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Evaluating the Performance of Green Mussels (Perna viridis) as a Biofilter to Improve Seawater Quality in Pantai Kalibaru

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Abstract
This study explores the potential of green mussels (Perna viridis) as a natural biofiltration system in mitigating water pollution in Jakarta's coastal waters, particularly in the Pantai Kalibaru area of Jakarta Bay. Seawater samples were tested for color, turbidity, soluble solids, coliform levels, and heavy metal content before and after the addition of green mussels. Results showed a significant improvement in water clarity, with turbidity reduced from 128.6 NTU to 7.08 NTU and color from 13.6 TCU to 7.17 TCU. Coliform levels decreased substantially, indicating the mussels' ability to filter biological contaminants. However, no significant reductions in heavy metal concentration were observed. Although improvements in water quality were observed, they did not exceed Indonesian National Standards (SNI) for drinking and potable water, suggesting that while Perna viridis effectively improves some parameters, additional measures are necessary to meet regulatory standards. This study highlights the potential of green mussels as a natural biofiltration method for improving coastal water quality in urban areas.

Keywords: Perna viridis, seawater quality, biofiltration, coliform reduction

I. Introduction

Indonesia, recognized as the largest archipelagic state, boasts a vast marine territory of 6.32 million km^2–nearly four times larger than its land area of only 1.91 million km^2 (Badan Pusat Statistik Indonesia, 2021). This enormous area of seawater, stretching along the Indian Ocean to the Pacific Ocean, is home to one of the richest coral reef ecosystems in the world, positioning Indonesia as a global biodiversity hotspot for marine life. Indonesia's saltwater fish constitute approximately 37% of the world's total fish species (SIT Al Haraki, n.d.).

Despite the rich marine biodiversity present, the environmental quality of Indonesia's coastal waters has been steadily deteriorating. Rapidly growing cities like Jakarta and Surabaya due to urbanization, especially in emerging and developing countries such as Indonesia, pose a threat to ecological balance (Dsikowitzky et al., 2020). As expected, the expanding urban population, excessive anthropogenic activities, primarily urban runoff, untreated domestic wastewater, and industrial and agricultural pollutants have led to the degradation of the natural environment, especially marine and coastal ecosystems (Adyasari et al., 2021). The ongoing pollution has a direct and severe impact on marine fisheries, which play an important role in Indonesia's economy (Rahmizal, 2022). The livelihoods of local fishermen who depend on these fisheries have been severely affected, with their incomes declining by as much as 30% over the past 10 years (Relung, 2024). The socioeconomic importance of marine ecosystems to local communities creates an urgent need for sustainable, practical solutions to mitigate pollution. Developing such solutions will also undoubtedly improve environmental conditions across Indonesia: seawater will require less filtration to be used for bathing or washing, local biodiversity will be conserved, and ecotourism will flourish as locals are more likely to find a sense of safety in their oceans.

One promising approach involves utilizing green mussels (Perna viridis), a species native to Indonesian waters. Green mussels are renowned not only as an affordable source of protein for coastal communities but also for their ecological resilience and unique biofiltration capabilities (Noor et al., 2019). They have been shown to possess the remarkable bioaccumulation ability of both organic and inorganic contaminants, effectively acting as natural filters in polluted environments (Setyarini & Adharini, 2022). This attribute enhances seawater clarity, crucial for maintaining healthy coral reefs and supporting marine biodiversity (Zhang et al., 2020).

Jakarta, one of the most populated megacities in the world, exemplifies the challenges posed by urbanization and pollution. The city's rivers, heavily polluted with domestic and industrial waste, contribute to significant seasonal flushing into coastal areas, exacerbating the degradation of marine life (Adyasari et al., 2021). Addressing these challenges requires not only technological innovation but also the integration of nature-based solutions, such as deploying green mussels to serve as biofilters, which offer a simple, cost-effective, and sustainable method for improving coastal water quality affected by pollution.

This study explores how green mussels can specifically mitigate water quality issues in Pantai Kalibaru. Although previous research has already proven that green mussels are useful for biofiltration, there are limited applications of such research in Indonesia in particular. It is important to note the sheer volume of pollution in Pantai Kalibaru because of many nearby industry plants and incoming exports from foreign countries, which produce constant organic waste. Most of Jakarta's rivers also experience the same struggles, thus being a suitable site to test the feasibility of green mussels as a natural biofiltration system. This approach may provide a scalable solution to protect the livelihood of local fishermen, promote biodiversity conservation, and support the long-term sustainability of Indonesia's marine ecosystems.

