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Phytoremediation of ammonia and water quality improvement in common carp (*Cyprinus carpio*) culture using *Ipomoea aquatica* and *Lemna minor*

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ABSTRACT

This study aims to evaluate the effectiveness of aquatic plants water spinach (*Ipomoea aquatica*) and duckweed (*Lemna minor*) in reducing ammonia concentration and improving water quality in common carp (*Cyprinus carpio*) aquaculture ponds through phytoremediation. Four treatments were tested: P1 (water spinach), P2 (duckweed), P3 (combination of both), and K (control), with observations conducted on day 0, day 7, day 14, and day 21.The results showed that treatment P1 provided the most significant reduction in ammonia concentration (from 0.12 mg/L to 0.05 mg/L), BOD (from 206 mg/L to 20.4 mg/L), COD (from 505 mg/L to 51.1 mg/L), and TDS (from 731 mg/L to 477 mg/L). Treatment P3 also demonstrated good effectiveness, particularly in reducing ammonia and COD, although not as efficiently as P1. In contrast, treatment P2 showed a sharp increase in ammonia on day 7 (6.4 mg/L), followed by a drastic decrease, indicating high fluctuation. The control treatment (K) showed no significant changes across all parameters.These findings indicate that water spinach has strong potential as a phytoremediation agent in freshwater aquaculture systems, with the ability to absorb ammonia and significantly improve water quality. This approach offers an eco-friendly and sustainable solution to enhance the efficiency and environmental health of common carp farming.

Keywords: phytoremediation, *Ipomoea aquatica*, *Lemna minor*, ammonia, *Cyprinus carpio*, freshwater pond.

INTRODUCTION

Freshwater fish farming systems represent a form of resource management in aquaculture practices and have been widely implemented in the freshwater fisheries industry (Sadono et al., 2021). This sector has seen significant development in Indonesia due to its high economic value and stable market demand (Gajah et al., 2025). Among the various freshwater aquaculture commodities, common carp (*Cyprinus carpio*) stands out as a leading species cultivated across numerous regions in Indonesia. Economically, common carp farming contributes substantially to local incomes, particularly in major production centers (Dharmawantho and Supriyanto, 2021).

A key factor influencing the productivity of common carp ponds is the quality of water within the pond compartments, as water serves as the primary medium for fish growth. Therefore, improving water quality is essential to enhance the productivity of common carp farming (Sadono et al., 2021). However, the intensification of common carp aquaculture often leads to environmental challenges, including pollution and the accumulation of organic waste in the ponds. This waste primarily consists of ammonia (NH_3), which originates from uneaten feed, fish feces, and decomposing fish (Fahruddin et al., 2025).

Ammonia is one of the nitrogenous compounds commonly found in aquaculture systems, primarily as a byproduct of fish metabolism and the decomposition of organic matter such as uneaten feed and feces. In aquatic environments, ammonia exists in two forms: ammonium ion (NH_4^+), which is relatively non-toxic, and free ammonia (NH_3), which is highly toxic to fish (Israeli-Weinstein and Kimmel, 1998). The breakdown of organic materials from feed generates toxic ammonia that can inhibit fish growth and, in severe cases, lead to mortality. Moreover, elevated ammonia concentrations increase the susceptibility of common carp to disease (Hossam, 2006).

Ammonia is a pollutant parameter in common carp aquaculture systems due to its toxicity, which can induce stress and even death in fish when its concentration exceeds the threshold for total ammonia (NH_3 + NH_4^+). High levels of ammonia exacerbate infections caused by pathogenic bacteria by weakening the immune system of common carp and creating favorable conditions for bacterial proliferation. In extreme cases, fish may die from respiratory failure and damage to vital organs (Abdella et al., 2024).

Overfeeding or providing feed that does not meet the nutritional requirements of fish is one of the primary causes of elevated ammonia concentrations in aquaculture water (Joshua et al., 2017). Feeds with high protein content contribute to increased ammonia production, as proteins are metabolized into nitrogenous compounds that are subsequently excreted by fish into the water. Additionally, poor water quality – characterized by low dissolved oxygen, high pH, and elevated temperatures can accelerate the conversion of ammonium (NH_4^+) into free ammonia (NH_3), which is significantly more toxic to fish (Owaes et al., 2024; Jahanbani and Orcid, 2023).

Accumulated ammonia in aquaculture water can disrupt fish physiological processes, thereby reducing productivity and survival rates. Consequently, controlling ammonia levels is a critical aspect of water quality management in common carp ponds, encompassing parameters such as BOD, COD, TDS, and pH. Various methods have been employed to reduce ammonia concentrations, ranging from water exchange and biological filtration to the application of environmentally friendly technologies such as phytoremediation (Ali et al., 2020; Elya et al., 2023).

Phytoremediation is a water quality restoration method that utilizes the ability of aquatic plants to absorb, accumulate, and degrade organic pollutants in fish pond water. water spinach and duckweed are two types of aquatic plants that grow abundantly in Indonesia's tropical climate. These plants have the potential to absorb nitrogenous compounds, including ammonia, and improve water quality parameters such as biochemical oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solids (TDS), and pH (Tanjung et al., 2019). In addition to being easily cultivated and widely available, both species exhibit rapid growth rates and strong tolerance to polluted aquatic environments (Mishra, 2023; Afiah et al., 2025).

Several relevant studies support this approach. Research by Obinna and Ebere (2019) demonstrated that water spinach and duckweed could reduce levels of COD, total suspended solids (TSS), and ammonia nitrogen (NH_3–N). Another study by Sarkheil et al. (2023) found that water spinach was more effective than duckweed in reducing TSS and improving the quality of wastewater in tilapia aquaculture systems.

Furthermore, a study conducted by Alkimin et al. (2019) demonstrated that duckweed possesses phytoremediation capabilities in treating wastewater contaminated with dyes. Similarly, research by Suherman et al. (2021) revealed that water spinach has the potential to accumulate heavy metals such as lead (Pb) and chromium (Cr) at high concentrations in hospital wastewater samples, indicating its suitability as a phytoremediation agent for polluted substances.

Although numerous studies have investigated the effectiveness of water spinach and duckweed in phytoremediation, comparative research evaluating the performance of these two aquatic plants – either individually or in combination – within the context of carp aquaculture ponds remains limited. Therefore, this study is essential to assess the phytoremediation potential of both species and to identify the most effective combination for reducing ammonia concentrations in relation to water quality in carp farming systems.

