



Effectiveness of Integrated Moringa *Oleifera* Seed Coagulation and Composite Diatomaceous Earth, Activated Carbon, and Zeolite Filter for Poultry Wastewater Purification

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ABSTRACT:

Water pollution caused by various sources, particularly untreated poultry wastewater, poses a growing environmental concern. This study evaluated the use of Moringa *oleifera* seed powder as a natural coagulant and a composite filter consisting of activated carbon, diatomaceous earth, and zeolite. The study aimed to determine improvements in selected physicochemical characteristics of the treated water, including total dissolved solids (TDS), chemical oxygen demand (COD), pH, and phosphate concentration. The untreated wastewater had a pH of 6.71, a COD of 401 mg O₂/L, a TDS of 658 mg/L, and a phosphate concentration of 5.70 mg PO₄³⁻-P/L before treatment. After treatment, the pH increased to 7.05, while COD decreased to 120 mg O₂/L, TDS to 380 mg/L, and phosphate concentration to 1.20 mg PO₄³⁻-P/L. These changes resulted in reductions of 70.07% in COD, 42.25% in TDS, and 78.95% in phosphate concentration, while the pH increased by 0.34 units toward neutral conditions. Among the measured parameters, phosphate concentration showed the greatest percentage reduction, followed by COD and TDS. The findings indicated that the combined coagulation and composite filtration approach was effective in improving the selected physicochemical characteristics of poultry wastewater under the conditions of the study. However, the treatment did not completely remove the measured pollutants, and the results alone could not establish that the treated wastewater was safe for discharge or reuse. Further research should focus on appropriate control comparisons, replications, the application of the combined system under real-world conditions, and the inclusion of other water quality parameters to enhance treatment performance and improve the reliability of the findings.

Keywords: Poultry wastewater, Moringa *Oleifera* seed powder, Coagulation, Composite filtration, Physicochemical characteristics.

1. INTRODUCTION

Water is a vital natural resource that is essential for living things survival. Unfortunately, water pollution persists as one of the most critical environmental concerns globally, posing a severe hazard to aquatic ecosystems, public health, and sustainable development. According to the World Health Organization (WHO) and United Nations Children's Fund (UNICEF), approximately 2.2 billion people worldwide continue to experience a deficiency in safe drinking water, while an estimated 485,000 diarrheal deaths every year are attributed to waterborne contamination and improper sanitation.

Water pollution originates from various sources, such as plastics, urban sewage, oil spills, and agricultural runoff. However, agricultural wastewater remains one of its major sources, particularly wastewater generated by livestock and poultry production. Poultry farming activities, such as cleaning poultry houses, washing equipment, and handling waste, contribute significantly to the generation of poultry wastewater. Poultry wastewater poses a threat to the environment and public health since it contains suspended solids, organic matter, nutrients, phosphate and nitrogen compounds, and microorganisms. According to Abdallah et al. (2022), wastewater from poultry-related activities may contain high concentrations of pollutants, including elevated chemical oxygen demand (COD), biochemical oxygen demand (BOD), and suspended solids, which require proper treatment before discharge. If it is discharged without proper treatment, these contaminants can compromise water quality. Improper poultry wastewater disposal can rapidly migrate to surrounding aquatic bodies, such as rivers and groundwater, resulting in contamination, eutrophication, oxygen depletion, and the destruction of aquatic ecosystems. Furthermore, high nutrient loading leads to eutrophication and algal blooms, which lower dissolved oxygen levels and often cause massive fish kills and the degradation of aquatic species. Poultry wastewater may also contain pathogenic microorganisms, namely Salmonella and Escherichia coli, pathogens that are typically known to contaminate water sources and increase the risk of waterborne illnesses.

Nevertheless, the poultry industry contributes significantly to Philippine agriculture by providing food security, employment, and economic opportunities. According to the Philippine Statistics Authority (2024), chicken production reached 1.95 million metric tons (liveweight) in 2023, while egg production also increased. Central Luzon remains one of the country's leading poultry-producing regions, with Bulacan as a major center for the

industry. However, official records from the Municipal Environment and Natural Resources Office (MENRO) indicate that as the industry expands to meet high demand, the wastewater generated by poultry farms also increases. Diego et al. (2024) further explained that poultry wastewater treatment systems in the Philippines contain diverse bacterial communities that may pose environmental and public health concerns. Addressing these hazardous impacts requires effective and efficient wastewater treatment methods, particularly in areas dominated by large-scale poultry production.

