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Environmental carrying capacity of Batujai Reservoir-Praya, Central Lombok in terms of water quality and the role of eichhornia crassipes in nutrient and lead (Pb) removal

Siti Raudhatul Kamali[1*], Immy Suci Rohyani[1], Ernawati[1], Annisa Arimbi Murfi[1], Zulvi Amelia Sari[1], Lalu Malik Fajar[1]

[1] *Department of Environmental Science, Faculty of Mathematics and Natural Sciences, Universitas of Mataram, Mataram, West Nusa Tenggara, 83125, Indonesia*

*Correspondence: sitikamali@unram.ac.id

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ABSTRACT

Background: The Batujai Reservoir faces challenges related to nutrient pollution and heavy metal contamination. Phytoremediation using Eichhornia crassipes has been recognized for its potential to mitigate water quality issues. This study evaluates the environmental carrying capacity of the Batujai Reservoir, focusing on water quality and the role of Eichhornia crassipes in the removal of nutrients and the heavy metal lead (Pb). **Methods**: Water quality analysis was conducted by measuring pH, temperature, dissolved oxygen (DO), and total dissolved solids (TDS). Analysis of concentrations of total phosphorus, total nitrogen, and Pb at both the inlet and outlet of the reservoir. **Findings:** The study found that DO levels remained high and stable at both the inlet and outlet, with a slight reduction at the outlet due to organic matter decomposition. Eichhornia crassipes contributed to maintaining DO levels through photosynthesis. The pH ranged from 7.94 to 8.30, slightly alkaline, supporting Pb stabilization as precipitates. The temperature increased from inlet to outlet but remained within normal limits. Low TDS (154.33–159.67 mg/L) indicated good water quality, while a decrease in conductivity from inlet to outlet suggested the absorption of dissolved ions by Eichhornia crassipes. The plant effectively absorbed nitrogen, phosphate, and Pb, confirming its role as a phytoremediation agent. However, uncontrolled growth could result in mass decomposition and oxygen depletion, which may harm the ecosystem. **Conclusion**: The study concludes that the Batujai Reservoir has stable water quality, supporting its capacity to maintain aquatic life. Nevertheless, careful management of Eichhornia crassipes is required to prevent ecological imbalance caused by overgrowth and decomposition. **Novelty/Originality of this Study:** This study contributes new insights into the dual role of Eichhornia crassipes in maintaining water quality and acting as a phytoremediation agent for nutrient and heavy metal (Pb) removal in the Batujai Reservoir. It highlights the importance of balancing Eichhornia crassipes growth to optimize environmental carrying capacity.

KEYWORDS: carrying capacity; Eichhornia crassipes; lead; nutrients; water quality.

1. Introduction

The Batujai Reservoir, located in Central Lombok Regency, West Nusa Tenggara Province, is a vital infrastructure serving as a water source for irrigation, raw water supply, and flood control. Despite its essential role, the reservoir faces serious challenges related to water quality and environmental pollution, particularly by heavy metals such as lead (Pb).

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Evaluating the environmental carrying capacity of the reservoir's waters is becoming increasingly crucial as human activities in the surrounding areas intensify, potentially worsening the water quality conditions.

Water quality is one of the main factors in determining the environmental carrying capacity of an aquatic ecosystem. Physical and chemical parameters such as temperature, pH, Dissolved Oxygen (DO), Total Dissolved Solids (TDS), and nutrient concentrations like Nitrogen (N) and Phosphorus (P) greatly influence the balance of aquatic ecosystems. Nitrogen and phosphorus are often identified as drivers of eutrophication, which can lead to excessive algal growth, reduced DO levels, and ultimately disrupt aquatic life (Islam et al., 2015). Water pollution from agricultural activities, domestic waste, and industrial runoff around the reservoir has the potential to increase the levels of nutrients and heavy metals in the water, directly impacting water quality and environmental carrying capacity (Ouyang et al., 2010). In agricultural regions like Lombok, runoff from fertilizers containing nitrogen and phosphorus into open waters often poses a significant issue affecting reservoir water quality.