MATERIALS AND METHODS

Sample collection and preparation

Aquatic plants water spinach (*Ipomoea aquatica)* and duckweed (*Lemna minor)* were collected from rice fields located in Bone Regency, South Sulawesi Province (Figure1) . The plants were rinsed thoroughly with running water and placed in plastic containers filled with water for acclimatization over a period of four days. Water samples were collected

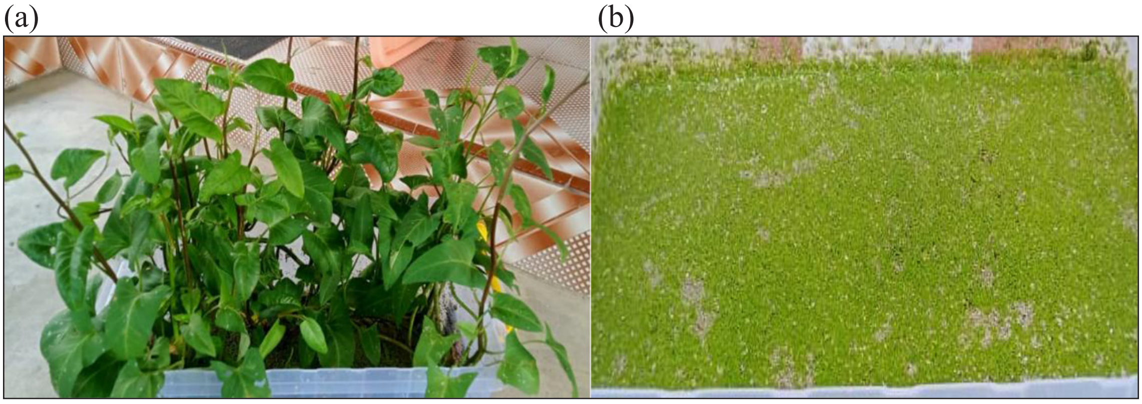

Figure 1. Two types of aquatic plants used in the phytoremediation of common carp pond water: (a) water spinach (*Ipomoea aquatica)* and (b) duckweed (*Lemna minor)*

from carp aquaculture ponds located in Boccoe Village, Bone Regency, South Sulawesi Province.

Water characterization of carp ponds

Initial characterization of the pond water used for common carp cultivation was conducted through various analytical methods. Nitrate concentration was measured using the spectrophotometric method, while nitrite levels were determined via colorimetric analysis. Ammonia and phosphate concentrations were both analyzed using spectrophotometry. The pH value was measured using a pH meter. Total nitrogen content was assessed using the Kjeldahl method, and potassium levels were determined through Atomic Absorption Spectrophotometry (AAS).

Phytoremediation treatment

Water samples from common carp aquaculture ponds, previously characterized, were placed into plastic containers with a volume of 15 liters each (Figure 2). Aquatic plants – water spinach*)* and duckweed were acclimatized and weighed at 100 grams each before being introduced into the treatment containers. The treatments were as follows: P1 – addition of water spinach; P2 – addition of duckweed; P3 – combination of water spinach and duckweed; K – no plant addition (control). The treatments were maintained for a duration of 21 days. Water quality parameters – including ammonia concentration, nitrate, biochemical oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solids (TDS), and pH were measured on day 0, day 7, day 14, and day 21.

Ammonia concentration measurement

Determination of ammonia concentration was conducted by the phenate method based on the formation of the blue colored complex compound indophenol. A sample of 10 mL of groundwater was pipetted into a 25 mL cell sample, then added with 0.4 mL of phenol solution, 0.4 mL of sodium nitroprusside, and 1 mL of oxidizing solution. The mixture was then homogenized and let to stand for 1 hour. Measurement was then conducted with a UV-Vis spectrophotometer at a wavelength of 640 nm.

Nitrate concentration measurement

The concentration of nitrate in carp pond water samples was determined using the cadmium reduction method. In this procedure, nitrate in the water sample is reduced to nitrite by passing it through a column containing cadmium metal. The resulting nitrite is then reacted with diazotizing reagents – sulfanilamide and NED (N-(1-naphthyl) ethylenediamine dihydrochloride) – to form a pink-colored azo compound. The intensity of the color is measured using a spectrophotometer at a wavelength of approximately 543 nm.

Measurement of BOD

A 300 mL water sample of common carp pond water was divided into two portions: one designated for the initial analysis and the other for post-incubation assessment. The latter was stored in a sealed container at 20°C for a duration of five days to inhibit the exchange of oxygen with the environment. The concentration of dissolved oxygen in the initial sample was determined using the

Figure 2. Phytoremediation treatments applied to common carp pond water include: P1 – addition of water spinach; P2 – addition of duckweed; P3 – combination of water spinach and duckweed; P4 – no plant addition (control)

titration-iodometric method with a 0.025 N sodium thiosulfate solution, and the same procedure was applied to the incubated sample. By comparing the dissolved oxygen levels before and after the incubation period, the resulting difference provides the BOD value for the water sample.

Measurement of COD

A volume of 100 ml of the water sample intended for treatment was collected. Potassium dichromate reagent ($K_2Cr_2O_7$) and concentrated sulfuric acid (H_2SO_4) were subsequently introduced to facilitate the oxidation of organic materials present in the sample. To mitigate the potential interference from chloride ions, which could affect the reaction mercury sulfate ($HgSO_4$) was incorporated. The sample was then subjected to heating in a test tube at approximately 150°C for a duration of two hours. Following the cooling phase, titration was performed using ferrous ammonium sulfate (FAS) until a color transition from green to reddish-brown was observed. The COD of the water sample is determined by calculating the difference in the volume of potassium dichromate utilized before and after the titration process.

Measurement of total dissolved solids

The gravimetric method was employed to measure total dissolved solids. A 10 mL sample of water from the carp pond was filtered using filter paper and then transferred into a petri dish. The sample was evaporated in a water bath until completely dry. Subsequently, the petri dish containing the dried sample was placed in an oven at 105 °C until it was thoroughly dried. After drying, the petri dish was cooled in a desiccator for 15 minutes and then weighed until a stable mass was achieved. TDS was calculated using the formula, as shown in Equation (1)

$$TDS = \frac{a - b}{V} \quad (1)$$

where: V – volume of the sample (mL), a – weight of the petri dish with the dried sample (mg), b – weight of the empty petri dish (mg)

Measurement of pH

The pH measurement was performed utilizing a pH meter that had been previously calibrated with buffer solutions at pH 4 and pH 7, followed by a stabilization period of 15 minutes. Subsequently, the electrode of the pH meter was placed into the water sample collected from the carp pond water, and after a brief interval, the pH value was recorded from the scale of the pH meter.

