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Pollution index and load of total nitrogen and phosphate on agriculture and fisheries in Jatigede Reservoir

Indeks dan beban pencemaran total nitrogen dan fosfat pada pertanian dan perikanan di Waduk Jatigede

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ABSTRACT

Jatigede Reservoir has an area of approximately 4,122 Ha, the purpose of Jatigede dam construction is to increase rice production with a range irrigation network system. Problems arising from the use of chemical fertilizers, regarding the development of agricultural land used to increase agricultural productivity, support food security and also activities in floating net cages (FNC) can result in a decrease in reservoir water quality, siltation of reservoirs, etc. Organic waste from FNC cultivation feed, for example nitrogen and phosphate. The purpose is to determine the pollution index of each observation station and the concentration of total nitrogen and total phosphor pollutant loads from the agriculture and fisheries sectors in Jatigede Reservoir so that it can be analyzed which activities have the most influence on pollution and determine effective countermeasures a decrease in water quality in Jatigede Reservoir. The quantitative method uses a survey method is processing data from laboratory tests using the Pollution Index and total nitrogen and phosphate pollution loads. The results of the highest pollution index are at station three of 6.08 with moderate pollution status caused by runoff from Cihonje inlet waste and FNC activities. The nitrogen parameter pollution load has a high amount of 192.13 kg/day then the amount of phosphate pollution load is 34.16 kg/day. As for good pollution control, by reducing the burden of pollution by involving the community in managing the reservoir environment, routine monitoring of reservoir water quality and mapping potential pollutant sources at each location so that problems will be quickly resolved.

Keywords: agriculture, fisheries, Jatigede reservoir, pollution index, pollution load

ABSTRAK

Waduk Jatigede memiliki luas sekitar 4.122 Ha, tujuan pembangunan Waduk Jatigede adalah untuk meningkatkan produksi padi dengan sistem jaringan irigasi rentang. Permasalahan yang ditimbulkan terkait penggunaan pupuk kimiawi, mengenai perkembangan lahan pertanian yang digunakan untuk meningkatkan produktivitas pertanian dan mendukung ketahanan pangan dan juga kegiatan budidaya ikan karamba jaring apung (KJA) dapat mengakibatkan terjadinya penurunan kualitas air waduk, pendangkalan waduk, dan lain-lain. Limbah organik sisa pakan budidaya KJA yang terbuang ke dalam perairan contohnya yaitu nitrogen dan fosfat. Tujuan penelitian ini adalah untuk menentukan index pencemaran dari setiap stasiun pengamatan dan konsentrasi beban pencemar total nitrogen dan total fosfat dari sektor pertanian dan perikanan di Waduk Jatigede sehingga dapat dianalisis kegiatan mana yang paling berpengaruh terhadap pencemaran dan menentukan penanggulangan yang efektif untuk mencegah penurunan kualitas air di Waduk Jatigede. Metode yang digunakan adalah *mix method* (metode campuran). Metode kuantitatif menggunakan metode survey yaitu pengolahan data hasil uji laboratorium. Menganalisis tingkat pencemaran di setiap stasiun, menggunakan Index Pencemaran dan analisis beban pencemaran nitrogen dan fosfat. Hasil dari index pencemaran paling tinggi terdapat di stasiun tiga sebesar 6,08 dengan status tercemar sedang disebabkan oleh limpasan dari limbah inlet cihonje dan aktivitas KJA dan untuk beban pencemaran parameter nitrogen memiliki jumlah yang tinggi yaitu 192,13 kg/hari kemudian jumlah beban pencemaran fosfat 34,16 kg/hari. Adapun pengendalian pencemaran yang baik yaitu dengan pengurangan beban pencemaran dengan melibatkan masyarakat dalam pengelolaan lingkungan waduk, pemantauan rutin kualitas air waduk dan memetakan sumber-sumber pencemar potensial pada setiap lokasi sehingga permasalahan akan cepat teratasi.

