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# Phytoremediation of Domestic Wastewater Using Coontail for Enhanced Biochemical Oxygen Demand Removal

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**Abstract**
Domestic wastewater containing high organic loads can adversely affect receiving water bodies when discharged without adequate treatment. This study evaluated the potential of Coontail (Ceratophyllum demersum) as a low-cost, environmentally friendly phytoremediation agent to reduce Biochemical Oxygen Demand (BOD) in the effluent of the Centralised Domestic Wastewater Treatment System (SPALD-T) in Sungai Langka Village, Indonesia. Four reactors containing 10 L of wastewater were used: a control without plants (Reactor A) and three treatment reactors containing 50 g (Reactor B), 60 g (Reactor C), and 70 g (Reactor D) of Coontail. The experiment was conducted for 18 days, with BOD measurements taken on days 0, 6, 12, and 18, and pH and temperature monitored throughout the treatment period. The results showed that temperatures remained relatively stable at 25–27.5°C, whereas the planted reactors experienced an increase in pH to approximately 9–10. At the end of treatment, Reactor D achieved the highest BOD removal efficiency of 68.18%, followed by Reactors B and C at 66.67% and 63.64%, respectively. In contrast, the control reactor showed a negative removal efficiency of −27.27%. Statistical analysis indicated that treatment duration ($p = 0.996$) and plant biomass ($p = 0.533$) had no significant effects on BOD removal efficiency. Overall, Ceratophyllum demersum demonstrated potential as a sustainable post-treatment option to improve the quality of rural domestic wastewater effluent, although further optimisation of operating conditions and experimental replication are required.

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## 1. Introduction

Water pollution caused by domestic wastewater remains a serious environmental problem in developing countries, including Indonesia. Domestic wastewater is commonly generated from household activities, commercial areas, offices, schools, and other public facilities, and it is often discharged directly into drainage channels or water bodies without adequate treatment (BOD & AMONIA, n.d.; Statistik, 2018). This condition increases the organic pollutant load in receiving waters and may degrade environmental quality and public health. Therefore, effective domestic wastewater management is essential to prevent further degradation of water resources.
One approach to managing domestic wastewater is the Centralised Domestic Wastewater Management System, known as SPALD-T. This system collects and treats wastewater from several households

before discharging the treated effluent into the environment (Emilia & Ilonka, n.d.). In rural areas, SPALD-T can provide a practical solution for improving sanitation services. However, its performance is often influenced by technical maintenance, community participation, operational costs, and the availability of continuous supervision (Nur et al., 2024).

The SPALD-T facility in Sungai Langka Village, Gedong Tataan District, Pesawaran Regency, has been operating since 2023 and serves approximately 50 household connections. Initial testing of its effluent showed that the Biochemical Oxygen Demand (BOD) concentration was 33 mg/L, slightly exceeding the domestic wastewater quality standard of 30 mg/L under the Regulation of the Minister of Environment of the Republic of Indonesia No. 11 of 2025 (BAB, n.d.). This indicates that although the existing treatment system has reduced pollutant loads, additional treatment is still required to ensure the effluent fully meets environmental standards.

Phytoremediation is considered a suitable alternative treatment because it is economical, environmentally friendly, and relatively easy to operate. This method uses aquatic plants to absorb, accumulate, stabilise, or degrade pollutants in contaminated water (H. Ali et al., 2013; Sood et al., 2012). Compared with conventional treatment technologies, phytoremediation requires lower operational costs and minimal maintenance, making it appropriate for rural wastewater treatment applications (Irhamni et al., 2017). In addition, aquatic plants can support natural ecosystem recovery by improving water quality and reducing excess nutrients.

Coontail (Ceratophyllum demersum) is one of the aquatic plants with high potential for wastewater phytoremediation. This submerged, rootless plant absorbs nutrients and pollutants directly through its stems and leaves, enabling it to survive in nutrient-rich, polluted aquatic environments (Keskinkan et al., 2004). Coontail is also known for its ability to tolerate a range of water conditions and to produce oxygen through photosynthesis, which can support microbial degradation of organic matter (Lupitasari & Kusumaningtyas, 2020). Previous studies have shown that Ceratophyllum demersum can reduce BOD, COD, nutrients, and heavy metals in wastewater and polluted water bodies (Al-Ubaidy & Rasheed, 2015; Kadaria, 2017; Kulasekaran et al., 2014).

