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Coagulation Using Aloe Vera Gel and Coconut Shell Charcoal Filtration To Reduce Iron in Parit Banjar River Water

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A B S T R A C T

River water in the Parit Banjar area, Pontianak, contains iron (Fe) levels that exceed acceptable limits for hygiene and sanitation use. This study aimed to evaluate the efficiency of a combined treatment using Aloe vera gel as a natural coagulant and coconut shell charcoal as a filtration medium to reduce Fe concentration in river water. This study employed a quasi-experimental pretest-posttest design with a control group. Raw river water samples were treated with 40 grams of Aloe vera gel, stirred at 40 rpm for 2 minutes, allowed to stand for 60 minutes, and then filtered through coconut shell charcoal media with thickness variations of 60, 70, 80, 90, and 100 cm. Each treatment was repeated five times. Fe concentration was measured before and after treatment, and removal efficiency was calculated descriptively. The mean initial Fe concentration was 4.32 mg/L, while the control group showed a mean of 4.18 mg/L. Coagulation using Aloe vera gel alone reduced Fe to 3.56 mg/L with an efficiency of 17.44%. The combined treatment produced greater reductions at all filter thicknesses. The best result was obtained at 100 cm, reducing Fe to 0.55 mg/L with an efficiency of 87.36%. Increasing filter thickness consistently improved Fe removal. The combination of Aloe vera gel coagulation and coconut shell charcoal filtration was effective at reducing the Fe concentration in the Parit Banjar river water. A thicker filtration medium provided better removal performance, with 100 cm identified as the most effective condition.

Air sungai di daerah Parit Banjar, Pontianak, mengandung kadar besi (Fe) yang melebihi batas yang dapat diterima untuk penggunaan higienis dan sanitasi. Penelitian ini bertujuan untuk mengevaluasi efisiensi pengobatan gabungan menggunakan gel lidah buaya sebagai koagulan alami dan arang tempurung kelapa sebagai media filtrasi untuk mengurangi konsentrasi Fe dalam air sungai. Penelitian menggunakan *quasi-experimental pretest-posttest design* dengan kelompok kontrol. Sampel air sungai diolah dengan 40 gram gel lidah buaya, diaduk dengan kecepatan 40 rpm selama 2 menit, didiamkan selama 60 menit, kemudian disaring melalui media arang tempurung kelapa dengan variasi ketebalan 60, 70, 80, 90, dan 100 cm. Setiap perlakuan diulang lima kali. Konsentrasi Fe diukur sebelum dan sesudah perlakuan, dan efisiensi penghilangan dihitung secara deskriptif. Rata-rata konsentrasi Fe awal adalah 4,32 mg/L, sedangkan kelompok kontrol menunjukkan rata-rata 4,18 mg/L. Koagulasi menggunakan gel lidah buaya saja mengurangi Fe menjadi 3,56 mg/L dengan efisiensi 17,44%. Perlakuan gabungan menghasilkan pengurangan yang lebih besar pada semua ketebalan filter. Hasil terbaik diperoleh pada ketebalan 100 cm, mengurangi Fe menjadi 0,55 mg/L dengan efisiensi 87,36%. Peningkatan ketebalan filter secara konsisten meningkatkan penghilangan Fe. Kombinasi koagulasi gel lidah buaya dan filtrasi arang tempurung kelapa efektif dalam mengurangi konsentrasi Fe dalam air sungai Parit Banjar. Media filtrasi yang lebih tebal memberikan kinerja penghilangan yang lebih baik, dengan ketebalan 100 cm diidentifikasi sebagai kondisi yang paling efektif.

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1. Introduction

Water is a fundamental resource for human life, public health, and environmental sustainability. In daily life, communities depend on water for drinking, cooking, bathing, washing, and many other domestic activities (Souza et al., 2025). Therefore, water quality must meet acceptable standards in terms of physical, chemical, biological, and aesthetic characteristics before it can be safely used. Among the chemical parameters of concern, iron (Fe) is one of the most common contaminants in natural waters, particularly in groundwater and surface water influenced by peat soils and reducing environments (Pemerintah RI, 2024). Excessive iron in water may cause discoloration, metallic taste, staining, sediment deposition in pipes, and operational problems in water distribution systems. Although iron is an essential element, elevated concentrations in water remain undesirable because they reduce acceptability and may complicate household and sanitation use. International and national guidance, therefore, continues to emphasize the control of iron as an important component of water quality management (Pradeka & Nadir, 2025).