Kata kunci: beban pencemaran, index pencemaran, pertanian, perikanan, Waduk Jatigede

INTRODUCTION

The construction of dams (reservoirs) plays a role in overcoming problems of raw water supply, drinking water shortages, and lack of energy resources. Reservoirs can also increase food production and food security, increase community income, solve the problem of a raw water crisis, control floods, increase electricity production, and are useful as conservation areas and nature tourism (Rizal, 2012). The deterioration of river water quality has threatened the health of aquatic ecosystems and clean water supply resulting in disruption of public health because the poor quality of raw water will be dangerous if consumed by residents (Susanti *et al*., 2012). The last condition of Jatigede Reservoir in December 2021 turned into a sea of garbage.

Household activities produce waste that has the potential to reduce the condition of reservoir water quality. Waste is the main problem in every water body, be it rivers, lakes or reservoirs (Nur, 2021). The problems caused by the use of chemical fertilizers are related to the development of agricultural land used to increase agricultural productivity and support food security (Yustiani *et al*., 2018), and fish farming activities in floating net cages (FNC) can result in a decrease in reservoir water quality, siltation of reservoirs, etc, allegedly due to the large amount of organic waste left over from FNC cultivation that is wasted into the waters, for example, nitrogen and phosphate (Anas *et al*., 2017). Nitrogen is one of the nutrients that limit phytoplankton growth in water (Wardhani, 2016).

Phosphorus is an important element in aquatic ecosystems. Phosphorus in waters is available in the form of dissolved and particulate phosphate compounds (Meirinawati, 2015). Phosphorus is a limiting nutrient that controls primary production (energy production), especially in freshwater ecosystems (Baldwin, 2013). The main source of phosphorus is naturally from the waters themselves through the process of decomposition, weathering, decomposition of plants, and the remains of dead organisms. In addition, anthropogenic sources of phosphorus come from land discharges such as domestic waste (Handayani *et al*., 2016).

This study will determine the pollution index at each observation station and the total nitrogen and total phosphate pollutant load that pollutes Jatigede Reservoir as a result of agricultural and fisheries activities so that it can be analyzed which activities or as a result of activities from which sector are dominant in influencing the pollution of Jatigede Reservoir, then effective countermeasures can be arranged for Jatigede Reservoir pollution so that Jatigede Reservoir is maintained from pollution. The purpose of this study is to determine the pollution index at each observation station and the concentration of total nitrogen and total phosphate pollutant loads from the agriculture and fisheries sectors in Jatigede Reservoir so that it can be analyzed which activities from which sectors have the most influence on pollution and determine effective countermeasures to prevent a decrease in water quality in the reservoir.

MATERIALS AND METHODS

This research was conducted in August 2022 and the method used in the research is mixed method. Quantitative methods for primary data using survey methods, namely processing data from laboratory test results, to analyze the level of pollution at each station, using the Pollution Index and analysis of total nitrogen and total phosphate pollution loads. The research and sampling locations in Jatigede Reservoir are six station points. Determination of six station points in reservoir waters based on reservoir zoning (riverine, transitional, and lacustrine) and reservoir utilization (Figure 1). The variables used in this study are temperature, brightness, pH, *Biochemical Oxygen Demand* (BOD), *Dissolved Oxygen* (DO), CO_2, total nitrogen, and total phosphate (Table 1).

According to Permen (2003), the Pollution Index formula for determining the level of pollution of a water body is as follows:

$$Pi_j = \sqrt{\frac{(C_i/L_{ij} + (C_i/L_{ij})^2_R}{2}}$$

Note:

PI_j = Pollution index for designation (j)

C_i = Concentration of water quality parameter (i) from the analysis result

L_{ij} = Concentration of water quality parameter in the quality standard of water designation (j)

$(C_i/L_{ij})M$ = Maximum C_i/L_{ij} value

$(C_i/L_{ij})R$ = Average C_i/L_{ij} value

The classification for pollution status is in Table 2.

As for knowing the pollution load, especially in the parameters of total nitrogen and total phosphate. According to Permen (2010), the formula for calculating pollution load is as follows:

$$BPs = Qs \times Cs(j) \times f$$

Note:
BPs = River pollution load (kg/day)
Qs = River water discharge (m^3/second)
Cs(j) = Concentration of pollutant element j (mg/L)
F = Conversion factor to kg/day

The qualitative approach in this study uses interview techniques. Respondents came from the party responsible for the Jatigede Reservoir, namely the Jatigede Reservoir Management Unit, and the Jatigede Reservoir community who make a living as farmers and activists of KJcultivation, to find out the habits of farmers and KJA activists.