Several previous studies have reported the effectiveness of Coontail in reducing organic pollutants. Al-Ubaidy (2015) found that Ceratophyllum demersum could reduce BOD by up to 90% in wastewater treatment, while Kulasekaran et al. (2014) reported BOD removal efficiency of 94.6–97.5% after phytoremediation. Another study also showed that Coontail could reduce BOD in fish-washing wastewater by 80.6% within five days (Vania & SKM, 2025). These findings support the potential use of Coontail as a natural treatment agent for improving domestic wastewater effluent quality.

The specific objective of this study is to analyse the efficiency of Coontail (Ceratophyllum demersum) in reducing BOD concentration in the effluent from the SPALD-T Sungai Langka Village, and to evaluate the effects of contact time and variations in plant weight on BOD removal efficiency. The novelty of this study lies in the application of Coontail as a post-treatment phytoremediation agent for rural SPALD-T effluent, particularly under local wastewater characteristics in Sungai Langka Village. This study also provides practical information on the use of different plant weights and contact times as a low-cost, environmentally friendly strategy to improve the quality of domestic wastewater effluent.

## 2. Methodology

This research was conducted from February to April 2025 using effluent samples from the Centralised Domestic Wastewater Treatment System (SPALD-T) located in Sungai Langka Village, Gedong Tataan District, Pesawaran Regency, Lampung Province, Indonesia. The Biochemical Oxygen Demand (BOD) analysis was conducted at the UPTD Health Laboratory of Lampung Province. The main purpose of this experimental study was to evaluate the ability of Coontail plants (Ceratophyllum demersum) to reduce BOD concentration in domestic wastewater effluent.

The materials used in this study consisted of 40 L of SPALD-T effluent, 200 g of Coontail plants, 5 L of distilled water, 15 L of well water, and a buffer solution for pH meter calibration. The equipment included four 10 L plastic reactors, one 16 L plastic container for acclimatisation, jerry cans, a pH meter, a DO meter, Winkler bottles, an incubator, laboratory glassware, and supporting equipment for BOD analysis.

Wastewater samples were collected from the SPALD-T effluent using the grab sampling method based on SNI 6989.59:2008. The samples were taken using clean plastic equipment and stored in closed containers. Initial wastewater characteristics were analysed by measuring pH directly in the field, while BOD was measured in the laboratory. The initial analysis was conducted to assess the quality of the effluent before the phytoremediation process.

Before being used in the phytoremediation experiment, the Coontail plants were acclimatised for seven days in a 16-L plastic container filled with well water. This process was conducted to allow the plants to adapt to the new environmental conditions. During acclimatisation, the physical condition of the plants was observed daily, especially changes in leaf and stem colour. Plants that remained fresh and green were selected for the next stage of the experiment.

The phytoremediation process was conducted in four plastic reactors, each containing 10 L of SPALD-T effluent. Reactor A was used as the control without plants; Reactor B contained 50 g of Coontail; Reactor C contained 60 g of Coontail; and Reactor D contained 70 g of Coontail. The experiment was observed for 18 days, with sampling conducted on days 0, 6, 12, and 18. During the experiment, pH, temperature, BOD concentration, and the physical condition of the plants were monitored.

BOD analysis was performed in accordance with SNI 6989.72:2009. Two Winkler bottles were prepared for each sample to measure dissolved oxygen at the initial condition and after five days of incubation. One bottle was analysed immediately, while the other was incubated at 20 ± 1°C for five days. The BOD value was then determined based on the difference in dissolved oxygen concentration before and after incubation.

The BOD removal efficiency was calculated by comparing the initial and final BOD concentrations after phytoremediation. The efficiency value was expressed as a percentage using the standard removal efficiency equation. The final BOD concentration was then compared with the domestic wastewater quality standard stated in the Regulation of the Minister of Environment of the Republic of Indonesia No. 11 of 2025.

