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The Effectiveness of Phytoremediation in Fish Pond Wastewater Using Various Plant Species to Improve Water Quality

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ABSTRACT

The increase in fish farming activities has led to the accumulation of organic waste from feces and uneaten feed, which contain high levels of ammonia and phosphate. If left unmanaged, this waste can trigger eutrophication and threaten the survival of fish due to declining water quality. Phytoremediation has emerged as an environmentally friendly technology that utilizes aquatic plants to neutralize these pollutants. This study aims to analyze the effectiveness of various phytoremediation plants in improving the quality of fish pond effluent, evaluate the pollution index (PI) of the water, and test the suitability of the treated water for the survival rate of goldfish. This study was conducted at the Sugih Makmur Fish Farming Group (Pokdakan) in Banjarbaru, using a Completely Randomized Design (CRD) experimental method with five treatments and three replicates. The treatments tested included Control (without plants), Mosquito fern (A), Water lettuce (B), Water Hyacinth (C), and Salvinia (D), each with a plant mass of 100 grams in 10 liters of water from a catfish pond. The water quality parameters measured were pH, PO4, BOD, DO, and ammonia. The results of the study show that salvinia (D) and Water Hyacinth (C) are the most effective in improving water quality. Water hyacinth was able to drastically increase dissolved oxygen (DO) levels from 0.6 mg/L to 5.87 mg/L and reduce ammonia from 2.18 mg/L to 0.03 mg/L. Based on the Pollution Index (PI), treatments C (0.90) and D (0.91) successfully changed the water status from "Slightly Polluted" to "Meets Quality Standards." This positively correlated with the survival rate of goldfish, which reached a maximum of 93% in both treatments, compared to only 40% in the control group. In conclusion, the use of water hyacinth and salvinia is highly recommended as an efficient and environmentally friendly wastewater management system for aquaculture.

Keywords: Phytoremediation, Water Quality, Pollution Index (PI), Survival Rate (SR)

INTRODUCTION

Phytoremediation is defined as the use of plants to remove, transport, stabilize, or break down pollutants, whether organic or inorganic compounds. This technology is an environmentally friendly and more cost-effective method of waste decontamination compared to other remediation systems. Plants used in this process generally possess specific characteristics, such as rapid growth, the ability to consume large amounts of water in a short time, and high tolerance to pollutants. The increase in fish farming activities in Indonesia has led to a rise in aquaculture waste production. This aquaculture waste is complex, containing nutrients such as ammonium and phosphate derived from uneaten feed and fish feces. If this organic waste is not promptly removed, ammonia levels in the water will rise drastically, threatening the survival of farmed organisms. Furthermore, discharging waste directly into natural water bodies without prior treatment can damage ecosystems and trigger eutrophication.

Ammonia is one of the primary pollutants in aquaculture systems, where approximately 80–90% of nitrogen is excreted by fish through osmoregulation, with the remainder excreted via feces and urine. The negative impacts of this waste accumulation include reduced growth rates, increased susceptibility to disease due to environmental stress, and even mass fish mortality. Therefore, an effective waste management system is needed to improve the quality of effluent so that it can be reused or safely discharged into water bodies. Previous studies have shown that aquatic plants such as water lettuce, water hyacinth, and salvinia are effective in improving water quality by influencing pH levels, nitrite levels, and Total Suspended Solids (TSS). However, a comparative assessment of the effectiveness of various types of macrophytes such as mosquito fern, water lettuce, water hyacinth, and salvinia in reducing the specific pollutant load in catfish aquaculture ponds still requires further study. Each plant has different growth requirements and metabolic mechanisms for absorbing pollutants.

This study aims to analyze the effectiveness of various phytoremediation plants in improving the quality of fish pond effluent and to evaluate water quality based on the Pollution Index (PI). Additionally, this study also assesses the suitability of the treated water as a medium by observing the survival rate of goldfish (*Carassius auratus*). The results of this study are expected to serve as both an academic reference and a practical guide for fish farmers in implementing an efficient, economical, and sustainable water management system.

MATERIALS AND METHODS

Materials Methods

The equipment used in this study included 15 basins used as experimental units, as well as water quality instruments such as a pH meter (to measure acidity and alkalinity), a spectrophotometer (to measure PO4 and NH3), a BOD meter (to measure the oxygen demand of microorganisms), and a DO meter (to measure dissolved oxygen levels). The main materials used in this study included 150 liters of water from a catfish pond taken from the pond's outlet, phytoremediation plants 300 grams each of mosquito fern, water lettuce, water hyacinth, and salvinia and 75 goldfish (*Carassius auratus*) used to test water suitability after the phytoremediation process.