RESULTS AND DISCUSSION

Results

General condition of Jatigede reservoir

Based on statistical data regarding existing land use, 43% of the agricultural system in the Jatigede area is dryland farming, and 39% is wetland farming. Other agricultural activities such as yards, fish ponds, and grazing. The agricultural crops cultivated in the Jatigede area are rice 73%, cassava 12.5%, corn 9%, peanuts

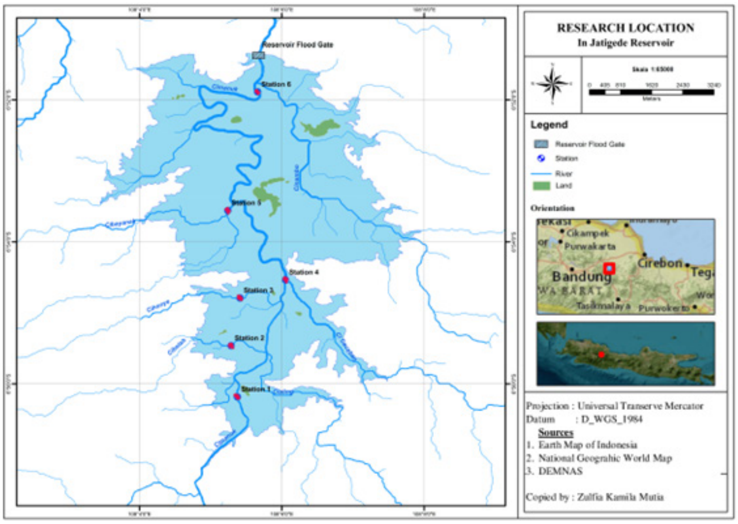

Figure 1. Map of sample points.

Table 1. Observation parameters.

Variables	Unit	Tools	Analysis Method
Temperature	^oC	Thermometer	SNI 06-6989.23-2005
Brightness	cm	*Secchi Disk*	Direct reading
pH	-	pH meter	SNI 6989.11:2019
BOD	mg/L	Titration tools	SNI 6989.72:2009
DO	mg/L	DO meter	Direct reading
CO_2	mg/L	Titration tools	APHA 2310 **
Total Nitrogen	mg/L	Spectrophotometer	Method standard 4500-NORG B
Total Phosphate	mg/L	Spectrophotometer	Method Standard year 2017 item 4500 P B.3 and E

Table 2. Classification of pollution status (Permen, 2003).

Value of PI	Description
$0 \leq PIj \leq 1,0$	Good conditions
$1,0 < PIj \leq 5,0$	Mildly polluted
$5,0 < PIj \leq 10$	Medium polluted
$PIj > 10$	Heavily polluted

2.6%, and the rest are cassava vines, soybeans, and green beans. Jatigede residents who are involved and dependent on agricultural activities are 83%. Resident fisheries activities in the Jatigede area include pond fisheries, rice field fisheries, lake fisheries, and types of aquaculture entrepreneurs and capture fisheries.

Aquaculture comprises hatcheries and enlargement in rice fields and ponds (RKL-RPL Report, 2021). The types of fish in the waters of the Jatigede Reservoir lalawak fish (*Barbodes balleroides*), Nile tilapia (*Oreochromis niloticus*), and hampala barb (*Hampala macrolepidota*), broom fish (*Acanthicus hystrix*), common carp (*Cyprinus carpio*), Asian redtail catfish (*Hemibagrus nemurus*), marble goby (*Oxyeleotris marmorata*), and catfish (*Pangasius pangasius*) (Melani, 2022). At this time, Jatigede Reservoir is utilized for land irrigation of 87.830 ha as raw water with a discharge of 3.5 m^3/sec and 2×55 MW hydropower plans. Morphological and hydrological data of Jatigede Reservoir are presented in Table 3.

Water quality parameters

The results of the Jatigede Reservoir water quality testing at six different stations based on reservoir utilization are presented in Table 4.

