

Impacts of Dissolved Organic Waste from Artificial Feed on Aquatic Environmental Quality of Nile Tilapia (*Oreochromis niloticus*) Culture Ponds: A Case Study of Pokdakan Sugih Makmur, South Kalimantan, Indonesia

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ABSTRACT

The intensive use of artificial feed in Nile tilapia (*Oreochromis niloticus*) aquaculture contributes to the accumulation of dissolved organic waste, potentially degrading aquatic environmental quality. This study aimed to evaluate the impacts of dissolved organic waste derived from artificial feed on water quality in culture ponds managed by Pokdakan Sugih Makmur, Mentaos Subdistrict, South Kalimantan, Indonesia. Water quality assessment was conducted using physical, chemical, and biological parameters, including total organic matter, ammonia, total coliform, plankton, and macrozoobenthos. The results indicated that total organic matter exceeded permissible standards at all monitoring stations, while ammonia concentrations at the outlet station surpassed the threshold of 0.5 mg/L. Elevated total coliform levels were recorded at several stations, indicating significant microbiological contamination. Biological indicators showed low to moderate diversity

with dominance of tolerant species, reflecting ecological stress conditions. Based on these findings, the implementation of a Strength–Threat (ST) management strategy is recommended, emphasizing the use of bioindicators as an early warning system, enhancement of farmers' capacity, development of environmentally friendly technologies, and strengthening multi-stakeholder collaboration. This study highlights the importance of integrated environmental management to ensure sustainable tilapia aquaculture practices.

Keywords: Artificial feed; Dissolved organic waste; Nile tilapia; Water quality; Aquaculture management

INTRODUCTION

Nile tilapia (*Oreochromis niloticus*) is one of the most widely cultivated freshwater fish species in Indonesia due to its high adaptability, rapid growth rate, and strong market demand [1]. Indonesia is the world's second-largest tilapia producer, contributing

approximately 25.89% to global production [2]. The enormous production of tilapia in Indonesia necessitates a large amount of commercial feed [3]. Artificial feed is commonly used in intensive aquaculture systems to enhance productivity and production efficiency.

Excessive use of artificial feed may generate dissolved organic waste originating from uneaten feed and fish metabolic by-products [4]. If not properly managed, this waste can increase nutrient concentrations, reduce dissolved oxygen, and disrupt aquatic ecosystems. Excessive feeding generates dissolved organic waste from uneaten feed and fish metabolic by-products [5]. Intensive aquaculture practices are closely associated with increased feed input, which may lead to inefficient nutrient utilization and accumulation of organic residues in culture systems. Several studies have demonstrated that only a portion of feed nutrients is converted into fish biomass, while the remainder is released into the aquatic environment in dissolved or particulate forms [6]. Dissolved organic waste contributes to elevated concentrations of nitrogenous compounds such as ammonia, nitrite, and nitrate, which may disrupt ecological balance and reduce water quality. Despite numerous studies on feed efficiency and production performance, limited research has specifically examined the integrated physicochemical and biological responses of pond ecosystems to dissolved organic waste in small-scale farmer groups.

An integrated assessment combining chemical parameters (e.g., total organic matter, ammonia, dissolved oxygen), microbiological indicators (total coliform), and biological communities (plankton and macro zoobenthos) is essential to provide a comprehensive understanding of environmental impacts [7]. Biological indicators are particularly important because they reflect cumulative environmental stress over time rather than short-term fluctuations. Therefore, this study adopts a

multidisciplinary approach to evaluate environmental quality and formulate sustainable management strategies for tilapia culture ponds.

Pokdakan Sugih Makmur, located in Mentaos Subdistrict, Banjarbaru City, South Kalimantan, has practiced intensive tilapia culture using artificial feed. Although this approach improves production output, concerns have arisen regarding its environmental impacts on pond water quality. Previous studies have emphasized that organic waste accumulation in aquaculture systems may lead to eutrophication and microbiological pollution, posing risks to both aquatic organisms and the sustainability of aquaculture activities [8]. Therefore, this study aims to assess the water quality conditions of tilapia culture ponds at Pokdakan Sugih Makmur and to formulate appropriate environmental management strategies based on the findings.