RESULTS AND DISCUSSION

Initial characterization of fish pond water

The results of the chemical characterization of water from a common carp (*Cyprinus carpio*) pond are presented in Table 1, including parameters such as ammonia, nitrate, nitrite, total nitrogen, phosphate, and potassium. This characterization was conducted in accordance with specific requirements for freshwater aquaculture ponds as stipulated by the Government of Indonesia and the Food and Agriculture Organization (FAO). The analysis aimed to assess the initial condition of the pond water. Based on the chemical parameters, the pond water was classified as polluted, as several values exceeded the established environmental quality standards. Notably, the ammonia concentration reached 2.57 mg/L, surpassing the permissible threshold of >0.5 mg/L, which poses a risk of fish mortality (Sadono et al., 2021; Wang et al., 2021).

Observation of phytoremediation treatments

Phytoremediation using aquatic plants, specifically water spinach and duckweed, was employed to evaluate their potential in reducing ammonia concentrations and improving water quality parameters, including nitrate levels, BOD, COD, TDS, and pH. The observations are summarized as follows:

Ammonia concentration

Observations of ammonia concentration over a 21-day period revealed that all treatments exhibited changes in ammonia concentration, each following a distinct pattern (Figure 3). In treatment P1, which used only water spinach, ammonia concentration consistently decreased from 0.12 mg/L on day 0 to 0.04 mg/L on day 14, followed by a slight increase to 0.05 mg/L on day 21. In treatment P2, which used only duckweed, a sharp increase was observed on day 7, reaching 6.4 mg/L, before decreasing to 3.33 mg/L on day 14 and 0.11 mg/L on day 21. In treatment P3, which combined both aquatic plants, ammonia levels rose to 4.39 mg/L on day 7, then dropped significantly to 0.06 mg/L and 0.04 mg/L on days 14 and 21, respectively. In the control group (K), ammonia concentration remained constant at 0.12 mg/L throughout the observation period.

These observations indicate that water spinach was effective in reducing ammonia concentration due to its ability to absorb nutrients from the pond water (Hossam, 2006). According to Enduta et al. (2011), water spinach can reduce ammonia concentration by up to 87%, which is attributed

Table 1. Initial characterization of common carp pond water samples

Parameter	Test result (mg/L)	Quality standard	Pollution category
Nitrate	21.4	20 mg/L	Polluted
Nitrite	0.35	0.06 mg/L	Polluted
Phosphate	1.2	0,2 mg/L	Polluted
Potassium	11.08	10 mg/L	Polluted
Total nitrogen	3.6	2 mg/L	Polluted
Ammonia	2.57	0.5 mg/L	Polluted
pH	7.2	6 – 9	Normal

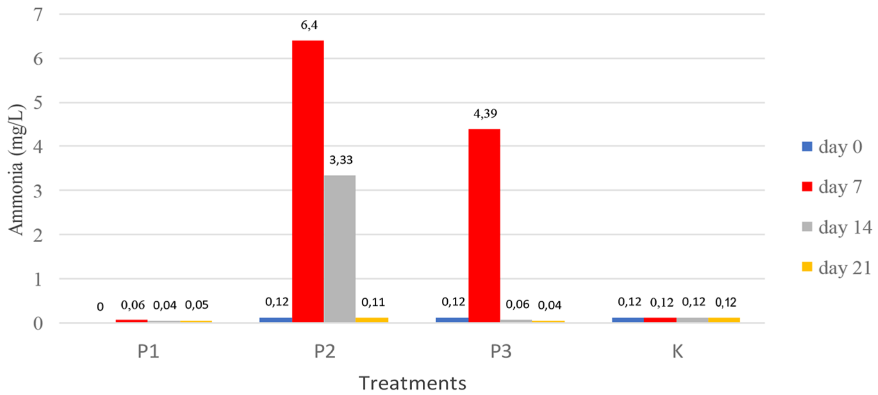

Figure 3. Ammonia concentration under phytoremediation treatments in common carp pond water, with treatments including: P1 – addition of water spinach; P2 – addition of duckweed ; P3 – combination of water spinach and duckweed; K – no plant addition (control)

to its long fibrous roots that efficiently absorb nutrients, thereby facilitating ammonia breakdown. In treatment P2, the initial increase in ammonia concentration with duckweed may have resulted from biological activity or plant excretion, followed by a decrease possibly due to adaptation or other natural processes (Fahruddin and Tanjung, 2019). Abdul et al. (2020) reported that duckweed has very low and unstable effectiveness in reducing ammonia concentration, likely due to stress conditions caused by salinity and environmental pressures. In contrast, treatment P3, which combined both aquatic plants, showed enhanced effectiveness, potentially due to complementary growth forms and nutrient uptake mechanisms.

Nitrate concentration

The analysis of nitrate levels over a 21-day observation period showed that all treatments were effective in reducing nitrate concentration from the initial value of 2.64 mg/L, although with varying outcomes (Figure 4). In treatment P1, which utilized water spinach alone, nitrate concentration consistently decreased, reaching 0.79 mg/L by day 21. In treatment P2, which used duckweed alone, nitrate levels initially increased to 3.40 mg/L on day 7, followed by a gradual decline to 0.96 mg/L by day 21. Treatment P3, which combined both aquatic plants, showed a gradual reduction in nitrate concentration, reaching 1.13 mg/L on day 21. In the control group (K), nitrate concentration remained constant at 2.64 mg/L throughout the observation period.

These findings indicate that water spinach is highly effective in absorbing nitrate from fish pond water through phytoremediation, demonstrating high efficiency via leaf and root tissues (Prayogo, 2019). In treatment P2, the initial increase in nitrate may be attributed to the metabolic activity of duckweed, which produces nitrate, followed by a decrease likely due to nitrification and microbial uptake (Sahi and Smain, 2023). Similarly, treatment P3 showed enhanced overall effectiveness through root tissue interactions and microbial activity, suggesting that the combination of both aquatic plants is effective in reducing nitrate concentrations in fish pond water (Liu et al., 2017; Zulfahmi et al., 2021).

BOD values

Observations of BOD values over a 21-day period (Figure 5) revealed a significant reduction in treatment P1, which involved only water spinach, from 206 mg/L to 20.4 mg/L. Similarly, treatment P2, which utilized only duckweed, showed a decrease to 26.6 mg/L. Treatment P3, which combined both aquatic plants, resulted in a reduction to 88.9 mg/L. In contrast, the control treatment (K) maintained a consistently high BOD level at 206 mg/L.

These observations indicate that water spinach is highly effective in reducing BOD levels, demonstrating strong phytoremediation capabilities in removing dissolved organic matter that demands oxygen. Water spinach contributes to water aeration through photosynthesis, facilitating the absorption of pollutants via sedimentation and adsorption processes. Additionally, its root structure provides a substrate for microbial activity that aids in the decomposition of organic matter.