This issue is especially relevant in peatland areas, where raw water commonly has a brownish color, acidic pH, and high concentrations of dissolved organic matter and metals (Yu et al., 2025). Recent review literature explains that peat water is characteristically rich in natural organic matter, particularly humic and fulvic substances, which contribute to low pH and poor visual quality and often require treatment before domestic use (Qada et al., 2023). In many parts of Southeast Asia, peat-associated water remains a crucial source for communities. However, its treatment remains challenging because many studies have primarily focused on reducing color and pH. At the same time, the removal of other important parameters, including dissolved metals, has not been explored to the same extent (Rendana & Ibrahim, 2024). In the study area at Jalan Parit Banjar, Pontianak, the preliminary measurement reported in the background document showed an Fe concentration of 4.35 mg/L, indicating that the raw water condition is far above the acceptable level for hygiene and sanitation purposes and requires effective treatment. Although this study uses river water as the research subject, the sampled water originates from a river system strongly influenced by surrounding peatland ecosystems. Consequently, the water exhibits several characteristics commonly associated with peat water, including brownish coloration, acidic conditions, and elevated concentrations of dissolved organic matter and metals. Therefore, the term "peat-influenced river water" is considered more appropriate for describing the water source investigated in this study. This distinction is important because the interaction between river water and peatland drainage can substantially affect water quality and increase the complexity of treatment requirements.

Conventional treatment for iron-containing water typically relies on physicochemical processes, including coagulation-flocculation, sedimentation, oxidation, and filtration (Propolsky & Romanovski, 2025). These methods are widely recognized as effective, but their implementation may be less attractive in low-resource settings because they rely heavily on synthetic chemicals, require careful operational control, and entail relatively higher costs. For this reason, recent water treatment research has shown increasing interest in natural coagulants and low-cost adsorbent media derived from locally available biomass. Natural materials are considered promising because they are more environmentally friendly, potentially safer for household-scale applications, and often easier to obtain in rural or peri-urban areas. Biomass-derived adsorbents are considered economically attractive because they are derived from abundant agricultural residues and locally available waste materials that require relatively simple processing before utilization (Ullah et al., 2024). Among these materials, coconut shells represent one of the most abundant agro-industrial wastes in tropical countries and are frequently underutilized after consumption or processing activities (James & Yadav, 2021). The conversion of coconut shells into charcoal or activated carbon not only increases the economic value of agricultural waste but also produces an effective adsorbent material for water treatment applications (Fauzi et al., 2024). Therefore, coconut shell-derived filtration media have received considerable attention as sustainable and cost-effective alternatives to conventional adsorbents, particularly in developing countries (María et al., 2026). The growing attention to plant-based coagulants and bio-based filtration media reflects a broader shift toward sustainable and accessible water treatment technologies (Propolsky & Romanovski, 2025).

Various natural coagulants have been investigated for water treatment applications, including Moringa oleifera seeds, cactus extracts, chitosan, and plant-derived polysaccharides (Benalia, Derbal, Amrouci, et al., 2024). However, Aloe vera was selected in the present study for several reasons. First, Aloe vera gel contains polysaccharides, mucilage compounds, and functional groups that have demonstrated coagulation activity in previous studies (Abderrezzaq et al., 2024). Second, unlike some natural coagulants that require seed harvesting, extraction of specific plant parts, or more complex preparation procedures, Aloe vera gel can be obtained and processed relatively easily (Lwasa et al., 2024). Third, Aloe vera is widely cultivated in many Indonesian communities as an ornamental and medicinal plant, making it readily accessible for household-scale water treatment applications (Singh et al., 2021). Taken together, these characteristics underscore its practical relevance as a sustainable coagulant option for treating peat-influenced river water (Wilson, 2024).

One of the natural materials that has attracted attention is Aloe vera. Recent studies have shown that Aloe vera-based coagulants can perform well in water clarification due to the presence of polysaccharides and other bioactive compounds that assist particle destabilization and floc formation (Oliveira et al., 2025). Benalia et al. (2024) reported that Aloe vera demonstrated strong coagulation performance in jar-test and hydraulic-system experiments and that filtration remained necessary to improve the quality of treated water further. Earlier work also suggested that Aloe vera extract has potential as a natural coagulant in potable water treatment applications. These findings support the view that Aloe vera is not only abundant and relatively safe but also functionally relevant to the development of sustainable water treatment (Konkobo et al., 2024).

In addition to biocoagulation, coconut shell charcoal is also relevant as a filtration or adsorption medium because of its porous structure and carbon-rich composition. Recent studies have reported that coconut shell-based charcoal or activated carbon can remove metal ions from aqueous solutions, thereby improving water quality through adsorption mechanisms (Nurhilal et al., 2025). Zahra et al (2022) demonstrated that modified coconut shell charcoal has measurable potential for iron removal from aqueous media. These findings suggest that coconut shell-derived media have strong potential for water treatment applications, particularly in regions where coconuts are abundant and low-cost. However, most published studies have examined Aloe vera and coconut shell media separately, or have focused on synthetic water, potable water clarification, turbidity removal, or other metals rather than directly evaluating an integrated treatment sequence for iron-rich river water from peat-influenced environments (Nigussie & Habtu, 2023).