Lead (Pb) is a toxic heavy metal frequently found in aquatic environments due to anthropogenic activities such as industrial waste, agriculture, and domestic waste disposal. Lead has bioaccumulation properties, meaning that it can accumulate in the bodies of aquatic organisms and magnify up the food chain, posing health risks to humans and animals consuming fish from contaminated waters (Briffa et al., 2020; Amić & Tadić, 2021). In aquatic ecosystems, lead pollution can cause various harmful effects, including decreased survival, reproduction, and growth in organisms (Islam et al., 2015; Thakur et al., 2023). Lead concentrations exceeding permissible limits can cause physiological damage to aquatic biota, while its toxic effects on humans include damage to the nervous system, kidneys, and circulatory system (Naggar et al., 2018). Therefore, monitoring and evaluating Pb concentrations in reservoir waters is crucial to minimize the impact of pollution on environmental and public health.

Environmental carrying capacity refers to the ability of an ecosystem to support the life of various organisms without experiencing degradation (Aji & Ghozali, 2019). In the Batujai Reservoir, increasing human activities such as the expansion of agricultural land, settlements, and industry, potentially add pressure to the aquatic ecosystem. Uncontrolled use of pesticides and fertilizers around the reservoir risks elevating nitrogen, phosphorus, and heavy metal levels, all of which affect the environmental carrying capacity of the waters (Naz et al., 2022). To assess the condition of the environmental carrying capacity in the Batujai Reservoir, a comprehensive analysis of water quality parameters and heavy metal pollution, especially lead (Pb), is needed to understand how these factors affect the aquatic ecosystem within it.

2. Methods

The research was conducted at the Batujai Reservoir, located in Central Lombok Regency. Water samples were collected at two main points: the inlet and the outlet. This study employed a quantitative approach by measuring water quality parameters and lead (Pb) concentrations at several sampling points within the Batujai Reservoir. The aim of this method was to assess the reservoir's environmental carrying capacity by evaluating water quality and the extent of heavy metal contamination. Measurements were taken for water quality parameters including DO, pH, temperature, TDS, and conductivity. Simultaneously, measurements of Eichhornia crassipes were conducted, focusing on total nitrogen (N), total phosphorus (P), and Pb concentrations. The collected data were compared to the water quality standards regulated by Indonesia Government Regulation (PP No. 22 of 2021). The locations of the inlet and outlet used for water quality sampling at Batujai Reservoir is shown in Fig. 1.

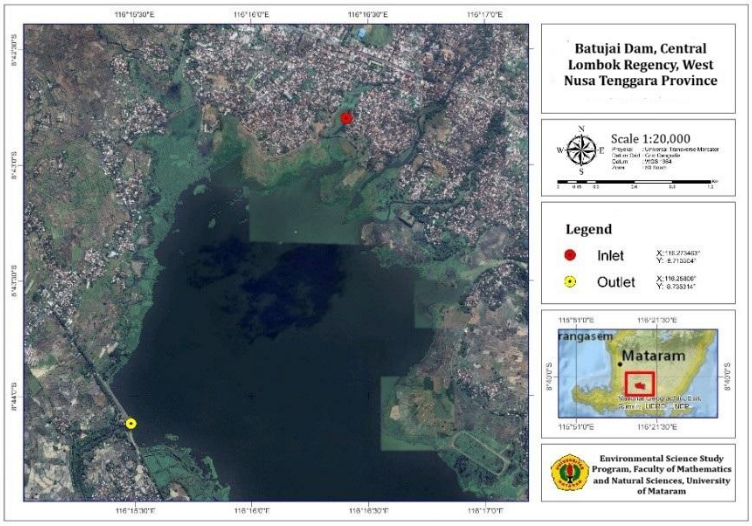

Fig. 1. Water sampling points of Batujai Reservoir, Central Lombok, NTB Province

3. Results and Discussion

3.1 Water quality analysis of Batujai reservoir

The measurements taken at the inlet and outlet of the reservoir without any treatment provide insights into the natural changes in water quality as it flows through the reservoir was shown in Table 1. These variations are likely due to natural processes occurring within the reservoir, such as sedimentation, nutrient uptake by aquatic organisms, or other environmental factors. Table 1 shows the comparison the water quality parameters measured at both the inlet and outlet of the reservoir, providing insight into natural changes in water quality. Some parameters comply with environmental standards.