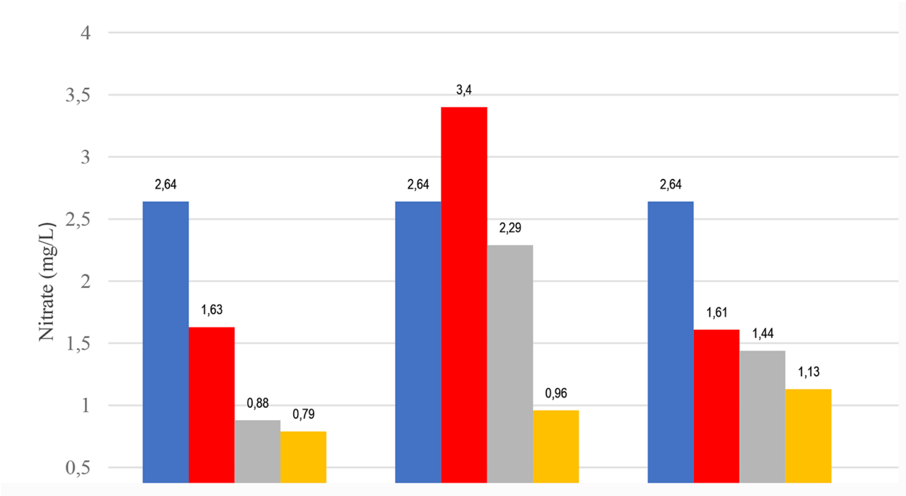

Figure 4. Nitrate concentration under phytoremediation treatments in common carp pond water, with treatments including: P1 – addition of water spinach; P2 – addition of duckweed; P3 – combination of water spinach and duckweed; K – no plant addition (control)

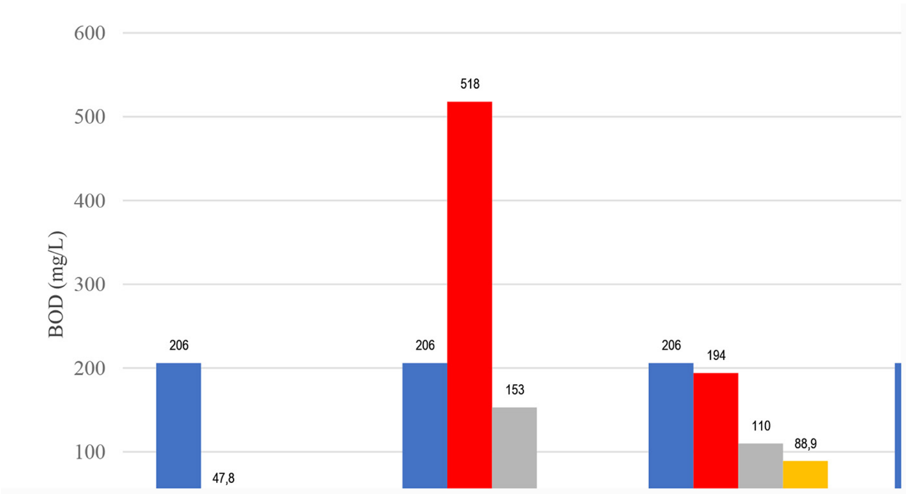

Figure 5. BOD values under phytoremediation treatments in common carp pond water, with treatments including: P1 – addition of water spinach; P2 – addition of duckweed ; P3 – combination of water spinach and duckweed; K – no plant addition (control)

Duckweed also contributes to the absorption of dissolved organic substances through metabolic processes occurring in its roots (Ahmad and Ridhayani, 2019; Fahruddin et al., 2021).

However, the combination of both aquatic plants in treatment P3 showed a less effective reduction in BOD compared to water spinach alone. This may be attributed to interactions between by-products released by duckweed that interfere with the absorption of organic matter, particularly in fish pond water. Furthermore, competition for space and nutrients between the two species may reduce the rate of organic matter uptake, resulting in suboptimal efficiency in treatment P3 (Ahmadi and Sukru, 2024). The relatively high concentration of organic matter around the roots may also affect microbial activity in decomposing organic substances, leading to a less significant decrease in BOD compared to treatments where each plant was used individually (Fahruddin et al., 2019). Additionally, the accumulation of toxic by-products may inhibit microbial metabolism (Othman et al., 2016), which can reduce the overall biodegradation process and consequently lower oxygen consumption, thereby decreasing BOD. Chemically, the presence of specific phytochemicals in both aquatic plants may also influence microbial activity, contributing to the stabilization of oxygen demand (Tangahu and Putri, 2017; Abdullahi et al., 2021).

COD values

A significant reduction in COD values was observed on day 21 (Figure 6). In treatment P1, which involved only water spinach, COD levels decreased markedly from an initial 505 mg/L to 51.1 mg/L by day 21. Similarly, in treatment P2 using duckweed, COD levels dropped to 65.8 mg/L. However, in treatment P3, which combined both aquatic plants, the reduction was slower, reaching 101.1 mg/L. In contrast, the control treatment (K) maintained a consistently high COD level of 505 mg/L.

Water spinach proved effective in reducing the organic load in aquaculture pond water, demonstrating strong phytoremediation potential, although it did not reach the water quality standard of 40 mg/L for carp aquaculture ponds (Hisama et al., 2022). In treatment P2, duckweed also contributed to COD reduction, although the values remained relatively high due to biological activity and the excretion of organic substances that added to the COD load (Usman et al., 2025). However, the combined treatment of both aquatic plants was less effective than the single-plant treatment with water spinach. This may be due to interactions between duckweed by-products and the limited absorption capacity of water spinach (Nur et al., 2022).

These findings are consistent with research by Sa'at (2017), which reported that *Ipomoea aquatica* Forsk. has the potential to reduce COD by up to 90%. Duckweed treatment is associated with its floating leaves, which support pollutant uptake through bioaccumulation and biosorption mechanisms (Srilestari and Anita, 2021; Krishnaswamy and Gustavo, 2025).

In contrast, the combined treatment was relatively less effective than single-plant treatments in reducing COD levels. Each plant species has different capabilities in degrading pollutants (Hebrianti et al., 2025). The organic matter content around the roots of both aquatic plants tends to be higher and requires chemical decomposition processes involving oxygen. As a result, COD levels may increase with the accumulation of organic matter, indicating a greater oxygen demand for the oxidation of all organic substances present in the water (Prariska et al., 2017; Fahruddin, 2020).