The data were analysed statistically using multiple linear regression with IBM SPSS Statistics 26. The analysis was conducted to determine the effect of contact time and plant weight variation on BOD removal efficiency. Before regression analysis, classical assumption tests were performed, including tests for normality, multicollinearity, and heteroscedasticity. Hypothesis testing was conducted using the partial t-test, the simultaneous F-test, and the coefficient of determination analysis at a significance level of 5%.

## 3. Result & Discussion

The performance of the phytoremediation process using Coontail (Ceratophyllum demersum) was evaluated based on changes in wastewater quality and BOD removal efficiency during the experimental period. The main parameters observed in this study included pH, temperature, and Biochemical Oxygen Demand (BOD), which were monitored to assess the wastewater's physicochemical conditions and the effectiveness of Coontail in reducing organic pollutants. Variations in plant biomass and treatment duration were also evaluated to determine their potential influence on phytoremediation performance. The results demonstrated distinct changes in pH, relatively stable temperature profiles, and variations in BOD removal efficiency between the control and planted reactors. These findings provide important insights into the interactions among Coontail, environmental conditions, and organic matter degradation during the phytoremediation process and are discussed in detail in the following sections.

The pH was monitored throughout the phytoremediation experiment as an important water quality parameter that can influence plant physiological processes, microbial activity, and organic matter degradation. Changes in pH values in each reactor during the experimental period are presented in **Fig. 1**. As shown in **Fig. 1**, different pH trends were observed among the four reactors (A, B, C, and D) during the 19-day observation period. Reactor A, which served as the control without Coontail, maintained relatively acidic conditions, with pH values ranging from approximately 5 to 6. Although a slight increase in pH was observed during the experimental period, the change was relatively limited compared with those observed in the reactors containing Coontail. In the absence of aquatic plants, the increase in pH may be limited because plant-mediated biological processes that reduce the concentration of hydrogen ions ($H^+$) in the wastewater are absent (Yuliasni et al., 2023).

In contrast, Reactors B, C, and D, which contained 50, 60, and 70 g of Coontail, respectively, exhibited a substantial increase in pH beginning approximately on day 3. The pH values gradually increased, reaching alkaline conditions of approximately 9–10 between days 9 and 18. The considerable difference between the control reactor and the reactors containing Coontail indicates that the presence of aquatic plants influenced the physicochemical conditions of the wastewater during phytoremediation. The increase in pH may also be associated with the decomposition of organic matter by microorganisms, which can alter the ionic composition of wastewater and promote the formation of hydroxide ions ($OH^-$), thereby increasing pH (Yulita et al., 2022).