Table 1. Water Quality Parameters of Batujai Reservoir

Parameter	Unit	Measurement Results		Quality Standard (PP No. 22, Year 2021)
		Inlet	Outlet	
Temperature	^{0}C	28.17 ± 0.15	28.30 ± 0.17	Dev 3
pH		8.30 ± 0.31	7.94 ± 0.03	6-9
DO	mg/L	10.13 ± 0.05	9.17 ± 0.42	3
Conductivity	µS/cm	310 ± 7.21	259 ± 11.00	-
TDS	mg/L	154.33 ± 6.43	159.67 ± 22.28	1000

3.1.1 Temperature

The temperature shows a slight increase from the inlet to the outlet. This minor temperature change may be due to solar heat absorption as water flows through the reservoir, especially if the flow is slower. Sunlight exposure contributes to temperature increases, a common phenomenon in shallow water bodies such as lakes or reservoirs (Wang et al., 2024).

Additionally, the decomposition of organic matter by microorganisms generates heat, which may contribute to the temperature rise. As microbes break down organic materials like decaying aquatic plants, heat is produced as a byproduct, although the temperature increase from this process is usually limited (Datry et al., 2018). Anaerobic decomposition in areas with slow water circulation, such as the reservoir's bottom, can affect local temperatures (Dang et al., 2009). However, the water temperature at both points remains within normal limits and does not significantly impact overall water quality. This minor increase is not enough to disrupt the water body's environmental carrying capacity, but continuous temperature monitoring is essential as a potential indicator of environmental changes or anthropogenic impacts.

3.1.2 pH

The pH at both points is within a slightly alkaline range. In the context of slightly alkaline pH (around 7.94 to 8.30) in the Batujai Reservoir, several factors contribute to the increase in pH, particularly at the outlet. The photosynthesis of aquatic plants like Eichhornia crassipes can raise the pH because this process reduces the amount of carbon dioxide (CO_2) in the water, naturally lowering water acidity (Nahar & Sunny, 2023; Spencer & Bowes, 1986). The reduction of CO_2 results in a more alkaline pH, often observed in water bodies with active plant growth. This is relevant to ecosystems like reservoirs, where hyperaccumulator plants like Eichhornia crassipes are abundant.

Moreover, heavy metals such as lead (Pb) are more likely to precipitate at an alkaline pH. However, pH fluctuations caused by variations in the physical and chemical conditions of the water, such as changes in temperature or water mixing, can alter the state of heavy metals. Precipitated lead can dissolve back into the water if the pH drops, making it more available and potentially increasing toxicity risks for aquatic organisms (Zhao et al., 2024). Thus, although the higher pH at the outlet indicates greater biological activity, particularly from aquatic plants, proper management is required to prevent the resuspension of precipitated heavy metals.

The stable pH condition within the alkaline range supports a healthy aquatic ecosystem. However, significant changes in pH, especially those caused by anthropogenic activities or natural events, could alter the bioavailability of heavy metals, potentially reducing the environmental carrying capacity of the aquatic ecosystem (Zhao et al., 2024).

3.1.3 Dissolved oxygen (DO)

The dissolved oxygen levels at both the inlet and outlet are very high and relatively stable, with a minor difference between the two points. High DO levels indicate good water conditions, with sufficient oxygen to support aquatic organisms. However, the slight decrease at the outlet is due to the decomposition of organic matter or respiration by organisms that consume small amounts of oxygen as the water flows.

