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Integrated Water Treatment System for Peat Water Treatment

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The supply of clean water is a major problem in both developed and developing countries. The abundant amount of peat water can be a potential source of clean water in areas with peatlands. Peat water treatment can be conducted effectively and efficiently by integrating various existing methods, such as aeration, sedimentation, and filtration using shell sand and activated carbon. The results show that the parameters of color, turbidity, Ferrum (Fe), microbiological parameters, and pH of peat water can be conditioned according to clean water standards. The average peat watercolor parameter before processing is 866.7 PtCo, 10.96 NTU turbidity, 2.48 mg L^{-1} Fe, Fe, 4.30 pH, and coliform (microbial) peat water at 1068 CFU and after passing the color combination treatment to 28.83 PtCo, turbidity 2.19 NTU, Fe 0.22 mg L^{-1}, and coliform 20 CFU and pH 6.83. Integrated peat water treatment is the most effective at the filtration and adsorption stages.

1. Introduction

Peat water is a potential water source that meets clean water requirements. In Indonesia, peat water is abundant, because of the extent of the peatland area. Indonesia has the largest area of peat in the tropical zone, estimated at 21 Mha, representing 70% of the peat area in Southeast Asia and 36% of the world's tropical peatlands.[1,2] These peatlands are concentrated in three large islands: Sumatra (35%), Kalimantan (32%), and Papua (30%). They spread from the lowlands to the highlands.[2,3] The quantity of peat water is abundant, but has inferior physical, chemical, and biological qualities. Peat water has a characteristic high color that is caused by humic substances, namely organic molecules that occur naturally through the breakdown of animal and vegetable matter. Humic and fulvic acids that dissolve in water are highly complex with unclear compositions.[4] Peat water has a low pH and high iron (Fe) Ferrum content,[5,6] and is surface water that is susceptible to biological contamination, which increases the range of pathogenic microbes.[7]

The complexity of peat water pollutants requires integrated peat water treatment using several methods. Several peat water treatment studies have been conducted to remove humic substances and organic matter using activated carbon.[4,8] The acidic nature of peat water results in a high level of solubility of metals, such as Fe, that can be treated with oxygen in the peat water. Studies that have been conducted in Fe processing include aeration and filtration,[9] the combination of chlorination and filtration,[10] and a combination of potassium permanganate and filtration.[10–12] Each method has its own advantages and disadvantages. Water treatment using aeration has the advantage of being a more efficient and straightforward process. Water treatment using filters has been studied in previous research to reduce the color, Fe, Mn, and microbiology with filter materials such as silica sand, activated carbon, and manganese zeolites. Filters using silica sand effectively reduce turbidity and bacteria in the water formed from the biofilm layer.[13–15]

Several water treatment methods for peat water treatment that have been conducted need to be refined with processing, selecting media, and filtering tools that are readily available for rural communities. In optimizing water treatment results by integrating several water treatment methods, integrated water treatment methods are selected based on the availability of

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Table 1. Classification and concentration of pollutants in peat water.

Classification	Concentration
Color	866.17 PtCo
Turbidity	10.96 NTU
pH	2.48
Ferro (Fe)	4.30 mg L^{-1}
Total coliform	1068 CFU

materials in the local area, low cost, ease of manufacture, and results that meet health requirements.[16–19] Several methods of peat water treatment include aeration, sedimentation, filtration using mollusk sand media, and activated carbon.[20–22] The integration of peat water treatment is expected to reduce the parameters of turbidity, color, Fe content, and microbes, and increase the pH to meet the health requirements of clean water.

The filter material consisted of mollusk sand and activated carbon from the coconut shell. Mollusk sand is abundant in coastal areas, especially along the north coast of West Kalimantan, and has advantages over quartz sand in peat water treatment. Mollusk sand contains $CaCO_3$, which serves to increase the pH and thus reduces the solubility of metals such as Fe in peat water.[23,24] In addition to increasing pH, mollusk sand can form biofilms that act as bacterial plaques and are useful as decomposers of organic material in water.[13]

The use of activated coconut shell charcoal further optimized the filtering and absorption processes compared to wood or other activated carbons. The filtration and absorption process with activated carbon filters and absorbs Fe and other pollutants soluble in peat water.[25,26] Filter function and absorption can occur because coconut shell-activated carbon exhibits micropores and mesopores.[24,25] In addition, activated carbon is an adsorbent in which the carbon atom structure is disordered, consisting mostly of free carbon, and has an inner surface, so it has a good absorption ability.[24–26] This study aimed to conduct a simple research on peat water treatment by developing an existing integrated method to optimize the reduction of turbidity, color, microbes, and Fe content and increase the pH of peat water to meet health requirements.

2. Experimental Section

2.1. Characteristics of Peat Water

Peat swamp water uses peat water from the Kubu Raya Regency, West Kalimantan. In Borneo Island, peat water has the following water quality: temperature range (26.85–32.90°C), pH (3.03–3.84), dissolved oxygen (DO; 1.99–8.05 mg L^{-1}), conductivity (42.07–98.72 μS cm^{-1}), total suspended solids (TSS; 1–54 mg L^{-1}), turbidity (0.39–9.80 NTU), biological oxygen demand (BOD; 0.5–9.8 mg L^{-1}), chemical oxygen demand (COD; 0–17 mg L^{-1}) and ammonia nitrogen (0.2–0.42 mg L^{-1}).[27] The peat water was analyzed in the morning and evening. **Table 1** presents the characteristics of peat water.

