JPPIPA 11(11) (2025)

Jurnal Penelitian Pendidikan IPA

http://jppipa.unram.ac.id/index.php/jppipa/index

Analysis of the Impacts of Dam Construction on Water Quality and the Surrounding Ecosystem of the Pamukkulu Dam, Takalar Regency

Fajar N. Utomo[2], Syafrudin[1], Anik Sarminingsih[1*]

[1] Department of Environmental Engineering, Faculty of Engineering, Universitas Diponegoro, Semarang, 50275, Indonesia.
[2] Master of Enviromental Engineering, Universitas Diponegoro, Semarang, Indonesia 50275.

Received: September 01, 2025
Revised: October 12, 2025
Accepted: November 25, 2025
Published: November 30, 2025

Corresponding Author:
Anik Sarminingsih
aniksarminingsih@lecturer.undip.ac.id

DOI: 10.29303/jppipa.v11i11.13010

Abstract: Dam construction offers substantial benefits to society, including the raw water supply. However, such projects also exert significant impacts on water quality and the surrounding ecosystems. This study aims to examine changes in water quality and their subsequent effects on the local ecosystem, as well as to propose appropriate mitigation strategies. The methodology employed includes the measurement of physico-chemical water parameters and biodiversity surveys. A case study was conducted at the Pamukkulu Dam by comparing water quality conditions at two sites (the upstream and downstream) before and after construction. The findings reveal a deterioration in water quality attributable to sediment accumulation, eutrophication, and alterations to natural habitats and local biodiversity within one year following impoundment. Notably, BOD levels downstream increased from 1.07 mg/L to 6.18 mg/L, while COD levels rose from 7.04 mg/L to 105.68 mg/L. Ammonia concentrations downstream increased from <0.001 mg/L to 1.09 mg/L, and total coliform counts escalated from 11 MPN/100 mL to 2,800 MPN/100 mL. Furthermore, oil and fat levels downstream rose from <0.02 mg/L to 0.19 mg/L, and MBAS levels increased from <0.01 mg/L to 0.01 mg/L. This study concludes that dam construction significantly affects water quality and ecosystems, particularly within the reservoir and downstream river areas.

Keywords: Construction impact; Dam; Water quality

Introduction

A dam is defined as an artificial barrier (either an embankment or another type) designed to store water, either naturally or artificially, including its foundations, abutments, ancillary structures, and equipment (Kamus Istilah Bidang Pekerjaan Umum, 2009) Dams represent critical infrastructure whose risk levels require continuous assessment and management (Fluixá-Sanmartín et al., 2019). The Pamukkulu Dam in South Sulawesi provides strategic benefits, including irrigation water supply, raw water provision, hydroelectric power generation, and flood control. Nevertheless, dam construction can induce substantial environmental changes, particularly in water quality and surrounding ecosystems. Several studies have shown that dam construction can alter the composition of macroinvertebrates that serve as bioindicators of water quality in affected areas, as revealed by Vasco et al. (2021) and Ilmi et al. (2023). In Vasco et al.'s study, it was found that the presence of dams caused changes in macroinvertebrate communities that had implications for water quality assessment, including EPT values that indicated changes in water quality at different locations before and after dam construction. This is consistent with the findings of Ilmi et al., who observed the

How to Cite:
Utomo, F. N., Syafrudin, & Sarminingsih, A. (2025). Analysis of the Impacts of Dam Construction on Water Quality and the Surrounding Ecosystem of the Pamukkulu Dam, Takalar Regency. *Jurnal Penelitian Pendidikan IPA*, *11*(11), 985–995. https://doi.org/10.29303/jppipa.v11i11.13010

distribution of macroinvertebrate functional groups in rivers connected to dams, indicating changes in community structure due to the impact of dams (Ilmi et al., 2023; Maroneze et al., 2014).This finding is supported by Rahmadi et al., who emphasize the importance of environmental management to maintain river water quality, especially in Aceh province, where dam construction and other industrial activities contribute to increased water pollution (Rahmadi et al., 2023).

Rivers serve not only as aquatic ecosystems but also as vital resources supporting local livelihoods. Various anthropogenic activities, such as washing, fishing, industrial processes, and agriculture, can degrade water quality (Yusuf et al., 2021). Iqtashada and Febrita also revealed similar findings, showing how land use and waste discharged into rivers reduce water quality, especially in the Cisadane River, which is vital to the people of Bogor (Iqtashada & Febrita, 2023). In addition to anthropogenic pressures, hydrological conditions also significantly influence river water quality. Seasonal fluctuations in flow rates affect dissolved oxygen concentrations, with lower flows typically reducing oxygen levels and higher flows enhancing aeration (Sari & Wijaya, 2019). Additionally, dam-induced alterations in flow regimes, such as stagnation, can modify water physical-chemical parameters and disrupt aquatic ecosystems. This is in line with Caissie's findings, which explain that river temperatures disrupted by dams can affect the distribution of aquatic species and water quality (Caissie, 2006).

In the case of the Pamukkulu Dam, the relationship between human activities and water quality changes is evident both before and after its construction. Before construction, upstream water quality remained relatively undisturbed, whereas downstream areas were already impacted by agriculture and settlement. Following the dam's commissioning, inundation of the upstream reservoir area transformed the ecosystem, potentially leading to eutrophication and oxygen depletion due to increased organic matter accumulation and longer water residence times. These dynamics underscore the significant influence of both natural and anthropogenic factors on water quality. A study by Hanjaniamin et al. documented the effect of water storage in reservoirs on dissolved oxygen concentrations and eutrophication assessment in Yamchi Reservoir in Iran. This study showed that certain strategies, such as reducing water retention time and preventing agricultural drainage, can help manage ongoing eutrophication (Hanjaniamin et al., 2023). Nutrient discharge, especially phosphorus and nitrogen, into reservoirs due to agricultural activities and urbanization is also an important factor in water quality degradation. Research by Zeng et al. explains that spatial variations in nutrient status in lakes and reservoirs in the Yangtze River basin are significantly influenced by natural factors and human activities (Zeng et al., 2025).