Furthermore, previous studies have generally evaluated Aloe vera and coconut shell charcoal independently, with most investigations focusing on turbidity reduction, color removal, or treatment of synthetic laboratory-prepared water (Katubi et al., 2021). Only limited information is available on their sequential application for treating natural waters with elevated iron concentrations under field conditions. In addition, few studies have specifically examined water originating from peat-influenced environments, where high organic matter content may interfere with both coagulation and adsorption processes. Therefore, the present study contributes not only by combining two environmentally friendly treatment methods within a single treatment train but also by evaluating their performance using actual peat-influenced river water from Pontianak under locally relevant conditions (Hadary et al., 2025).

Based on this review, the scientific gap of the present study lies in the limited evidence on the combined use of Aloe vera gel as a biocoagulant and coconut shell charcoal as a filtration medium to reduce Fe concentration in river water under local field conditions. Accordingly, this study addresses the following research problem: Is the combination of coagulation with Aloe vera gel and filtration with coconut shell charcoal effective in reducing the iron concentration in river water from Jalan Parit Banjar, Pontianak? The working hypothesis is that the combined treatment will significantly reduce Fe concentration and that greater filter thickness will improve removal efficiency.

To address this research problem, this study adopted a treatment approach integrating biocoagulation with Aloe vera gel and coconut shell charcoal filtration at varying media thicknesses. This approach was selected because coagulation can destabilize suspended and dissolved contaminants in the early stage, while filtration provides additional removal through physical retention and adsorption. Therefore, the purpose of this article is to analyze the efficiency of the combination of Aloe vera gel coagulation and coconut shell charcoal filtration in reducing iron levels in river water from Jalan Parit Banjar, Pontianak, and to identify the filtration thickness that provides the most effective reduction under the tested conditions.

2. Methods

Water is a fundamental resource for human life, public health, and environmental sustainability. In daily life, communities depend on water for drinking, cooking, bathing, washing, and many other domestic activities (Souza et al., 2025). Therefore, water quality must meet acceptable standards in terms of physical, chemical, biological, and aesthetic characteristics before it can be safely used. Among the chemical parameters of concern, iron (Fe) is one of the most common contaminants in natural waters, particularly in groundwater and surface water influenced by peat soils and reducing environments (Pemerintah RI, 2024). Excessive iron in water may cause discoloration, metallic taste, staining, sediment deposition in pipes, and operational problems in water distribution systems. Although iron is an essential element, elevated concentrations in water remain undesirable because they reduce acceptability and may complicate household and sanitation use. This study used a quasi-experimental pretest-posttest control-group design to assess changes in iron (Fe) levels in river water before and after treatment. The independent variable was the thickness of the coconut shell charcoal filter media, varied at five levels (60 cm, 70 cm, 80 cm, 90 cm, and 100 cm), with each level combined with the addition of aloe vera gel coagulant. The dependent variable was the iron (Fe) levels in river water, measured before and after treatment. Controlled variables included raw water volume (20 L), coagulant dosage (40 g per 20 L), stirring speed and duration (40 rpm for 2 minutes), settling time (60 minutes), and filtration contact time (5 minutes). The control group was raw water, not treated with a coagulant or filtered.

Raw water samples were taken from the river water in the Perdamaian Ujung Jalan Parit Banjar area. This study focused on evaluating the reduction in iron (Fe) levels as the primary parameter, in line with the study’s objective of assessing the efficiency of the coagulation-filtration combination in removing this metal contaminant. Other raw water quality parameters, such as pH, turbidity, color, total dissolved solids (TDS), and organic matter content, were not measured in this study because they were outside the established scope. More comprehensive characterization of the raw water is recommended in future research to evaluate the performance of the coagulation-filtration process better.

The research stage begins with preparing the media and designing a small-scale water treatment system. The initial reservoir was made from a 20 L paint bucket placed on a tower about 1 meter high; River water is pumped through a PVC pipe into the tank. The filtration unit is made from a 3-inch-diameter PVC pipe about 1.2 meters long, modified with several holes for the inlet, outlet, and filter circuit.

Coconut shell charcoal is inserted into the filter tube as the main filtration medium, with the media thickness determined by the treatment level (60–100 cm). Aloe vera gel is prepared by washing, peeling, cutting, and grinding the aloe vera flesh, followed by filtration to obtain the gel (Zahra et al., 2022).

Washing was performed by placing 20 L of river water in the initial reservoir and then adding 40 g of aloe vera gel. The mixture was stirred at 40 rpm for 2 minutes, then left for 60 minutes to allow coagulation. Next, the water passes through a filter tube containing coconut shell charcoal and is held in the filtration unit for 5 minutes. The processed water from the outlet is collected in a 700 mL sample bottle and labeled according to the treatment group. This procedure is repeated according to the specified number of replications.

