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# Water quality assessment to improve the ecological function of waters: the South Coast of the Yogyakarta Shrimp Farming Area

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**Abstract:** This study aims to assess the quality of lagoon water used as a dumping ground for shrimp farming waste. The research uses the descriptive method. The research was conducted at the Shrimp Cultivation Site in the Banaran Kulon Progo Village, Special Region of Yogyakarta, Indonesia. The research focuses on physicochemical parameters, including temperature, pH, total suspended solid (*TSS*), dissolved oxygen (*DO*), ammonium ($NH_4$-N), nitrate ($NO_3$-N), and phosphate. The sampling technique is based on SNI 6989.57:2008. Sampling was carried out 48 times in 3 lagoons during rainy and dry seasons. Dialysis data was descriptively classified with the help of Storage and Retrieval of Water Quality Data System (STORET) and water quality was generally classified as C (moderately polluted) and D (heavily polluted) categories in dry and rainy seasons. The results showed that in the rainy season the highest pH, nitrate and phosphate levels of 8.3, and 6.1 and 20.8 mg·dm$^{-3}$, were up to 15% less than in the dry season in the same point. Thus, it can be concluded that these values from the STORET in the dry season are larger than those in the rainy season. The study results are expected to become a basis for the evaluation of the quality of shrimp farming wastewater so that environmental health can be controlled and the risk of waste pollution reduced.

**Keywords:** aquatic ecology, ecological function, shrimp farming, waste, water quality

## INTRODUCTION

Along with the development of the aquaculture industry, many countries implement studies in the field of water quality management in breeding farms, and several cases of this type of research are given in this category (Galappaththi *et al.*, 2020; Sherafatizangeneh *et al.*, 2022; Suzuki, Nam and Lee, 2023). Aquaculture is one of the business sectors generating large profits. In recent years, due to growing demand and promising advantages, aquaculture has grown rapidly (Ray *et al.*, 2021; Ali *et al.*, 2022). Aquaculture is one of the priorities for aquaculture development in Indonesia (Takarina *et al.*, 2020). As one of the priorities, the government seeks to increase income for cultivators by improving aquaculture production quality (Musa *et al.*, 2023). Maximum and sustainable production can support policy developers in strategies and programmes to encourage increased production quality (Antunes *et al.*, 2018; Khorsandi *et al.*, 2022). However, fish farming in Indonesia works against the preservation of the environment and ecosystems, such as land and coastal waters.

Among other seafood products, shrimp is considered one of the commodities in high demand worldwide. As a result, intensive shrimp farming developed rapidly in the mid-1980s, especially in Southeast Asia (Plichta *et al.*, 2021). As a result, the average production of shrimp culture worldwide reaches around $4 \cdot 10^9$ kg, with the most significant production from Asia, such as China, India, Vietnam, Indonesia, and Thailand (Booncharoen and Anal, 2021). Shrimp production rates have increased mainly due to expanding aquaculture areas and intensive farming practices (Ishenin *et al*., 2021; Parra *et al*., 2021).

The effluent from shrimp lagoons contains high level of nutrients and can cause eutrophication, reducing dissolved oxygen (*DO*) in waters (Kajornkasirat *et al*., 2021). Consequences to the environment include oxygen deficit due to the decomposition of organic matter and eutrophication due to the accumulation of nitrogen and phosphorus (Gholivand *et al*., 2021). In addition, ammonium is always present in lagoon waste, mainly from shrimp excretion and protein hydrolysis from feed dissolved in water. The breakdown of protein into amino acids and the oxidative deamination process produce ammonium (Ghodbane *et al*., 2022; Tightiz and Yoo, 2022). Intensive and super-intensive shrimp farming reduces the quality of coastal waters in several countries (Vu-Khac *et al*., 2018). Shrimp farming produces large amounts of waste, e.g. faeces, feed residues, and dead organisms that accumulate and are discharged directly into water without treatment (Cieśla and Gruca-Rokosz, 2023; Nanjappa and Jayaprakash, 2023). Waste is discharged every day in small amounts for clean water exchange and disposed of entirely at the time of shrimp harvest (Ghrair *et al*., 2020). Water quality characteristics and indicators are used for water data sources, such as physical, chemical, and biological parameters (Fakhimi and Motamedi, 2020; Shariati *et al*., 2013). The current research assesses the quality of lagoon water used as a dumping ground for shrimp farming waste.