2.2. Research Design

Experimental studies with pre- and postcontrol designs were used. This study investigated the effectiveness of an integrated

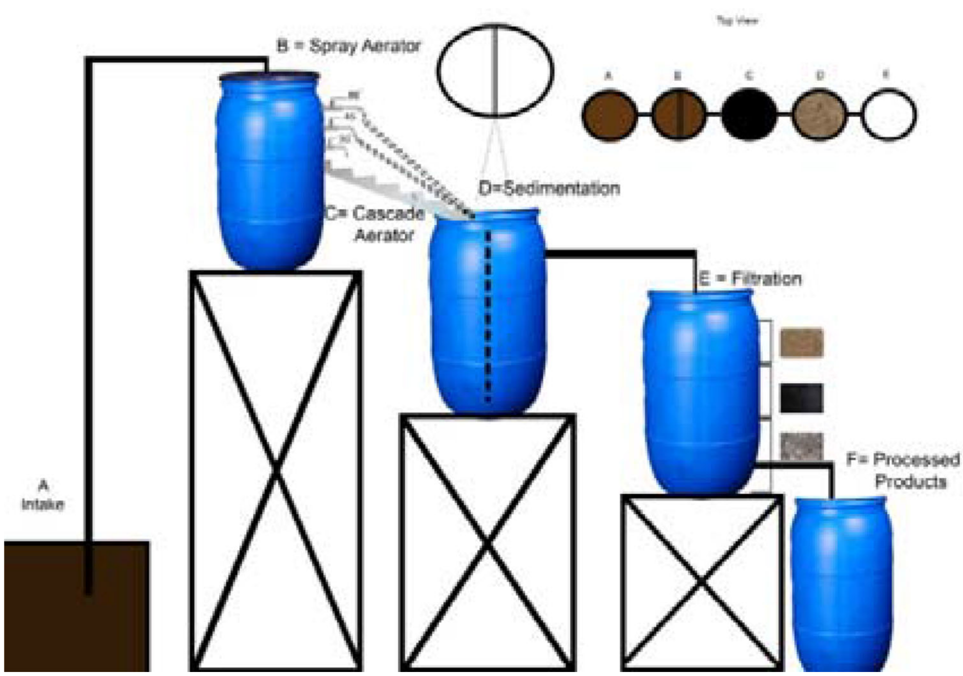


Figure 1. Integrated peat water treatment process flow.