Methods

This study employed an experimental method using a completely randomized design (CRD) consisting of 5 treatments and 3 replicates

Research Methodology:

K: Control (pond water without plants).

A: Mosquito fern (100g).

B: Water lettuce (100g).

C: Water Hyacinth (100g).

D: Salvinia (100g).

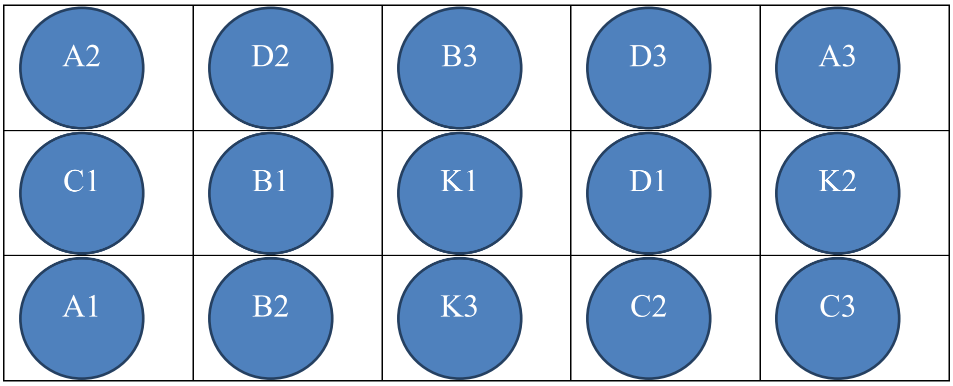

Figure 1 Experimental Setup

This study began with the preparation of containers filled with 10 liters of water from a catfish pond. The phytoremediation phase involved placing plants into the containers at a density of 100 grams per container and allowing them to remain there for 3 weeks (21 days). Water quality parameters such as pH, PO4, BOD, DO, and ammonia were measured before and after the phytoremediation process in the laboratory and in the field. Finally, a survival rate test was conducted after the phytoremediation process by placing 5 goldfish in each basin and rearing them for 10 days to calculate the percentage of surviving fish.

Statistical Methods

This study measured water quality based on pH, PO4, BOD, DO, and ammonia levels using the Pollution Index (PI) method in accordance with Ministry of Environment Regulation No. 115 of 2003: [2]

$$PIj = m\sqrt{(Ci/Lij)_M^2 + (Ci/Lij)_R^2}$$

Information:
PIj = Pollution index for allocation j
Ci = concentration of water quality parameters i
Lij = the concentration of water quality parameters i listed in the water allocation standard
M = maximum
R = average
(Ci /Lij) R = average index
(Ci /Lij) M = maximum index
Where m = the balancing factor The critical state is used to calculate the value of m PIj = 1.0 if the maximum value of Ci/Lij = 1.0 and the mean value of Ci/Lij = 1.0 then

$$1.0 = m\sqrt{(1)^2 + (1)^2}$$

$$M = 1 / \sqrt{2}$$

$$PIj = \sqrt{\frac{(Ci/Lij)_M^2 + (Ci/Lij)_R^2}{2}}$$

$0 \leq PIj \leq 1.0$: Good Condition (Meets quality standards)
$1.0 < Pij \leq 5.0$: Slightly Contaminated
$5.0 < Pij \leq 10$: Moderately Contaminated
$Pij > 10$: Severely Contaminated

Based on Government Regulation No. 22 of 2021, the water quality of rivers exposed to waste is categorized into four classes of use: [5]
Class I: Raw water for drinking.
Class II: Recreational facilities, fish farming, and livestock farming.
Class III: Fish farming and crop irrigation.
Class IV: For landscaping/irrigation only
Survival rate analysis is used to analyze the effect of water quality on goldfish using the following formula:

$$\mathbf{SR = \frac{Nt}{No} X\ 100\%}$$

Notes:
SR = Survival rate (%)
No = Number of live fish at the start of the rearing period (individuals)
Nt = Number of live fish at the end of the rearing period (individuals)
The data were analyzed using a completely randomized design (CRD) with preliminary tests for normality (Lilliefors) and homogeneity (Bartlett). An ANOVA was

conducted to determine the significant effects of the treatments. Post-hoc tests were determined based on the Coefficient of Variation (CV) values:
High CV: Duncan's test.
Moderate CV: Least Significant Difference (LSD) test.
Low CV: Honest Significant Difference (HSD) test.