Although conventional wastewater treatment systems are effective, they often come with major drawbacks, including expensive facilities, specialized equipment, and continuous maintenance. These requirements may not be feasible for small- to medium-scale poultry farms, which frequently struggle to adopt them due to severe financial and operational limitations. Recognizing this crucial gap, researchers are actively exploring the use of natural, affordable, and locally available materials as sustainable alternatives to standard treatment methods. In response to these environmental concerns, *Moringa oleifera*, commonly known as Malunggay, has emerged as a promising natural coagulant because of its biodegradability, low toxicity, and potential as an environmentally friendly alternative. Lester-Card et al. (2023) described that *Moringa oleifera* can provide a sustainable and cost-effective option for wastewater treatment while minimizing concerns associated with chemical residues and sludge.

Existing studies have proven that *Moringa oleifera*, commonly known as Malunggay, has emerged as a promising natural coagulant for wastewater treatment. *Moringa oleifera* is a fast-growing, drought-resistant tree that thrives in tropical climates without requiring intensive care or expensive fertilizers. It is widely grown in the Philippines, making the plant an accessible and sustainable resource. In many Filipino households, it is traditionally used for clarifying drinking water in rural areas where modern filtration systems are unavailable. Furthermore, Varsani et al. (2022) explained that the effectiveness of *Moringa oleifera* as a bio-coagulant is associated with its ability to promote particle aggregation through the properties of its seed-based material. These positively charged proteins can be extracted using a distilled water solution, ethanol solution, or saline solution. Previous studies have shown that *Moringa oleifera* seeds can effectively reduce suspended solids and other organic pollutants in wastewater. In addition, Tong et al. (2022) demonstrated the potential of *Moringa oleifera* seed extract as a natural coagulant in wastewater treatment. Compared with conventional treatment that heavily relies on chemical coagulants, such as aluminum sulfate and ferric salts, *Moringa oleifera* presents a viable and safe alternative because it is biodegradable, affordable, locally accessible, and environmentally friendly.

Alongside coagulation, filtration can further improve wastewater quality by removing contaminants that remain after coagulation. Although filtration has been explored in many ways, relatively few studies have focused on poultry wastewater treatment using a composite filter made of diatomaceous earth, activated carbon, and zeolite. A composite filter made of these materials combines different purification mechanisms into a single treatment process. According to Benouis et al. (2022), diatomaceous earth has properties that allow it to function as a sustainable material for wastewater treatment through filtration and adsorption. In addition, Chen et al. (2022) demonstrated the potential of diatomite-based materials for phosphate removal. Activated carbon adsorbs dissolved organic and inorganic compounds that contribute to colors of and odor, while its extensive surface area may contribute to the reduction of organic pollutants and chemical oxygen demand. Piai et al. (2020) explained that activated carbon can remove dissolved substances through adsorption onto its extensive surface area. Moreover, zeolite removes dissolved ions through adsorption and ion exchange due to its porous crystalline structure. Cuomo et al. (2023) described the potential of zeolite filters in wastewater treatment through these adsorption and ion-exchange properties. Combining these materials improves the overall efficiency of poultry wastewater treatment by utilizing their different and complementary removal mechanisms.

Rather than relying on a single filtration material, combining different media may improve treatment performance by increasing the contact between contaminants and materials with different removal properties. Mažeikienė and Šarko (2022) demonstrated that layered filter media can improve contaminant removal by combining materials with different properties. These findings support the use of a composite filter consisting of diatomaceous earth, activated carbon, and zeolite, where each material may contribute differently to the overall treatment process.

Although *Moringa oleifera* as a natural coagulant and filtration has been investigated in many ways, relatively few studies have focused on poultry wastewater treatment using a composite filter made of these materials and have examined their combined use as an integrated treatment system for poultry wastewater under Philippine conditions. Previous studies have commonly examined *Moringa oleifera* and different filtration materials separately and have focused on municipal, domestic, synthetic, or other types of wastewaters rather than actual poultry wastewater. Additionally, limited studies have evaluated their effects on selected physicochemical characteristics, including pH, phosphate concentration, total dissolved solids (TDS), and chemical oxygen demand (COD).