The stability of DO is attributed to the photosynthesis of aquatic plants, such as water hyacinth, which releases oxygen into the water during the daytime (Wang et al., 2024). Photosynthesis increases DO levels, especially in shallow waters with ample sunlight, where plants like Eichhornia crassipes significantly contribute to water oxygenation. However, this process can reverse at night, when respiration and organic matter decomposition consume oxygen, particularly during plant decay (Li et al., 2024).

In the context of environmental carrying capacity, the high DO stability in the Batujai Reservoir shows that this ecosystem still has the capacity to support aquatic life without experiencing significant environmental degradation. However, without proper management, such as controlling excessive aquatic plant growth, conditions may change. For instance, the mass decay of Eichhornia crassipes can lead to a drastic decline in dissolved oxygen, potentially causing hypoxia or even dead zones in the ecosystem (Breitburg et al., 2018).

3.1.4 Conductivity

The drop in conductivity from the inlet (310 μS/cm) to the outlet (259 μS/cm) in the Batujai Reservoir indicates a reduction in dissolved ions such as salts, minerals, or pollutants as the water flows through the ecosystem. Conductivity in water is closely related to the amount of dissolved substances, and this decrease can be attributed to several natural mechanisms, including sedimentation, deposition, and uptake by aquatic vegetation such as Eichhornia crassipes (Bhaskaran et al., 2013). Aquatic vegetation can absorb nutrients and metal ions from the water, reducing dissolved substances and lowering conductivity levels at the outlet (Nagar et al, 2018).

The absorption of ions by aquatic plants, particularly nutrients like nitrogen and phosphorus, also plays a role in reducing conductivity. Aquatic plants use these nutrients for growth, leading to a decrease in dissolved ions in the water (Eyre et al., 2013). Additionally, the deposition of suspended particles and minerals at the bottom of the reservoir contributes to the reduction of dissolved substances carried to the outlet (Kettenring et al., 2014).

Lower conductivity at the outlet compared to the inlet indicates that the ecosystem can regulate dissolved substances, positively contributing to the water body's environmental carrying capacity. Lower conductivity levels suggest that the water in this reservoir is not heavily ionically polluted, allowing the aquatic ecosystem to continue supporting organisms that depend on good water quality.

3.1.5 The total dissolved solids (TDS)

The Total Dissolved Solids (TDS) values at the inlet (154,33 mg/L) and outlet (159,67 mg/L) are well below the 1000 mg/L threshold, indicating that the water quality in the Batujai Reservoir is good. TDS measures the amount of dissolved substances in water, including salts, minerals, and metals, which can affect the health of aquatic ecosystems. Low TDS levels in this water indicate that the reservoir does not contain many dissolved substances that could harm aquatic organisms or degrade water quality overall (Adjovu et al., 2023).

The decrease in TDS from inlet to outlet could result from several factors, including sedimentation and uptake by aquatic plants. This process removes some dissolved substances from the water, such as nitrogen and phosphorus nutrients, which can be absorbed by vegetation like Eichhornia crassipes growing along the reservoir. These aquatic plants act as natural biofilters that absorb nutrients and heavy metals from the water, thereby reducing dissolved substances at the outlet (Nifong & Taylor, 2021).

Overall, this low TDS level positively contributes to the reservoir's environmental carrying capacity, as aquatic ecosystems with low TDS tend to be more stable and support biodiversity. Low TDS also means that the risk of excessive salt or mineral deposition, which could disrupt biological and chemical processes within the ecosystem, is minimized. Thus, low TDS conditions support ecosystem balance and maintain a high environmental carrying capacity (Eyre et al., 2013).

3.2 Nutrient and lead concentrations in eichhornia crassipes of Batujai reservoir

Fig. 2 displays the differences in nitrogen, phosphorus, and lead concentrations between the inlet and outlet of the reservoir. The bar graph shows that while nitrogen levels decrease slightly, phosphorus and lead concentrations rise significantly, indicating potential environmental risks downstream.