RESULTS AND DISCUSSION

Water Quality

The results obtained in this study include water quality data for the parameters pH, PO_4, BOD, DO, and NH_3, which were used to assess the effectiveness of phytoremediation plants on the water quality of fish pond effluent, the effectiveness of phytoremediation plants on the water pollution index of fish ponds, and the suitability of the phytoremediated water as a medium for fish survival. These data are presented in Table 1 below.

Table 1. Water Quality Data

Treatment	pH (0-14) ± SD	PO_4 (mg/L) ± SD	BOD (mg/L) ± SD	DO (mg/L) ± SD	NH_3 (mg/L) ± SD
Initial	6.82	1.06	6.2	0.6	2.18
K	5.93 ± 0.37^c	1.34 ± 0.41^a	6.10 ± 0.17^a	0.41 ± 0.28^b	2.07 ± 0.07^a
A	7.28 ± 0.07^b	0.54 ± 0.02^b	2.93 ± 0.32^b	2.87 ± 0.76^b	1.12 ± 0.07^b
B	7.31 ± 0.17^b	0.36 ± 0.22^b	1.84 ± 0.08^c	5.10 ± 0.45^a	0.56 ± 0.04^c
C	7.14 ± 0.10^b	0.22 ± 0.06^b	0.99 ± 0.10^d	5.87 ± 0.55^a	0.05 ± 0.03^d
D	7.84 ± 0.13^a	0.22 ± 0.05^b	0.94 ± 0.01^d	5.87 ± 0.15^a	0.03 ± 0.01^d

The results of the study show that all treatments had a significant effect on improving water quality compared to the initial conditions and the control group, with Treatment D emerging as the most effective method. The initial conditions, characterized by high ammonia levels of 2.18 mg/L and very low dissolved oxygen (DO) levels of 0.6 mg/L, were gradually improved through Treatments A through D, reaching its peak in treatment D with a DO value of 5.87 ± 0.15a mg/L and ammonia reduction to nearly zero at 0.03 ± 0.01d mg/L.

Pollution index and survival rate

Table 2. Pollution index and survival rate

Treatment	PI (Pollution Index)	SR (*survival rate*) %
K	Slightly polluted	40
A	Slightly polluted	73
B	Slightly polluted	86
C	Meets quality standards	93
D	Meets quality standards	93

The pollution index and survival rate of goldfish show a very strong positive correlation between improvements in water quality and the survival rate of the test organisms. In the control treatment (K), the survival rate was at its lowest at 40% with a pollution index status falling into the slightly polluted category, which then gradually increased in treatments A and B to 73% and 86%, respectively, although they remained in the same quality status category. Optimal results were observed in treatments C and D, where water quality improved to the point of meeting quality standards, which directly led to a significant increase in the survival rate, reaching a maximum of 93%.

DISCUSSION

Water Quality

pH (Potential of Hydrogen) indicates that treatment K had the lowest pH of 5.92, while treatment D had the highest pH of 7.84. pH values are influenced by several parameters, including biological activity, temperature, oxygen content, and ions. Biological activity produces CO_2 gas, which is a byproduct of respiration. The more CO_2 produced by respiration, the more the reaction proceeds and releases H^+ ions, causing the water's pH to decrease. Conversely, photosynthetic activity, which requires large amounts of CO_2, causes the water's pH to rise (Warman, 2015). [9]

PO_4 (phosphate) levels were lowest in treatments C and D at 0.22, while treatment K had the highest value at 1.34. Phosphorus is an essential macronutrient for plants, which is absorbed in the form of phosphate ions. In both soil and water, these ions are generally absorbed as orthophosphate ions, specifically $H_2PO_4^-$ and HPO_4^{2-}. However, an excessive amount of orthophosphate ions in water bodies can lead to negative impacts, one of which is triggering uncontrolled algal growth (*algae blooming*) (Suryawan, 2018). [8] The high phosphate content at the start of the study 1.06 was caused by uneaten feed, whether commercial feed or offal. The increase in phosphate is related to the pH value; during the phytoremediation process, the pH ranged from 5.5 to 7.99.

