Jurnal Info Kesehatan
Vol. 24, No. 1, March 2026, pp. 25-32
P-ISSN 0216-504X, E-ISSN 2620-536X
DOI: 10.31965/infokes.Vol24.Iss1.2313
Journal homepage: https://jurnal.poltekkeskupang.ac.id/index.php/infokes

RESEARCH Open Access

Synergistic Impacts of Water Hyacinth Bloom and Organic Pollution on Water Quality and Public Health Risk

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Received: 25 December 2025 Revised: 10 February 2026 Accepted: 20 March 2026

Abstract

Multifunctional tropical reservoirs face increasing threats from water quality degradation due to anthropogenic activities, posing significant risks to both the ecosystem and public health. This study evaluates the synergistic impacts of water hyacinth (Eichhornia crassipes) bloom and organic pollution on Cengklik Reservoir. It assessed the combined effect of these factors on oxygen dynamics and inferred the potential risks to human health for communities reliant on the reservoir. The research utilized historical data (2020-2024) for Biochemical Oxygen Demand (BOD) and Dissolved Oxygen (DO) from the official BBWS Surakarta website. Standard test methods (SNI 6989.72.2009 for BOD and APHA 2017 for DO) were used to ensure data quality. This study indicates a synergistic interaction between organic pollution and water hyacinth proliferation that contributes to water quality degradation and conditions favorable for pathogen and toxin occurrence. A temporal trend analysis and a comparison with national water quality standards were performed. The analysis revealed a significant increase in average BOD concentrations (4.3-7.9 mg/L) and a decrease in average DO (3.78 mg/L) throughout the study period. These values exceeded the Class II water quality standard for BOD (3 mg/L) and did not comply with the DO standard (>4 mg/L) as per PP RI No. 22 of 2021. Linier regression= 0.820 (Not statistically significant. Simultaneously, BOD does not have a significant effect on DO. This indicates that the BOD variable is not an effective predictor of the DO variable). These findings indicate a high organic load and widespread oxygen depletion. This highlights the urgent need for an integrated management strategy to protect the reservoir's ecological sustainability and the health of the surrounding community.

Keywords: Cengklik Reservoir, Organic Pollution, Oxygen Dynamics, Public Health, Water Hyacinth.

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1. INTRODUCTION

The reservoir plays a crucial role as a multifunctional water resource. It is a key pillar supporting agricultural irrigation activities in the surrounding area and serves as a source of raw water for domestic and industrial needs (Elmahdi, 2024). It also contributes to the tourism and fisheries sectors, making it a vital ecological and economic asset for the local communities surrounding the reservoir (Maharani et al., 2025). Increased anthropogenic activities around the reservoir have significantly triggered water quality degradation (Akhtar et al., 2021). The main problem is massive organic pollution exceeding regulatory limits, which exacerbates water hyacinth blooms, degrades water quality, and increases public health risks. This organic pollution stems, in part, from fish farming activities using floating net cages (Gao & Dong, 2023). Leftover fish feed and fish waste (feces) that accumulate at the bottom of the water are the main sources of organic pollutants. These organic pollutants increase the pollution load BOD (Biochemical Oxygen Demand) and COD (Chemical Oxygen Demand) and reduce dissolved oxygen (DO) levels in the water (Kurniati et al., 2021).

There are many reservoirs exacerbated by wastes in Indonesia. One was found by previous research in the Cengklik Reservoir where is also exacerbated by the influx of various other types of waste (Krisnawati et al., 2020). Culinary waste from food stalls along the reservoir's edge flows directly into the water, and residential areas surrounding the reservoir also contribute to an increase in organic matter (Bbosa et al., 2024). Agricultural activities along the reservoir's edge and in the catchment area cause pesticide residues to enter the reservoir's water body through rainwater runoff. This can pose a threat to aquatic life and human health (Chai et al., 2023).

The accumulation of organic pollutants and nutrients (nitrate and phosphate) from these anthropogenic sources has triggered a severe eutrophication phenomenon (Tiwari & Pal, 2022). This condition directly causes the explosive and uncontrolled growth of water hyacinth (Eichhornia crassipes). Massive water hyacinths cover the reservoir's surface, blocking sunlight penetration and oxygen exchange which limit the oxygen to the organisms under the water (Yan et al., 2017). Therefore, the problem in the Cengklik Reservoir is not just a single source of pollution but rather a synergistic interaction of various sources that requires urgent attention.