TDS values

Based on TDS observations (Figure 7), treatment P1, which involved only water spinach, showed a significant reduction in TDS from 794 mg/L on day 7 to 477 mg/L on day 21. In treatment P2 using duckweed, TDS levels increased sharply to 942 mg/L on day 7, followed by a gradual decrease to 651 mg/L. In treatment P3, which combined both aquatic plants, the highest TDS value was recorded on day 7 at 968 mg/L and remained relatively high at 701 mg/L on day 21. In the control treatment (K), TDS levels remained constant throughout the observation period at 731 mg/L.

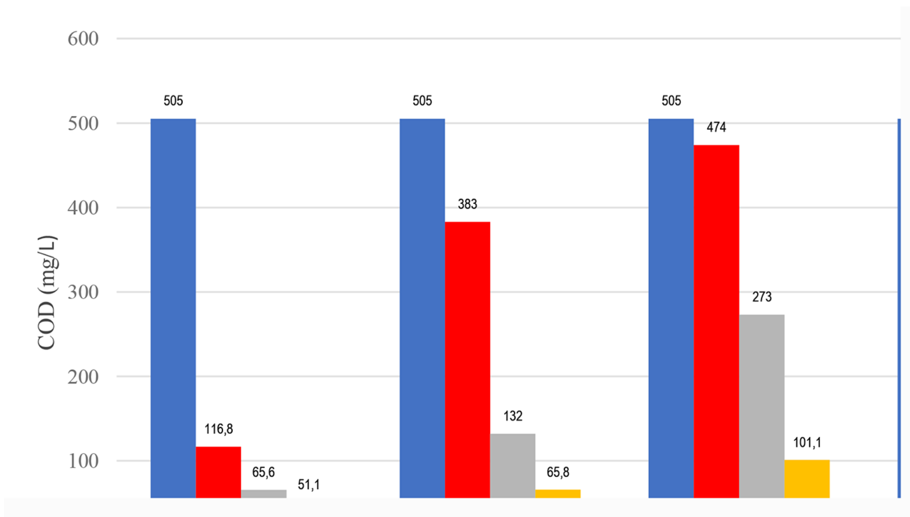

Figure 6. COD values under phytoremediation treatments in common carp pond water, with treatments including: P1 – addition of water spinach; P2 – addition of duckweed; P3 – combination of water spinach and duckweed; K – no plant addition (control)

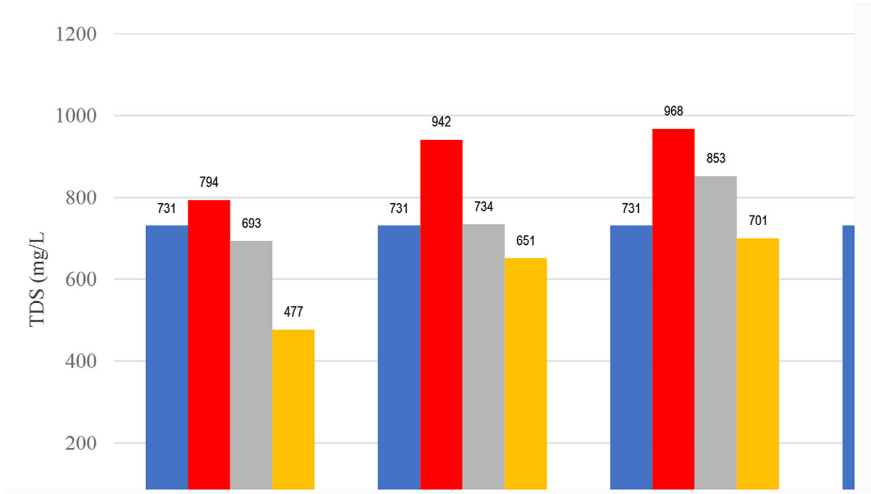

Figure 7. TDS values under phytoremediation treatments in common carp pond water, with treatments including: P1 – addition of water spinach; P2 – addition of duckweed; P3 – combination of water spinach and duckweed; K – no plant addition (control)

These results indicate that treatment P1 had a distinct impact on TDS levels over the 21-day observation period. The reduction suggests that water spinach possesses effective phytoremediation capabilities in absorbing or reducing dissolved substances in water (Nur et al., 2022). Treatments P2 and P3 exhibited different patterns. Although both showed a substantial increase in TDS on day 7, the subsequent reductions were not as efficient as in P1. This may indicate that the plant type or combination used in treatments P2 and P3 was less optimal in absorbing dissolved compounds. The decomposition of organic matter from these aquatic plants may have contributed to an increased TDS load in the water (Hisama et al., 2022; Basri et al., 2024).

According to Umar et al. (2023), the reduction in TDS observed in P1 is attributed to pollutant absorption through rhizofiltration mechanisms in the plant's root system. In contrast, the less optimal reduction in P2 may be due to plant adaptation processes and the release of root exudates (Widiyanti et al., 2020; Shabrina et al., 2025). For the combined treatment, the minimal reduction is likely due to plant overcrowding, which may hinder nutrient uptake and slow growth (Paolacci et al., 2021; Aziz et al., 2022).

pH values

Observations of pH changes across treatments (Figure 8) revealed that in treatment P1, which involved only water spinach, the pH gradually decreased from 8.0 to 7.30 by day 21. In treatment P2 using duckweed, the pH dropped sharply to 6.57 on day 7, then increased to 7.50 by day 21. Similarly, in treatment P3, the pH decreased to 6.74 but rose more significantly to 7.70 by day 21.

These observations suggest that water spinach influences the chemical balance of pond water through biological processes and the absorption of substances that affect acidity. Duckweed also contributes to pH reduction through its biological activity (Hisama et al., 2022). However, the measured pH values across treatments generally ranged between 6 and 7, which is still considered neutral. This pH range is suitable for the growth and development of aquatic organisms, as it does not disrupt their metabolic processes (Rahmadi et al., 2025; Saleh et al., 2025).

In the combined treatment (P3), the increase in pH may be attributed to the interaction of both plant root systems, which likely reduced the concentration of dissolved carbon dioxide (CO_2) in the water, thereby increasing pH levels (Israeli-Weinstein and Kimmel, 1998). Additionally, the decomposition of organic matter from aquatic plants can release hydroxyl (OH) and carboxyl (COOH) functional groups. The accumulation of these groups can bind free hydrogen ions (H^+) in the water, ultimately raising the pH toward optimal conditions for aquatic life (Abdella et al., 2024).

According to Hasyim et al. (2025), pH changes are influenced by nutrient uptake from the plants. Therefore, plant-based phytoremediation systems do not pose critical risks to pH levels and remain safe for application in freshwater aquaculture contexts.