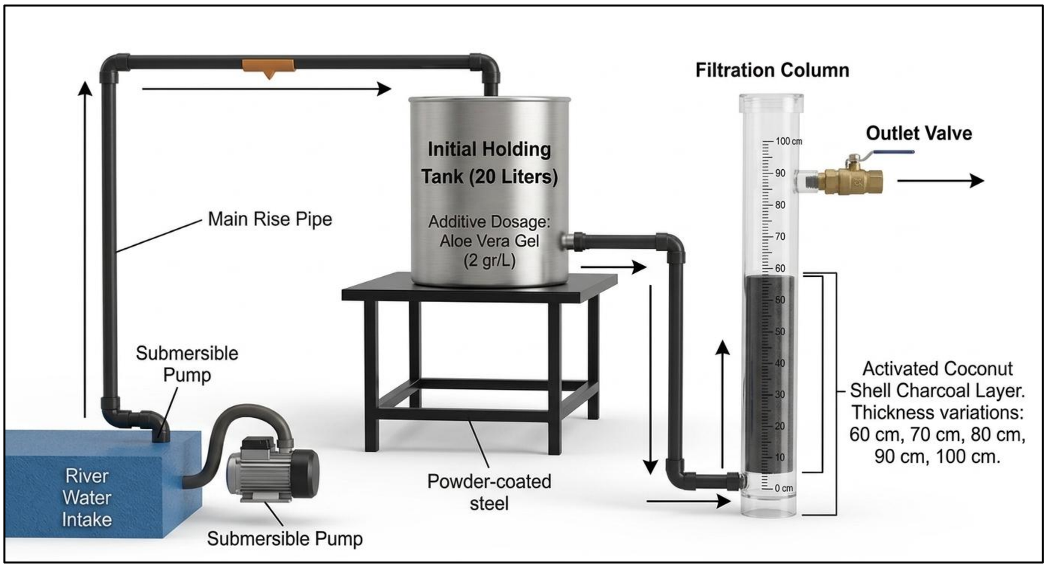

Figure 1. Water treatment equipment design

The aloe vera gel coagulant dosage used (40 g per 20 L of raw water, equivalent to 2 g/L) was adapted from the optimum dosage reported by Putri (2020) for river water treatment using aloe vera coagulant, where 1 g per 500 mL (equivalent to 2 g/L) achieved the highest turbidity reduction. Stirring conditions (40 rpm for 2 minutes) and settling time (60 minutes) were based on operating ranges commonly reported in coagulation-flocculation studies using similar natural coagulants, which generally apply fast stirring speeds of 30–300 rpm and settling/sedimentation times of 30–60 minutes, and follow the standard jar test procedure framework (National Standardization Agency, 2025).

The determination of the aloe vera dosage used in this study was based on the results of a study conducted by (Putri, 2022) entitled Processing River Water into Clean Water by Electroflotation-Biocoagulation Process Using Aloe vera and Corn (Zea mays). The study reported that the optimal dosage of aloe vera used as a biocoagulant was 1 g per 500 mL of air sample. Using a proportional-scale approach, this dosage was equivalent to 40 g for a sample volume of 20 L, providing a scientific basis for the aloe vera dosage used in this study. However, the study by Putri (2022) and this study differ in operational parameters. Putri (2020) applied rapid stirring for 30 seconds, followed by slow stirring for 30 minutes, using a magnetic stirrer, whereas this study used a stirring speed of 40 rpm for 2 minutes. Furthermore, the 60-minute duration reported in the study by Putri (2022) represents the electroflotation process time, not the sedimentation time in the coagulation process. Therefore, this reference was used to determine the biocoagulant dosage, while other process parameters were adjusted in accordance with the research plan and objectives.

The data were analyzed quantitatively using one-way Analysis of Variance (ANOVA) to examine differences in average Fe levels among treatment groups (control and five levels of charcoal media thickness). Before conducting the ANOVA test, the assumptions of independence between groups, homogeneity of variance, and normality of the data distribution in each group were assessed. The decision-making criteria were: if $p \leq 0.05$, H0 was rejected and a significant difference in efficiency between treatment groups was concluded; conversely, if $p > 0.05$, H0 was accepted and no significant difference was concluded. In addition to the ANOVA test, formula Efficiency = $\frac{(A-B)}{A} X\ 100\%$,with A as the Fe level before treatment and B as the Fe level after treatment (Sugiharto, 1987).

3. Results

Table 1 shows the results of the experiment with six treatment variations (P0-P5) and five replications (R1-R5). The Fe concentrations of the raw water before treatment were 4.30 and 4.35 mg/L. After treatment, the research results obtained the highest average Fe in treatment Po (coagulation with aloe vera gel), namely 3.58 mg/L.

The lowest was in P5 (a combination of aloe vera gel coagulation and 100 cm coconut shell charcoal filtration), namely 0.55 mg/L. In treatments P2-P4, Fe concentration ranged from 0.83 to 1.45 mg/L.