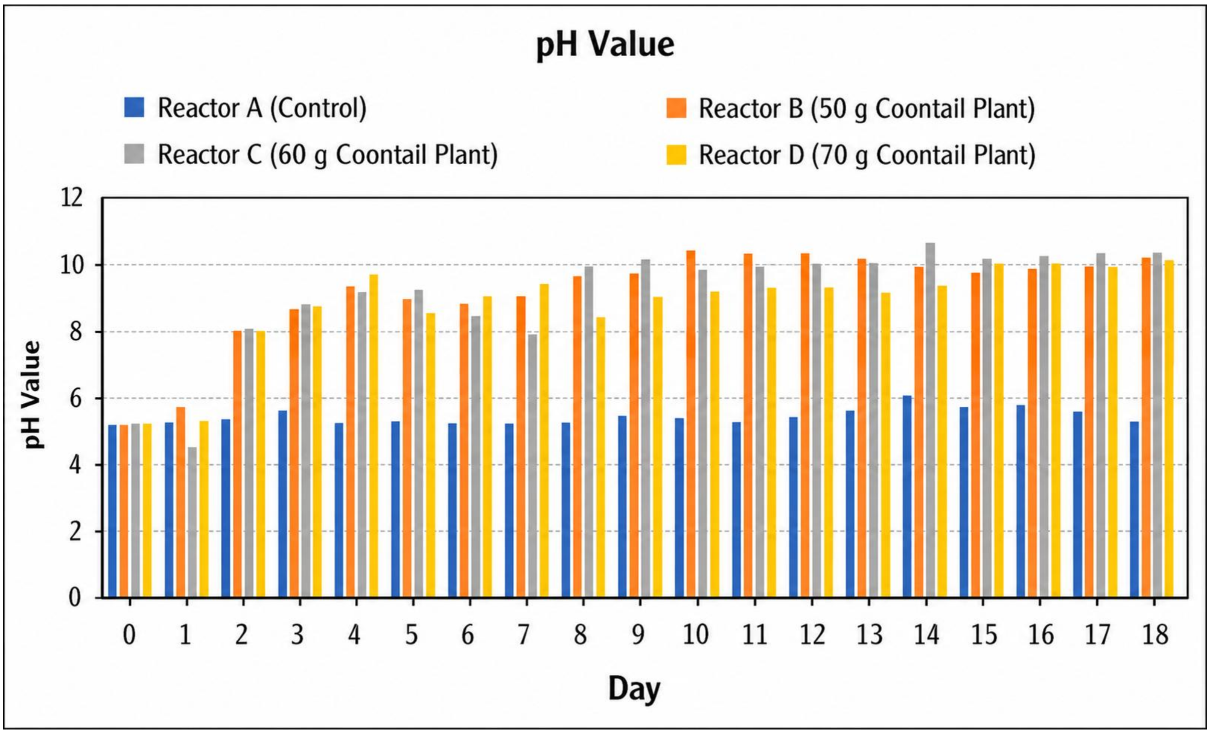


**Fig. 1.** pH Measurements in Each Reactor

Changes in pH during phytoremediation may result from complex interactions among plants, microorganisms, organic matter, and chemical compounds in the wastewater. The interaction of $OH^-$ ions with wastewater constituents may contribute to variations in pH during the treatment process. Environmental conditions, including temperature, may also affect the chemical and biological processes occurring within the reactors. Temperature changes can influence dissolved oxygen solubility and biological activity, which may indirectly affect the acid–base equilibrium of the wastewater (Munandar, 2017). However, because temperature remained relatively stable at approximately 25–27.5°C throughout the experiment, extreme temperature fluctuations were unlikely to have been the primary factor responsible for the substantial increase in pH observed in the reactors containing Coontail.

The observed increase in pH may be more closely associated with changes in the carbon dioxide ($CO_2$) and bicarbonate equilibrium within the phytoremediation system. The concentration of dissolved $CO_2$ is strongly related to water pH because higher $CO_2$ concentrations can promote the formation of carbonic acid and increase hydrogen ion concentration, thereby decreasing pH (K. & Tancung, 2010). Conversely, submerged aquatic plants such as Ceratophyllum demersum can utilise dissolved $CO_2$ and bicarbonate ($HCO_3^-$) as inorganic carbon sources during photosynthesis. The consumption of these carbon sources can reduce $H^+$ concentrations, decrease acidity, and consequently increase the pH of the wastewater (Pedersen et al., 2013).

Photosynthetic activity may therefore explain the considerable increase in pH observed in Reactors B, C, and D compared with the control reactor. During periods of sufficient light availability, Coontail utilises dissolved inorganic carbon for photosynthesis and releases oxygen into the surrounding water. The reduction in dissolved $CO_2$ and changes in the carbonate–bicarbonate equilibrium may gradually shift the wastewater toward alkaline conditions. Furthermore, increased dissolved oxygen concentrations can support aerobic microbial activity and the oxidation of biodegradable organic compounds, thereby reducing the accumulation of acidic compounds and further contributing to alkaline conditions in the wastewater (Jia et al., 2024).

The substantial increase in pH observed in the reactors containing Coontail also suggests that plant biomass may have influenced the intensity of biological and physicochemical processes within the phytoremediation system. Differences in plant biomass among Reactors B, C, and D could affect photosynthetic activity, nutrient uptake, microbial colonisation, and oxygen transfer. Nevertheless, because the present study primarily evaluated the effects of treatment duration and plant biomass on BOD removal efficiency, the relationship between plant biomass and pH variation was not statistically analysed. Therefore, differences in pH among the planted reactors should be interpreted as descriptive observations rather than evidence of a statistically significant effect of Coontail biomass.