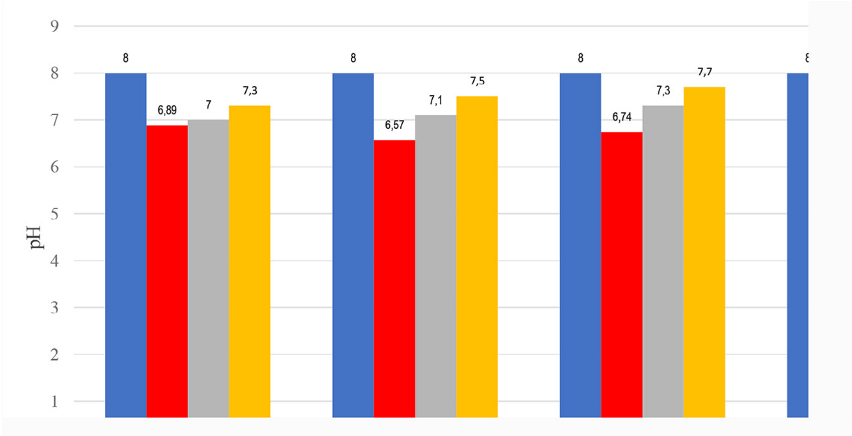

Figure 8. pH value under phytoremediation treatments in common carp pond water, with treatments including: P1 – addition of water spinach; P2 – addition of duckweed ; P3 – combination of water spinach and duckweed; K – no plant addition (control)

CONCLUSION

This study demonstrates that water spinach *(Ipomoea aquatica*) is highly effective in reducing ammonia levels and improving water quality in common carp (*Cyprinus carpio*) aquaculture through phytoremediation. Among the four treatments tested, the use of water spinach (P1) showed the most significant reductions in ammonia, BOD, COD, and TDS. The combination treatment (P3) also showed good performance, though not as effective as P1. In contrast, the duckweed-only treatment (P2) exhibited high fluctuations in ammonia levels, and the control group (K) showed no notable changes. These findings highlight the strong potential of water spinach as an eco-friendly and sustainable phytoremediation agent to enhance water quality and environmental health in freshwater aquaculture systems.

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REFERENCES

1. Abdella, B., Shokrak, N.M., & Abozahra, N.A. (2024). Aquaculture and *Aeromonas hydrophila*, a complex interplay of environmental factors and virulence. *Aquaculture International,* 32, 7671–7681. https,//doi.org/10.1007/s10499-024-01535-y
2. Abdullahi, A. B., Siregar, A. R., Pakiding, W. & Mahyuddin. 2021. The analysis of BOD (biological oxygen demand) and COD (chemical oxygen demand) contents in the water of around laying chicken farm. *IOP Conference Series: Earth and Environmental Science, 788* (1),1–6. https://doi.org/10.1088/1755 1315/788/1/012155
3. Abdul, A., Marlia, M. H., Nasrun, H. H., & Putri, A. S. F. (2020). Phytoremediation of TSS, NH3-N and COD from sewage wastewater by *Lemna minor* L., *Salvinia minima*, *Ipomea aquatica* and *Centella asiatica*. *Applied science*, 10, 5397. https://doi.org/10.3390/app10165397
4. Afiah, N., Fahruddin, F., Samawi, M. F. (2025). Utilizing activated sludge substrates the conduit tofu and slaughterhouse industries to treatment greywater. Ecological Engineering & Environmental Technology, *26*(7), 392-402. https://doi.org/10.12912/27197050/205572
5. Ahmadi, A. W. & Sukru, D. (2024). Assessing the efficiency and role of duckweed (*Lemna Minor*) in the removal of pollutants from wastewater treatment plant secondary clarifier tanks: a comprehensive review. *Central Asian Journal of Water Research*, *10*(1), 115-125. https://doi.org/10.29258/CAJWR/2024-R1.v10-1/115-125.eng
6. Ahmad, H. A. & Ridhayani, A. (2019). The Effectiveness of Phytoremediation Method Using Water Hyacinth and Water Spinach in Reducing BOD and TSS Levels in Tofu Industrial Wastewater. *Pharmaceutical Journal*, *8*(2, 31–38. http://dx.doi.org/10.32583/farmasetis.v8i2.599
7. Ali, A., Naeem, M., Singh, S., & Alzuaibr, F. M. (2020). Phytoremediation of contaminated waters : An eco-friendly technology based on aquatic macrophytes application. *The Egyptian Journal of Aquatic Research*, *46*(4), 371–376. https://doi.org/10.1016/j.ejar.2020.03.002

