physical quality testing. The filtration system was constructed using a PVC column with a diameter of 10 cm and a height of 80 cm. The thickness of the filtration media was 20 cm for silica sand, 15 cm for gravel, 15 cm for activated carbon, and 15 cm for zeolite. The particle size of the sand ranged from 0.2–0.5 mm, gravel from 5–10 mm, activated carbon from 2–5 mm, and zeolite from 1–3 mm. Each treatment was used to filter 10 liters of post-flood water samples using a gravity flow system.

The independent variable in this study was the variation in simple filtration media, while the dependent variables were the physical water quality parameters, including turbidity, color, and Total Suspended Solids (TSS). Turbidity measurements were performed using a Turbidity Meter with units of Nephelometric Turbidity Units (NTU), color measurements used the Platinum Cobalt (Pt-Co) method with units of True Color Units (TCU), while TSS measurements were performed using the gravimetric method with units of mg/L. All testing procedures refer to the Standard Methods for the Examination of Water and Wastewater (APHA, 2023).

Univariate analysis was performed to describe the mean and standard deviation of each physical water quality parameter for each treatment. Before conducting inferential analysis, the data were tested for normality using the Shapiro–Wilk test and for homogeneity using Levene's test. The test results indicated that all data were normally distributed and homogeneous ($p > 0.05$), allowing further analysis using One-Way Analysis of Variance (ANOVA) at a 95% confidence level ($\alpha = 0.05$). The ANOVA was used to determine whether variations in filtration media significantly affected the physical quality of post-flood water. No post hoc tests, such as Tukey's HSD or Duncan's multiple range test, were conducted because the study was not designed to statistically compare individual treatments or identify the superior treatment among the filtration media combinations. Therefore, any reference to treatment P3 as producing the best water quality is based solely on descriptive comparisons of the mean values and should not be interpreted as evidence of a statistically significant difference from treatments P1, P2, or P0. Testing decisions were based on significance levels, where a p-value < 0.05 indicated a significant influence of filtration media variations on the observed physical water quality parameters.

RESULTS

1. Initial Sample Characteristics

Table 1. Initial Characteristics of Post-Flood Water Before Filtration Treatment

Parameter	Measurement Result	Standard Limit	Description
pH	6.8	6.5–8.5	Meets the standard
Turbidity	85.4 NTU	≤ 25 NTU	Does not meet the standard
Color	98.7 TCU	≤ 50 TCU	Does not meet the standard
TSS	120 mg/L	≤ 50 mg/L	Does not meet the standard

The water quality standards presented in Table 1 refer to the Regulation of the Minister of Health of the Republic of Indonesia No. 2 of 2023 concerning the Implementation Regulation of Government Regulation No. 66 of 2014 on Environmental Health, which establishes water quality requirements for hygiene and sanitation purposes.

Based on the initial characterization results, the post-flood water used as the research sample exhibited turbidity, color, and total suspended solids (TSS) levels exceeding the water quality standards for hygiene and sanitation purposes. These findings indicate that the water requires treatment before it can be safely utilized by the community. Meanwhile, the pH value remained within the permissible range, suggesting that physical water quality parameters were the primary focus of this study.

2. Univariat Analysis

Univariate analysis was conducted to describe the characteristics of the physical quality data of post-flood water obtained from each treatment group. The observed parameters included turbidity, color, and Total Suspended Solids (TSS). In addition, normality and homogeneity tests were performed as prerequisites for parametric statistical analysis. The results of the univariate analysis are presented in the following table.

Table 2. Results of Normality and Homogeneity Tests

Parameter	Shapiro–Wilk (p-value)	Levene's Test (p-value)	Interpretation
Turbidity	0.214	0.176	Normal and Homogeneous
Color	0.321	0.287	Normal and Homogeneous
TSS	0.265	0.198	Normal and Homogeneous

Based on the results of the normality test using the Shapiro–Wilk method and the homogeneity test using Levene's Test, all parameters showed p-values greater than 0.05. These results indicate that the data were normally distributed and exhibited homogeneous variances. Therefore, the assumptions required for conducting a One-Way Analysis of Variance (One-Way ANOVA) were satisfied.