## MATERIALS AND METHODS

The research uses the descriptive method. The research was conducted at the Shrimp Cultivation Site in the Banaran Kulon Progo Village, Special Region of Yogyakarta, Indonesia. The research focuses on physicochemical parameters, which include temperature, pH, total suspended solid (*TSS*), dissolved oxygen (*DO*), ammonium ($NH_4$-N), nitrate ($NO_3$-N), and phosphate. Sampling was carried out 48 times in 3 lagoons during the rainy and dry seasons and chemical and physical properties of water determined. The lagoon used in the study was divided into 3 sections. General information about the lagoon used in the study is included in Table 1.

The measurement of physical and chemical parameters of water was carried out at eight lagoon sample points. Replicated surface water samples from 8 points are representative and located in close proximity to pollution sources. Sampling technique based on SNI 6989.57:2008. The sampling location coordinates are presented in Table 2.

**Table 1.** General description of the studied lagoon located at the Shrimp Cultivation Site in Banaran Kulon Progo Village, Special Region of Yogyakarta, Indonesia

| Shrimp lagoon | Length | Width | Depth | Number of outlets |
|---|---|---|---|---|
| | m | | | |
| Big lagoon | 468.1 | 68.6 | 2.6 | 8 |
| Small lagoon A | 81.4 | 35.7 | 1.0 | 3 |
| Small lagoon B | 86.7 | 35.7 | 1.0 | 3 |

Source: own elaboration.

**Table 2.** Location of the measurement points

| Sampling point | Coordinate | Elevation (m) | Distance from an outlet (m) |
|---|---|---|---|
| LB1 | 07°58'38.33" S 110°12'01.36" E | 10 | 5.0 |
| LB2 | 07°58'38.43" S 110°12'01.40" E | 11 | 39.3 |
| LB3 | 07°58'43.81" S 110°12'05.34" E | 14 | 52.4 |
| LB4 | 07°58'36.27" S 110°11'54.10" E | 12 | 81.9 |
| LKA1 | 07°58'34.08" S 110°11'53.99" E | 11 | 4.3 |
| LKA2 | 07°58'34.63" S 110°11'51.78" E | 15 | 35.7 |
| LKA3 | 07°58'33.36" S 110°11'51.11" E | 16 | 3.0 |
| LKA4 | 07°58'33.78" S 110°11'48.17" E | 15 | 40.1 |

Source: own elaboration.

Based on eight observation points, the research location is presented in Table 2 and discussed in the article.

Sampling was carried out in time series – three times during different periods of the rainy and dry seasons. Samples were collected and stored in acid-washed polyethylene bottles, following the sampling procedures established for water quality studies (Nashar *et al*., 2020). The laboratory tests were analysed descriptively by comparing test results with Government Regulation No. 82 of 2001 to determine the suitability of water quality designation. The analysis of water quality status using the STORET is based on Decree of Environment No. 115 of 2003.

## RESULTS AND DISCUSSION

### MEASURED FACTORS IN SHRIMP FARMS

In order to investigate the water quality status in shrimp farms located in the Banaran Kulon Progo Village, Special Region of Yogyakarta, Indonesia, some physical and chemical parameters affecting the growth of shrimp, such as water temperature, pH, dissolved oxygen (*DO*), nitrite, ammonium, clarity and phosphate in three areas (three lagoon in each farm), were studied during a six-month breeding period. The results showed that the increase of the water quality can have a direct effect on the increase of the shrimp harvesting productivity.

### WATER QUALITY

The variation of water quality parameters in shrimp farming waste control is essential. The results of measuring water quality in the dry season can be seen in Figure 1.

The results showed that in the dry season, the highest *DO* at LB3 was 6.8 mg·dm$^{-3}$. The lowest *DO* was at LKA4 1.9 mg·dm$^{-3}$. Point LKA3 showed the highest *BOD*, *TSS*, ammonium, and