II. Literature Reviews

Green mussels (Perna viridis) are bivalve mollusks that play a vital role in marine ecosystems through their effective filtration capabilities (Setyarini & Adharini, 2022). These organisms are filter feeders, meaning they draw in water through their siphons to extract particulate matter, including phytoplankton, organic debris, and pollutants. The filtration process begins by actively pumping water through the mussel's gills. This is accomplished via ciliary action, where tiny hair-like structures on the gill surfaces create a current that facilitates the movement of water. The gills are covered with a mucous layer that traps food particles, allowing the mussels to efficiently filter substantial volumes of seawater (Wong & Cheung, 2001). This is essential for promoting benthic and littoral primary production alongside the livelihood of marine ecosystems (Zhang et al., 2020).

Studies have shown that a kilogram of green mussels can filter at least ten liters of water per hour per individual, depending on these environmental conditions (Wong & Cheung, 2001). At higher concentrations of phytoplankton or organic matter, smaller mussels tend to exhibit increased filtration rates, while larger individuals may reach a peak efficiency before declining at extreme concentrations. This adaptive mechanism allows them to thrive in varying ecological conditions while contributing to nutrient cycling within their habitats.

In addition to active filtration, green mussels produce pseudofaeces as a means of expelling unwanted materials. This process not only helps manage the accumulation of non-nutritive particles but also plays a role in sediment stabilization within their ecosystems (Argente, 2024). Furthermore, recent research has highlighted the ability of green mussels to bind heavy metals through their byssus—the structure that anchors them to substrates. This binding is facilitated by specific proteins rich in histidine and cysteine residues that interact with metal ions, thus providing a dual function in both filtration and bioremediation (Zhang et al., 2019). Such mechanisms underscore the ecological significance of green mussels in maintaining water quality and mitigating pollution in marine environments.

Numerous studies have focused on the ecological and physiological aspects of green mussels, particularly regarding their filtration efficiency and environmental adaptability. In Indonesia, several key studies have examined these aspects within local contexts. For instance, research conducted in Jakarta Bay explored the bioaccumulation of heavy metals in green mussels and found that high levels of pollutants such as mercury, cadmium, and lead resulted in significant morphological changes in the mussels (Irnidayanti et al., 2023). Another study focused on the oceanographic conditions affecting green mussel cultivation in South Sulawesi revealed how variations in temperature, turbidity, and nutrient levels can lead to muscle tissue increasing in size after changes were recorded (Ramli et al., 2021). However, these studies do not indicate the death of green mussels. Research on the food habits of green mussels in Banda Aceh also identified diverse food sources, emphasizing the importance of phytoplankton composition for their growth (Abdullah Abbas et al., 2022).

Much of the existing literature focuses on specific regions that may not be as significantly polluted alongside the lack of evaluation of biological parameters.

This paper intends to expand the geographical focus by investigating green mussels and their impact on biological water content specifically in Pantai Kalibaru, Jakarta, thus providing localized data that can inform regional conservation efforts. The need to improve fisheries and preserve biodiversity will start with cleaner oceans that provide the right nutrients and living environments for Indonesia's coastal areas to thrive. These findings will help inform future decisions on ecosystem health due to how stakeholders like fishermen, tourism sites, and local citizens will benefit from improved water quality.

III. Methods

3.1 Study Design

Seawater collection for this study involved taking a boat to Jakarta Bay, where sampling was conducted at designated coordinates. Seawater was collected at 50 meters below sea level using a specialized Niskin bottle to ensure samples were representative of deeper water quality conditions. The Niskin bottle was lowered carefully to avoid contamination from the surface layers, and multiple samples were taken to ensure consistency. Collected seawater was then homogenized and separated equally into six 15-liter glass aquariums, labeled A1-A3 and B1-B3. The setup followed the provisions of SNI 6964.8:2015. Treatment was applied by adding 1 kilogram of green mussels, sourced from a local vendor in Jakarta, into aquariums B1-B3. The mussels were acclimated in a National Research and Innovation Agency (BRIN) laboratory for 24 hours before the study and removed after the 6-hour treatment period. Seawater samples from aquariums A1-A3 (control) and B1-B3 (treatment) underwent mercury tests using 500 mL of seawater, and 100 mL each for nitrates, iron, turbidity, soluble solids, and coliforms, analyzed at Sucofindo Laboratory in Jakarta. The mussels were kept under refrigeration after the study.

3.2 Data Collection

120 liters of seawater from Kalibaru, Jakarta Bay (coordinate point 6P58WV9M+Q9) were collected on 15th of July, 2024 (11.00 a.m. Western Indonesian Time) at 50 meters below sea level using a Nansen Sampler. The seawater was stored in a cooler to maintain a temperature below 6°C during transport to minimize changes in bacterial activity.

3.3 Data Analysis

Physical parameter measurements, including color, taste, smell, temperature, turbidity, soluble solids, and pH, were conducted for each aquarium before and after treatment. Color was assessed visually using a standardized color scale, while taste and smell were evaluated manually by a sensory panel trained in water quality analysis. Temperature was measured using a digital thermometer (°C), and turbidity was quantified using a turbidity meter (NTU). Soluble solids were measured with a refractometer (mg/L), and pH was recorded using a calibrated pH meter.