Numerous previous studies have documented the impacts of organic pollution and eutrophication in tropical reservoirs, including the Cengklik reservoir. This research has clearly identified fish farming activities using floating net cages (KJA/Keramba Jaring Apung) as the primary source of organic pollution. This is indicated by increased BOD and COD levels. On the other hand, the problem of water hyacinth proliferation/blooming has also been widely studied as a serious threat that hinders light penetration and oxygen exchange in the water, thus disrupting aquatic ecosystems (Wisnu et al., 2019). However, although these two problems often occur simultaneously in many reservoirs in Indonesia, the existing literature still has gaps. Most existing studies examine organic pollution and water hyacinth proliferation in isolation, which limits understanding of the feedback mechanisms through which organic enrichment accelerates hyacinth growth and, in turn, further degrades water quality. An integrated assessment is therefore essential to capture these synergistic interactions and to more accurately evaluate their combined impacts on aquatic ecosystems and public health, which are often underestimated in single-factor analyses.

Organic pollution from floating net cages (KJA) not only causes water quality degradation but also directly triggers explosive growth (blooming) of water hyacinth due to an excessive supply of nutrients. Massive water hyacinth blooms exacerbate the anoxic (oxygen-deficient) conditions already present due to organic pollution. Therefore, organic pollution and water hyacinth synergistically accelerate reservoir degradation. Therefore, this research offers important new insights for more effective and integrated environmental management strategies. This study aimed to analyze historical BOD and DO data to evaluate organic pollution trends, and the impact of water hyacinth, showing how both factors synergistically affect water quality and increase public health risks.

2. RESEARCH METHOD

This study employed secondary water quality data obtained from the Surakarta River Basin Agency (Balai Besar Wilayah Sungai/BBWS Bengawan Solo). The dataset represents water quality conditions in the Cengklik Reservoir over a five-year period (2020–2024). The use of secondary data allows for the evaluation of long-term trends and relationships in water quality parameters. The link of dataset can follow link: https://hidrologi.bbws-bsolo.net/kualitasair.

Sampling was conducted at regular intervals following the agency's standard monitoring protocol, ensuring temporal consistency across the study period. The dataset represents surface water conditions at fixed monitoring locations that are routinely used for reservoir water quality assessment. As this study relies on an official monitoring database, detailed information on station coordinates, sampling depth, and field procedures follows the institutional guidelines established by BBWS Bengawan Solo.

The parameters analyzed in this study were Biochemical Oxygen Demand (BOD) and Dissolved Oxygen (DO). These parameters were selected because they are widely recognized indicators of aquatic environmental quality, organic pollution, and ecosystem health. BOD reflects the amount of oxygen required by microorganisms to decompose organic matter in water, while DO represents the availability of oxygen necessary to sustain aquatic organisms. The interaction between BOD and DO plays a critical role in determining the ecological condition of freshwater systems.

Prior to analysis, the dataset was screened for completeness and consistency. Observations with missing values or clearly anomalous measurements were excluded from the analysis to minimize bias. Because the data were generated through standardized laboratory and field procedures implemented by a government authority, measurement uncertainty and quality assurance were assumed to be within acceptable regulatory limits. Nonetheless, the analysis focused on overall trends and relationships rather than point-specific values to reduce sensitivity to potential measurement errors.

To assess the relationship between organic pollution and oxygen availability, a linear regression analysis was conducted to examine the effect of BOD as the independent variable on DO as the dependent variable. Before running the test, the normality test was done to observe the distribution of the data. This analysis aimed to quantify the extent to which variations in organic load influence dissolved oxygen levels in the reservoir.

Furthermore, a Mann–Kendall trend test was applied to detect temporal trends in BOD and DO data over the study period. The Mann–Kendall test is a non-parametric statistical method that is suitable for environmental datasets that are often non-normally distributed and exhibit fluctuations. This test was used to validate observed trends in water quality parameters and to identify significant increasing or decreasing patterns over time.

In addition to quantitative analysis, this study incorporated a qualitative approach to support the discussion and conclusions. Qualitative data were obtained through the review of official reports and media news articles documenting environmental conditions in the Cengklik Reservoir. Particular attention was given to reports describing the proliferation of water hyacinth (Eichhornia crassipes) and occurrences of upwelling events, which have been associated with mass fish mortality. This qualitative analysis provided contextual information linking water quality dynamics with observed ecological disturbances in the reservoir.

3. RESULTS AND DISCUSSION

Based on Table 1, it can be seen that the average BOD value in the last 5 years (2020-2024) shows a trend above the quality standard value for all (> 3 mg/L). The highest average BOD value occurred in 2020 at 7.9 mg/L. In 2024, the highest BOD value was 25.2 mg/L. Conversely, the DO parameter in the last 3 years (2020-2023) showed low values (below the recommended value of > 4 mg/L). The average DO in 2023-2024 was also relatively low at only 4.2 and 4.5 mg/L (at the recommended limit of > 4 mg/L). The minimum DO value reached 0.4 mg/L in 2020; this is in contrast to the high average BOD value in 2020, namely 7.9 mg/L. This data indicates that the dissolved oxygen conditions in the reservoir are getting worse.