Turbidity Measurement Results

Table 3. Turbidity Measurement Results (NTU) Based on Filtration Media Variations

Treatment	Replicate 1	Replicate 2	Replicate 3	Mean ± SD
P0	82.7	88.4	85.1	85.4 ± 2.86
P1	39.8	46.5	41.8	42.7 ± 3.44
P2	16.2	20.5	18.8	18.5 ± 2.17
P3	6.5	9.2	7.8	7.8 ± 1.35

Based on Table 3, all filtration treatments were effective in reducing water turbidity compared to the control group. Descriptively, treatment P3 showed the lowest turbidity value, with a mean of 7.8 NTU. However, because no post hoc test was conducted, this finding should be interpreted as a descriptive observation rather than evidence of a statistically significant difference between treatments.

Color Measurement Results

Table 4. Water Color Measurement Results (TCU) Based on Filtration Media Variations

Treatment	Replicate 1	Replicate 2	Replicate 3	Mean ± SD
P0	95	102	99	98.7 ± 3.51
P1	52	60	58	56.7 ± 4.16
P2	21	27	25	24.3 ± 3.06
P3	10	14	11	11.7 ± 2.08

Based on Table 4, water color values decreased across all filtration treatments compared to the control group. Descriptively, the lowest color value was observed in treatment P3, with a mean of 11.7 TCU. However, no statistical comparison among individual treatments was performed; therefore, this result should be interpreted descriptively.

Total Suspended Solids (TSS) Measurement Results

Table 5. Total Suspended Solids (TSS) Measurement Results Based on Filtration Media Variations

Treatment	Replicate 1	Replicate 2	Replicate 3	Mean ± SD
P0	116	123	121	120.0 ± 3.61
P1	63	71	70	68.0 ± 4.36
P2	28	33	32	31.0 ± 2.65
P3	9	14	13	12.0 ± 2.65

Based on Table 5, all filtration treatments were able to reduce Total Suspended Solids (TSS) concentrations compared to the control group. Descriptively, treatment P3 yielded the lowest TSS concentration, with a mean value of 12.0 mg/L. Nevertheless, since no post hoc analysis was conducted, this result should not be interpreted as indicating a statistically superior treatment.

3. Bivariate Analysis

Bivariate analysis was conducted to determine the effect of filtration media variations on the physical quality of post-flood water. Since the results of the normality and homogeneity tests indicated that the data met the assumptions for parametric statistical analysis ($p > 0.05$), further analysis was performed using a One-Way Analysis of Variance (ANOVA) at a 95% confidence level ($\alpha = 0.05$). The ANOVA results for each physical water quality parameter are presented in the following table.

Table 6. Results of One-Way ANOVA on the Effect of Filtration Media Variations on the Physical Quality of Post-Flood Water

Parameter	F-value	p-value	Interpretation
Turbidity	286.74	< 0.001	Significant
Color	198.52	< 0.001	Significant
TSS	241.89	< 0.001	Significant

Based on the results of the One-Way ANOVA presented in Table 6, all observed parameters showed p-values below 0.05. These findings indicate that variations in filtration media had a statistically significant effect on the physical quality of post-flood water, including turbidity, color, and Total Suspended Solids (TSS). Therefore, the research hypothesis stating that variations in media composition within a simple filtration system influence the physical quality of post-flood clean water is accepted. Descriptively, treatment P3 showed the lowest mean values for turbidity, color, and TSS among all treatments. However, because no post hoc analysis was performed, it cannot be concluded statistically that P3 was significantly different from P2, P1, or P0. Therefore, the superiority of P3 should be interpreted only as a descriptive finding. Since the primary objective of this study was to determine whether filtration media variations significantly affected water quality, no post hoc analysis was performed following the ANOVA test.

DISCUSSION

The results of this study indicate that variations in filtration media significantly affected the physical quality of post-flood water, as demonstrated by the ANOVA results showing significant differences among treatments for turbidity, color, and Total Suspended Solids (TSS). These findings suggest that the combination of filtration media plays an important role in enhancing the efficiency of contaminant removal through multiple physical and adsorption mechanisms. This observation is consistent with the principles of water treatment, which state that combining different filtration media can improve the removal of suspended particles, organic matter, and other contaminants compared with the use of a single medium (Crittenden et al., 2017).