This study, therefore, aims to evaluate changes in water quality at upstream and downstream sites before and after the construction of the Pamukkulu Dam, analyze the implications of these changes for the surrounding ecosystem, and assess compliance with Class IV water quality standards for irrigation (Goverment Regulation no. 22. 2021) to determine the suitability of reservoir water for its designated uses. The findings are expected to inform strategies for sustainable water quality and ecosystem management in dam-related environments. Pollution is something that humans constantly face today, especially water pollution. Water pollution can come from garbage, liquid waste, and other pollutants such as fertilizers, pesticides, the use of detergents as cleaning agents, the use of packaging materials that produce a lot of waste, and so on (Khairuddin et al., 2019; Cadas, 2025).

The novelty of this study lies in its integrated assessment of pre- and post-construction water quality across both upstream and downstream sites of the Pamukkulu Dam—a perspective rarely addressed in dam-related studies in Indonesia. Most previous research has focused solely on post-construction impacts or single-site evaluations, overlooking the transitional dynamics that occur during dam establishment. By comparing spatiotemporal water quality changes relative to national irrigation water standards (Class IV, Government Regulation No. 22 of 2021), this study provides a comprehensive understanding of how dam-induced environmental alterations affect water usability and ecosystem integrity.

This research is crucial because the Pamukkulu Dam is a newly commissioned strategic project expected to serve multiple purposes—irrigation, water supply, and power generation—within a region that relies heavily on agricultural productivity. Understanding how water quality evolves during and after dam construction is essential for ensuring sustainable reservoir operation, preventing ecological degradation, and maintaining water suitability for its intended uses. The findings will offer practical guidance for policymakers and environmental managers in implementing adaptive water quality management strategies for multipurpose dams in tropical catchments.

Method

This study was conducted at the Pamukkulu Dam, located approximately 50 km from Makassar City, South Sulawesi Province, specifically in Kale Ko'mara Village, North Polombangkeng District, Takalar Regency. The Pamukkulu Irrigation Area (DI) extends across the Cakura and Polombangkeng Selatan districts.

Geographically, the dam is situated at approximately 5°24′03″ S and 119°35′33″ E. Geomorphologically, the site is characterized by rolling hills with elevations ranging from 25 to 100 m above sea level. The local climate is influenced by distinct rainy and dry seasons, with average monthly rainfall ranging from 11.7 to 653.6 mm; the rainy season typically occurs from November to May (Takalar Regency by Number, 2024).

Figure 1. Pamukkulu Dam

Water quality measurements were conducted at two main locations: upstream of the river and downstream of the dam. The upstream sampling point was located approximately 5.9 km upstream (5025′34.55″ S – 119038′20.15″ E) of the reservoir, representing the natural river condition before entering the impoundment area and was unaffected by construction or inundation. The downstream point was set approximately 1.5 km downstream (5023′39.14″ S – 119034′45.42″ E) of the dam, capturing water conditions as it exits the reservoir through the spillway and reflecting the direct influence of flow regime alterations due to the dam.

This design allows the upstream data to serve as a baseline control, while downstream measurements reflect the cumulative impacts of dam construction, reservoir flooding, backwater effects, and modified flow patterns. The study by Pinayungan et al. highlights the importance of water quality and composition data at two points upstream and downstream to provide a complete picture of the cumulative impact of dam construction and the effects of altered flow patterns (Pinayungan et al., 2025). Figure 1 illustrates the upstream and downstream sampling locations at the Pamukkulu Dam. Water sampling was conducted across two periods representing different hydrological conditions: the rainy season and the dry season. Each period included one pre-construction sampling event and two post-construction events. Specifically: (a) Pre-construction: February 2016 (rainy season), representing baseline river water quality conditions prior to dam influence. (b) Post-construction: July 2024 (dry season) and February 2025 (rainy season), representing water quality conditions following reservoir impoundment.

Monthly rainfall data were obtained from the Malolo Rainfall Station (5°23′26.0″ S, 119°32′56.6″ E), located approximately 7 km from the dam site, to ensure accurate characterization of seasonal conditions during the sampling periods (Table 1).

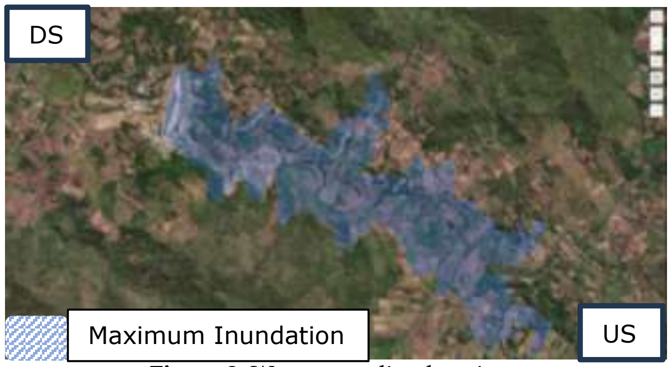

Figure 2. Water sampling locations
(Source: https://tanahair.indonesia.go.id/map/)

Table 1. Water Sampling Locations

Month	Season	Note
February 2016	Rainy season	Pre- construction
July 2024	Dry season	Post- construction
February 2025	Rainy season	Post construction

The research flowchart can be seen in the following figure.