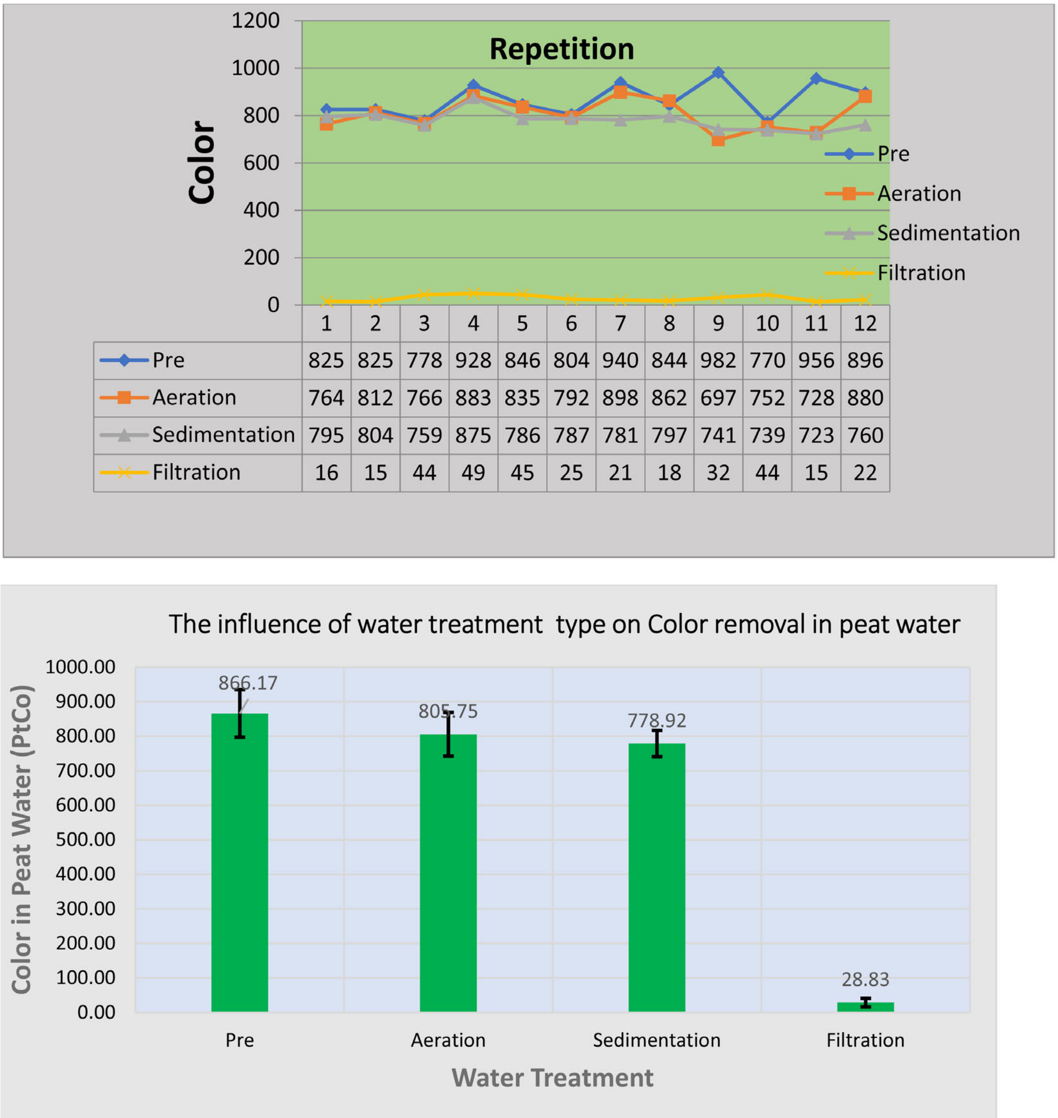


Figure 2. The influence of water treatment type on color removal in peat water.

water treatment system for peat water treatment. Peat water treatment techniques integrate aeration, sedimentation, and filtration methods using activated carbon media and mollusk sand to remove turbidity, color, Fe, total coliform, and increase the pH of peat water.[4,8–11,25,26]

2.3. Objects and Flow of Research

This research uses appropriate technology by integrating several existing water treatment techniques with modifications, such as using spray and cascade aerators,[12] sedimentation,[13] mollusk sand filtration,[14] and absorption by activated carbon.[5,6,8] Peat swamp water uses river water from the Naim Kubu Raya River, West Kalimantan. The slope levels of the cascade aerator were 30°, 45°, and 60°, respectively. The parameters measured were turbidity, color, total coliform, Fe, and pH of the peat swamp water. **Figure 1** illustrates the processing flow.

2.4. Materials

The aerator spray used a 3/4-inch PVC pipe with a length of 30 cm and a 1 mm hole, with a hole distance of 3 cm each. The pressure pushes the airflow to 21 m. Each aerator cascade is a ladder aerator made of a 2 m ironwood board, and is given a ladder with a distance of 25 cm each, installed with a slope of 30°, 45°, and 60°.[30,31] The sedimentation tank was made of a 200 L plastic drum. The remaining water in the tube was removed after aeration for 30 min. Filtration and absorption tube materials were a 200 L plastic drum filled with gravel to a height of 15 cm. Thereafter, mollusk sand was added to a thickness of 35 cm. The following processing stage used an adsorption technique with activated carbon made from coconut shells with a thickness of 25 cm. This activated carbon material was placed on a 200 L plastic drum on a sand shell.[34]

2.5. Research Flow and Sampling Techniques

Peat water samples were obtained from the Naim River, Kubu Raya, West Kalimantan. The integrated treatment system for peat water used aeration, sedimentation, filtration, and adsorption. Measurement of sample quality included turbidity, color, Fe, coliform, and pH. The research was conducted from February to October 2019. The pH, turbidity, and color of peat water samples were examined in the Pontianak Health Polytechnic Laboratory of Health. Meanwhile, the examination of Fe and total coliform was conducted at the Laboratory of Microbiology, Physics, and Chemistry, Tanjungpura University, Pontianak.

2.6. Data Analysis

ANOVA was used to analyze the differences between the intervention groups, which included pretreatment (control), spray aeration and cascade aeration, sedimentation, filtration, and adsorption. The *t*-test was used to determine the average treatment difference between the two treatments, namely, differences in turbidity, color, pH, Fe, and peat swamp water total coliform before and after processing.

3. Results and Discussion

3.1. The Influence of Water Treatment on Color Removal in Peat Water

Color removal in the performance evaluation of peat water treatment using the integrated water treatment system is illustrated in **Figure 2**. The color for the different stages, aeration and sedimentation, decreased on average, and subsequent processing using filtration and absorption resulted in a further decrease. Color is difficult to remove using aeration and sedimentation because the color is formed from colloidal and complex humic substances.[4,8] The color in the aeration and sedimentation stages decreased in the range of 888.17 to 805.75 PtCo and 778.92 PtCo. However, at the filtration stage, it significantly is reduced to 28.83 NTU with a statistical value of $p \leq 0.001$, as shown in **Table 2**. The color in peat water can be absorbed by activated carbon and filtered by mollusk sand. Mollusk sand has the ability to absorb humic substances because, besides being a filter medium, mollusk sand contains $CaCO_3$, which can increase the pH of peat water. Humic substances are macromolecular compounds with complex structures, especially the —COOH, —OH phenol, OH alcoholic, ethanol, and —C=O groups will be easily absorbed by activated carbon that has the main structure H—AC.[23,24] Integrated water treatment systems for peat water can reduce color to meet the requirements for clean water.