This study aims to evaluate the effectiveness of an integrated *Moringa oleifera* seed coagulation and composite filtration system using diatomaceous earth, activated carbon, and zeolite in improving the physicochemical characteristics of poultry wastewater. Furthermore, this study promotes the United Nations Sustainable Development Goal 6 (SDG 6), Clean Water and Sanitation, particularly Target 6.3, which seeks to improve water quality by reducing pollution and increasing safe wastewater treatment. Evaluation of an integrated, low-cost treatment system contributes to the support of sustainable water resource management and environmental conservation. Weather forecasts have a wide range of applications. Weather warnings are crucial forecasts because they safeguard people and property. Agricultural forecasts based on temperature and precipitation are critical, and traders in commodities markets rely on them. Many people use weather forecasts to decide what to wear on a given day on a daily basis. Because heavy rain, snow, and wind chill significantly limit outdoor activities, forecasts can be used to schedule activities around these phenomena, as well as to prepare ahead and survive them.

Statement of the Problem

This study aims to determine the effectiveness of *Moringa oleifera* seed coagulation and a composite filter consisting of diatomaceous earth, activated carbon, and zeolite in the purification of poultry wastewater. Specifically, it seeks to answer the following questions:

1. What are the physicochemical characteristics of poultry wastewater before treatment?
2. How does the application of *Moringa oleifera* seed coagulation and the composite filter affect the physicochemical characteristics of poultry wastewater?
3. How effective is the combined *Moringa oleifera* seed coagulation and composite filtration system in improving the quality of poultry wastewater?

2. METHODOLOGY

2.1 Materials and Sample Collection

Approximately 4 liters of poultry wastewater was collected from a poultry farm in San Ildefonso, Bulacan, using clean polyethylene containers. The samples were properly labeled and transported immediately to the laboratory at room temperature. The 2L portion of the collected wastewater was reserved for baseline laboratory analysis, while the remaining 2L wastewater was used for the treatment process.

2.2 Authentication of Moringa oleifera Seeds

Moringa oleifera seeds were collected from mature seed pods and authenticated. Only clean and undamaged seeds were selected for this study.

2.3 Preparation of Moringa oleifera Seed Powder

The selected seeds were dried, manually dehulled, and ground using a mortar and pestle, followed by a laboratory blender. The resulting powder was sieved to obtain a uniform particle size and stored in airtight containers until use.

2.4 Production of Activated Carbon

Coconut shell charcoal was the material used for activated carbon production. The charcoal was washed with distilled water to remove dust and ash, then air-dried. It was then soaked in a 10% food-grade citric acid solution for 24 hours. After soaking, the charcoal was air-dried, crushed using a mortar and pestle, and sieved through a 35-mesh sieve to obtain a uniform particle size. The activated carbon was stored in airtight containers until needed for filter construction. Although referred to as activated carbon in this study, the material is produced by low-cost acid-washed methods and is not equivalent or contain all the properties of standard commercialized activated carbon.

2.5 Construction of the Composite Filter

A cylindrical filtration column was constructed using three natural filtration media. The filtration media were prepared at a 2:24:24 volume ratio of diatomaceous earth, zeolite, and activated carbon, respectively. The filter was assembled in the following order from top to bottom: sponge, coarse activated carbon, a thin layer of super-fine activated carbon, filter paper, sponge, zeolite, sponge, diatomaceous earth, and a final layer of filter paper. Dimensions and thicknesses of the filtration layers are presented in Figure 2. The biochemical cotton sponge layers provided support to the filtration media and helped maintain the stability of the composite filter during filtration. The filter paper acted as a barrier between selected layers to prevent the movement of fine particles. Before the actual experiment, the composite filter was inspected for proper assembly, structural stability, and leakage to ensure efficient performance during treatment.