Table 1. Description of Cengklik Reservoir Water Quality Parameter Data BOD **and DO**.

Year	Rate-BOD Rate (mg/L)	Class II Quality Standard	Max BOD (mg/L)	Min BOD (mg/L)	Average DO (mg/L)	Class II Quality Standard	Max DO (mg/L)	Min DO (mg/L)
2020	7.9	3 mg/L	14.8	4.2	3.1	≥4mg/L	5.9	0.4
2021	5.6	3 mg/L	13.3	2.9	3.9	≥4mg/L	8.4	1.3
2022	4.2	3 mg/L	11.6	1.5	3.1	≥4mg/L	6.4	0.8
2023	3.4	3 mg/L	11.1	1.7	4.2	≥4mg/L	6.6	1.8
2024	6.2	3 mg/L	25.2	1.9	4.5	≥4mg/L	6.2	2.1

Based on Table 2 above, it can be concluded that the results of the simple linear regression test, the p-value = 0.082. Because the p-value > 0.05, this regression model is not statistically significant. Simultaneously, BOD does not have a significant effect on DO. This indicates that the BOD variable is not an effective predictor of the DO variable in this data.

Table 2. Statistical Test Results of the Effect of BOD on DO.

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.192	1	.192	.052	.820[b]
	Residual	212.732	58	3.668		
	Total	212.924	59			

Based on the data from 2020 to 2024, BOD values in the Cengklik Reservoir showed temporal fluctuations but consistently exceeded the recommended water quality standard (> 3 mg/L). The highest BOD concentration was recorded in 2024 (25.2 mg/L), while the lowest value occurred in 2022 (1.5 mg/L). In contrast, DO concentrations remained generally low throughout the study period, with average values below the recommended standard (< 4 mg/L). In 2020, elevated BOD levels (7.9 mg/L) coincided with lower DO concentrations (3.1 mg/L); however, this observation represents a single-year pattern and does not imply a statistically significant temporal trend.

Elevated BOD and reduced DO levels are observed in the reservoir and are descriptively associated with anthropogenic activities such as floating net cage (KJA) aquaculture, untreated domestic wastewater, culinary industry effluents, and agricultural runoff; however, formal trend analysis indicates that these patterns do not constitute statistically significant temporal trends. Organic inputs from uneaten feed and fish excreta increase microbial decomposition, intensifying oxygen demand and leading to lower DO levels, which may threaten aquatic organisms (Nathanailides et al., 2023).

Waste resulting from anthropogenic activities of communities around the reservoir, apart from floating net cages, includes domestic and industrial waste (culinary industry, food stalls) on the edge of the reservoir. Untreated waste from households and industries will add organic matter to the water, causing an increase in BOD and a decrease in DO (dissolved oxygen). Meanwhile, agricultural waste on the edge of the reservoir that uses fertilizers and pesticides can cause runoff of nutrients and organic matter into the reservoir waters. This will increase the organic load and reduce water quality (Nathanailides et al., 2023; Wisnu et al., 2019). Other anthropogenic activities carried out by communities around the reservoir produce plastic and organic waste that is dumped directly into the reservoir waters. This can also increase the load of organic matter into the water and deplete dissolved oxygen (DO) in the water so that the DO content decreases (Kurniati et al., 2021; Brebu, 2020).

The increasing organic pollution load, as indicated by the BOD trend in the Cengklik Reservoir, indicates that the reservoir is experiencing eutrophication. This condition is the main trigger for the massive growth of water hyacinth (Kurniawan, Khasanah, et al., 2022). Organic pollution from leftover feed and floating net cage (KJA) waste releases large amounts of nutrients, especially nitrate and phosphate, into the water (Kurniawan, Kasanah, & Jayatri, 2022). Excess nutrients act as fertilizer for the water hyacinth, causing it to grow rapidly and uncontrollably (bloom) (Asmaranto & Suryono, 2017). This organic pollution and water hyacinth bloom cause reservoir degradation. Water hyacinth covering the water surface inhibits the entry of oxygen from the air into the water and hinders photosynthesis, which would otherwise produce oxygen. The water hyacinth layer that blocks the penetration of sunlight into the water pond results in algae and phytoplankton below being unable to photosynthesize, which is the main process of producing oxygen in the water (Correa-Mejía & Garcés-Gómez, 2025). The synergy of organic pollution and water hyacinth bloom accelerates the degradation of the reservoir environment, coupled with oxygen consumption by microorganisms to decompose organic pollution, causing anoxia (lack of oxygen). This phenomenon causes mass fish deaths and disrupts the ecological function of the reservoir (Krisnawati et al., 2020; May et al., 2020).