Temperature

The processes that occur in the reservoir are influenced by water temperature. Temperature measurement aims to determine the condition of the waters and the relationship between temperature and the health of aquatic biota in it (Puspitasari *et al*., 2016). Temperature patterns in a river ecosystem will experience differences based on the depth of the water layer and are influenced by the intensity of annual sunlight. Also, the canopy factor (vegetation cover) of the trees growing on the edge of the reservoir water is not covered by vegetation cover, sunlight still reaches into the reservoir water, and the temperature in the water is still maintained.

The temperature value at each observation station is still included in the average quality standard value. Namely, at stations 2-6, the temperature is 29ºC. Only station 1 has a temperature of 26ºC because it is an active area of agricultural activities. So, there are still many overflows of organic substances that enter the reservoir water, which blocks the entry of sunlight.

pH

The pH value is the concentration of hydrogen ions in a solution. Aquatic organisms can live, generally between 7-8.5. Waters that are very

Table 3. Morphology and hydrology of Jatigede Reservoir.

Component	Unit	Value
Elevation (above sea level)	m	260
Water volume	m^3	980.57×10^6
Inundation area	km^2	39.52
Inundation length	km	10.18
Average depth	m	23.77
Outgoing water discharge	Millions m^3/year	123.69

Source: Jatigede Reservoir nonvertical work unit.

Table 4. Water quality testing results.

Parameters/sample code	Unit	Station					
		1	2	3	4	5	6
Temperature	Celcius	26	29	29	29	29	29
pH	-	8.01	7.9	8.4	8.42	8.45	8.4
DO	mg/L	5.3	4	4	4.2	4.8	4.6
CO_2	mg/L	7.92	7.92	3.96	3.96	3.96	3.96
Transparency	Cm	19	90	111	97	108	103
total phosphate	mg/L	0.092	0.161	0.053	0.045	0.09	0.007
total nitrogen	mg/L	0.338	0.196	0.139	0.273	0.591	0.431
BOD	mg/L	7.6	5.6	6	4.6	5	3.9

acidic or very alkaline can endanger the survival of organisms because it will cause the mobility of various heavy metal compounds that are toxic (Puspitasari *et al*., 2016). The pH quality standard value for class two is 6-9, pH at each station in Jatigede Reservoir doesn't exceed or less than the standard quality value, meaning that organisms in the waters of Jatigede Reservoir can survive because the atmosphere of the reservoir waters is not too acidic and not too alkaline.

DO (*Dissolved oxygen*)

The increase in temperature will cause the solubility of oxygen (DO - Dissolved Oxygen) in water to decrease (Puspitasari *et al*., 2016), and the higher the dissolved oxygen content, the better the water quality (Yuliantari *et al*., 2021). The standard quality value for the second class is at least 4 mg/L. In comparison, each sampling station has no DO value less than 4 mg/L, meaning that the heat exchange between water and the surrounding air is still good, so the oxygen solubility value is still high.

CO_2

One of the chemical parameters in the water is carbon dioxide gas (CO_2) which is influenced by water quality. Suppose there is more carbon dioxide (CO_2) in the water. In that case, it will affect phytoplankton organisms and aquatic plants that carry out the respiration process, while if it is less, it will affect the photosynthesis process (Idrus, 2018). The Standard quality value for carbon dioxide gas in water is not more than 12 mg/L. The importance of carbon dioxide gas at each station is at most 12 mg/L, so carbon dioxide gas levels are still expected. It does not affect organisms in the waters to carry out the process of respiration and photosynthesis.

Transparency (Brightness)

Brightness is the penetration of light to penetrate the depth of the sea. If the waters are turbid, then the penetration of sunlight decreases, resulting in low water brightness (Patty *et al*., 2020). The standard quality value for class two is 4 meters, while for observation stations in Jatigede Reservoir, the average is 1 m, none of which reaches the standard quality value. The observation station with the lowest brightness value is station one along 19 cm. Station one is an area near the inlet of Cimanuk and is densely agricultural, so it contains a lot of suspended matter derived from organic matter from the runoff of agricultural activities that gather in the station one area.