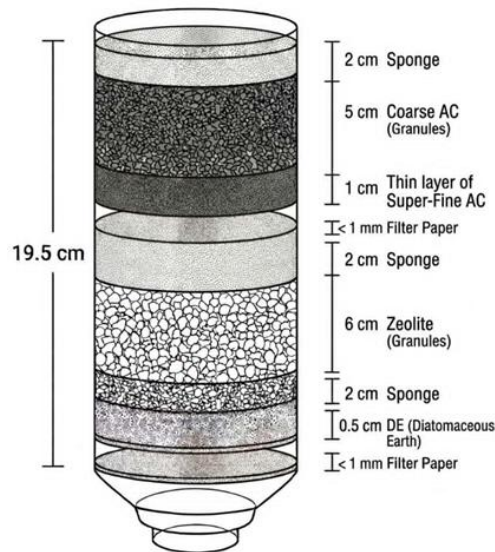


Figure 2. Measurements of Composite Filter

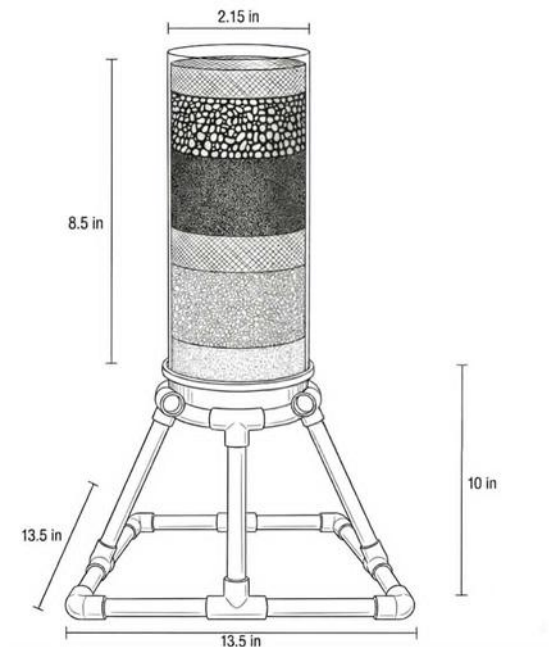


Figure 3. Measurements of Filter Stand

2.6 Integrated Wastewater Treatment

A total of 2 L of the collected poultry wastewater was used for the treatment process, while the remaining 2 L was retained as the untreated sample for baseline comparison. A dosage of 0.8 g of *Moringa oleifera* seed powder was added to the 2 L of wastewater intended for treatment. The mixture underwent rapid mixing at 150 rpm for two minutes, following the method described by Desta and Bote (2021), followed by slow mixing at 35 rpm for ten minutes, based on the procedure of Ahmad et al. (2025). A magnetic stirrer was used for both mixing stages. The mixture was then allowed to settle for one hour to facilitate coagulation and sedimentation. After settling, 2L of the clarified supernatant was collected and passed through the composite filter by gravity. The filtered water was collected in clean containers and prepared for post-treatment laboratory analysis.

Post-Treatment Water Quality Analysis

The treated and the untreated wastewater were submitted to the Sugar Regulatory Administration (SRA) for laboratory analysis. The same physicochemical parameters measured during the baseline analysis were pH, Phosphate concentration, Total Dissolved Solids (TDS), and Chemical Oxygen Demand (COD). The laboratory results obtained after treatment were compared with the baseline results to determine the effectiveness of the integrated treatment system.

3. Results

Each result is stated in sentence form, followed by a table presenting the relevant measurements. The discussion for each result is organized into three paragraphs: the first describes the data, the second explains their implication, and the third compares the findings with related studies. The percentage decrease for COD, TDS, and phosphate was calculated using $[(\text{before-treatment value} - \text{after-treatment value}) \div \text{before-treatment value}] \times 100$. The pH result is described as a numerical change because pH is logarithmic.

Physicochemical Profile of Poultry Wastewater Before Treatment

Table 1 presents the measured physicochemical characteristics of the poultry wastewater before treatment.

Table 1. Physicochemical characteristics of poultry wastewater before treatment.

Sampling Condition	pH	COD (mg O ₂ /L)	TDS (mg/L)	Phosphate (mg PO ₄ ³⁻ -P/L)
Before Treatment	6.71	401	658	5.70

Note: Before-treatment values represent the baseline laboratory results supplied for this study. COD = chemical oxygen demand; TDS = total dissolved solids.

The baseline results show that the untreated poultry wastewater contained measurable levels of organic matter, dissolved solids, and phosphate. The COD value was 401 mg O₂/L, indicating the presence of chemically oxidizable substances in the wastewater. The TDS value was 658 mg/L, showing that the wastewater contained dissolved substances and fine material that remained in the water sample. The phosphate concentration was 5.70 mg PO₄³⁻-P/L, while the pH was 6.71, indicating slightly acidic to nearly neutral conditions before treatment.