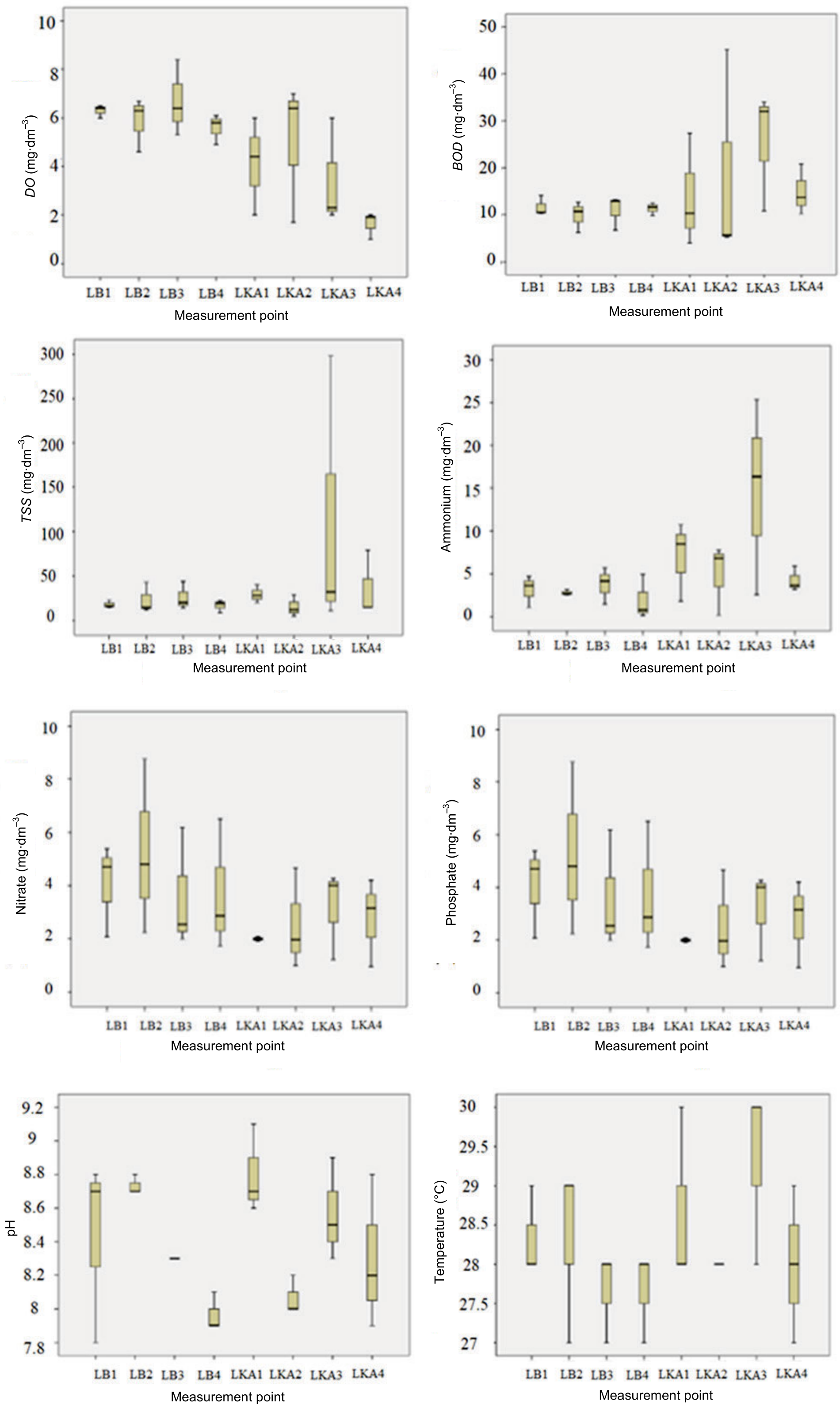


**Fig. 1.** Water quality in shrimp farming waste control in dry season at measurement points; *DO* = dissolved oxygen, *BOD* = biological oxygen demand, *TSS* = total suspended solid; measurement points as in Tab. 2; source: own study

temperature compared to other locations, namely 31.9 mg·dm$^{-3}$, 161.3 mg·dm$^{-3}$, 22.1 mg·dm$^{-3}$, and 29.9°C. Nitrate of 6.9 mg·dm$^{-3}$, phosphate of 24.99 mg·dm$^{-3}$, and pH of 8.9 were the highest values at the LKA1 point. If we correctly increase the rate of water exchange to reduce the effects of temperature, we can reduce stress and increase shrimp production per unit area.

Information about the level of pollution in water is necessary as a basis for pollution control and environmental management. Water quality in the lagoon was deduced to exhibit spatial and temporal variations related to shrimp farming activity in the studied zone (Mojahed, Mohamadkhani and Mohamadkhani, 2022). Residual feed and shrimp metabolism residues directly affected receiving waters quality in the area adjacent to the lagoon but the impact was reduced at points far from waste disposal (Zhang *et al.*, 2019). The results of measuring water quality in the rainy season can be seen in Figure 2.