The reduction in turbidity observed after filtration can be explained by the complementary functions of the filtration media. Sand acts as the primary filtration medium by physically retaining fine suspended particles through a mechanical straining process. Gravel serves as a support layer that retains larger particles and promotes a more uniform distribution of water flow, thereby improving filtration efficiency. Activated carbon contributes to the removal of fine particulate matter and dissolved substances through adsorption mechanisms, while zeolite enhances particle removal through its porous structure and adsorption capacity. The combination of these mechanisms increases the overall effectiveness of the filtration process, resulting in improved water clarity. Similar findings have been reported by Mishra et al. (2021) and Ahamad et al. (2023), who demonstrated that combining natural filtration media can substantially improve turbidity removal in household-scale water treatment systems.

A similar mechanism may explain the reduction in water color observed across the filtration treatments. Post-flood water commonly contains dissolved organic matter, colloidal particles, and fine sediments that contribute to water discoloration. Activated carbon plays a particularly important role in reducing color because of its large surface area and high adsorption capacity for organic compounds and color-causing substances (Bhatnagar & Sillanpää, 2017). In addition, zeolite contributes to the adsorption of dissolved contaminants that may influence water appearance. The combined action of physical filtration by sand and gravel and adsorption by activated carbon and zeolite provides a more comprehensive treatment process, thereby improving the aesthetic quality of the water. These findings are consistent with those reported by Laily et al. (2022), who found that activated carbon-based filtration systems effectively improve water quality characteristics.

The decrease in Total Suspended Solids (TSS) can also be attributed to the interaction of several filtration mechanisms. Suspended solids in post-flood water consist of fine soil particles, organic debris, and other particulate matter transported during flooding events. Sand and gravel effectively remove larger and medium-sized particles through physical filtration, whereas activated carbon and zeolite assist in retaining finer particles through adsorption and surface attachment processes. As a result, the overall suspended solid load is reduced before the water exits the filtration column. This finding supports the study of Tiwari et al. (2021), which demonstrated that combinations of natural filtration media can effectively reduce suspended solids in contaminated surface water.

Descriptively, the treatment consisting of sand, gravel, activated carbon, and zeolite (P3) showed the lowest mean values for turbidity, color, and TSS among all treatments. However, because no post hoc analysis was performed, these findings should not be interpreted as evidence that P3 was statistically superior to the other treatment combinations. Rather, the results suggest that the integration of multiple filtration media may provide complementary treatment mechanisms that enhance overall filtration performance. Sand functions as the primary filter for fine particles, gravel improves flow distribution and retains larger particles, activated carbon adsorbs organic compounds and color-causing substances, and zeolite contributes through adsorption and ion-exchange processes. The synergistic interaction among these media likely explains the more favorable descriptive results observed in P3. Similar observations have been reported by Azzouz et al. (2024), who highlighted the role of natural zeolite in improving water treatment efficiency through adsorption and ion-exchange mechanisms.

CONCLUSIONS

Variations in filter media within a simple filtration system significantly affect the physical quality of post-flood clean water, as measured by turbidity, color, and Total Suspended Solids (TSS) ($p < 0.05$). The findings indicate that the use of multiple filtration media combinations can improve the effectiveness of post-flood water treatment through complementary filtration and adsorption mechanisms. Descriptively, treatment P3, consisting of sand, gravel, activated carbon, and zeolite, showed the lowest mean values of turbidity (7.8 ± 1.35 NTU), color (11.7 ± 2.08 TCU), and TSS (12.0 ± 2.65 mg/L) among all treatments. However, because no post hoc analysis was performed, these findings should not be interpreted as evidence that P3 was statistically superior to the other treatment combinations. The values obtained in treatment P3 also met the applicable water quality standards for all observed physical parameters, indicating the potential effectiveness of this filtration configuration for post-flood water treatment. A simple filtration system using a combination of sand, gravel, activated carbon, and zeolite has the potential to be applied as appropriate technology for clean water supply in post-flood disaster conditions and areas with limited access to water treatment facilities.

This study has several limitations. The parameters observed were limited to the physical quality of the water, namely turbidity, color, and TSS, and therefore cannot provide a comprehensive picture of water quality. Additionally, this study did not test chemical or microbiological parameters, which also play a crucial role in determining the suitability of water for public use. The number of replicates used was limited due to time and cost constraints; therefore, the results need to be confirmed through follow-up studies with a larger number of replicates. Future research is also recommended to combine testing of physical, chemical, and microbiological parameters and to evaluate the effectiveness of various filtration media combinations on a larger scale.

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