Table 2. The effectiveness of an integrated water treatment system for peat water treatment.

Descriptive statistics					$p^{a)}$
Parameter	Treatment	Mean	Std. Deviation	*n*	
Color	Pretreatment	866.17	71.87468	12	≤0.001*
	Aeration	805.75	66.27920	12	
	Sedimentation	778.92	39.86217	12	
	Filtration	28.83	13.23105	12	
Turbidity	Pretreatment	10.96	6.04536	12	≤0.001*
	Aeration	10.74	5.97844	12	
	Sedimentation	9.32	4.44317	12	
	Filtration	2.19	1.82315	12	
Fe	Pretreatment	2.48	0.54385	12	≤0.001*
	Aeration	2.34	0.56313	12	
	Sedimentation	2.33	0.56838	12	
	Filtration	0.22	0.25667	12	
pH	Pretreatment	4.30	0.15853	12	≤0.001*
	Aeration	4.94	0.30319	12	
	Sedimentation	5.05	0.34208	12	
	Filtration	6.83	0.18647	12	
Coliform	Pretreatment	1068.0	160.92008	12	≤0.001*
	Aeration	969.75	172.80263	12	
	Sedimentation	914.17	162.05826	12	
	Filtration	20.0	16.15831	12	

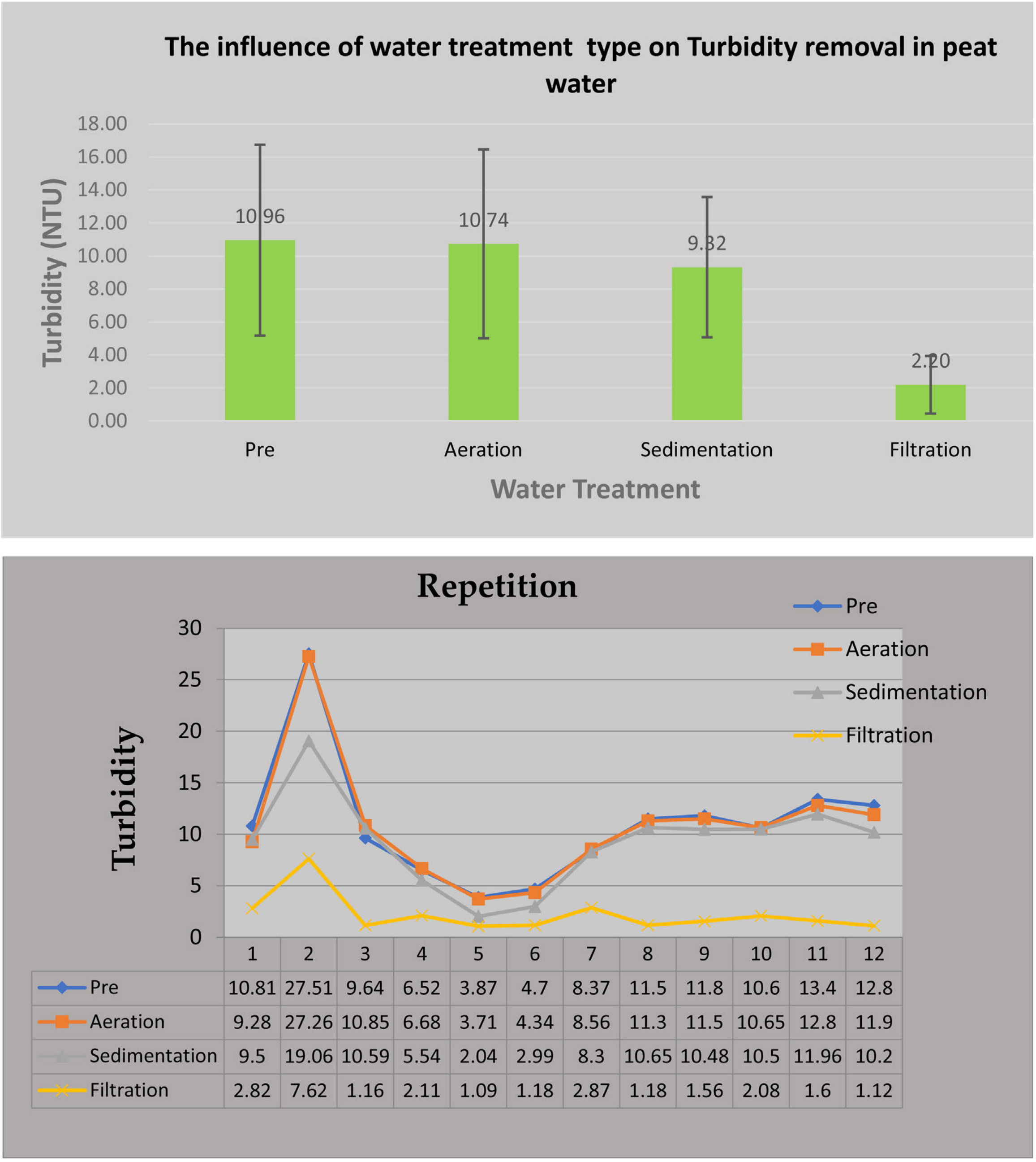
a) ANOVA; *Significant ≤0.05.