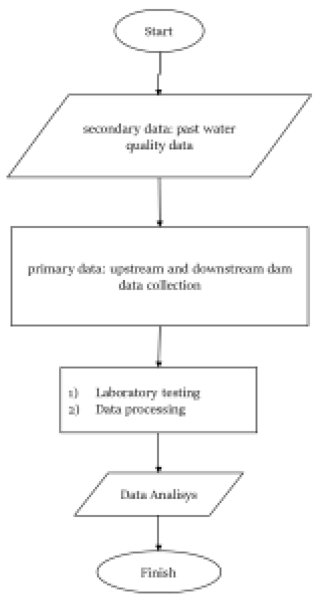

Figure 3. Research flowchart

Results and Discussion

TSS and TDS

Total Suspended Solids (TSS) represent the concentration of suspended particles in water, which may consist of soil particles (such as mud or fine sand) and microscopic organisms. Sako and McManamay describe that the development of impervious surface areas increases runoff, which contributes to erosion and pollution problems due to increased TSS flow (Sako & McManamay, 2023). These findings emphasize that changes in land use can exacerbate soil erosion and result in sediment accumulation in water bodies. Measuring TSS is essential for quantifying the load of solid particles (expressed in mg/L) entering the reservoir. Before the construction of the Pamukkulu Dam, TSS levels reached 97 mg/L downstream, but post-construction monitoring recorded a substantial decrease to 15 mg/L in July 2024 and 4 mg/L in February 2025. This marked reduction highlights the reservoir's effective sediment-trapping capacity, where sediments settle at the bottom, leading to clearer downstream water. Pujiastuti et al. observed that sedimentation patterns in Jatibarang Reservoir resulted in reduced volumes of suspended sediments reaching downstream areas, indicating that such reservoirs can act as filtration systems for receiving waters (Pujiastuti et al., 2023).

Conversely, upstream TSS levels increased slightly from 8 mg/L to 27 mg/L during the 2025 rainy season, likely due to intensified surface runoff and bank erosion. Similar findings were observed by Meiwinda and Lucyana, who reported sediment reductions in impounded areas where flow velocity decreased significantly (Meiwinda et al., 2022).

Total Dissolved Solids (TDS) represent dissolved minerals and salts. The concentration decreased from 169 mg/L (pre-construction) to 79.2 mg/L downstream (post-construction). This reduction indicates improved water clarity and minimal additional dissolved load. The absence of significant TDS increases between upstream and downstream sites implies that the reservoir effectively buffers dissolved substances through dilution and precipitation processes. Morsy et al. indicate that environmental alterations caused by dam constructions affect suspended sediment dynamics and turbidity levels, reinforcing the notion that significant upstream and downstream disparity in TDS is not typically observed due to these mediating factors (Morsy et al., 2021).

The complete TSS and TDS measurement results are presented in Table 2. Overall, the trends indicate that post-construction water conditions are relatively clearer and lower in solid content, particularly during the dry season, owing to the reservoir's role as an effective sediment trap.

Table 2. Changes in TDS and TSS Values

Parameter	Location	Unit	Pre- construction		Post- construction
			February 2016	July 2024	February 2025
TDS	US	mg/l	96	64	75.6
	DS	mg/l	169	172	79.2
TSS	US	mg/l	17	8	27
	DS	mg/l	97	15	4

Table 2 indicates that in February 2025 (approximately one year after dam operation commenced), TSS levels upstream increased slightly to 27 mg/L compared to 8 mg/L in July 2024. This increase is likely attributable to heightened rainfall during February (the rainy season), which intensifies soil erosion and introduces additional suspended solids into the upstream flow. Nevertheless, downstream TSS remained very low at 4 mg/L in February 2025, indicating that sediments mobilized during the rainy season were effectively retained within the reservoir and did not pass downstream. Downstream TDS exhibited a slight increase in July 2024 (172 mg/L), possibly due to higher concentrations of dissolved salts during the dry season, but subsequently decreased to 79.2 mg/L in February 2025 as a result of dilution from increased rainfall.

Overall, the impact of dam construction on TSS and TDS appears positive in terms of reducing the solid load in downstream waters, thereby resulting in clearer water discharge. This trend aligns with the findings of Meiwinda and Lucyana (2022), who reported reductions in suspended sediment concentrations in river segments where flow velocity decreased (such as in floodplain or impounded areas) prior to re-entering downstream channels (Meiwinda et al., 2022).

BOD, COD, and DO

Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) are critical parameters for assessing the concentration of dissolved and suspended organic matter in water. BOD reflects the amount of dissolved oxygen required by microorganisms to biologically degrade organic matter, whereas COD indicates the total oxygen demand needed to chemically oxidize all organic substances in the sample (Atima, 2015). An increase in BOD and COD values generally signifies a higher load of organic pollutants, which can result in reduced dissolved oxygen (DO) levels and deteriorated water quality. Good quality water is a basic human need, just as air containing oxygen is (Khairuddin et al., 2016).

BOD and COD serve as primary indicators of organic pollution. Following impoundment, both parameters increased considerably, signifying enhanced organic matter decomposition. Upstream BOD increased from 1.12 mg/L to 2.58 mg/L, while downstream values rose sharply from 1.07 mg/L (pre-construction) to 6.18 mg/L in February 2025. COD showed a more dramatic rise—from 7.04 mg/L to 105.68 mg/L, far exceeding the Class III standard (50 mg/L) as regulated by Government Regulation (PP) No. 22 of 2021.