Although the increase in pH demonstrates active biological processes within the planted reactors, the relatively high pH values of 9–10 observed during the later stages of treatment should also be considered when evaluating the overall performance of the phytoremediation system. Excessively alkaline conditions may influence microbial activity, nutrient availability, plant physiological responses, and the suitability of the treated effluent for discharge into receiving water bodies. Therefore, the effectiveness of phytoremediation should not be evaluated solely based on BOD removal efficiency but should also consider changes in other water quality parameters, particularly pH.

Overall, the pH results demonstrate a clear difference between the control reactor and the reactors containing Coontail. While Reactor A remained relatively acidic at pH 5–6, Reactors B, C, and D gradually shifted toward alkaline conditions, reaching pH values of approximately 9–10 during the later stages of the experiment. This trend was likely associated with the combined effects of Coontail photosynthetic activity, $CO_2$ and bicarbonate uptake, microbial degradation of organic matter, and changes in dissolved oxygen conditions (Jia et al., 2024; K. & Tancung, 2010; Pedersen et al., 2013). These findings indicate that Ceratophyllum demersum not only contributed to BOD removal but also substantially altered the physicochemical characteristics of the wastewater during phytoremediation. Consequently, optimising treatment duration and operating conditions is recommended to achieve effective removal of organic pollutants while maintaining the treated effluent pH within an appropriate range for environmental discharge.

Temperature was monitored throughout the phytoremediation experiment as an environmental parameter that may influence plant physiological activity, microbial processes, and the overall performance of wastewater treatment. The temperature variations recorded in each reactor during the experimental period are presented in **Fig. 2**. As shown in **Fig. 2**, the temperatures recorded in all four reactors during the phytoremediation process ranged from approximately 25°C to 27.5°C. This temperature range was relatively stable throughout the experimental period and was considered suitable for the growth and physiological activity of Coontail (Ceratophyllum demersum). According to (S. Ali et al., 2017), Ceratophyllum demersum can grow optimally at temperatures ranging from 20°C to 30°C and exhibits favourable physiological activity in the uptake and removal of organic pollutants and heavy metals from contaminated water. Therefore, the temperature conditions observed in this study were within the appropriate range for supporting the survival and phytoremediation activity of Coontail.