3.2. The Influence of Water Treatment on Turbidity Removal in Peat Water

Turbidity parameters were used as indicators of water treatment performance for peat water in combination with aeration, sedimentation, filtration, and absorption, and are shown in **Figure 3**. Turbidity decreased significantly during the filtration stage using mollusk sand and activated carbon. The turbidity decreased from the aeration stage with an intensity of 10.74 NTU, over the sedimentation stage with 9.32 to 2.91 NTU at the filtration stage significantly. Statistically, there is a significant difference in the integrated treatment method to reduce the intensity of turbidity ($p \leq 0.001$), as shown in Table 2. The aeration and sedimentation units did not significantly reduce turbidity. Filter media like mollusk sand and activated carbon can filter colloidal material when suspended in peat water.[4,8]

3.3. The Influence of Water Treatment on Iron (Fe) Removal in Peat Water

The Fe content of peat water before treatment was 2.48 mg L^{-1}. After treatment with spray aeration, cascading, and sedimentation, the Fe content in peat water decreased significantly (Table 2 and **Figure 4**). The level was 2.34 mg L^{-1} at the aeration stage, and after sedimentation, it was 2.33 mg L^{-1}. However, this level is still too high and is not suitable for use as a clean water source. In the

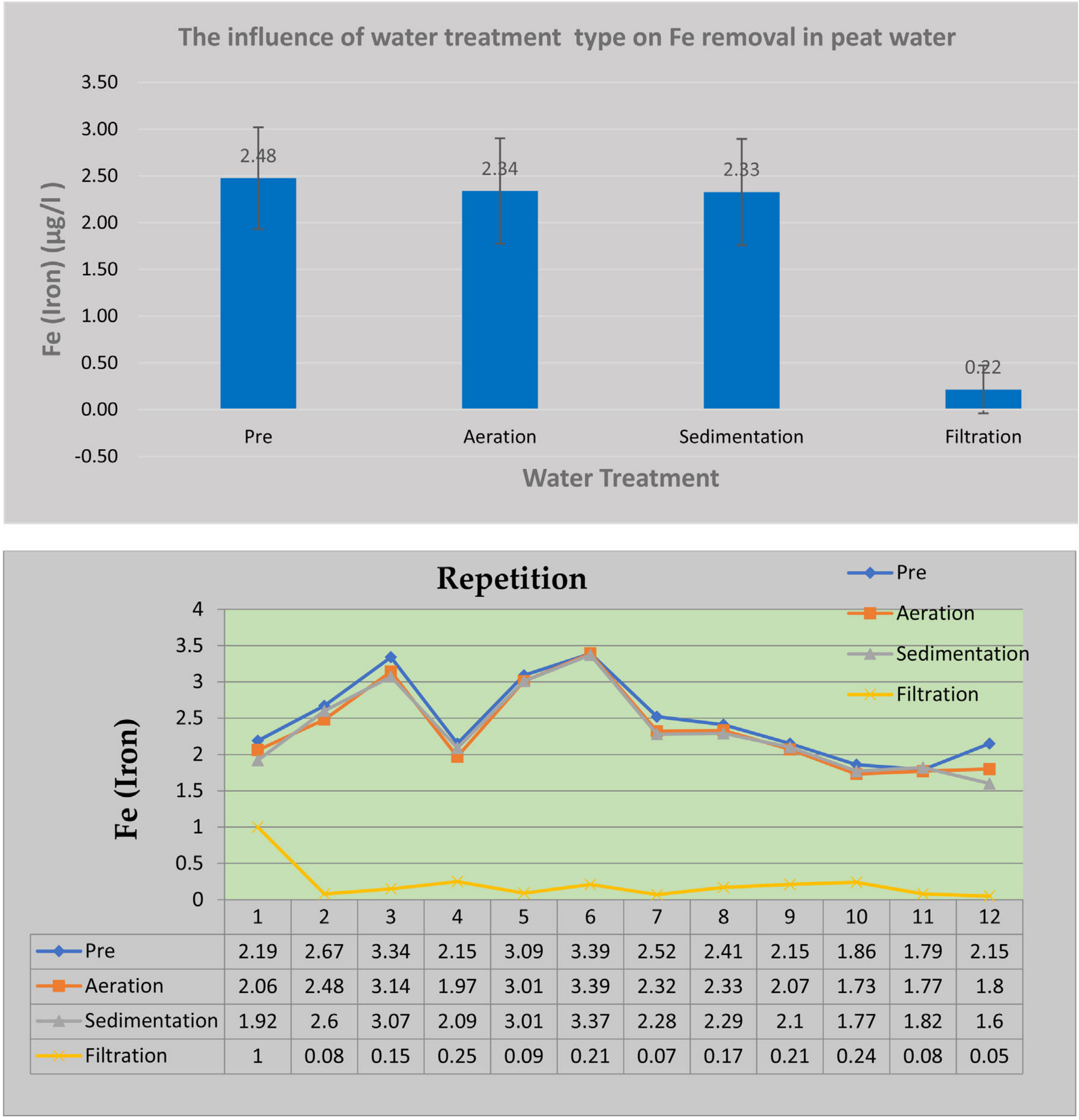


	1	2	3	4	5	6	7	8	9	10	11	12
Pre	10.81	27.51	9.64	6.52	3.87	4.7	8.37	11.5	11.8	10.6	13.4	12.8
Aeration	9.28	27.26	10.85	6.68	3.71	4.34	8.56	11.3	11.5	10.65	12.8	11.9
Sedimentation	9.5	19.06	10.59	5.54	2.04	2.99	8.3	10.65	10.48	10.5	11.96	10.2