MATERIALS & METHODS

Study Area

The study was conducted from March to April 2025 at Pokdakan Sugih Makmur, Mentaos Subdistrict, Banjarbaru City, South Kalimantan Province, Indonesia. The study area consists of approximately 30–40 earthen ponds operated under a traditional still-water system (Figure 1).

Sampling and Data Collection

Water sampling was carried out at seven monitoring stations representing inlet, culture, and outlet areas. The culture area consists of approximately 30–40 earthen ponds with an average pond size of ± 100 –200 m² per pond. Sampling stations were designated as follows: Station 1 (main water inlet), Stations 2–4 (active culture ponds), and Stations 5–7 (main outlet). Physical parameters measured included temperature, while chemical parameters comprised total organic matter, ammonia, pH, dissolved oxygen, nitrate, and nitrite. Biological parameters included plankton and

macrozoobenthos composition, as well as total coliform counts. Water samples were collected at a depth of approximately 30–50 cm below the surface using sterilized polyethylene bottles.

Plankton samples were collected using a plankton net (mesh size $\pm 25 \mu\text{m}$), while macrozoobenthos were collected using an Ekman grab sampler.

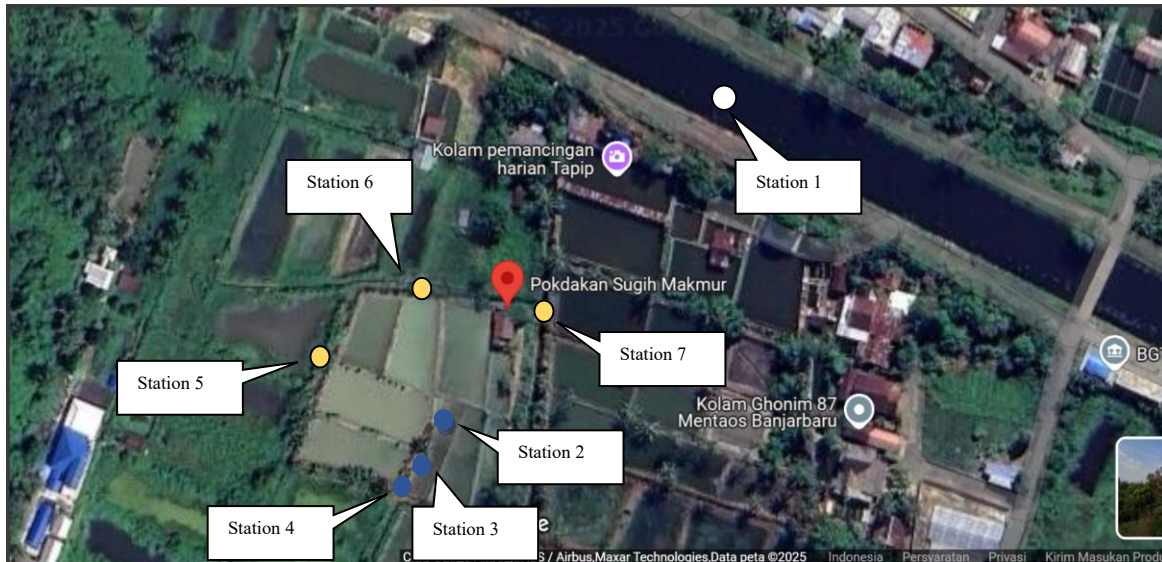


Figure 1. Research Sampling Stations at Pokdakan Sugih Makmur

Laboratory Analysis

Dissolved Organic Matter (Total Organic Matter/TOM) analysis was conducted using the permanganate titration method in accordance with national standard procedures (SNI 13-4717-1998 and SNI 13-4718-1998). Ammonia concentrations were determined using spectrophotometric methods, while total coliform analysis employed the Most Probable Number (MPN) technique. Dissolved oxygen and pH were measured in situ using a portable DO meter and pH meter, respectively. Plankton and macrozoobenthos samples were identified to the lowest possible taxonomic level, and ecological indices such as abundance, diversity (H'), and dominance were calculated.