The degradation of reservoir water quality, characterized by low dissolved oxygen (DO) and high biochemical oxygen demand (BOD), not only disrupts aquatic ecosystems but also poses significant risks to public health (Zewdu et al., 2024). ypoxic conditions resulting from organic pollution and extensive water hyacinth cover create favorable environments for anaerobic pathogenic bacteria such as Clostridium botulinum and Aeromonas hydrophila (Demelash Abera & Alefe Adimas, 2024). These pathogens may cause disease through contaminated water or the consumption of infected fish, raising serious food safety concerns (Cortés-Sánchez et al., 2021). Furthermore, eutrophication driven by organic pollution stimulates the growth of harmful algae, particularly cyanobacteria (blue-green algae) (Al Haffar et al., 2024). Cyanobacteria produce neurotoxic and hepatotoxic compounds that may cause health effects ranging from skin irritation to liver damage through direct exposure during activities such as swimming or fishing (Morris et al., 2025).

In addition to water quality degradation, the massive proliferation of water hyacinth indirectly exacerbates public health risks by degrading environmental sanitation and supporting disease vectors. Dense mats of water hyacinth provide ideal breeding and sheltering habitats for mosquitoes, particularly Aedes aegypti, the primary vector of dengue fever (Honlah et al., 2019; Mokoena, 2024). This condition is consistent with the high incidence of dengue fever reported in Ngemplak District, Boyolali Regency, where 296 cases were recorded in 2023. The extensive coverage of water hyacinth in the Cengklik Reservoir may therefore contribute to an increased risk of dengue transmission. Moreover, decaying water hyacinth releases organic matter into the water, further deteriorating water quality and environmental sanitation, which can place additional pressure on public health systems in surrounding communities..

The phenomenon of mass fish deaths due to upwelling in the Cengklik Reservoir causes fish to rot and deteriorates water quality. It also serves as a potential source of disease transmission and other health problems. Therefore, the degradation of the Cengklik Reservoir's water quality cannot be viewed solely as an environmental problem but as a complex and urgent public health issue (Ariyani et al., 2024). The results of a simple linear regression test indicate that the independent variable, BOD (Biochemical Oxygen Demand), has no significant effect on the dependent variable, DO (Dissolved Oxygen) (p-value 0.820). In principle, environmental health and water quality sciences demonstrate an inverse (negative) correlation between BOD and DO concentrations in a water body. An increase in organic load (measured as BOD) should trigger increased microbial activity to degrade the organic matter. This process consumes dissolved oxygen (DO), which ideally would lead to a decrease in DO in the water body. However, the results of this study contradict this theoretical principle, as increases or variations in BOD at the sampling points did not significantly trigger a decrease in DO concentrations. This finding warrants further exploration of the physical and hydraulic factors at the study site.

The non-significant effect of BOD on DO is likely influenced by the physical and hydraulic characteristics of the sampling location, which exert a stronger control on DO than oxygen consumption from BOD. High water discharge and rapid flow promote dilution, reducing BOD concentrations before they can significantly affect DO levels. In addition, turbulent and shallow flow conditions enhance reaeration, allowing oxygen to be replenished from the atmosphere faster than it is consumed by microbial decomposition. Consequently, DO remains relatively stable despite variations in BOD. Other factors such as water temperature, total suspended solids (TSS), and short retention time may also play a more dominant role in controlling DO dynamics at the study site.

4. CONCLUSION

This study contributes to the existing literature by providing an integrated assessment of organic pollution and oxygen dynamics in Cengklik Reservoir using long-term secondary monitoring data, combined with qualitative contextual evidence. While theoretical frameworks predict a negative relationship between biochemical oxygen demand (BOD) and dissolved oxygen (DO), the findings demonstrate that, at this site, BOD was not a statistically significant limiting factor for DO concentrations over the study period. Instead, DO levels appear to be maintained by physical processes such as dilution and reaeration, as well as by other environmental drivers not captured in the present analysis. By explicitly contrasting descriptive patterns with formal trend and regression analyses, this study highlights the importance of avoiding overinterpretation of water quality indicators when evaluating ecosystem and public health risks.

Several limitations should be acknowledged. First, the analysis relied on secondary data from routine monitoring, which constrained control over sampling frequency, spatial resolution, and measurement depth. Second, the study focused on only two water quality parameters (BOD and DO), thereby excluding other potentially influential variables such as nutrient concentrations, temperature, hydrodynamics, and microbial indicators. Third, the qualitative component was based on document and media review rather than primary field observations, which may limit the precision of ecological attribution. Despite these limitations, the findings underscore the need for an integrated, data-driven adaptive management and policy framework for Cengklik Reservoir, including strengthened pollution source control, regulation of floating net cage aquaculture, and continuous public health information dissemination.

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