Table 1. Fe treatment results

Treatment	Before (mg/L)	Replication (mg/L) R1	R2	R3	R4	R5	Average (mg/L)	Decrease (mg/L)	Efficiency (%)
Control	4.30	4.15	4.15	4.19	4.19	4.23	4.18	0.12	2.79
P0	4.30	3.65	3.76	3.41	3.38	3.58	3.56	0.75	17.44
P1	4.30	1.17	1.89	1.29	1.39	1.49	1.45	2.85	66.27
P2	4.30	1.52	1.18	1.07	1.02	1.14	1.19	3.13	72.79
P3	4.35	1.11	1.06	0.99	1.03	1.02	1.04	3.31	76.09
P4	4.35	0.79	0.96	0.83	0.81	0.74	0.83	3.52	80.91
P5	4.35	0.45	0.74	0.40	0.62	0.52	0.55	3.80	87.36

P0= Aloe vera gel coagulation; P1= Aloe vera gel coagulation and coconut shell charcoal filtration 60 cm; P2= Aloe vera gel coagulation and coconut shell charcoal filtration 70 cm; P3= Aloe vera gel coagulation and coconut shell charcoal filtration 80 cm; P4= Aloe vera gel coagulation and coconut shell charcoal filtration 90 cm; P5= Aloe vera gel coagulation and coconut shell charcoal filtration 100 cm

Figure 1 shows the difference in Fe concentration before and after treatment, as well as the efficiency of Fe removal in each treatment variation. In P0 (aloe vera gel coagulation), there was a decrease in Fe concentration of 0.75 mg/L (from 4.30 mg/L to 3.56 mg/L). In P1, the decrease was 2.85 mg/L (from 4.30 mg/L to 1.45 mg/L), and in P2, it was 3.13 mg/L (from 4.30 mg/L to 1.18 mg/L).

The decrease in Fe concentration in P3 was 3.31 mg/L (from 4.35 mg/L to 1.04 mg/L), and P4 reduced Fe from 4.35 mg/L to 0.83 mg/L. In the treatment variation P5, using a loe vera gel coagulation and coconut shell charcoal filtration (100 cm) achieved the largest Fe reduction (3.80 mg/L), from 4.35 mg/L to 0.55 mg/L.

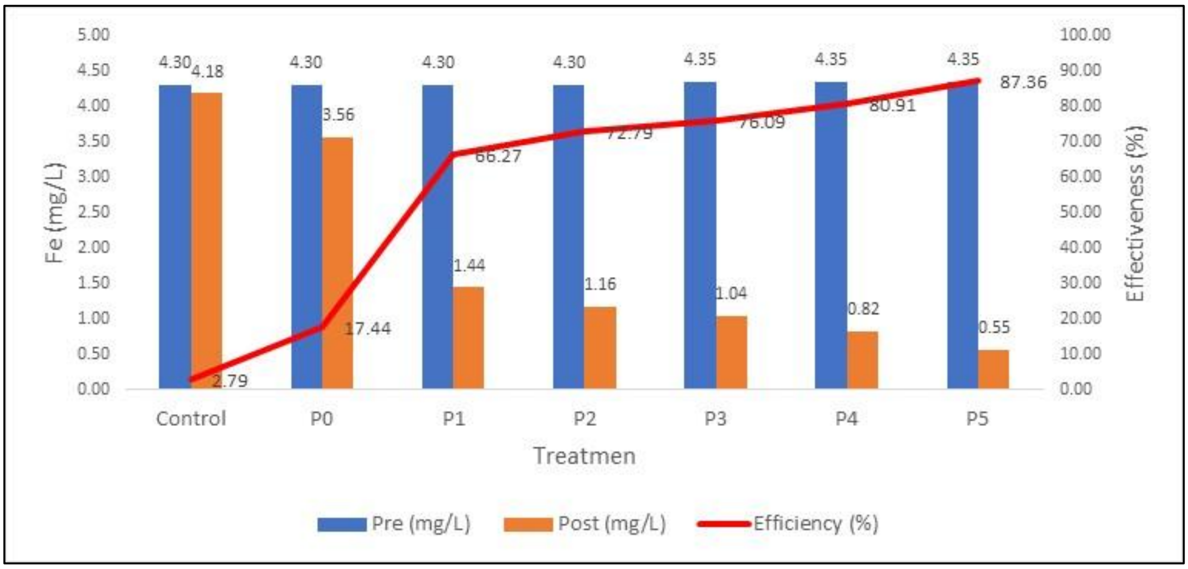

Figure 1. Fe concentration before and after treatment

Figure 1 also shows the increase in Fe removal efficiency across treatment variations. In the control group, the Fe reduction efficiency was only 2.79%. After treatment with aloe vera gel coagulation, the efficiency increased to 17.44%. These results indicate that aloe vera gel contributed to the initial reduction of Fe.