Parameters

Chemical parameter data were analysed descriptively and compared with Government Regulation of the Republic of Indonesia No. 22 of 2021 [9]. Biological data were analyzed using the following ecological indices:

1. Abundance (individual/L): Total number of individual organisms per unit volume of water sampled.
2. Shannon-Wiener Diversity Index (H'), using the equation:

$$H' = \sum \frac{n_i}{N} \ln \frac{n_i}{N}$$

where p_i is the proportion of the i th species. Values $H' < 1$ indicate heavily disturbed conditions, $1 \leq H' \leq 3$ indicate moderate conditions, and $H' > 3$ indicate stable conditions.

3. Dominance Index (D), using the equation:

$$D = \sum \left(\frac{n_i}{N} \right)^2$$

where n_i is the number of individuals of species i and N is the total number of individuals. Values approaching 1 indicate dominance by one or few species.

Ecological interpretation followed the classification of water quality status based on diversity index values. SWOT analysis was conducted using weighted scoring to determine strategic positioning of management strategies.

Data Analysis

Water quality conditions were evaluated by comparing measured values with national water quality standards as regulated in Government Regulation of the Republic of Indonesia No. 22 of 2021 [9]. Ecological conditions were interpreted based on biological indices. A SWOT analysis was employed to formulate environmental management strategies by integrating

internal and external factors affecting aquaculture sustainability.

RESULT

Water Quality Characteristics

Table 1 presents the summary of water quality parameters measured at the seven monitoring stations in tilapia culture ponds at Pokdakan Sugih Makmur.

Table 1. Water Quality Parameters at Pokdakan Sugih Makmur Culture Ponds

Parameter	Unit	Quality Standard*	Range of Observed Values
Total Organic Matter (TOM)	mg/L	≤ standard	Exceeded at all stations
Ammonia	mg/L	≤ 0.5	0.03 – >0.5 (Station 7)
Dissolved Oxygen	mg/L	≥ 4	3.3 – 7.1
pH	-	6 – 9	6.2 – 7.0
Total Coliform	MPN/100 ml	≤ 10,000	780 – 92,000

*Based on Government Regulation of the Republic of Indonesia No. 22 of 2021.[9]