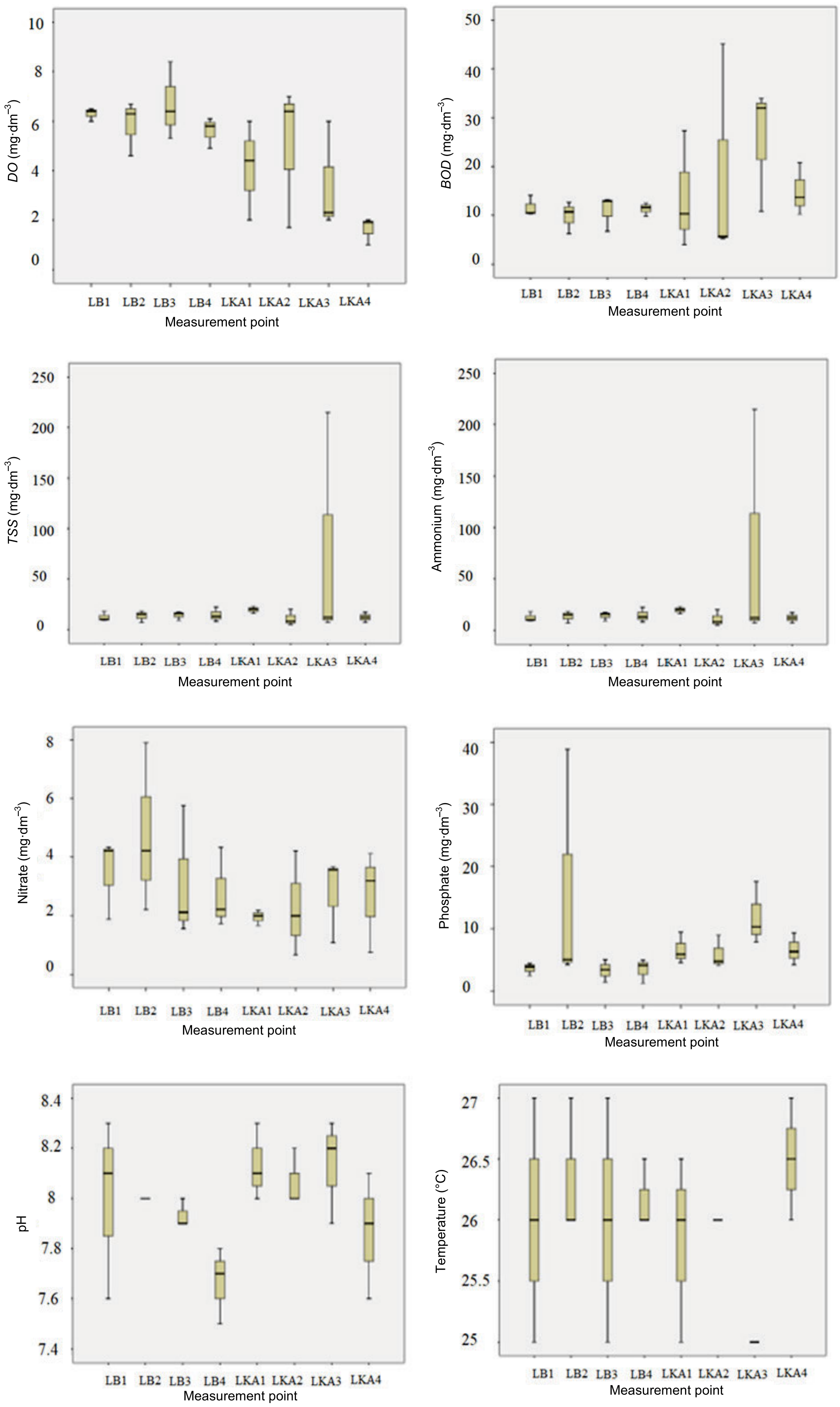


**Fig. 2.** Water quality in shrimp farming waste control in rainy season in various points; explanations as in Fig. 1; source: own study

In the rainy season, the study results showed that the highest *DO* was still at LB3 (7.3 mg·dm$^{-3}$). Point LKA3 still showed the highest *BOD*, *TSS*, ammonium and pH, compared to other locations. The highest nitrate and phosphate, parameters at LB2, and water quality in the lagoon in general did not provide a significant difference between seasons.

### PHYSICAL AND CHEMICAL PARAMETERS

The overall temperature in the dry and rainy seasons is normal. The highest temperature is around 29.9°C. The water temperature changes with the temperature of waste disposed in the lagoon (Samuelsen *et al*., 2020). Increasing temperature greatly affects oxygen levels (Tischler *et al*., 2019). The higher temperature is, the lower solubility of oxygen. The highest *TSS* in the rainy season was 113.66 mg·dm$^{-3}$. Organic matter can partially cover the surface layer of water in a lagoon. Therefore, *TSS* inhibits the penetration of the sunlight into water and affects the amount of dissolved oxygen. The highest pH is at LKA1 in the dry season. Shrimp lagoon waste has an alkaline pH of 7–9 and contains organic matter consisting of protein, carbohydrates, nitrogen, phosphorus, and ammonium.