Filtration	2.82	7.62	1.16	2.11	1.09	1.18	2.87	1.18	1.56	2.08	1.6	1.12

Figure 3. The influence of water treatment type on turbidity removal in peat water.

advanced stage of filtration treatment using mollusk sand and activated carbon, the peat water Fe content reached 0.22 mg L^{-1}. These results meet the health requirements and are suitable for use as clean water sources. The WHO stipulates that the maximum need for clean water is 1.0 mg L^{-1} and for drinking water, it is 0.3 mg L^{-1}.[35]

The application of slope variation in aeration, namely, 30°, 45°, and 60°, as used in the cascade aerator installation, **Figure 7**, shows that the proportion of Fe decrease is not significantly different between treatments. There was no statistically significant difference between the variations in the aerator slope cascade and Fe reduction. Aeration techniques in the form of spraying and cascade function contribute to the conversion of FeO_2 ions into FeO_3. With the change from ferro (FeO_2) to ferry (FeO_3), at the sedimentation stage the oxidized Fe ions will precipitate.[25,36] However, the levels are still high, so further processing is needed by filtration techniques with shell sand and absorption of activated carbon from coconut shells. Through this technique, the level of processed water decreases and meets health standards.[24,25]



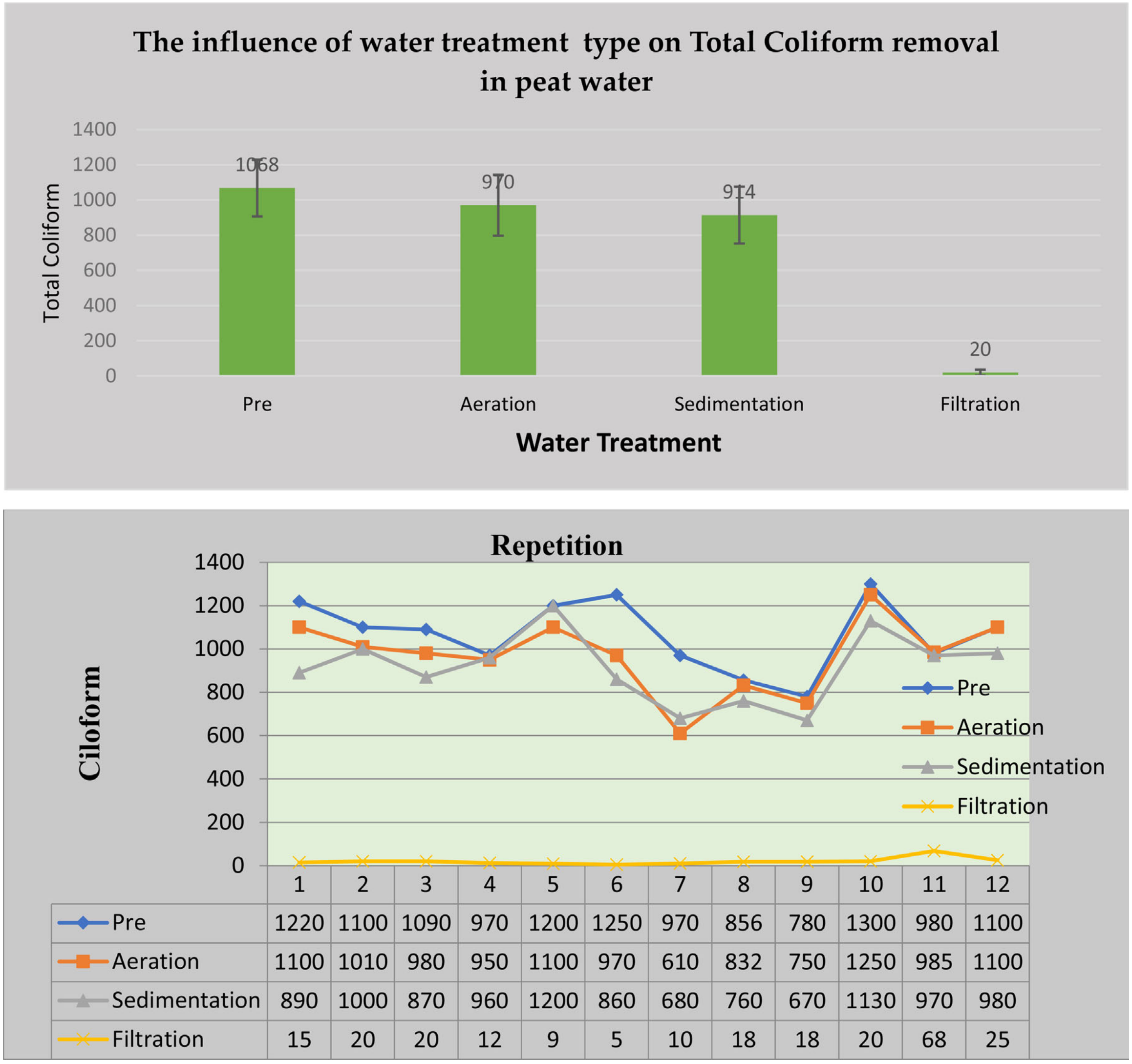
	1	2	3	4	5	6	7	8	9	10	11	12
Pre	2.19	2.67	3.34	2.15	3.09	3.39	2.52	2.41	2.15	1.86	1.79	2.15
Aeration	2.06	2.48	3.14	1.97	3.01	3.39	2.32	2.33	2.07	1.73	1.77	1.8
Sedimentation	1.92	2.6	3.07	2.09	3.01	3.37	2.28	2.29	2.1	1.77	1.82	1.6
Filtration	1	0.08	0.15	0.25	0.09	0.21	0.07	0.17	0.21	0.24	0.08	0.05