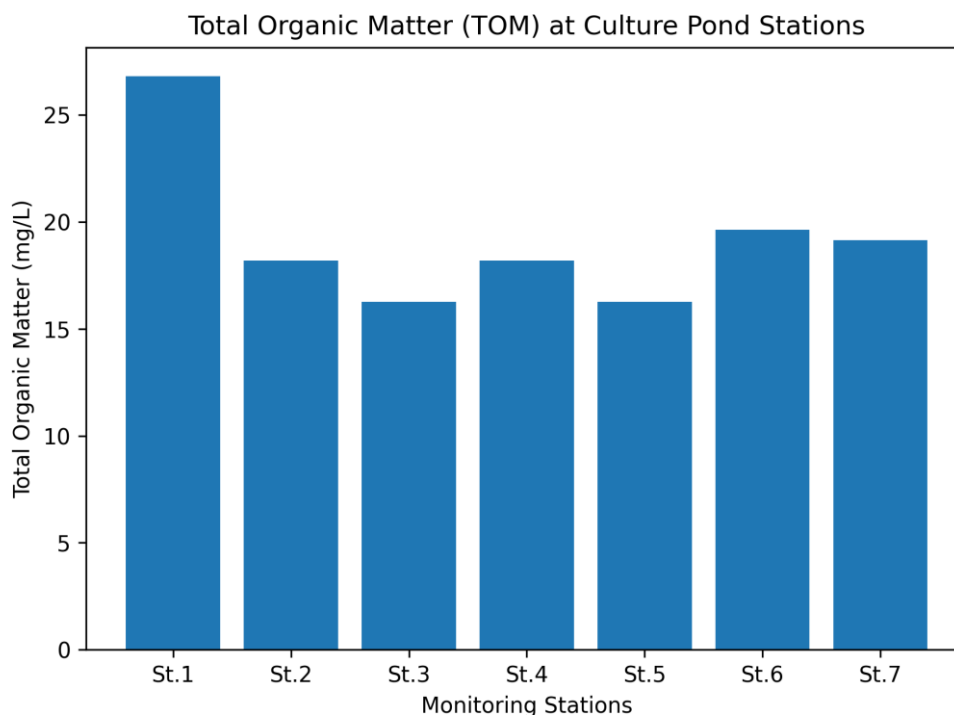


Figure 2. Total Organic Matter (TOM) Concentration at Monitoring Stations

Total organic matter concentrations exceeded permissible limits at all monitoring stations, demonstrating substantial accumulation of dissolved organic waste derived from uneaten artificial feed and fish metabolic residues. Ammonia concentrations were generally below the threshold value; however, Station

7 exhibited ammonia levels exceeding 0.5 mg/L, representing the outlet area where organic waste accumulates. Total coliform counts at Stations 1, 6, and 7 far exceeded the safe limit of 10,000 MPN/100 ml, indicating significant microbiological contamination.

Biological Indicators

Table 2. Plankton Community Structure in Tilapia Culture Ponds

Parameter	Value	Interpretation
Phytoplankton diversity (H')	Low–Moderate	Ecological stress due to nutrient enrichment
Zooplankton diversity (H')	Low–Moderate	Dominance of tolerant species
Dominant taxa	Pollution-tolerant groups	Indicative of organic loading

Table 3. Macrozoobenthos Community Structure in Tilapia Culture Ponds

Parameter	Value	Interpretation
Diversity index (H')	Low	Unstable benthic community
Dominant organisms	Tolerant taxa	Long-term organic accumulation
Ecological condition	Moderately–heavily disturbed	Organic matter deposition

Plankton community analysis showed low to moderate diversity indices (H') with dominance of pollution-tolerant taxa. Macrozoobenthos communities were characterized by low diversity and dominance of tolerant organisms.

Dominance index values approaching 1 indicated high dominance by single tolerant species at several stations.

SWOT Analysis Results

Table 4. SWOT Matrix for Environmental Management of Tilapia Culture Ponds at Pokdakan Sugih Makmur

Strengths (S) <ul style="list-style-type: none"> Experienced fish farmers Active farmer group institution Continuous water availability 	Weaknesses (W) <ul style="list-style-type: none"> Limited waste treatment technology High dependency on artificial feed Irregular water quality monitoring
Opportunities (O) <ul style="list-style-type: none"> Government support for sustainable aquaculture Availability of environmentally friendly technologies Collaboration opportunities with academic institutions 	Threats (T) <ul style="list-style-type: none"> Environmental pollution risks Stricter environmental regulations Declining water quality that may reduce aquaculture productivity