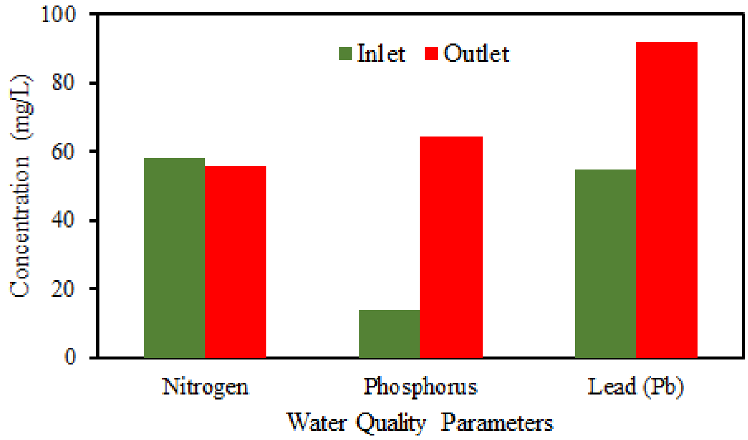

Fig. 2. Nitrogen, phosphorus, and lead concentrations in eichhornia crassipes

3.2.1 Nitrogen (N)

Nitrogen in Eichhornia crassipes tends to slightly decrease from inlet to outlet. This reduction may be due to the nitrogen uptake by plants to support their growth. Aquatic plants like water hyacinth are known for their ability to absorb nitrogen in the form of nitrate (NO_3^-) and ammonium (NH_4^+), the two most common forms of nitrogen found in water bodies (Nilsson et al., 2023; Su et al., 2019). Nitrogen is an essential nutrient for plants, and this absorption helps reduce nitrogen concentrations in the water.

The nitrogen reduction at the outlet indicates that some of the nitrogen in the water has been used by Eichhornia crassipes for vegetative growth, which in turn improves water quality by lowering the excess nutrients that could cause eutrophication (Chung & Ha, 2023). Although this reduction is minor, it demonstrates consistent absorption at both locations, indicating that Eichhornia crassipes serves as an effective phytoremediation agent for nitrogen removal from the water.

The ability of aquatic plants to absorb nutrients like nitrogen is crucial for controlling water quality and preventing excessive nutrient buildup, which can lead to algal blooms and other overgrowth of plants. This ensures that the aquatic ecosystem remains balanced and can optimally support other aquatic life (Brezinova & Vymazal, 2018).

3.2.2 Phosphorus (P)

The significant increase in phosphate content in Eichhornia crassipes at the outlet indicates a bioaccumulation process, where the plant absorbs phosphate from the water along the reservoir flow. Eichhornia crassipes is known as a hyperaccumulator plant that effectively absorbs phosphate and other nutrients from water to support its growth (Pang et al., 2023). The phosphate increase at the outlet could come from agricultural runoff around the reservoir or other sources that enrich phosphate in the water.

Hyperaccumulator plants like Eichhornia crassipes are widely used in phytoremediation, a natural environmental recovery technique that utilizes plants' ability to absorb and store nutrients or contaminants from the water (Tang et al., 2020, Zhang et al., 2024). By absorbing phosphate, water hyacinth helps reduce the nutrient load in the water, which could otherwise cause eutrophication, a condition where excessive algae growth damages the aquatic ecosystem. The phosphate absorbed by this plant can reduce further pollution risks, especially in water bodies vulnerable to agricultural runoff (Luo et al., 2020).

Thus, the increase in phosphate within water hyacinth at the outlet indicates that the plant is playing its role in controlling water quality. However, the presence of additional phosphate sources like agricultural runoff still needs to be monitored to ensure that the water ecosystem does not become overloaded with nutrients, which could reduce the reservoir's environmental carrying capacity.