8. Alkimin, G. D. De., Cintia, P., Elizabeth, A., and Bruno, N. (2019). Phytoremediation processes of domestic and textile effluents : evaluation of the efficacy and toxicological effects in *Lemna minor* and *Daphnia magna*. *Environmental Science and Pollution Research*. *27*(4), 4423–4441.
9. Aziz, A., Mohd, H. M., Halim, N. H., & Fidri, P. A. S. 2020. Phytoremediation of TSS, NH_3-N and COD from Sewage Wastewater by *Lemna minor* L., *Salvinia minima*, *Ipomea aquatica* and *Centella asiatica*. *Applied Sciences*, *10*(16), 5397. https://doi.org/10.3390/app10165397
10. Basri, S.A.A., Muhammad, F.S., & Fahruddin. (2024). Bioconcentration and translocation of heavy metals in mangrove *avicennia sp*. and *rhizophora sp*. in diesel powel plant. *Ecological Engineering & Environmental Technology*, *25*(9), 223–230 https://doi.org/10.12912/27197050/190754
11. Dharmawantho, L. & Supriyanto. (2021). Applied Study on the cultivation of fast-growing superior hybrid common carp in flowing water ponds, Kasomalang, Subang. *Buletin Teknik Litkayasa Akuakultur*, *19*(1), 25–27 https://doi.org/10.15578/btla.19.1.2021.25-27
12. Elya, P. P., Diana, A., & Fisma, J. A. (2023). Review: Physiological Response of Fish to Its Environment. *Aquatic Journal*, 6(2), 71–83. https://doi.org/10.35508/aquatik.v6i2.12921
13. Enduta, A., Jusoh, A., Ali, N., & Wan, W. B. N. (2011). Nutrient Removal from Aquaculture Wastewater by Vegetable Production in Aquaponics Recirculation System. *Desalination and Water Treatment*, *32*(1-3), 422–430. https://doi.org/10.5004/dwt.2011.2761
14. Fahruddin, F., Mustika, T., Muhammad, F.S., As'adi, A., Ghea, F.T.P., & Elisurya, I.(2025). Potential of biofilm bacteria for ammonia degradation in shrimp pond. *Egyptian Journal of Aquatic Biology and Fisheries*, *29*(1), 413–429. https://doi.org/10.21608/ejabf.2025.405683
15. Fahruddin, F. & Tanjung, R. E. (2019). The study of bacteria population in phyremediation of bacteria populations in phytoremediation of cadmium using *Eichhornia crassipes*. *Journal of Physics*: Conference series, *1341*(2). https://doi.org/10.1088/1742-6596/1341/2/022019
16. Fahruddin, F., Abdullah, A., Nurhaedar, N., & La Nafie, N. (2020). Estuary sediment treatment for reducing sulfate in acid mine water. *Environment and Natural Resources Journal*, *18*(2), 191-199. https://doi.org/10.32526/ennrj.18.2.2020.18
17. Fahruddin, F., Samawi, M. F., Tuwo, M., & Tanjung, R. E. (2021). The effect of lead (pb) on the growth of ammonia-degrading bacteria and physical changes of *Eichhornia crassipes* in groundwater phytoremediation. *International Journal of Advanced Information Science, Engineering, and Technology*, *11*(3), 994–1000. https://doi.org/10.18517/ijaseit.11.3.12588
18. Gajah, N., Lubis, E. S., Arifana, A., Roito, E. L., Harahap, H., & Simamora, M. (2025). The Impact of the Existence of a goldfish cultivation village on the socio-economic life of the Sibulele Muara Village Community, Batang Angkola District. *Larisma Community Service Journal*, *9*(1), 506. https://doi.org/10.31604/jim.v9i1.2025.506-515
19. Handayani, K. S., Irawan, B., & Soegianto, A. (2020). Short-term mercury exposure in tilapia (*Oreochromis niloticus*) at different salinities: its impact on serum osmoregulation, hematological parameters, and Na+/K+-ATPase levels. *Heliyon*, *6* (7), e04404. https://doi.org/10.1016/j.heliyon.2020.e04404
20. Hasyim, A., Fahruddin, Rahmadi, T., Khusnul, Y., Eymal D. M., & Magdalena. L. (2025). Assessment of eutrophication parameters in Lake Balang Tonjong Makassar. *Egyptian Journal of Aquatic Biology & Fisheries*, *29*(1), 2065 – 2079.
21. Hebrianti, H., Fahruddin, F., and Dwyana, Z. 2025. Combination of *Moringa oleifera* seeds and Acanthus ilicifolius leaves as a natural coagulant for groundwater treatment. *Journal of Ecological Engineering*, 26, 365–380.
22. Hisama, N.I.B., Mohd, Z.Z., Azman, A., Mohd, F.A.B., & Mohd, S.S. 2022. Phytoremediation Process of Water Spinach (*Ipomoea aquatica*) in Absorbing Heavy Metal Concentration in Wastewater. *Journal of Agrobiotechnology*, *13*(1S),131–144. https://doi.org/10.37231/jab.2022.13.1S.322
23. Hossam, A. (2006). Acute toxicity of ammonia to common carp fingerlings (*Cyprinus carpio*) at different pH Levels. *Pakistan Journal of Biological Sciences*, *9*(12), 2215-2221. https://doi.org/10.3923/pjbs.2006.2215.2221.
24. Jahanbani, A. & Orcid, M. M. (2023). Adaptive mechanisms of fish under ammonia poisoning. *Russian Journal of Marine Biology*, *49*(3), 152–163. https://doi.org/10.1134/S1063074023030070
25. Joshua, O., Adogbeji, P., Bussa, N., Campus, A., & Bussa, N. (2017). Factors Affecting feed intake in farmed fish species: A. review. *Animal Research International*, *14*(2), 2697–2709.
26. Israeli-Weinstein, D. & Eitan, K. (1998). Behavioral response of carp (*Cyprinus carpio*) to ammonia stress. *Aquaculture, 165* (1-2), 81–93. https://doi.org/10.1016/S0044-8486(98)00251-8
27. Krishnaswamy, U. R. & Gustavo H. R. D. S. (2025). Floating treatment wetland with microbial fuel cell for removing pollutants, energy utilization, recovery of nutrients – review on sustainable technology. *Desalination and Water Treatment*, 323, 101264. https://doi.org/10.1016/j.dwt.2025.101264