This substantial increase indicates the accumulation of organic pollutants within the reservoir, which are subsequently released downstream during water discharge events. Potential sources of these organic loads include the decomposition of biomass (e.g., vegetation and forest debris) inundated by the reservoir, residues of organic materials from construction activities, and runoff carrying organic matter from surrounding land during rainfall events. Similar findings were reported by research in Way Kuripan, Bandar Lampung, which also confirmed that the influx of organic matter from domestic waste contributed to the increase in BOD. Human activities such as kitchen waste disposal, washing, and toilet waste resulted in a significant increase in BOD parameters in the river, indicating that BOD_5 is a clear indicator of pollution (Bakri & Yushananta, 2023). Research by Igbinosa and Okoh also shows that domestic wastewater discharge in rural areas causes significant changes in the physicochemical quality of water, including an increase in BOD levels beyond the established threshold (Majed & Islam, 2022).

Dissolved Oxygen (DO) levels are intrinsically linked to BOD and COD dynamics. When organic loads are high, microbial respiration consumes greater amounts of oxygen, resulting in lower DO levels. In this study, upstream DO decreased from 6.42 mg/L (pre-construction) to 3.43 mg/L (February 2025), while downstream DO declined from 6.39 mg/L to 2.06 mg/L over the same period (see Table 3). The drastic reduction in downstream DO (~2 mg/L) indicates conditions of severe oxygen depletion, which can be detrimental to fish and other aerobic aquatic organisms. DO values below 3 mg/L are generally classified as heavily polluted for Class III river waters (Regulation No. 22 of 2021). Rajwa-Kuligiewicz et al. showed that increased biological activity, when combined with morphological characteristics of rivers such as the presence of pools, can cause hypoxic conditions, where DO levels can fall below 2 mg/L. This phenomenon often occurs when there is an imbalance in the biological processes of aquatic life due to various transport processes and the availability of dissolved substances and particles (Rajwa-Kuligiewicz et al., 2015). This shows how complex the interactions between organic load, pollution, and dissolved oxygen levels are, which affect the river ecosystem as a whole

This low DO is consistent with the elevated BOD and COD values observed. According to Novianta et al., the increase in BOD and COD values correlated with low DO values indicates that high organic loads in water greatly affect the amount of dissolved oxygen available for aquatic life. (Novianta et al., 2024).

Table 3. Changes in COD, BOD, and DO Values

Parameter	Location	Unit	Pre- construction		Post- construction
			February 2016	July 2024	February 2025
COD	US	mg/l	8.80	8.80	58.32
	DS	mg/l	7.04	6.50	105.68
BOD	US	mg/l	1.12	1.93	2.58
	DS	mg/l	1.07	4.10	6.18
DO	US	mg/l	6.42	12.60	3.43
	DS	mg/l	6.39	5.80	2.06

Ammonia, Nitrite, and Nitrate

Increases in nutrient concentrations, such as ammonia (NH_3/NH_4^+), nitrite (NO_2^-), and nitrate (NO_3^-), in reservoir water can occur due to the decomposition of organic matter and nutrient runoff from surrounding land. In this study, ammonia concentrations increased markedly following dam construction. Upstream ammonia levels increased from <0.001 mg/L (recorded as 0.001 mg/L in the table) to 0.67 mg/L in February 2025, while downstream levels rose from <0.001 mg/L to 1.09 mg/L. This downstream increase, reaching approximately 1 mg/L, is particularly notable.

The elevated ammonia concentrations are likely attributable to the decomposition of organic matter (e.g., leaves, grasses, tree branches, and animal remains) submerged within the reservoir. When vegetation is inundated, anaerobic microbial decomposition processes release ammonia as a byproduct. Panjaitan et al. emphasize that microbial decomposition processes, especially under anaerobic conditions, affect gas emissions, including ammonia (Panjaitan et al., 2015).

Ammonia in water is toxic to aquatic biota at high concentrations, especially in the form of free NH_3, which becomes more prevalent at elevated pH levels.

For nitrite, the overall trends were relatively small but exhibited fluctuations. Upstream nitrite levels initially measured 0.013 mg/L, decreased slightly to 0.006 mg/L (July 2024), and subsequently increased to 0.011 mg/L (February 2025). Downstream concentrations decreased from 0.012 mg/L pre-construction to 0.003 mg/L (July 2024), then rose to 0.016 mg/L (February 2025). These low nitrite concentrations suggest that nitrification (oxidation of ammonia to nitrite) is occurring but does not lead to significant accumulation, likely because nitrite is rapidly converted to nitrate or lost through denitrification under oxygen-limited conditions.

Nitrate levels upstream also showed variability: initially measured at 1.129 mg/L, decreasing to 0.800 mg/L (July 2024), and then increasing again to 1.144 mg/L (February 2025). Downstream nitrate concentrations rose from 0.65 mg/L pre-construction to 1.00 mg/L (July 2024) and further to 1.059 mg/L (February 2025). Overall, there is a clear trend of increasing nitrate levels downstream following reservoir impoundment. This may be related to the nitrification process (oxidation of ammonia into nitrate) while the water is in the reservoir. This trend may be linked to the nitrification process occurring within the reservoir, where ammonia generated from organic matter decomposition is partially converted into nitrate by nitrifying bacteria, thereby increasing downstream nitrate levels. Research by Vazhaeparambil et al. explains that dams affect nitrification in surrounding ecosystems, showing that nitrate levels are often higher downstream of dams due to interrupted water flow (Schmutz & Moog, 2018). However, it is important to note that absolute nitrate concentrations remain relatively low (<2 mg/L) and are well below the Class III water quality standard (10 mg/L for NO_3-N).