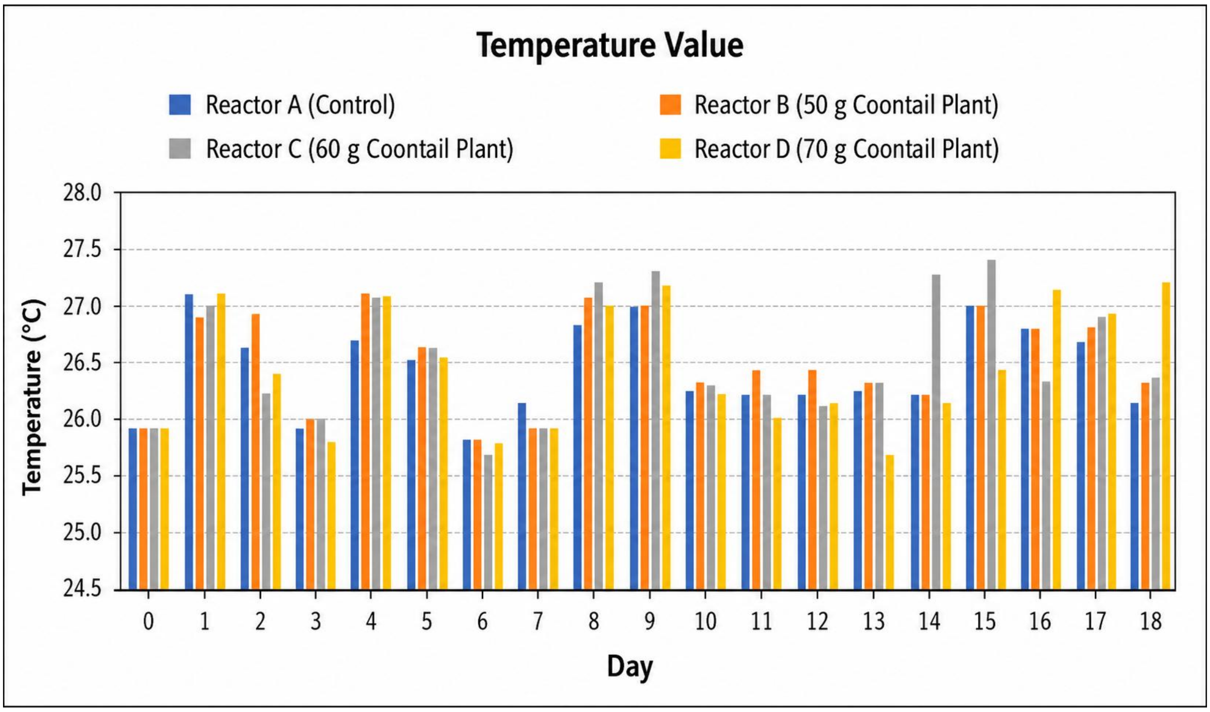


**Fig. 2.** Temperature Measurements in Each Reactor

The relatively favourable temperature conditions may have facilitated Coontail's adaptation to the domestic wastewater environment and its maintenance of physiological activity during the treatment period. Temperature is an important environmental factor in phytoremediation systems because it affects plant metabolism, photosynthetic activity, microbial growth, oxygen transfer, and the biodegradation rate of organic pollutants. A previous study (Rai, 2008) also demonstrated that Coontail can maintain its ability to efficiently absorb metal ions and organic compounds under relatively stable tropical temperatures. Thus, the temperature range observed in this study may have provided suitable environmental conditions for the interaction between Coontail and microorganisms involved in the degradation of organic matter.

Nevertheless, slight temperature fluctuations were observed among the reactors and throughout the experimental period. These variations may have been caused by changes in environmental conditions, including sunlight intensity, ambient air temperature, and daily weather conditions during the experiment. The reactors were placed near an open laboratory window, thereby constituting a semi-open experimental system, through which heat, light, and air were exchanged between the reactors and the surrounding environment (Guo et al., 2012). Consequently, changes in external environmental conditions may have directly influenced the water temperature within each experimental reactor.

Differences in temperature among the reactors may also have resulted from variations in light exposure. Different levels of solar radiation received by each reactor can affect the amount of heat absorbed by the wastewater medium (Aulia et al., 2019). Reactors exposed to greater light intensity may experience slightly higher temperatures than those receiving less direct light. In addition, differences in plant biomass among Reactors B, C, and D may have influenced light penetration and heat distribution within the wastewater. However, the relatively narrow temperature range observed throughout the study suggests that these environmental variations did not lead to extreme temperature changes that could adversely affect the phytoremediation process.

Maintaining a relatively stable temperature is important for the effectiveness of aquatic phytoremediation systems, as substantial temperature fluctuations can negatively affect plant growth and physiological activity (Renjani et al., 2025). Extreme temperature changes can influence photosynthetic performance, plant metabolism, microbial activity, and the biological degradation of organic pollutants. In the present study, the temperature remained within the optimal tolerance range for Ceratophyllum demersum, suggesting that temperature was unlikely to have acted as a major limiting factor during the phytoremediation process.

Overall, the temperature conditions observed during the experiment provided a favourable environment for Coontail growth and phytoremediation. The relatively stable temperature range of 25–27.5°C may have supported plant physiological processes and microbial activity associated with organic matter degradation. Although minor fluctuations occurred because of environmental factors and the semi-open experimental conditions, the recorded temperatures remained within the optimal growth range reported for Ceratophyllum demersum (S. Ali et al., 2017). Therefore, the temperature conditions during the experiment were considered suitable for supporting the phytoremediation process and may have indirectly contributed to the reduction of BOD concentrations observed in the reactors containing Coontail.

Biochemical Oxygen Demand (BOD) measurements were conducted on days 6, 12, and 18 to assess the effectiveness of Coontail (Ceratophyllum demersum) in reducing organic pollutants in the effluent from the Centralised Domestic Wastewater Treatment System (SPALD-T) in Sungai Langka Village. The average BOD removal efficiency in each reactor during the phytoremediation process is presented in **Fig. 3**. **Fig. 3** shows the BOD removal efficiency (%) of four reactors with different Coontail biomass variations during 18 days of treatment. Reactor A served as the control without plants, while Reactors B, C, and D contained 50, 60, and 70 g of Coontail, respectively. The differences in removal efficiency among the reactors indicate variations in phytoremediation performance with plant biomass and treatment duration.