These baseline measurements establish the pollution conditions that the treatment system was intended to improve. The COD and phosphate values are particularly important because organic matter can consume oxygen during decomposition, while phosphorus-containing nutrients may contribute to eutrophication when discharged in excessive amounts. The TDS value indicates that the wastewater contained dissolved substances that may not be completely removed through simple settling alone. The slightly acidic-to-neutral pH provides a useful starting point for evaluating whether the treatment process caused a major chemical shift.

The baseline profile agrees with the general description of poultry wastewater in existing literature. Abdallah et al. (2022) described poultry-related wastewater as containing organic matter and suspended or dissolved pollutants that require treatment before discharge. Similarly, Mkilima et al. (2022) emphasized that nutrient-containing wastewater can contribute to eutrophication and oxygen depletion, while Relucio-San Diego et al. (2024) reported that poultry wastewater treatment systems in the Philippines deal with complex wastewater characteristics. The present baseline values therefore provide a reasonable starting profile for evaluating a treatment approach, although direct numerical comparison should be made carefully because wastewater composition varies with farm operations, cleaning practices, sample timing, and dilution.

Changes in the Physicochemical Characteristics of Poultry Wastewater Following Integrated Treatment

Table 2 shows the changes in the selected physicochemical characteristics after the poultry wastewater underwent the integrated coagulation and filtration process. The table presents the two sampling conditions and the corresponding laboratory values used to determine the direction and magnitude of change.

Table 2. Changes in physicochemical characteristics after integrated treatment

Sampling Condition	pH	COD (mg O ₂ /L)	TDS (mg/L)	Phosphate (mg PO ₄ ³⁻ -P/L)
Before treatment	6.71	401	658	5.70
After treatment	7.05	120	380	1.20

Note: Compared with the before-treatment values, pH increased by 0.34 unit, while COD decreased by 281 mg O₂/L, TDS decreased by 278 mg/L, and phosphate decreased by 4.50 mg PO₄³⁻-P/L.

The table indicates that COD decreased from 401 to 120 mg O₂/L, TDS decreased from 658 to 380 mg/L, and phosphate decreased from 5.70 to 1.20 mg PO₄³⁻-P/L. These correspond to reductions of 70.07%, 42.25%, and 78.95%, respectively. In contrast, pH increased by 0.34 units, from 6.71 to 7.05. Thus, the direction of change was favorable for the three pollutant indicators measured as concentrations, while the pH moved modestly closer to neutral.

The observed changes suggest that the treatment sequence affected both the organic and dissolved constituents measured in the wastewater. *Moringa oleifera* seed proteins may have destabilized suspended particles and helped form settleable flocs. After settling, the filter media could have retained fine particles and provided adsorption or ion-exchange sites for remaining contaminants. The decrease in COD suggests that some oxidizable organic

matter was removed, while the decrease in phosphate indicates that the concentration of measured phosphate was substantially reduced following treatment. The pH shift was small enough to indicate that the integrated process did not cause a severe change in acidity or alkalinity under the conditions of this trial. Additionally, the baseline sample had been stored before treatment, which may have influenced its physicochemical characteristics and should therefore be considered when interpreting the observed changes.

The pattern of change is consistent with previous research on the individual components of the system. Desta and Bote (2021) and Varsani et al. (2022) reported that *Moringa oleifera* can function as a natural coagulant by promoting particle aggregation and improving wastewater quality. For filtration and adsorption, Maharani et al. (2020) found that combined adsorbent media containing zeolite and activated charcoal could support agro-industrial wastewater treatment, while Mažeikienė and Šarko (2022) demonstrated the value of layered filter media for nutrient removal. Chen et al. (2022) also showed the potential of diatomite-based materials for phosphate removal. The present findings extend the relevance of these studies to a combined treatment sequence for poultry wastewater, but the different materials, operating

Effectiveness of the Integrated Treatment System in Improving Poultry Wastewater Quality

Table 3 presents the overall effectiveness of the integrated treatment system by comparing the baseline and post-treatment values and reporting the calculated percentage change for each concentration-based parameter.