Table 4. Changes in Ammonia, Nitrite, and Nitrate Values

Parameter	Location	Unit	Pre- construction February 2016	July 2024	Post- construction February 2025
Ammonia	US	mg/l	0.001	0.01	0.67
	DS	mg/l	0.001	0.06	1.09
Nitrite	US	mg/l	0.01	0.006	0.01
	DS	mg/l	0.01	0.003	0.02
Nitrate	US	mg/l	1.13	0.80	1.14
	DS	mg/l	0.65	1.00	1.06

An increase in ammonia concentration to levels exceeding 1 mg/L downstream indicates deteriorating water quality, as ammonia (particularly in the NH_3 form) is toxic to fish at these concentrations, especially under alkaline pH conditions. However, given that the water pH at this site is generally neutral (approximately pH 7), a portion of the ammonia exists as ammonium ions (NH_4^+), which are less toxic to aquatic organisms. Nevertheless, elevated ammonia levels highlight the need for improved management of organic matter within the reservoir. For instance, vegetation and organic debris should be removed prior to impoundment to minimize subsequent decomposition. According to research by Henny, lake water quality can be disrupted by the accumulation of pollutants such as ammonia, so managing organic waste and vegetation in the area surrounding the dam, including vegetation within the reservoir, is an important preventive measure (Henny, 2023). Furthermore, controlling nutrient inputs from surrounding areas, such as domestic and agricultural waste, is essential to prevent further increases in ammonia concentrations.

Total Coliform

Total coliforms are a group of indicator bacteria comprising Gram-negative, facultative anaerobic, rod-shaped organisms that naturally inhabit soil, water, and the gastrointestinal tracts of animals and humans. The presence of coliforms in water is commonly used as an indicator of fecal contamination and poor sanitation conditions.

Test results reveal a substantial increase in total coliform levels following dam construction. Upstream, pre-construction concentrations were <2 MPN/100 mL, indicating very low bacterial contamination, likely due to relatively pristine spring water sources. However, after reservoir formation, upstream total coliform levels surged dramatically to 6,800 MPN/100 mL. Downstream concentrations also increased markedly, from 11 MPN/100 mL before construction to 2,800 MPN/100 mL afterward.

The pronounced rise in coliform levels, especially upstream, may be attributed to the reservoir's stagnant water conditions, which create a calm aquatic environment favorable for bacterial proliferation. Additionally, potential sources of fecal contamination, including inputs from wildlife, livestock, and human activities in the reservoir vicinity, may have contributed to these elevated bacterial counts. Agricultural practices also contribute to fecal pollution. For example, Powers et al. stated that rainwater runoff can transport fecal waste from agricultural lands into nearby water bodies, suggesting that even during dry periods, leaking sanitation infrastructure can lead to significant microbial contamination in aquatic ecosystems (Powers et al., 2020).

Table 5. Changes in Total Coliform Values

Parameter	Location	Unit	Pre- construction	Post- construction	
			February 2016	July 2024	February 2025
Total coliform	US	MPN/100 ml	2	1600	6800
	DS	MPN/100 ml	11	210	2800

Downstream, although total coliform levels increased to 2,800 MPN/100 mL, this concentration remains below the Class III water quality threshold of 5,000 MPN/100 mL (Government Regulation No. 22 of 2021). Nevertheless, the upward trend in coliform counts highlights the need for improved sanitation measures in the reservoir area. Elevated coliform populations pose a potential risk of waterborne disease outbreaks if the water is used for domestic purposes without adequate treatment. This observation is further supported by Neufeld et al., who noted that unprotected drinking water sources in Kenya are plagued by high levels of fecal coliforms, largely due to inadequate waste management practices (Neufeld et al., 2020).

Oil, Fat Parameter, and MBAS

Oil and fat parameters in water represent contamination by non-polar organic compounds, including mineral oils (e.g., fuel and lubricants), vegetable oils, and animal fats. Oil and fat contamination can form a surface film that impedes gas exchange (particularly oxygen diffusion) and degrades the quality of aquatic habitats.

Laboratory analyses show an increase in oil and fat concentrations both upstream and downstream following reservoir impoundment. Prior to dam construction, levels were very low: <0.001 mg/L upstream and <0.02 mg/L downstream. After reservoir formation, concentrations rose to 0.202 mg/L upstream and 0.196 mg/L downstream in February 2025 (rainy season). A notably higher concentration of 1.4 mg/L was measured downstream in July 2024 (dry season), likely resulting from temporary accumulation due to oil spills associated with construction machinery or project vehicles during the construction phase. The use of heavy equipment and project vehicles during the construction phase increases the risk of oil spills, resulting in potential environmental pollution (Utomo et al., 2024).

These findings suggest the presence of oil and fat inputs from various sources, including runoff from roads and construction areas (engine oil), domestic activities (e.g., disposal of cooking oil and animal fats), and possible tourism- or boat-related discharges within the reservoir. While the values around 0.2 mg/L remain ecologically low, proactive management is necessary to prevent further increases.

The MBAS (Methylene Blue Active Substances) parameter serves as an indicator of anionic detergent contamination. Initial MBAS concentrations at both locations were very low (<0.01 mg/L, near detection limits). After reservoir impoundment, MBAS levels increased slightly to 0.003 mg/L upstream and 0.011 mg/L downstream. These values remain very low and do not indicate significant detergent pollution. There was no significant increase in MBAS, indicating that the population around the upstream area has not increased or changes in washing/detergent activities are not significant. In other words, the Pamukkulu Dam has not yet experienced detergent pollution issues.

According to Asok et al. stated that the active ingredient in alkylbenzene sulfonate (LAS) solutions, which has a chemical structure and physical properties similar to MBAS, can have harmful effects on aquatic organisms. It was found that concentrations of this substance exceeding 0.2 mg/L can damage the structure and biological function of aquatic species, emphasizing the importance of monitoring MBAS and other compounds in water bodies (Asok et al., 2015). In this study, MBAS values remained well below this threshold (<0.02 mg/L), indicating no immediate ecological risk. The slight increases observed are likely attributable to human activities in the reservoir vicinity but do not yet represent a serious threat.