BOD (*Biochemical oxygen demand*)

Biochemical oxygen demand (BOD) is a general measure of water quality that reflects the pollution level of organic matter from aquatic materials through the ability to decompose by microorganisms. The BOD quality standard for class two is 3 mg/L, and the BOD value in Jatigede Reservoir, which exceeds the quality standard for class three, is at all observation stations. Station one has the highest BOD value of 7.6 mg/L, meaning that microorganisms must decompose the more significant the BOD value, the more organic matter because station 1 is located near the inlet of the Cimanuk River, which has agricultural activities.

Total phosphate

Phosphorus is essential for the life of aquatic organisms because it functions in the storage and transfer of energy in cells and functions in the genetic system (Putri *et al*., 2014). Phosphorus in waters is in the form of phosphate compounds, which consist of dissolved phosphate and particulate phosphate. Dissolved phosphate is divided into organic phosphate and inorganic phosphate consisting of orthophosphate and polyphosphate (Rumhayati, 2010). Phosphorus is considered a macronutrient that affects the productivity rate of a water body or is referred to as a limiting factor (Nabilla *et al*., 2019). Phosphorus, in the form of orthophosphate as a limiting nutrient, plays a crucial role in photosynthesis (primary productivity) (Ikhsan *et al*., 2020).

The standard quality value of total phosphate for class two is 0.03 mg/L. In Jatigede Reservoir water quality, the phosphate value during the wet-dry season exceeds the quality standard, meaning that the runoff of organic matter in the form of phosphate originating from agricultural activities or KJA fisheries, which ranges from 0.007-0.161 mg/L affects the decline in Jatigede Reservoir water quality.

Total nitrogen

The second-class quality standard value for total nitrogen is 0.75 mg/L. While the total nitrogen value in this dry season for each observation station all exceeds the standard quality value, which ranges from 0.139-0.591 mg/L, meaning that nitrogen runoff from agricultural and fishery activities causes the total nitrogen value to exceed the quality standard or causes a decrease in Jatigede Reservoir water quality because according to Yanti (2017), low rainfall or in the dry season, rivers or reservoirs can experience volume shrinkage so that the turbidity level is very high.

Pollution index

The pollution index is one of the methods used to determine water quality status. Water quality status shows the source water quality conditions by comparing the established quality standards (Sari & Wijaya, 2019). The pollution index value can be seen in Table 5.

Table 5 shows that station one has a lightly polluted quality status of 2.85, while stations 2-6 have a medium contaminated level that ranges from 5.29-5.61. The highest pollution index is found at station three, the Cihonje inlet area. There are FNC activities that can affect the water quality of the Jatigede Reservoir because of continuous feeding, and sometimes the fish do not eat all the feed, so some are left and settle to the bottom, then can also come from fish feces in FNC.

Pollution load

Calculation of pollution load can be calculated by multiplying the discharge variable with the concentration of each variable analyzed, namely total nitrogen and total phosphate, according to Permen (2010). The value of the pollution load can be seen in Table 6.

Based on the calculation of the pollution load in Jatigede Reservoir, the highest pollution load is in the total nitrogen parameter of 192.13 kg/day, meaning that as much as 192.13 kg of nitrogen pollutants enter the waters of Jatigede Reservoir every day. Dissolved inorganic nitrogen (DIN) compounds in waters are one of the pollutant compounds that have the potential to cause fertilization in waters that can cause water system disturbances. The presence of nitrogen in the waters is strongly influenced by liquid waste discharges from domestic, industrial, and fertilization activities (Lestari, 2014).

The total phosphate pollution load entering the Jatigede Reservoir waters every day is 5.693 kg. The class 2 quality standard for total phosphate pollution load is 2.93 kg/day, so it is necessary to control pollution, especially phosphate content. If the amount of phosphate is high, it will result in vast algae growth and a lack of sunlight entering the waters. When the algae die, bacteria break it down using dissolved oxygen in the water (Green, 2018).

The highest total nitrogen and total phosphate pollution load results are found at observation

Table 5. Pollution index value of Jatigede Reservoir.

Station	Pollution Index	Quality Status
1	2.85	Mildly Polluted
2	5.29	Medium Polluted
3	5.61	Medium Polluted
4	5.41	Medium Polluted
5	5.51	Medium Polluted
6	5.55	Medium Polluted

Table 6. Pollution load value of Jatigede Reservoir.