On day 6, Reactor B exhibited the highest BOD removal efficiency of 69.70%, followed by Reactor D at 60.61%, whereas the control reactor (Reactor A) achieved only 1.52% removal efficiency. Meanwhile, the BOD concentration in Reactor C was not detected (N.D.), indicating it was below the analytical method's detection limit and therefore could not be quantitatively determined. This finding is consistent with a previous study [61], which demonstrated that phytoremediation using certain aquatic plant species can effectively reduce organic pollutant concentrations to levels below analytical detection limits. The rapid reduction in BOD during the initial treatment period suggests that Coontail and the associated microbial communities contributed to the degradation and removal of biodegradable organic matter from the wastewater.

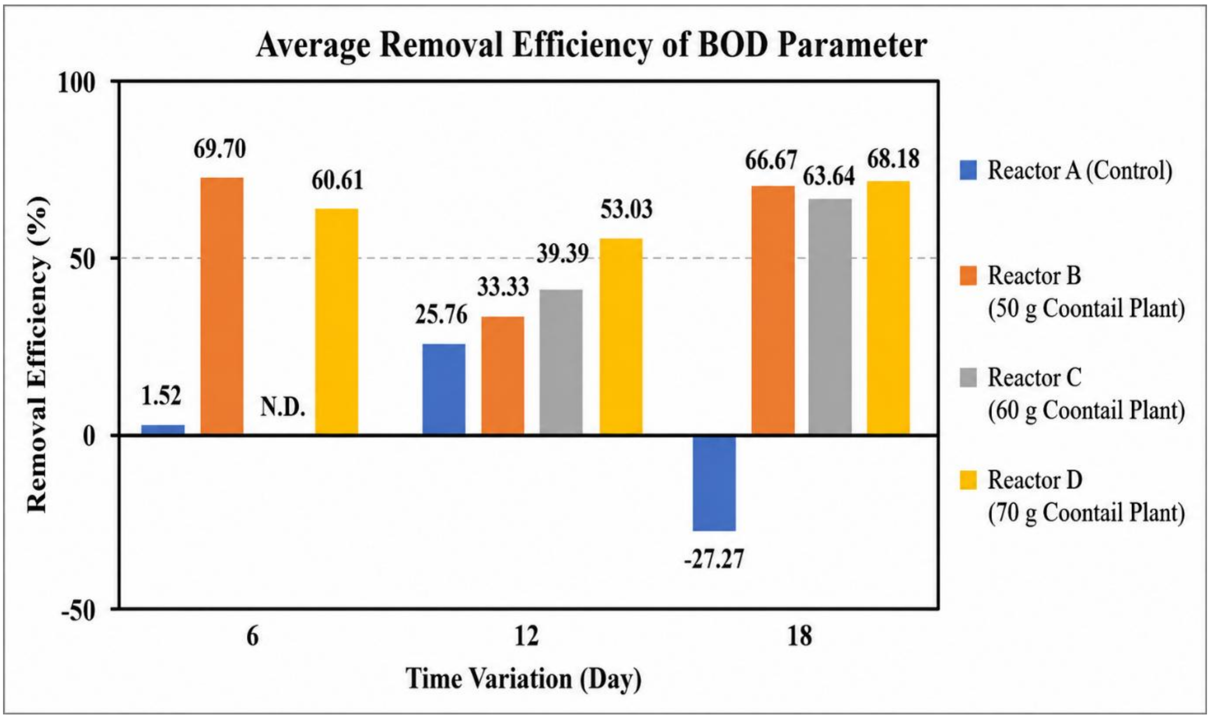


**Fig. 3**. Average BOD Removal Efficiency in Each Reactor

On day 12, Reactor D showed the highest BOD removal efficiency of 53.03%, followed by Reactor C at 39.39%, while Reactor B showed the lowest at 33.33%. Changes may have influenced the variation in removal efficiency observed during this period in plant physiological conditions, microbial activity, organic matter availability, and environmental conditions within the reactors. Fluctuations in BOD removal during phytoremediation can occur because the treatment process involves complex interactions among aquatic plants, microorganisms, dissolved oxygen, and organic pollutants.