These results are consistent with the assumption that the population within the catchment area has not increased substantially, resulting in relatively stable domestic pollutant loads (cooking oil, detergents) (Sari et al., 2021). Nevertheless, routine monitoring remains essential, particularly given the potential for future development of tourism in the reservoir area, which could elevate detergent and oil-related inputs (e.g., from water-based recreational activities).

Table 6. Changes in Oil and Fat Value and MBAS

Parameter	Location	Unit	Pre- construction		Post- construction
			February 2016	July 2024	February 2025
Oil and Fat parameters	US	mg/l	0.001	0.003	0.20
	DS	mg/l	0.02	1.4	0.20
MBAS	US	mg/l	0.01	0.05	0.003
	DS	mg/l	0.01	0.05	0.01

Table 6 summarizes that oil and fat levels peaked downstream during the 2024 dry season (1.4 mg/L) but subsequently declined during the rainy season. This pattern may be attributed to minimal flow conditions in the dry season, which allow pollutants such as oil to accumulate in stagnant pools. Conversely, during the rainy season, increased flow and flushing processes facilitate pollutant dispersion and reduce concentrations. Similarly, MBAS levels at both sampling locations decreased in February 2025 compared to July 2024. This reduction is likely due to dilution effects from higher rainfall as well as natural biodegradation of surfactants by microorganisms.

Impacts on the Surrounding Ecosystem

The changes in water quality described above have direct consequences for both aquatic and terrestrial ecosystems surrounding the dam. A decline in water quality, characterized by reduced dissolved oxygen (DO) levels and increased nutrient concentrations (ammonia, nitrate), can promote eutrophication within the reservoir. Elevated nutrient levels, particularly nitrate and phosphate (although phosphate was not measured in this study), stimulate excessive growth of algae and aquatic macrophytes. In severe cases, declining water quality can lead to mass fish mortality events, as has been documented in other Indonesian reservoirs following algal blooms and upwelling of anoxic bottom layers. Consistent with the findings of Ovane et al. (2016) on the Jatibarang Dam, variations were observed in key water quality parameters such as BOD, COD, DO, nitrite, nitrate , and total coliform before and after dam construction (Tiana et al., 2016).

The observed increase in total coliform concentrations also indicates potential sanitation issues. Water contaminated with coliform bacteria can serve as a reservoir for pathogenic microorganisms (e.g., Escherichia coli), posing health risks if consumed without appropriate treatment. While the impact on wild fauna drinking reservoir water may be minimal, caution is warranted for humans (e.g., tourists, fishermen) regarding direct consumption or recreational contact.

Increased turbidity (TSS), particularly during the rainy season, can reduce light penetration into the water column, thereby inhibiting photosynthesis in aquatic plants and phytoplankton. However, because TSS generally decreases downstream of the reservoir (resulting in clearer water during the dry season), aquatic vegetation may benefit and flourish under such conditions. In this study, decreased TSS levels downstream suggest that sediment is being retained within the reservoir, leading to sediment accumulation. Excessive sedimentation can reduce the reservoir's effective storage capacity and alter benthic habitats. Land use changes in the upstream area of Pengga Reservoir directly affect water quantity, increasing sedimentation and water volume fluctuations (Ulayya et al., 2023). For aquatic biota, changes in parameters such as increased ammonia and turbidity may suppress the diversity of plankton and macrozoobenthic communities.

Overall, the ecological impacts of Pamukkulu Dam construction are evident in: (a) a decline in water quality, marked by elevated organic loads, nutrients, bacteria, and heavy metals in both reservoir and downstream waters, which can reduce habitat carrying capacity; (b) potential shifts in biotic community composition, favoring species tolerant of low oxygen conditions (e.g., certain pollution-tolerant fish and algal species); and (c) increased health risks due to bacterial contamination. Nevertheless, when compared to Class IV water quality standards (for irrigation and livestock use), most parameters (with the exception of DO, and COD) remain within permissible limits (Government Regulation No. 22, 2021). Accordingly, water from the Pamukkulu Reservoir remains suitable for agricultural irrigation and related uses. The primary challenge moving forward is to ensure that water quality does not deteriorate further, thereby safeguarding ecological integrity and supporting sustainable utilization. Theory-based education emphasizes environmental management, the importance of water for life, and water conservation through reforestation at the Jelantik Reservoir (Budianto et al., 2023).

Conclusion

The construction and impoundment of the Pamukkulu Dam have considerably influenced water quality and the surrounding ecosystem. Within less than a year of operation, water quality in the Pamukkulu area declined noticeably. BOD and COD levels, particularly downstream, increased by approximately sixfold and fifteenfold, respectively, indicating the buildup of organic matter and pollutant release from the reservoir. Nutrient enrichment (ammonia, nitrate) suggests the potential for eutrophication, while DO levels dropped to around 2 mg/L, creating hypoxic conditions that may endanger aquatic organisms. Moreover, post-construction COD concentrations reached 105.68 mg/L, surpassing established quality limits. Ecologically, habitat changes within the reservoir likely altered aquatic community structures and reduced species diversity. Downstream, altered flow and declining water quality may further stress riverine biota. Although most water quality indicators still comply with Class IV standards under Government Regulation No. 22 of 2021, parameters such as DO, COD, BOD, and Pb are nearing or exceeding permissible levels—indicating an urgent need for mitigation measures to prevent severe pollution.

Acknowledgments
The authors would like to express their gratitude to Balai Besar Wilayah Sungai Pompengan Jeneberang for providing data and technical support during this research. The authors also thank PT. WIKA – DMT, KSO for their valuable assistance and constructive discussions throughout the study.

Author Contributions
All authors contributed to writing this article.

Funding
No external funding.