28. Liu, C., Zheng, D., & Hongwen, S. (2017). Potential of duckweed (*Lemna minor*) for removal of nitrogen and phosphorus from water under salt stress. *Journal of Environmental Management,* 187, 497–503. https://doi.org/10.1016/j.jenvman.2016.11.006
29. Manisha, M. & B. Chaitanya, R. (2019). Ascertaining the removal efficiency of *Lemna minor* in froth diminution by using phytoremediation. *International Research Journal of Engineering and Technology*, *6*(6), 2316–2321.
30. Munthe, N. A., Anang, N., & Rosana, E. (2021). The effectiveness of water spinach (*Ipomoea aquatica forsk*) in reducing laundry waste. *Journal of Tropical Fisheries*, *16*(1), 1–8.
31. Mishra, R. K. (2023). The Impact of eutrophication on drinking water. *British Journal of Multidisciplinary and Advanced Studies*, *4*(1), 7–20.
32. Munguti, J. M., Kirimi, J. G., Obiero, K. O., Ogello, E. O., Kyule, D. N., Liti, D. M., & Musalia, L. M. (2021). Aquatic feed waste: impacts on natural systems and practical mitigation – A Review. *Journal of Agricultural Sciences*, *13*(1), 111. https://doi.org/10.5539/jas.v13n1p111
33. Nur, M., Nasir, M., Irfandi, R., Yani, A., Fauziah, S., Danur, R.F., Raya, I., & Fudholi, A. (2022). Phytoremediation of zinc, copper, and lead using *Ipomoea aquatica* in water contaminants. *International Journal of Design & Nature and Ecodynamics*, *17*(5),701–709. https://doi.org/10.18280/ijdne.170507
34. Obinna, I. B. and Ebere, E. C. (2019). Phytoremediation of polluted waters with aquatic plants: recent developments in heavy metal and organic pollutants. *Journal of Analytical Methods in Environmental Chemistry*, *2*(3), 5–38. https://doi.org/10.24200/amecj.v2.i03.66
35. Othman, Z., Zubairi, T., Saiful S. and Aziz, R. (2016). Environmental friendly biopesticide Rotenone extracted from Derris sp.: a review on the extraction method,toxicity and field effectiveness. Jurnal Teknologi, *78*(8), 47–69. DOI: https://doi.org/10.11113/jt.v78.5942
36. Owaes, M., Gani, K. M., Kumari, S., Seyam, M., & Bux, F. (2024). Implementation of partial nitrification in wastewater treatment systems through operational strategy modifications – a review. *Environmental Technology Reviews*, *13*(1), 379–397. https://doi.org/10.1080/21622515.2024.2354518
37. Paolacci, S., Vlastimil, S., & Marcel, A. K. J. (2021). Estimation of the potential of *lemna minor* for effluent remediation in integrated multi-trophic aquaculture using newly developed synthetic aquaculture wastewater. *Aquaculture International*, 29: 2101–2118. https://doi.org/10.1007/s10499-021-00736-z
38. Prariska, D., Tanbiyaskur & Azhar, M. H. 2017. Toxicity test of tuba root extract (Derris Elleptica) on red tilapia (Oreochromis sp). Jurnal Ilmu-Ilmu Perikanan dan Budidaya Perairan, *12*(1), 41–48. https://doi.org/10.31851/jipbp.v12i1.1413
39. Prayogo, P. (2019). The Comparison of water spinach (*Ipomoea aquatica*) density using aquaponic system through reduced concentration of ammonia (NH3), nitrite (NO_2), nitrate (NO_3) and its influence on conversion rate and feed efficiency to increase the survival rate and growth rate of African Catfish (*Clarias* sp.) intensive. *Journal of Aquaculture and Fish Health*, *8*(2),113. https://doi.org/10.20473/jafh.v8i2.13626
40. Rahmadi, A.I., Indah, R., Muhammad, F.S., Fahruddin, & Mahatma, L. (2025). Analysis of eutrophication levels in the coastal waters of Parepare City. *Egyptian Journal of Aquatic Biology & Fisheries, 29*(3), 1061 – 1075.
41. Sa'at, S. K. M. (2017). Suitability of *Ipomoea Aquatica* for the treatment of effluent from palm oil mill. *Journal of Built Environment, Technology and Engineering*, 2: 39–44.
42. Sadono, D.T., Darwis, A.N., & Zulkarnain, U. (2011). Economic analysis of common carp (*Cyprinus carpio*) cage culture in the Koto Panjang Hydroelectric Reservoir. *Dinamika Lingkungan Indonesia*, *8*(1), 29-41. https://doi.org/10.31258/dli.8.1.p.29–41
43. Sahi, W. & Smain, M. (2023). Evaluation of *Lemna minor* phytoremediation performance for the treatment of dairy wastewater. *Water Practice and Technology, 18*(5), 1138–1147. https://doi.org/10.2166/wpt.2023.074
44. Saleh, M. A., Ryan, M. P., Trusler, J. P. M., & Krevor, S. (2025). The interface process that controls the mineralization of carbon dioxide in magnesium and calcium silicates. *Fuel*, 380, 132969. https://doi.org/10.1016/j.fuel.2024.132969
45. Sarkheil, M., Zahedi, S., Safari, O., & Ahmadniaye, H. (2023). The effect of humic acid on nutrient absorption efficiency in aquatic duckweed (*Lemna minor*) and growth performance and hemato-biochemical parameters of tilapia (*Oreochromis niloticus*) cultivated in a recirculating water system. *International Journal of Phytoremediation*, *26*(9), 1–12. https://doi.org/10.1080/15226514.2023.2250459
46. Shabrina, M.H., Fahruddin, F., & Muhammad, F.S. 2025. Bioaccumulation and translocation of heavy metals mercury and lead in mangroves *Rhizophora apiculata* and *Sonneratia sp*. in the estuarine waters of Malili River. *Ecological Engineering & Environmental Technology*. *26*(4), 88–96. https://doi.org/10.12912/27197050/200653
47. Srilestari, E. & Anita, M. (2021). Effectiveness of subsurface flow-wetlands to reducing tss levels and stabilizing ph in tofu liquid waste. *Journal*

of Tropical Biology, *21*(1), 15-21. http://dx.doi.org/10.29303/jbt.v21i1.2360

48. Suherman, Rahmawati, S., Said, I., Nurbaya, Armiyanti, S., & Thamrin, N. (2021). The Use of water spinach plants (*Ipomoea aquatica forsk.*) for phytoremediation of hospital waste. *Journal of Physics: Conference Series*, 2126. doi:10.1088/1742-6596/2126/1/012026
49. Tanjung, R. E., Fahruddin, F., & Samawi, M. F. (2019). The relationship of lead (Pb) phytoremediation by *Eichhornia crassipes* to pH, BOD, and COD in groundwater. J*ournal of Physics*: Conference Series, *1341*(2), 1–6. https://doi.org/10.1088/1742-6596/1341/2/022020
50. Tangahu, B. V. & Putri, A. P. (2017). The degradation of BOD and COD of batik industry wastewater using *Egeria densa* and *Salvinia molesta*. *Jurnal Sains &Teknologi Lingkungan*, 9(2), 82–91. https://doi.org/10.20885/jstl.vol9.iss2.art2
51. Umar, Y. P., Fajri, A., & Usman, T. (2023). Comparison of water spinach (*Ipomoea aquatica forck*) and microorganisms in efforts to reduce hexavalent chromium (Cr(VI)) in river water. *Journal of Natural Resources and Environment*, *10*(1), 41–49. https://doi.org/10.21776/ub.jsal.2023.010.01.5
52. Usman, U., Fahruddin, F., Taba, P., & Suarthawan, I. G. (2025). The Effect of tuba root extract (*Derris elliptica*) on BOD, COD, pH, and microbial population in brackish pond water. *Egyptian Journal of Aquatic Biology and Fisheries*, *29*(1), 2537–2551. https://doi.org/10.21608/ejabf.2025.414086
53. Wang, S., Li, X., Zhang, M., Jiang, H., Wang, R., & Qian, Y. (2021). Ecotoxicology and Environmental Safety. Ammonia stress disrupts the gut microbial community and amino acid metabolism of juvenile yellowtail catfish (*Pelteobagrus fulvidraco*). *Ecotoxicology and Environmental Safety*, *227,* 112932. https://doi.org/10.1016/j.ecoenv.2021.112932
54. Widiyanti, A., Lily, O., & Ari, S. (2020). Phytotechnology for liquid waste processing at the Sidoarjo regency fish marketing Depot (DPI) using water hyacinth (*Eichhornia crassipes*) and water spinach (*Ipomoea aquatic*). *Journal of Research and Technology*, *6*, 227–236.
55. Zulfahmi, I., Ravika, N. K., Feizia, H., Lina, R., Muliari, M., Kizar, A. S., & Mohammad, M. R. (2024). Phytoremediation of palm oil mill effluent (POME) using water spinach (*Ipomoea aquatica forck*). *Environmental Technology & Innovation*, *21*, 101260. https://doi.org/10.1016/j.eti.2020.101260