Table 3. Overall effectiveness of the integrated treatment system

Parameter	Before Treatment	After Treatment	Reduction/Change
COD (mg O ₂ /L)	401	120	70.07%
TDS (mg/L)	658	380	42.25%
Phosphate (mg PO ₄ ³⁻ -P/L)	5.70	1.20	78.95%
pH	6.71	7.05	+0.34 units

Note: Removal efficiency was 70.07% for COD, 42.25% for TDS, and 78.95% for phosphate. pH increased by 0.34 units. These calculations are descriptive and are based on one supplied before-treatment value and one supplied after-treatment value for each parameter.

Based on percentage reduction, phosphate exhibited the greatest decrease at 78.95%, followed by COD at 70.07% and TDS at 42.25%. In absolute concentration, COD decreased by 281 mg O₂/L, while TDS decreased by 278 mg/L. The post-treatment pH of 7.05 was close to neutral and differed from the initial pH by only 0.34 units. The results indicate that the treatment system affected several pollutant categories rather than only one parameter, which supports the value of combining coagulation with a composite filter instead of relying on a single treatment mechanism.

The results suggest that the integrated treatment system improved the selected physicochemical characteristics of the poultry wastewater under the conditions of the study. The decrease in COD indicates that the amount of chemically oxidizable substances in the treated wastewater was reduced, which may also lessen its potential oxygen demand. The reduction in phosphate shows that the concentration of this nutrient decreased after treatment, while the lower TDS indicates a decrease in the amount of dissolved substances present in the wastewater. Meanwhile, the increase in pH from 6.71 to 7.05 shows a slight movement toward neutral conditions. However, the treatment did not completely remove the measured pollutants, as COD, TDS, and phosphate were still present after treatment. Thus, the system was effective in improving the selected parameters measured in this study, but the results alone cannot establish that the treated wastewater is already safe for discharge, reuse, or direct contact.

The observed pattern is comparable to findings reported in previous studies. Etedali and Eslamian (2020) reported that natural and commercial adsorbents can reduce COD in wastewater, which is consistent with the observed reduction in COD following treatment. Mažeikienė and Šarko (2022) found that layered media can assist in nitrogen and phosphorus removal, consistent with the strong phosphate reduction observed here. Cuomo et al. (2023) discussed the role of zeolite filters in wastewater treatment, particularly through adsorption and ion-exchange behavior, while Maharani et al. (2020) reported benefits from combining adsorbent media. The present study is also consistent with the sustainability advantages described for *Moringa oleifera* by Lester-Card et al. (2023) and Nzeyimana and Mary (2024). Nevertheless, the present experiment used a single treatment run and did not separate the effects of coagulation and filtration. Therefore, the reported effectiveness values should be considered preliminary and should be confirmed through replicated trials and appropriate control comparisons.

Recommendations

The following recommendations are based on the results of the study:

1. Initial washing and conditioning of the filter media, including activated carbon, diatomaceous earth, and zeolite, should be conducted prior to use to minimize TDS leaching and prevent potential contamination.
2. Utilization of the combined system. The combined coagulation and composite filtration system may be applied in poultry facilities experiencing wastewater pollution concerns, particularly in resource-limited rural areas where accessible and affordable treatment methods are needed.
3. Proper storage and handling of poultry wastewater samples are recommended to maintain sample quality. The temperature of the samples should be monitored and maintained under suitable conditions, and the samples are recommended to be analyzed as soon as possible to ensure reliable physicochemical results.
4. Properly activated carbon should be produced and used as a filtration medium to enhance contaminant removal and provide more consistent filtration results.
5. Further research should include additional water quality parameters, such as ammonia, turbidity, replicated trials and microbial parameters, to strengthen the evaluation and validity of the treatment system's performance.

4. Conclusion

This study evaluated the effectiveness of integrating *Moringa oleifera* seed coagulation with a composite filter consisting of diatomaceous earth, activated carbon, and zeolite in treating poultry wastewater. The treatment resulted in reductions of 70.07% in chemical oxygen demand (COD), 42.25% in total dissolved solids (TDS), and 78.95% in phosphate concentration. Meanwhile, the pH increased from 6.71 to 7.05, remaining near neutral after treatment.

These findings indicate that the integrated treatment system improved the selected physicochemical characteristics of the poultry wastewater. The results also demonstrate the potential of combining natural coagulation with composite filtration as a low-cost and sustainable approach to wastewater

treatment. However, further testing involving additional water quality parameters and repeated trials may provide a more comprehensive evaluation of the system's effectiveness.

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