Conflicts of Interest
No conflict interest.

References

Asok, A. K., Fathima, P. A., & Jisha, M. S. (2015). Biodegradation of Linear Alkylbenzene Sulfonate (LAS) by Immobilized <i>Pseudomonas</i> sp. *Advances in Chemical Engineering and Science*, *05*(04), 465–475. https://doi.org/10.4236/aces.2015.54048

Atima, W. (2015). BOD dan COD sebagai parameter pencemaran air dan baku mutu air limbah. *Biosel Biology Science and Education, 4*(1), 83-93. https://doi.org/10.33477/bs.v4i1.532

Bakri, S., & Yushananta, P. (2023). Water Pollution and Water Quality Assessment of the Way Kuripan River in Bandar Lampung City (Sumatera, Indonesia). *Polish Journal of Environmental Studies*, *32*(2), 1061–1070. https://doi.org/10.15244/pjoes/153432

BPS. (2024). *Kabupaten Takalar Dalam Angka 2023*. Retrieved from https://takalarkab.bps.go.id/id/publication/2024/02/28/3b580a649b4f4957c3bc48b9/kabupaten-takalar-dalam-angka-2024.html

Budianto, M. B., Harianto, B., Supriyadi, A., & Setiawan, E. (2023). Edukasi Masyarakat tentang Konservasi Sumber Air Melalui Penghijauan Kawasan Waduk di Desa Jelantik Kecamatan Jonggat Lombok Tengah. *Portal Abdimas, 1*(1), 58-67. https://doi.org/10.29303/portalabdimas.v1i1.2366

Caissie, D. (2006). The thermal regime of rivers: A review. In *Freshwater Biology* (Vol. 51, Issue 8, pp. 1389–1406). https://doi.org/10.1111/j.1365-2427.2006.01597.x

Departemen Pekerjaan Umum. (2009). *Kamus Istilah Bidang Pekerjaan Umum 2009*. Jakarta: Kementrian Pekerjaan Umum

Fluixá-Sanmartín, J., Morales-Torres, A., Escuder-Bueno, I., & Paredes-Arquiola, J. (2019). Quantification of climate change impact on dam failure risk under hydrological scenarios: A case study from a Spanish dam. *Natural Hazards and Earth System Sciences*, *19*(10), 2117–2139. https://doi.org/10.5194/nhess-19-2117-2019

Hanjaniamin, A. E., Tabrizi, M. S., & Babazadeh, H. (2023). Dissolved oxygen concentration and eutrophication evaluation in Yamchi dam reservoir, Ardabil, Iran. *Applied Water Science*, *13*(1). https://doi.org/10.1007/s13201-022-01786-1

Henny, C. (2023). *Pengelolaan Kualitas Air Danau Melalui Pendekatan Biogeokimia*. BRIN. https://doi.org/10.55981/brin.875

Ilmi, F., Muntalif, B. S., Chazanah, N., Sari, N. E., & Bagaskara, S. W. (2023). Benthic macroinvertebrates functional feeding group community distribution in rivers connected to reservoirs in the midstream of Citarum River, West Java, Indonesia. *Biodiversitas*, *24*(3), 1773–1784. https://doi.org/10.13057/biodiv/d240352

Iqtashada, & Febrita, J. (2023). Pengaruh Tata Guna Lahan terhadap Kualitas Air Sungai Cisadane di Kota Bogor. *Jurnal Teknik Sipil Dan Lingkungan*, *8*(1), 9–18. https://doi.org/10.29244/jsil.8.1.9-18

Khairuddin, Yamin, M., & Syukur, A. (2016). Analisis Kualitas Air Kali Ancar dengan Menggunakan Bioindikator Makroinvertebrata. *Jurnal Biologi Tropis*, *16(2)*, 10–22. https://doi.org/10.29303/jbt.v16i2.220

Khairuddin, Yamin, M., & Syukur, A. (2019). Pelatihan Tentang Penggunaan Ikan Sebagai Indikator dalam Menentukan Kualitas Air Sungai di Ampenan Tengah Mataram. *JPMPIPA*, 25–29. https://doi.org/10.29303/jpmpi.v1i2.244

Majed, N., & Islam, M. A. S. (2022). Contaminant Discharge From Outfalls and Subsequent Aquatic

Ecological Risks in the River Systems in Dhaka City: Extent of Waste Load Contribution in Pollution. *Frontiers in Public Health*, *10*. https://doi.org/10.3389/fpubh.2022.880399

Maroneze, M. M., Zepka, L. Q., Vieira, J. G., Queiroz, M. I., & Jacob-Lopes, E. (2014). A tecnologia de remoção de fósforo: Gerenciamento do elemento em resíduos industriais. *Revista Ambiente e Agua*, *9*(3), 445–458. https://doi.org/10.4136/1980-993X

Meiwinda, E. R., & Lucyana. (2022). Kajian kualitas air Sungai Musi wilayah pada segmen sungai kecamatan Gandus dan Kertapati. *Journal of Civil Enginering*, *4*(2), 1-6. https://doi.org/10.31605/bjce.v4i2.1530

Morsy, K. M., Abdelatif, G., & Mostafa, M. K. (2021). Comprehensive Assessment for the Potential Environmental Impacts of the Grand Ethiopian Renaissance Dam on the Downstream Countries: Itaipu Dam in the Rearview Mirror. *Air, Soil and Water Research*, *14*. https://doi.org/10.1177/11786221211041964

Neufeld, D. G., Muendo, B., Muli, J., & Kanyari, J. (2020). Coliform bacteria and salt content as drinking water challenges at sand dams in Kenya. *Journal of Water and Health*, *18*(4), 602–612. https://doi.org/10.2166/WH.2020.192