High *BOD* levels are caused by high organic matter decomposed by microorganisms that utilise dissolved oxygen. Waste disposal from shrimp lagoons is the source of pollutants (Shukla *et al*., 2018). Dissolved oxygen is an important parameter that can be used to assess the condition of aerobic aquatic organisms and other chemical processes in aquatic ecosystems (Floris *et al*., 2021). The high ammonium level is recorded at the measurement point where shrimp lagoon waste is disposed of through the outlet. Shrimp manure and the activity of micro-organisms lead to the decay of organic matter rich in nitrogen (protein). This is the cause of high ammonium levels in water (Roon van, 2020).

Overall, ammonium levels have meet quality standards set in the Government Regulation (2001), which is 0.02 mg·dm$^{-3}$. The highest nitrate level is at LB2 in the dry season. Shrimp lagoon waste that accumulates in certain places results in high nitrate levels. Nitrate and nitrite cause nitrification in water, with ammonium oxidised aerobically. Nitrite, a substance toxic to aquatic animals, is usually released in small amounts to water because it normally changes into nitrate (Giao *et al*., 2021). Nitrite accumulates in water when the content of ammonium oxidation increases the nitrite oxidation and the denitrification by heterotrophic bacteria under anaerobic status (Fei *et al*., 2020). The highest phosphate level is at LB2 in both dry and rainy seasons. Shrimp lagoon waste accumulates resulting in high phosphate levels (Jerónimo *et al*., 2021). Total phosphate is an important factor in assessing and monitoring coastal water quality related to shrimp farming because it is a source of soluble inorganic phosphorus, a major metabolic nutrient for plant growth. The results of measuring the status of water quality can be seen in Table 3.

The calculation results show that the waters of the large lagoon are categorised as C (moderately polluted) both in dry and rainy seasons. The poor condition of water quality is reflected by water quality parameters. These parameters do not meet quality standards according to the Government Regulation (2001), i.e. *BOD*, ammonium, and nitrate content in water. The reason is that the lagoon waste discharged accumulates. This is exacerbated by the long dry season when pollutant concentrations remain high as no dilution occurs. Moderate pollution does not prevent natural fish breeding but cannot support intensive fish farming. This is because the productivity of intensively cultured fish must be kept high and minimal mortality can be detrimental.

The poor water quality is the result of water quality parameters that do not meet quality standards according to PP RI No. 82 of 2001. Most discharge from lagoon waste that enters the water accumulates. Long dry season conditions affects the pollutants and their concentrations. Therefore, in the future, water quality assessment and good management of shrimp culture are needed.

**Table 3.** Values from the Storage and Retrieval of Water Quality Data System and lagoon water quality status

| Measurement point | Season | | | |
|---|---|---|---|---|
| | rainy | | dry | |
| | value | water quality status | value | water quality status |
| LB | –30 | moderately polluted | –31 | moderately polluted |
| LKA1, LKA 2 | –31 | moderately polluted | –32 | heavily polluted |
| LKA3, LKA 4 | –32 | heavily polluted | –34 | heavily polluted |

Source: own study.

## CONCLUSIONS

The life cycle and optimal growth of shrimp depend to a large extent on water quality, so new water quality management methods can be very important to increase the production per unit area. Wide and unfavourable changes of water quality parameters can have harmful effects on the natural and stress-free growth of shrimp and can reduce the production per unit area. In three lagoons, based on eight research parameters, water quality can be classified as C (moderately polluted) and D (heavily polluted). The condition of the heavily polluted lagoon does not support the breeding of shrimps. Severe pollution can be deadly for these crustaceans. The water in the small lagoon can only be designated as class IV and can be used to irrigate rice fields. The results of this study are expected to provide a robust and universal method for assessing water quality in shrimp farming ecosystems.

The research results are expected to be used in water quality management. This study describes lagoon water quality at the shrimp farming site using the STORET method. Thus, relevant research and local management can provide more information about water quality and its distribution throughout waters surrounding the shrimp farming area. The lagoon water quality is generally classified as "moderate" and "severe" based on the STORET. Research shows eight significant spatial groups and eight environmental parameters. Thus, future research should investigate the treatment procedure applied to shrimp farming wastewater to enhance water quality and its reuse in shrimp productions or in other industries.

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