Figure 4. The influence of water treatment type on iron (Fe) removal in peat water.

The filtering process's capability with activated carbon serves to filter and absorb organic substances and Fe ions soluble in peat water. Activated carbon has a relatively large microvolume and mesoporous volume; therefore, it has a sizable surface area. Activated carbon has an amorphous structure, consisting mostly of free carbon, and has an inner surface, so it has good absorption ability.[24–26]

3.4. The Influence of Water Treatment on Total Coliform Removal in Peat Water

Figure 5 shows that the microbiological parameters used as indicators showed high values before the treatment steps (control) compared with aeration and sedimentation treatment. The total coliform content for control was 1068.0 colonies/100 mL and at the aeration stage, the number of bacteria decreased to 969.75 colonies/100 mL. A further significant decrease occurred after the filtration process with 20.0 colonies/100 mL ($p > 0.001$) (Table 2) and thus met the health requirements.[8,15,35] The total requirement for clean water for the coliform allowed in clean water is 50, the most probable number (MPN). Activated carbon is also useful as adsorption material and absorption of metal or microbial particles soluble in peat water.[17,18,37] Through the combination of aeration and filtration, the treated peat swamp water met health needs.



	1	2	3	4	5	6	7	8	9	10	11	12
Pre	1220	1100	1090	970	1200	1250	970	856	780	1300	980	1100
Aeration	1100	1010	980	950	1100	970	610	832	750	1250	985	1100
Sedimentation	890	1000	870	960	1200	860	680	760	670	1130	970	980
Filtration	15	20	20	12	9	5	10	18	18	20	68	25

Figure 5. The influence of water treatment type on total coliform removal in peat water.

3.5. The Influence of Water Treatment on pH Upgrade in Peat Water

Figure 6 shows that at the processing stage of aeration and sedimentation, the average pH has increased from 4.30 to 4.94. The pH value increased to 6.83 after treatment with mollusk sand and activated carbon. An integrated water treatment system including aeration, sedimentation, and filtration processes with mollusk sand and coconut shell activated carbon can increase peat water pH to a pH of <5. Mollusk sand contains $CaCO_3$, which results in an increase in the pH and thus reduces the solubility of metals as, for example, Fe in peat water. OH ions will be more prominent under alkaline conditions so that the metal cations are bound, and the pH of the treated peat water will increase.[23,24] Use of mollusk sand and activated carbon during the filtration stage increases the pH while also filtering or reducing turbidity in peat water. Optimal results are needed so that peat water can be used as a source of clean water.

4. Concluding Remarks

Peat water before treatment had an average color of 866.7 PtCo, with a turbidity of 10.96 NTU. It also had a high content of Fe (2.48 mg L^{-1}) and coliform (1068 MPN) and a low pH of 4.3, thus not suitable as a clean water source. After conducting an integrated water treatment system for peat water, including aeration and sedimentation stages, the levels decreased to 778.92 PtCo for color parameters, turbidity of 9.32 NTU, 2.32 mg L^{-1} Fe, and 914.17 MPN for coliform, but still did not meet health standards. Advanced processing using mollusk sand and activated carbon showed a decrease in color and other parameters, namely, color of 28.83 PtCo, turbidity of 2.19 NTU, 0.22 mg L^{-1} Fe, total coliform of 20 MPN, and pH 6.83. The most effective integrated treatment systems for peat swamp water are at the last treatment stage, filtration and adsorption. A combination of aeration cascading, sedimentation, and filtration with sand that contains $CaCO_3$ and activated carbon from biomass can be used for peat water treatment.