BOD (Biological Oxygen Demand) shows that treatment D had the lowest value at 0.94, while treatment K had an average BOD of 6.16. According to Aditya Rahman KN (2020), Factors affecting BOD include the content and types of organic matter, temperature, plankton density, dissolved oxygen, pH value, and the presence of microbes. High BOD levels will result in the depletion of dissolved oxygen through the decomposition process of organic matter under aerobic conditions, as well as a decrease in the pH value within a water body. In the previous data on pH, it was found that treatment K had a low pH, while treatments A, B, C, and D had higher pH levels, which consequently influenced BOD levels. [3]

DO (Dissolved Oxygen) shows that treatments C and D had the highest values at 5.87, while treatment K had the lowest value at 0.09. This aligns with Zidni (2013) statement that dissolved oxygen concentrations in water within cultivation media combined with plants are relatively higher than in cultivation media without plants, due to the photosynthetic activity of plants during the day, which produces O_2. From the above statement, it is evident that DO levels increase when plant photosynthesis occurs. [10]

NH3 (ammonia) levels were highest in treatment K at 2.07, while treatment D had the lowest level at 0.03. A decrease in ammonia levels can influence the metabolic activity of anaerobic and aerobic bacteria. Additionally, aquatic plants play a role in remediating ammonia levels, particularly through their roots. The roots of aquatic plants serve as a site for the attachment of bacteria that can break down ammonia into nitrate or nitrite. Aquatic plants also act as a source of oxygen that bacteria use to remediate ammonia levels (Putri, 2022). [7]

PI (Pollution Index)

The Pollution Index (PI) indicates that treatments K, A, and B had a PI indicating slight pollution, with PI values greater than 1, whereas treatments C and D met quality standards and had PI values less than 1. Treatment K falls into the slightly polluted category because no phytoremediation plants were present to help improve water quality, whereas the other treatments utilized plants, allowing the initially slightly polluted water quality to be improved to good. One alternative technology used for treating liquid waste is phytoremediation. Phytoremediation is the use of plants for waste decontamination (Putra, 2014). [6] Phytoremediation utilizes aquatic plants to remove, extract, and detoxify pollutants from the environment. [1]

Based on Annex VI of Government Regulation of the Republic of Indonesia No. 22 of 2021 concerning the Implementation of Environmental Protection and Management, national water quality standards (for rivers) are divided into four categories based on water use. Category I, Class 1, consists of water intended for use as raw water for drinking water and/or other purposes requiring water quality equivalent to that of drinking water. Class 2 consists of water intended for infrastructure/facilities, water recreation, freshwater fish farming, livestock, irrigation, and/or other uses requiring water quality equivalent to those purposes. Class three consists of water intended for freshwater fish farming, livestock, irrigation for plant growth, and/or other uses requiring water quality equivalent to those purposes. Class four consists of water intended for irrigation and/or other uses requiring water quality equivalent to those purposes.

SR (Survival Rate)

Based on the survival rate data of goldfish under various phytoremediation treatments, it is evident that fish survival rates increased with the introduction of phytoremediation plants. The control treatment (K), which did not use phytoremediation plants, showed the lowest average survival rate 40% indicating water quality conditions that were unsuitable for goldfish. In contrast, treatments with phytoremediation plants showed significantly better results. Treatments C and D yielded the highest average survival rates of 93%, followed by treatment B, which reached 86%. Meanwhile, treatment A had an average of 73%, which was still significantly higher than the control. This indicates that the presence of phytoremediation plants is capable of improving water quality, thereby supporting the survival of goldfish more optimally.

This high survival rate is strongly believed to be related to the plants' ability to absorb pollutants such as ammonia, phosphate, and BOD, as well as to increase dissolved oxygen (DO) levels. The more effective the plants are at improving water quality, the greater the fish's chances of survival. This finding supports the theory that phytoremediation is an effective method for managing water quality in fish farming systems. According to Marbun *et al*. (2013), fish mortality is influenced by several factors, including water quality and the condition of the fish. Fish become weak due to an unsupportive environment, leading to a decline in immunity and increased susceptibility to parasites. **[4]**

CONCLUSION

Water Hyacinth (C), and Salvinia (D) proved to be the most effective in improving water quality compared to the control. The water hyacinth treatment significantly increased dissolved oxygen (DO) (from 0.6 to 5.87 mg/L) and reduced ammonia (from 2.18 to 0.03 mg/L) and BOD (from 6.2 to 0.94 mg/L) to their lowest levels. Treatments C and D successfully changed the water status from "Slightly Polluted" to "Meets Quality Standards" with Pollution Index (PI) values of 0.90 and 0.91, respectively. In contrast, water without plants (control) remained polluted with a PI value of 4.97. The improvement in water quality was positively correlated with the survival rate (SR) of goldfish, with Treatments C and D achieving an average of 93% (up to 100% in some replicates). This figure was significantly higher than the control, which achieved an SR of only 40%.

Declaration by Authors

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