A substantial increase in efficiency was observed when aloe vera gel coagulation was combined with coconut shell charcoal filtration. At a filtration media thickness of 60 cm (P0), the Fe removal efficiency increased sharply to 66.27%. The Fe removal efficiency continued to increase with increasing coconut shell charcoal filtration media thickness, namely 70 cm (72.79%), 80 cm (76.09%), and 90 cm (80.91%). The highest efficiency was achieved at a filtration media thickness of 100 cm, reaching 87.36%.

This pattern indicates that increasing the thickness of the filtration media increases the efficiency of Fe removal. The thicker coconut shell charcoal media provides a longer contact path between the water and the filtration surface. This condition can increase the adsorption of Fe onto the media surface, resulting in a greater reduction in Fe concentration in river water. Overall, the graph makes it easy to observe the differences between treatment groups. Coagulation of aloe vera gel alone did not achieve optimal removal efficiency, while the combination of coagulation and filtration produced significantly better results. This finding indicates that treatment efficiency is influenced not only by the coagulation process but also by the thickness of the filtration media.

Table 2. Statistic analysis results

No.	Statistical Test	Variable/Comparison	Statistical Value	Sig./p-value	Interpretation
1	Normality test	Fe concentration before treatment	-	0.000	The data were not normally distributed
2	Normality test	Fe concentration after treatment	-	0.000	The data were not normally distributed
3	Normality test	Variation in media thickness	-	0.015	The data were not normally distributed
4	Wilcoxon test	Fe concentration before treatment - Fe concentration after treatment	-	0.000	There was a difference in Fe concentration before and after treatment
5	Homogeneity test	Treatment variation based on the mean	-	0.169	The data met the homogeneity assumption
6	One Way ANOVA	Differences in Fe concentration based on treatment variations	F = 81.945	0.000	There were differences in Fe concentration among treatment variations

Based on Table 2, the normality test indicated that the Fe concentration before treatment, the Fe concentration after treatment, and the variation in media thickness had p-values of 0.000, 0.000, and 0.015, respectively. All p-values were lower than $\alpha = 0.05$, indicating that the data were not normally distributed. Therefore, the comparison of Fe concentration before and after treatment was continued using the Wilcoxon test. The Wilcoxon test showed a p-value of 0.000, indicating a significant difference between Fe concentration before and after treatment. This finding suggests that coagulation with aloe vera gel, combined with coconut shell charcoal filtration, reduced Fe concentration in river water.

Furthermore, the homogeneity test showed a p-value of 0.169. Since this value was greater than $\alpha = 0.05$, the data among treatment groups were considered homogeneous and met the assumption for One-Way ANOVA. The one-way ANOVA result showed an F-value of 81.945 with a p-value of 0.000. This result indicates a significant difference in Fe concentration among the treatment variations.

Based on Table 3, the post hoc test showed a significant difference between the filtration treatment groups and both the control and no-filter groups. This was indicated by a significance value of 0.000, which was lower than $\alpha = 0.05$. Therefore, the combination of aloe vera gel coagulation and coconut shell charcoal filtration significantly reduced Fe concentration compared with untreated water and water without filtration. Among the filtration media thickness variations of 60 cm, 70 cm, 80 cm, 90 cm, and 100 cm, the significance values were generally 1.000.

Table 3. Post Hoc test results

	Control	P0	P1	P2	P3	P4	P5
Control	-	0.000	0.000	0.000	0.000	0.000	0.000
P0	0.000	-	0.000	0.000	0.000	0.000	0.000
P1	0.000	0.000	-	1.000	1.000	1.000	1.000
P2	0.000	0.000	1.000	-	1.000	1.000	1.000
P3	0.000	0.000	1.000	1.000	-	1.000	1.000
P4	0.000	0.000	1.000	1.000	1.000	-	1.000
P5	0.000	0.000	1.000	1.000	1.000	1.000	-

Since these values were higher than α = 0.05, there was no statistically significant difference among the filtration thickness groups. This means that although the graph showed a descriptive trend of decreasing Fe concentration and increasing removal efficiency as the filtration media became thicker, the differences among the thickness variations were not statistically significant.

These findings indicate that coconut shell charcoal filtration after aloe vera gel coagulation played an important role in reducing Fe concentration. However, the increase in filtration media thickness from 60 cm to 100 cm was more evident as a descriptive trend than as a statistically significant difference between the two thickness levels. In other words, the use of filtration media significantly reduced Fe concentration compared with the control and no-filter groups. However, the efficiency across the 60–100 cm thickness range was statistically similar.

Overall, the results strengthen the evidence that the combination of coagulation and filtration was the primary factor driving Fe reduction in river water. Filtration media thickness remains important because the graph shows a consistent decreasing pattern, but the post hoc results indicate that differences across the kness level are interpreted with caution. Therefore, the 100 cm filtration thickness can be considered the best treatment, descriptively, because it produced the lowest Fe concentration and the highest removal efficiency. However, it did not differ statistically from the other filtration-thickness groups.