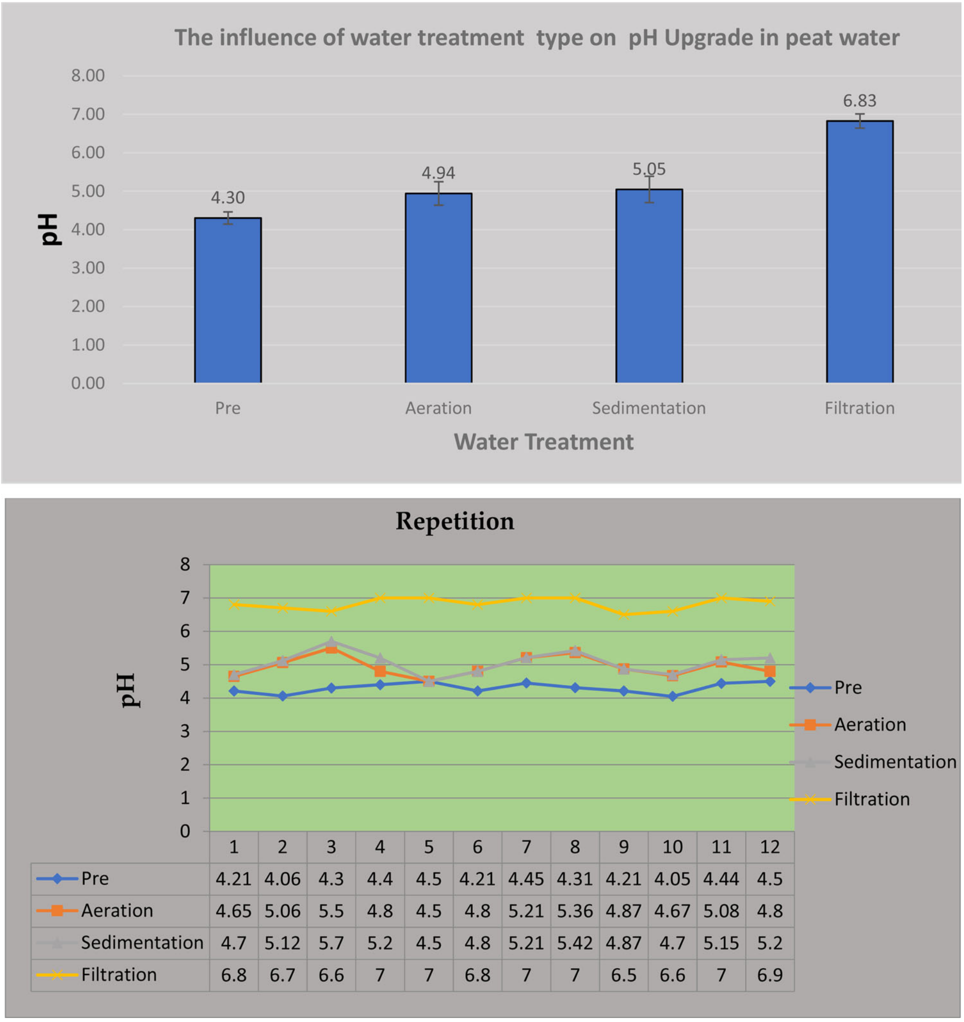


Figure 6. The influence of water treatment type on pH upgrade in peat water.

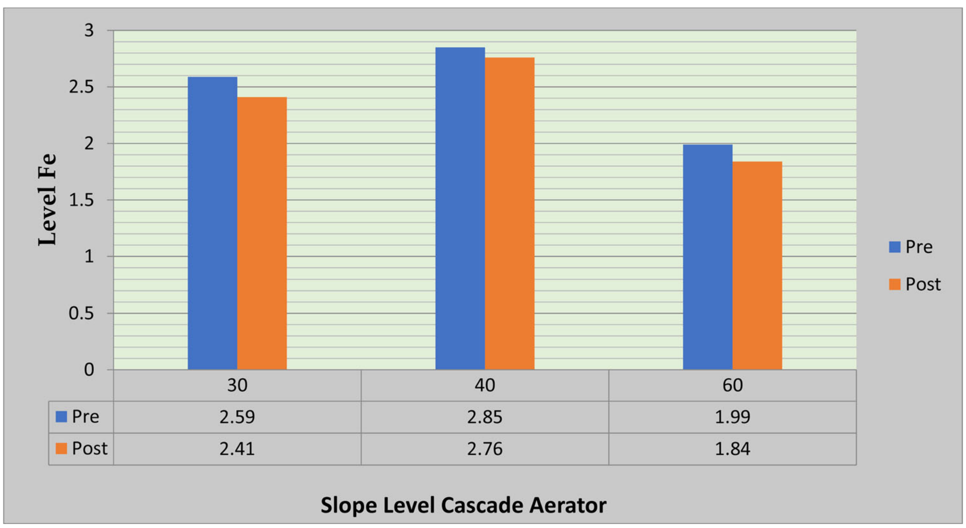


Figure 7. Slope level of cascade aerator on Fe content in peat water.

These combined techniques will help providing clean water that also will meet health standards.

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Conflict of Interest

The authors declare no conflict of interest.

Data Availability Statement

Research data are not shared.

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