Chemical parameters, including mercury, nitrate, and iron, were tested using standard protocols. Mercury levels were measured using cold vapor atomic absorption spectroscopy (CV-AAS) in micrograms per liter (µg/L), while nitrate concentrations were determined by UV spectrophotometry (mg/L). Iron content was analyzed using atomic absorption spectroscopy (AAS) (mg/L). Seawater samples for these chemical tests were collected at the beginning and end of the 6-hour treatment period and sent to the Sucofindo Laboratory for analysis, following proper storage and transport protocols to maintain sample integrity.

Biological parameters were assessed by measuring total coliform levels using the Most Probable Number (MPN) method (CFU/100 mL). Samples were collected from each aquarium and analyzed for coliform presence before and after treatment, with results used to evaluate the biological filtration efficacy of the green mussels.

These parameters were recorded at 1-hour intervals over the 6-hour treatment period. A video recording was used throughout the entire experiment to monitor changes in real-time. Each sample was tested under Indonesia's water quality standards, Standar Nasional Indonesia (SNI), which are standardized to ensure water safety for various uses, including drinking water and coastal waters. These standards define acceptable limits for physical, chemical, and biological parameters to protect public health and the environment. Sucofindo, an accredited laboratory licensed to analyze water quality, was used to ensure compliance and suitability for specific purposes. Justification for these methods was based on standard practices in water quality testing and the need for precise, time-sensitive measurements in a controlled environment.

IV. Results

Results were collected through continuous video recording, which captured the physical changes in the seawater throughout the 6-hour treatment period, and parameter analysis after seawater samples were sent to a Sucofindo laboratory for physical, chemical, and biological analysis.

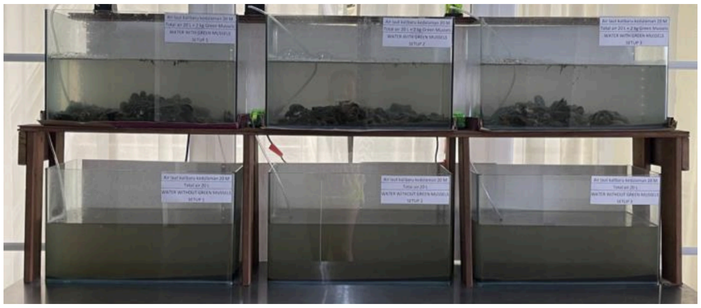

Figure 1. *Seawater Samples With (Above) and Without (Below) the Addition of Green Mussels*

Figure 2. *Seawater Samples B1-B3 (Left) and A1-A3 (Right) With/Without Green Mussels*

Screen captures from the video recording as shown in Figures 1 and 2 reveal a noticeable transformation in the water color after each hourly check. By the end of the 6-hour treatment period, the effects of the green mussels were visibly evident, as the water appeared significantly more filtered. The progressive change highlights the mussels' biofiltration capabilities in improving water quality over time.

Physical parameters such as color, taste, smell, and turbidity were measured visually, through sensory evaluation, and with a turbidity meter (NTU), while pH was tested using a calibrated pH meter.

Table 1. Physical Parameters of Seawater Samples

No.	Parameter	Sample A1	Sample A2	Sample A3	Sample B1	Sample B2	Sample B3
01.	Color (TCU)	26	7	8	7.57	7.23	6.71
02.	Taste	Tasteless					
03.	Smell	Odorless					
04.	Temperature (°C)	22.6					
05.	Turbidity (NTU)	212	134	40	8.75	7.23	5.27
06.	Soluble Solids (mg/L)	24000	23700	24600	21600	23400	23900
07.	pH	7.3					

As shown in Table 1, which includes data before green mussel treatment in samples A1-A3 and after green mussel treatment in samples B1-B3, significant improvements were observed. Although samples A1-A3 were control setups, they had identical results to samples B1-B3 before green mussel treatment. The color, taste, and smell of the seawater were consistently classified as "natural," which meets the standards for these parameters, but turbidity decreased but remained above the national standard at 7.08 NTU. Soluble solids did not experience any significant change. The pH level was 7.3, slightly exceeding the national standard of 7.

Chemical parameters like soluble solids were measured using a refractometer, and turbidity was further assessed by measuring suspended particles in NTU.

Table 2. Chemical Parameters of Seawater Samples

No.	Parameter (mg/L)	Sample A1	Sample A2	Sample A3	Sample B1	Sample B2	Sample B3
01.	Mercury	<0.0008					
02.	Nitrate	<0.02					
03.	Iron	<0.02					

As shown in Table 2, mercury, nitrate, and iron levels were within safe limits, as indicated by the analysis, though further details could be noted from the actual values recorded in the study.