4. Discussion

The principal finding of this study is that the combined treatment of Aloe vera gel coagulation followed by coconut shell charcoal filtration was markedly more effective at removing Fe than either no treatment or coagulation alone. The control condition produced only a minimal decrease in Fe, whereas Aloe vera coagulation alone reduced Fe to a limited extent. By contrast, the integrated treatment progressively lowered Fe as filtration thickness increased, with the best performance observed at 100 cm, where the final Fe concentration was 0.54 mg/L and the removal efficiency was 87.36%. This pattern indicates that the treatment effect was not incidental, but arose from the interaction between an initial destabilization step and a subsequent polishing step. In practical terms, these findings support the study’s hypothesis that the combined treatment is effective in reducing Fe in peat-influenced river water and that greater charcoal thickness enhances removal performance.

The relatively modest effect of Aloe vera used alone can be explained by the chemistry of peat-associated water. Peat water is typically rich in humic and fulvic substances, which contribute to acidic conditions, brown coloration, and the stabilization of metals in dissolved or colloidal forms (Abdul et al., 2023). In such water matrices, Fe is not always present as a readily settleable particulate species; part of it can remain associated with dissolved organic matter through complexation (Aleshina et al., 2024). This is important because natural coagulation works most effectively when contaminants can be destabilized and incorporated into flocs (Abujazar et al., 2022). Aloe vera mucilage contains polysaccharides, especially acemannan, together with hydroxyl and carboxyl-bearing functional groups that can promote particle bridging, charge neutralization, and floc growth (Venegas-Garc´ıa et al., 2024). However, when peat-derived organic ligands partly protect Fe, coagulation alone may be insufficient to remove it completely. This finding may explain why the present study observed only a moderate reduction in Fe after the Aloe vera coagulation stage. In contrast, previous studies have reported strong performance of Aloe vera for turbidity removal and water clarification in different water matrices (Murisa et al., 2024). In other words, Aloe vera was effective as an initiating treatment step, but not as a complete Fe-removal solution under the present conditions (Febrianti et al., 2023).

The sharp improvement after filtration shows that coconut shell charcoal functioned as the dominant Fe-polishing medium. Coconut-shell-derived activated carbon is known to possess a developed pore structure and oxygen-containing surface groups such as –OH, C=O, and C–O, which increase its affinity for dissolved contaminants, including metal ions (Tosin et al., 2025). Recent studies have shown that activated carbon derived from coconut shell has a high surface area and a strong capacity for Fe adsorption, with Fe(III) removal efficiencies exceeding 80% under optimized conditions (María et al., 2026). In the present study, the monotonic decline in Fe concentration from 60 to 100 cm is scientifically consistent with a bed-depth effect: thicker media provide more active sites, longer contact time, and greater opportunity for diffusion, adsorption, and physical retention of oxidized or floc-associated iron species. The trend was therefore expected. Even though the reduction did not increase in a perfectly linear step from one thickness to the next, that non-linearity is still reasonable because adsorption in real water depends not only on media depth but also on pore accessibility, Fe speciation, and competition with natural organic matter. Thus, the overall direction of the trend is more important scientifically than a perfectly constant increment between thickness levels (Uzun, 2025).

Another important scientific interpretation is that the success of this system lies in the complementarity of mechanisms. The coagulation step likely first reduced the colloidal and organic loads, thereby improving the efficiency of the downstream charcoal bed. This interpretation is consistent with the broader water treatment literature, which shows that hybrid systems generally outperform single-stage systems when raw water contains a mixture of dissolved organic matter and metal contaminants (Knap-bałdyga & Zubrowska-sudoł, 2023). For peat water specifically, U. Z. et al (2023) noted that many treatment studies still focus mainly on color and pH, while the treatment of other parameters remains limited. More specifically, Rendana & Ibrahim 2024) reported that a hybrid treatment combining a biocoagulant and a ceramic membrane removed 66.81% of Fe from peat water.

In contrast, Elma et al (2022) found that coagulation–adsorption pretreatment substantially improved the treatment of actual peat water by reducing the load on downstream filtration. Compared with those findings, the present study achieved a higher Fe removal efficiency under optimal conditions, suggesting that the Aloe vera–coconut shell sequence is a technically promising, low-cost alternative for iron-rich peat-influenced water. However, direct comparisons across studies must be made carefully because raw-water composition, operating conditions, and reactor designs differed.

To address this point more directly, the present findings can be compared more closely with previous studies in terms of both removal efficiency and the operating conditions under which that efficiency was obtained, rather than efficiency values alone. Febrianti et al (2023), already cited above, reported that Aloe vera, applied as a stand-alone coagulant, removed up to 70.85% of Fe from well water at an optimum dose of 1 mL, with rapid mixing at 120 rpm for 1 minute, followed by slow mixing at 30 rpm for 10 minutes. This efficiency is considerably higher than the 17.44% Fe removal achieved by Aloe vera coagulation alone in the present study. The contrast is informative rather than contradictory: well water generally carries a much lower load of dissolved humic and fulvic substances than peat-influenced river water, so Fe in that matrix is more readily present in a settleable form, whereas in the present study, a portion of Fe was likely complexed with peat-derived organic matter and therefore less responsive to coagulation alone. This comparison indicates that the moderate performance of Aloe vera coagulation observed here is attributable to the characteristics of the raw water rather than to a weakness of the coagulant itself.