At the end of the treatment period on day 18, the BOD removal efficiency increased in all reactors containing Coontail. Reactor D achieved the highest removal efficiency of 68.18%, followed by Reactor B at 66.67% and Reactor C at 63.64%. In contrast, Reactor A exhibited a negative removal efficiency of −27.27%, indicating an increase in organic matter concentration during the experimental period. This increase may have resulted from the natural decomposition of organic matter in the wastewater, as the control reactor received no additional contribution from nutrient uptake by plants or oxygen production through photosynthesis (Ajibade & Adewumi, 2017). These findings demonstrate the important role of Coontail in supporting organic matter removal compared with untreated wastewater conditions.

The overall results indicate that treatment duration may contribute to BOD reduction by providing sufficient time for interactions among Coontail, microorganisms, and organic pollutants. A longer contact period can increase the opportunity for organic matter uptake and microbial degradation within the phytoremediation system. The N.D. result observed in Reactor C on day 6 may indicate favourable phytoremediation conditions, including plant biomass, biofilm development, and oxygen production through photosynthesis, which may have accelerated the degradation of organic matter to concentrations below the analytical detection limit. A previous study [36] similarly reported that the application of Coontail to coffee wastewater reduced BOD concentrations by approximately 66% within 18 days. Furthermore, another study (Sulaiman et al., 2023) demonstrated that variations in Coontail biomass can influence phytoremediation performance in wastewater treatment systems.

Although Reactor D achieved the highest BOD removal efficiency of 68.18% at the end of the 18-day treatment period, statistical analysis showed that neither treatment duration nor plant biomass had a significant effect on BOD removal efficiency. The significance values for treatment duration and plant biomass were 0.996 and 0.533, respectively, both exceeding the significance level of 0.05. Therefore, the observed variations in BOD removal efficiency cannot be attributed solely to differences in treatment duration and Coontail biomass. Other factors, such as initial wastewater characteristics, microbial activity, dissolved oxygen concentration, temperature, pH, plant physiological conditions, and experimental variability, may also have influenced the phytoremediation performance. Nevertheless, the substantially higher BOD removal efficiencies observed in reactors containing Ceratophyllum demersum compared with the control reactor demonstrate the potential of Ceratophyllum demersum as an environmentally friendly post-treatment alternative for improving the quality of rural domestic wastewater effluent.

## 4. Conclusion

Based on the results of this study, Coontail (Ceratophyllum demersum) demonstrated its potential as a phytoremediation plant for reducing Biochemical Oxygen Demand (BOD) in the effluent of the Centralised Domestic Wastewater Treatment System (SPALD-T) in Sungai Langka Village. The highest BOD removal efficiency was recorded in Reactor D, which contained 70 g of Coontail, reaching 68.18% after 18 days of treatment. This result indicates that the presence of Coontail contributed to the reduction of organic pollutant concentrations in the wastewater through plant uptake, biological degradation, and interactions with microorganisms associated with the plant biomass. The final BOD concentration also met the applicable domestic wastewater quality standard, demonstrating that Coontail phytoremediation can be considered a low-cost and environmentally friendly post-treatment alternative for rural wastewater systems.

However, the statistical analysis showed that neither contact time nor plant weight had a significant effect on BOD removal efficiency within the tested experimental range. The significance values for contact time and plant weight were 0.996 and 0.533, respectively, both greater than the significance level of 0.05. These findings suggest that differences in treatment duration or plant biomass alone could not statistically explain the observed variation in BOD removal efficiency. Other factors, including initial wastewater characteristics, pH, temperature, plant physiological condition, microbial activity, and limited experimental replication, may have contributed to the treatment performance.

Overall, this study confirms that Ceratophyllum demersum can improve the quality of SPALD-T effluent and reduce BOD concentrations, although the effects of plant weight and contact time were not statistically significant. Further studies should employ a wider range of plant biomass types, longer treatment periods, additional experimental replicates, and additional water-quality parameters to determine the optimum operating conditions and strengthen the applicability of Coontail-based phytoremediation at a larger scale.

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