Biological parameters, specifically total coliform levels, were measured using the Most Probable Number (MPN) method to determine bacterial contamination in CFU/100 mL.

Table 3. Biological Parameter of Seawater Samples

Coliform Total (MPN/L)	Sample A1	Sample A2	Sample A3	Sample B1	Sample B2	Sample B3
	1000	250	400	48	63	58

As shown in Table 3, total coliform levels decreased drastically to an average value of 56.33 CFU/100 mL, a substantial reduction compared to the national standard of 1000 CFU/100 mL. Each individual sample also had an extremely low total coliform level. This significant decline underscores the green mussels' effectiveness in mitigating bacterial contamination and their potential as a natural biofiltration method for improving water quality.

The results of the green mussel treatment showed varying levels of compliance with Indonesia's national water quality standards compared to Tables 1 to 3. The color, taste, and smell of the treated seawater were categorized as "natural" and met national standards. However, turbidity, while improved, remained slightly above the national standard, measuring 7.08 NTU compared to the acceptable limit of 5 NTU. Soluble solids were not within the national standard range of 20-80 mg/L as indicated in Table 1. The pH level, at 7.3, failed to meet the national standard of 7, indicating a slight deviation. On a positive note, total coliform levels dropped significantly to 56.33 CFU/100 mL after calculating the average values from Table 3, which are far below the national limit of 1000 CFU/100 mL.

V. Discussion

No discernible differences in taste or smell were noted between the samples, and the temperature and pH remained consistent across all trials, with a steady temperature of 22.6°C and pH of 7.3 as indicated by hourly checks using a thermometer and pH meter. The temperature stability was attributed to uniform storage and room conditions throughout the experiment.

However, significant differences were observed in water color and clarity between the pretreatment and post-treatment samples. The color of the seawater was measured in True Color Units (TCU), showing a reduction after the treatment with green mussels. All samples had an average of 13.6 TCU before green mussels were added to samples B1-B3, whereas those samples exhibited a lower average of 7.17 TCU after green mussel treatment to indicate a notable improvement in water clarity. The specific color values for each sample ranged from 6.71-26 TCU.

In terms of turbidity, a remarkable improvement in seawater clarity was observed. Before the addition of green mussels, the average turbidity was recorded at 128.6 nephelometric turbidity units (NTU). Following the treatment, turbidity dropped to an average of 7.08 NTU across samples B1-B3, suggesting a significant enhancement in water transparency. The results are summarized in Table 1, where the reduction in turbidity strongly supports the hypothesis that green mussels can act as effective biofilters as proven in the literature review.

Furthermore, the total coliform count also decreased after the treatment, as shown in Table 3, demonstrating the green mussels' capacity to process biological contaminants. These findings align with previous studies indicating the species' ability to filter out harmful microorganisms and suspended solids, thereby improving water quality (Gyawali et al., 2021).

Despite these positive outcomes, the concentration of heavy metals in the seawater samples did not show any significant reduction as shown in Table 2. This contrasts with findings from prior research, which have reported that green mussels can accumulate and reduce heavy metal concentrations in polluted waters (Harsono et al., 2017). Previous research was conducted over greater periods of study and lesser volumes of water, which suggests that the filtration capacity of green mussels may vary depending on time intervals and environmental conditions.

Lastly, although turbidity and soluble solids improved after treatment, they still did not meet the national water quality standards as set by Perpres No. 21, 2021. This suggests that while green mussels show potential as natural biofilters for improving certain aspects of water quality, additional measures may be needed to fully comply with regulatory standards for seawater quality.

VI. Conclusion

This study demonstrated that green mussels (Perna viridis) effectively improve seawater clarity by filtering suspended particles. They also showed the ability to lower total coliform levels, further proving their capacity to process biological contaminants. However, the green mussels did not significantly reduce heavy metal content despite previous studies indicating their potential for this function.

While these results are promising, several adjustments are necessary to improve the study's outcomes. Increasing the number of green mussels and extending the study period would provide a more comprehensive understanding of their effectiveness to enhance water quality. These modifications would allow for a deeper analysis of the biofiltration capacity of green mussels over time and under varying conditions.

The treated seawater did not meet national standards for turbidity and soluble solids as per Perpres No. 21, 2021. This suggests that while green mussels can serve as natural biofilters, additional measures are necessary to meet regulatory standards, particularly for heavy metal reduction. Nonetheless, green mussels present a sustainable solution for mitigating pollution in coastal ecosystems.

VII. Acknowledgements

The authors declare that there are no conflicts of interest regarding the research, authorship, and publication of this study. All aspects of the research, including the study design, data collection, analysis, and interpretation, were conducted independently and without any influence from external entities that could have impacted the outcomes or findings.

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