Station	Debit (m^3/s)	Total Phosphate (mg/L)	Total Nitrogen (mg/L)	Pollution Load (kg/day)	
				Total Phosphate	Total Nitrogen
1	1.13	0.092	0.338	8.98	32.99
2	1.13	0.053	0.196	5.17	19.14
3	1.13	0.047	0.139	4.59	13.57
4	1.13	0.045	0.273	4.39	26.65
5	1.13	0.106	0.591	10.35	57.7
6	1.13	0.007	0.431	0.68	42.08
			Total	34.16	192.13
			Average	5.693	32.0217

station number five, with total phosphate of 10.35 kg/day and total nitrogen of 57.7 kg/day. Observation station number five at Jatigede Reservoir has agricultural activities and Cibayawak inlet. Most agricultural activities use urea and phonska fertilizers. Urea fertilizer has a nitrogen content of approximately 46%, while the Phonska content is 15% nitrogen, 10% phosphate, 12% potassium, and 10% sulfur (PG, 2019). In addition, the distance from the agricultural land to the reservoir waters is only 3-4 m, so the nitrogen and phosphate content at the observation station is also high because it comes from fertilizers that flow directly into the reservoir.

Pollution management in Jatigede Reservoir

The results of the pollution index research show that observation station number three has a high value because there are dense KJA activities. In contrast, the results of the pollution load show that observation station number five is the highest for the value of phosphate and nitrate pollution load because there are agricultural activities around observation station number five. Based on the utilization of the reservoir itself, mainly used for agricultural activities and floating net cage (FNC) fisheries. The control efforts that can be done in Jatigede Reservoir are:

Agricultural Activities

If agricultural waste in small amounts can be discharged into the soil, waters, or air so that the environment can still neutralize. If it exceeds the threshold value, it must be treated before the waste is disposed of. It is necessary to reduce the pollution load by involving the community in managing the river environment, implementing better waste management and management effectiveness, and involving more community participation in technical management. Increase research on agricultural waste utilization, including social, technological, and economic aspects.

Floating net cage (FNC) fishery activities

There needs to be an increase in law enforcement to FNC activists or other actors who pollute the Jatigede Reservoir and work with the community to supervise so that the perpetrators of activities in the Jatigede Reservoir do not pollute the Jatigede Reservoir. If they commit violations, strict legal sanctions should be given to the party. The need for routine monitoring of river water quality and mapping potential pollutant sources at that location so that problems will be quickly resolved. Especially to overcome the decline in water quality caused by the activities of FNC, there is a need for innovations to make FNC that are environmentally friendly.

CONCLUSION

Based on the research results obtained, it can be concluded that the concentration of pollution load from total nitrogen and total phosphate entering the Jatigede Reservoir waters is total nitrogen of 192.13 kg/day and total phosphate of 34.16 kg/day. Meanwhile, the class two quality standard value for total nitrogen pollution load is 73.22 kg/day, and total phosphate is 2.93 kg/day. This amount has the potential to cause a decrease in the water quality of Jatigede Reservoir, so it is necessary to have suitable countermeasures so that the pollutant load does not increase and remains under control. The results of the pollution index show that station three with the highest pollution index value of 5.61, and its status is moderately polluted.

At station three, there is a Cihonje inlet, and there are KJA activities where the source of pollution can come from feed and feces from fish in FNC cultivation. Control efforts that can be done in Jatigede Reservoir are it is necessary to reduce the pollution load by involving the community in managing the river environment, and it is necessary to carry out effective management and better waste management and involve more community participation in technical management. Suppose a small amount of agricultural waste can be discharged into the soil, water, or air so that the environment can still neutralize.

If it exceeds the threshold value, treatment is needed before the waste is disposed of. It is necessary to increase law enforcement to agricultural actors and FNC activists or other actors who pollute the Jatigede Reservoir and work with the community to supervise so that the perpetrators of activities in the Jatigede Reservoir do not pollute the Jatigede Reservoir, and if they violate must be given strict legal sanctions to the party. The need for routine monitoring of river water quality and mapping potential pollutant sources at this location so that problems will be quickly resolved. Especially to overcome the decline in water quality caused by FNC activities, innovations need to make FNC that are environmentally friendly.

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