Novianta, M. A., Syafrudin, & Warsito, B. (2024). Multiple Linear Regression Modeling for Analysis of Factors Affecting COD and BOD on River Water Quality in Yogyakarta, Indonesia. *E3S Web of Conferences*, *517*. https://doi.org/10.1051/e3sconf/202451716001

Panjaitan, E., Indradewa, D., Martono, E., & Sartohadi, J. (2015). Sebuah dilema pertanian organik terkait emisi metan (a dilemma on organic farming in relation to methane emission). *Jurnal manusia dan lingkungan, 22*(1), 66-72. Retrieved from https://shorturl.at/2H1nu

Pemerintah Republik Indonesia. (21 C.E.). *Peraturan Pemerintah Republik Indonesia No 22 tahun 2021*. Retrieved from https://peraturan.go.id/id/id-2021-pp22

Pinayungan, G. S., Bisri, M., & Andre Primantyo Hendrawan. (2025). Analisis Hidrogeokimia Air Tanah Dangkal di Desa Pojok Kecamatan Campurdarat Kabupaten Tulungagung. *Jurnal Teknologi Dan Rekayasa Sumber Daya Air*, *5*(1), 738–750. https://doi.org/10.21776/ub.jtresda.2025.005.01.070

Powers, N. C., Wallgren, H. R., Marbach, S., & Turner, J. W. (2020). Relationship between Rainfall, fecal pollution, antimicrobial resistance, and microbial diversity in an urbanized subtropical bay. *Applied and Environmental Microbiology*, *86*(19). https://doi.org/10.1128/AEM.01229-20

Pujiastuti, R., & Afifah, R. C. (2023). Studi Sedimentasi Guna Penentuan Umur Rencana Waduk Pada Waduk Jatibarang Kota Semarang: Umur Rencana Waduk. *JMTS: Jurnal Mitra Teknik Sipil*. https://doi.org/10.24912/jmts.v6i3.23685

Rahmadi, D., Machdar, I., & Syaubari, S. (2023). Analysis Of Water Quality And Quality Status In Aceh Rivers Based On Environmental Pollution Index. *Jurnal Rekayasa Kimia & Lingkungan*, *17*(2), 171–181. https://doi.org/10.23955/rkl.v17i2.28865

Sako, M. P., & McManamay, R. A. (2023). Balancing development and sustainability: Assessing risks and protecting aquatic biodiversity on US college and university campuses. *Conservation Science and Practice*, *5*(12). https://doi.org/10.1111/csp2.13039

Sari, D. S. I. P., Hariyadi, S., & Effendi, H. (2021). Hubungan kualitas air dengan parameter hidrologi di Sungai Batang Arau Sumatera Barat (2013-2020). *Jurnal Pengelolaan Lingkungan Berkelanjutan (Journal of Environmental Sustainability Management)*, 788-798. Retrieved from http://www.bkpsl.org/ojswp/index.php/jplbJPLB,5

Sari, E. K., & Wijaya, O. E. (2019). Penentuan Status Mutu Air Dengan Metode Indeks Pencemaran Dan Strategi Pengendalian Pencemaran Sungai Ogan Kabupaten Ogan Komering Ulu. *Jurnal Ilmu Lingkungan*, *17*(3), 486. https://doi.org/10.14710/jil.17.3.486-491

Schmutz, S., & Moog, O. (2018). Dams: Ecological Impacts and Management. In *Riverine Ecosystem Management* (pp. 111–127). Springer International Publishing. https://doi.org/10.1007/978-3-319-73250-3_6

Sikder, M. T., Kihara, Y., Yasuda, M., Yustiawati, Mihara, Y., Tanaka, S., ... & Kurasaki, M. (2013). River water pollution in developed and developing countries: judge and assessment of physicochemical characteristics and selected dissolved metal concentration. *CLEAN–Soil, Air, Water, 41*(1), 60-68. https://doi.org/10.1002/clen.201100320

Tiana, O., Alam, Y., Sarminingsih, A., & Dwi Nugraha, W. (2016). *Pengaruh Waduk Jatibarang Terhadap Kualitas Air Sungai Garang Di Intake Pdam Semarng*. Universitas Diponegoro. Retrieved from http://ejournal-s1.undip.ac.id/index.php/tlingkungan

Ulayya, A. G., Ramadhan, J. A., Agusti, L. W., & Kurnia, B. T. E. (2023). Pemanfaatan Sumberdaya Lokal Ijuk Aren Dalam Menghasilkan Air Jernih Di Desa Gegerung Kecamatan Lingsar, Kabupaten Lombok

Barat, NTB. *Prosiding Seminar Nasional Gelar Wicara*. Retrieved from https://proceeding.unram.ac.id/index.php/wicara

Utomo, I. S., Sanjaya Atmaja, D., & Infanther, W. D. (2023). Desain Alat Pengisi Minyak Pelumas Kompresor Pada Lokomotif. *Jurnal Penelitian Sekolah Tinggi Transportasi Darat, 14*(2), 90-95. https://doi.org/10.55511/jpsttd

Yusuf, S. M., Nugroho, S. P., Effendi, H., Prayoga, G., Permadi, T., & Santoso, E. N. (2021). Surface runoff of Bekasi River subwatershed. *IOP Conference Series: Earth and Environmental Science*, *744*(1). https://doi.org/10.1088/1755-1315/744/1/012108

Zeng, Y., Wang, Z., Zhao, Q., Huang, N., Li, J., Wang, J., & Sun, F. (2025). Assessment of the Effects and Contributions of Natural and Human Factors on the Nutrient Status of Typical Lakes and Reservoirs in the Yangtze River Basin. *Water (Switzerland)*, *17*(4). https://doi.org/10.3390/w17040559