3.2.3 Lead (Pb)

The significant increase in lead (Pb) concentration at the Batujai Reservoir outlet indicates that Eichhornia crassipes is highly effective in absorbing this heavy metal. Lead is one of the most hazardous heavy metals for aquatic ecosystems and organisms, due to its bioaccumulative properties and non-biodegradable nature. Eichhornia crassipes is one of the hyperaccumulator plants capable of absorbing heavy metals from the water through its roots and accumulating them in plant tissues, particularly in the roots and leaves (Ali et al., 2020; Pang et al., 2023).

The high lead content at the outlet could suggest the presence of lead pollution from human activities, such as runoff from agricultural or industrial areas around the reservoir. Additionally, lead previously trapped in the reservoir's sediment can dissolve back into the water if physical disturbances or pH changes occur, and it is then absorbed by Eichhornia crassipes (Pang et al., 2023). Thus, Eichhornia crassipes serves as a bioindicator of heavy metal pollution due to its ability to accumulate lead from contaminated environments.

The role of Eichhornia crassipes as a phytoremediation agent is crucial in maintaining the reservoir's environmental carrying capacity by reducing heavy metal concentrations in the water. However, this plant must be properly managed to prevent the potential release of lead back into the ecosystem when the Eichhornia crassipes dies or decomposes, which could further contaminate the water (Nagar et al., 2018; Pang et al., 2023).

4. Conclusions

Batujai Reservoir, Central Lombok, has a good carrying capacity to support the sustainability of aquatic life, based on several water quality parameters such as temperature, pH, DO, conductivity, and TDS. However, there is a potential negative impact related to high pollution from heavy metals like Pb, as well as elevated nitrate and phosphate nutrients. The Eichhornia crassipes growing in the Batujai Reservoir shows the ability to absorb nitrogen, phosphate, and lead from the water, with significant increases in phosphate and lead at the outlet. This indicates that the aquatic plant plays an essential role in bioaccumulation processes, but also reveals pollution concerns, particularly for lead. This pollution poses a risk to the reservoir's carrying capacity, affecting both aquatic life and human health, as the water is used for various purposes. Therefore, mitigation measures, improved waste management, and regular water quality monitoring are necessary to ensure that the Batujai Reservoir's environmental carrying capacity is maintained in the future.

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Author Contribution

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The authors declare no conflict of interest.

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Biographies of Authors

Siti Raudhatul Kamali, is a lecturer in the Environmental Science Department at the University of Mataram.

- Email: sitikamali@unram.ac.id
- ORCID: 0000-0002-9635-9469
- Web of Science ResearcherID: N/A
- Scopus Author ID: 57204546439
- Homepage: https://staf.unram.ac.id/home/detail_staf/198209082008122002?tahun=

Immy Suci Rohyani, is a lecturer in the Environmental Science Department at the University of Mataram.

- Email: Immysucy@yahoo.co.id
- ORCID: 0009-0002-8214-1183
- Web of Science ResearcherID: N/A
- Scopus Author ID: 57194185446
- Homepage: https://staf.unram.ac.id/home/detail_staf/197609192003122001?tahun=

Ernawati, is a lecturer at the Environmental Science Department, University of Mataram.

- Email: ernawati@unram.ac.id
- ORCID: N/A
- Web of Science ResearcherID: N/A
- Scopus Author ID: N/A
- Homepage: https://staf.unram.ac.id/home/detail_staf/199505032022032019?tahun=

Annisa Arimbi Murfi, is currently an undergraduate student in the Environmental Science Department at the University of Mataram.

- Email: annisaam@gmail.com
- ORCID: N/A
- Web of Science ResearcherID: N/A
- Scopus Author ID: N/A
- Homepage: N/A

Zulvi Amelia Sari, is an undergraduate student in the Environmental Science Department at the University of Mataram.

- Email: Zulvias@gmail.com
- ORCID: N/A
- Web of Science ResearcherID: N/A
- Scopus Author ID: N/A
- Homepage: N/A

Lalu Malik Fajar, is an undergraduate student in the Environmental Science Department at the University of Mataram.

- Email: lmfajar@gmail.com
- ORCID: N/A
- Web of Science ResearcherID: N/A
- Scopus Author ID: N/A
- Homepage: N/A