A similar pattern emerges at the filtration stage. Rendana and Ibrahim (2024), discussed above, achieved a maximum Fe removal of 66.81% from peat water using a chitosan biocoagulant combined with a ceramic membrane, at a chitosan dose of 200 mg and a contact time of 30 minutes, while Farma et al. (2021) reported 82.24% Fe removal from peat water using KOH-activated carbon derived from oil palm leaves. Both values are lower than or close to the 87.36% Fe removal obtained at a 100 cm filtration thickness in the present study, even though all three studies used a similarly organic-rich peat water matrix. This comparison suggests that the longer hydraulic contact time provided by a thick charcoal bed, relative to the shorter mixing or contact periods of 10 to 30 minutes applied in the cited studies, is a plausible operating-condition explanation for the relatively high Fe removal obtained in the present work, in addition to the surface chemistry of coconut shell charcoal discussed earlier. Taken together, these comparisons place the present results within a more concrete scientific context: the combined treatment performed comparably with, and in some respects better than, previously published Fe-removal methods applied to peat-influenced water, while the differences in coagulant type, dosage, contact time, and filtration design help explain why removal efficiencies vary across studies rather than leaving the comparison at the level of percentages alone.

From a scientific standpoint, the control data are also meaningful. Given that the control group exhibited only a minimal decrease in Fe concentration, the reduction observed in the treatment groups cannot be reasonably explained by natural settling alone. Instead, the data indicate that Fe reduction required an active treatment mechanism. The much lower residual Fe after the combined treatment confirms that the principal contribution came from the engineered sequence of coagulation and filtration rather than from passive sedimentation. This reinforces the interpretation that the treatment system altered the water chemistry and the distribution of contaminants sufficiently to enable Fe separation.

Overall, the findings clearly support the research hypothesis. The combined use of Aloe vera gel coagulation and coconut shell charcoal filtration was effective in reducing Fe concentration in river water from Jalan Parit Banjar, Pontianak, and increasing filtration thickness improved the removal outcome. Scientifically, this occurred because Aloe vera likely promoted the early destabilization of colloidal and organically associated contaminants. In contrast, the coconut shell charcoal provided stronger downstream removal through adsorption and retention of iron species. Therefore, the study contributes evidence that a locally available, biomass-based hybrid treatment can be developed as an environmentally relevant option for treating iron-rich water in peat-influenced settings.

5. Conclusions

This study aimed to determine whether the combination of Aloe vera gel coagulation and coconut shell charcoal filtration could reduce Fe concentrations in river water from Jalan Parit Banjar, Pontianak, and to identify the filtration thickness that produced the greatest reduction under the tested conditions. The Wilcoxon test ($p = 0.000$) and one-way ANOVA ($F = 81.945$, $p = 0.000$) showed that Fe concentrations differed significantly before and after treatment as well as between treatment variations, indicating that the combined treatment was effective for the studied river water source and supporting the first part of the research hypothesis. The lowest Fe concentration and the highest removal efficiency, 0.54 mg/L and 87.36%, respectively, were obtained at a filtration thickness of 100 cm, indicating that this thickness was descriptively the most effective among the variations tested.

However, post hoc tests revealed no significant differences in Fe concentrations across thicknesses of 60–100 cm, suggesting that the relationship between filtration thickness and removal efficiency is better described as a consistent downward trend than as a statistically confirmed incremental increase. Therefore, these findings only partially support the second part of the hypothesis and suggest that, within the 60–100 cm range, thinner media may already provide comparable benefits. Because the treatment was tested on a single river water source under controlled experimental conditions, these conclusions should be understood as applicable to river water with similar characteristics, rather than as a general claim for all river water. Field-scale validation at multiple locations will be required before wider application can be recommended.

Future research is recommended to determine the operational lifetime of the coconut shell charcoal layer, for example, through continuous flow tests that identify the point at which removal efficiency declines due to media saturation, so that an appropriate media replacement or regeneration schedule can be established. Future studies should also examine how key water quality parameters affecting coagulation and filtration performance, such as pH, turbidity, color, and organic matter content, influence Fe removal efficiency, as these factors regulate floc formation during coagulation and the adsorption capacity of the charcoal media during filtration. Overall, this study provides initial evidence that a locally available biomass-based hybrid treatment is a technically promising option for reducing Fe in river water, while also indicating that additional evidence is still needed before such a treatment can be recommended for wider field applications.

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