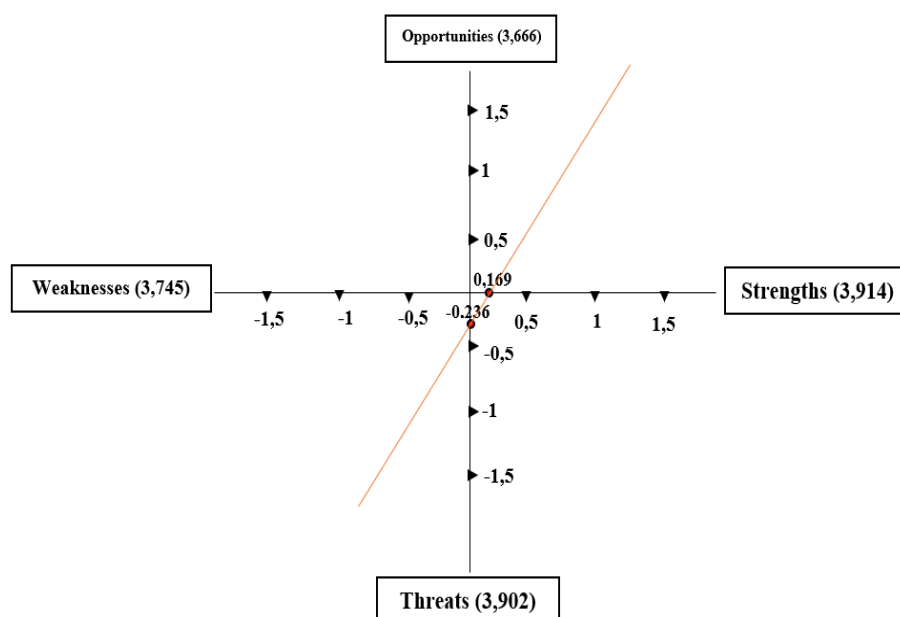


Figure 3. SWOT Quadrant Analysis Diagram

The SWOT analysis positioned the management strategy within the Strength–Threat (ST) quadrant, indicating that internal strengths should be utilized to mitigate external environmental threats.

DISCUSSION

Water Quality and Organic Loading

The consistently high TOM values across all stations indicate chronic organic loading within the pond system. This condition suggests that feed management practices may not yet be fully efficient [10]. Elevated organic matter promotes microbial decomposition, which increases oxygen demand and may explain the reduced dissolved oxygen values observed at certain stations [11]. These findings are consistent with previous studies demonstrating that organic waste accumulation in pond aquaculture promotes eutrophic conditions [8]. Ammonia accumulation at Station 7 (outlet) reflects downstream concentration of metabolic waste and uneaten feed residues. Ammonia toxicity risk increases under higher pH and temperature conditions, potentially affecting fish physiological performance [4]. Although ammonia levels at most stations were below the threshold, the exceedance at the outlet indicates insufficient waste dilution or treatment [12].

High coliform levels are closely associated with elevated organic matter and insufficient pond sanitation, posing risks to fish health and environmental sustainability [13]. Total coliform counts at Stations 1, 6, and 7 far exceeded the safe limit of 10,000 MPN/100 ml, indicating significant microbiological contamination that requires immediate management intervention [14].

Biological Community Response

The dominance of pollution-tolerant plankton taxa corresponds with elevated nutrient concentrations, confirming eutrophic tendencies. This plankton structure is commonly associated with eutrophic conditions in intensive

aquaculture systems [7]. Low macrozoobenthos diversity further indicates long-term organic sediment accumulation. Because macrozoobenthos are relatively sedentary, their community composition reflects long-term environmental conditions rather than short-term fluctuations [15].

These findings demonstrate a strong correlation between chemical parameters (TOM and ammonia) and biological responses, reinforcing the importance of bioindicators in aquaculture environmental monitoring [16]. The low diversity indices and high dominance of tolerant species serve as reliable indicators of organic stress conditions within the culture system [17].

Environmental Management Implications

The SWOT matrix positions the environmental management strategy in the Strength–Threat (ST) quadrant. This indicates that internal strengths, particularly institutional organization and farmer experience, should be leveraged to mitigate environmental threats such as regulatory tightening and declining water quality. Recommended strategies include: (1) application of plankton and macrozoobenthos as bioindicators for early detection of water quality degradation; (2) enhancement of farmers' technical capacity through training programs; (3) gradual adoption of eco-friendly waste management technologies; and (4) strengthening multi-stakeholder collaboration involving government agencies, academic institutions, and fish farmers [18].

Study Limitations and Future Research

This study was limited to a cross-sectional assessment within one culture cycle. Seasonal variation and long-term monitoring were not evaluated. Future research should incorporate temporal monitoring, sediment nutrient flux analysis, and feed efficiency optimization to develop more precise environmental load models.

CONCLUSION

The findings confirm that intensive artificial feed use significantly contributes to dissolved organic waste accumulation, resulting in measurable degradation of water quality parameters and ecological imbalance. Elevated total organic matter and microbiological contamination indicate increasing environmental pressure at all monitoring stations. Biological communities, including plankton and macrozoobenthos, reflected ecological stress conditions consistent with organic loading. Implementation of an ST-based management strategy emphasizing bioindicator monitoring, improved feed efficiency, and environmentally friendly technology adoption is necessary to ensure sustainable tilapia aquaculture at Pokdakan Sugih Makmur.

Declaration by Authors

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