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Regional Case Study

Jatiluhur Water Quality at Various Depth

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Abstract

The Jatiluhur Reservoir is an important building in West Java Province whose dams the Citarum River. The location of the Jatiluhur Reservoir, which is the most downstream of the Saguling and Cirata Reservoirs, is where domestic, industrial, and agricultural wastewater pollution is accommodated from water catchment areas so that water quality decreases. This study aims to analyze the water quality in this reservoir at various depths. The study was conducted in September 2020 at 16 sampling points at a depth of 0-8 meters. The water quality parameters analyzed were Temperature, Dissolved Residue (TDS), pH, Dissolved Oxygen (DO), Fluoride (F^-), Nitrate (NO_3^-N), Sulfate (SO_4^{2-}), BOD_5, COD, and Escherichia coli. Based on the study results, it was found that the concentrations of DO, BOD_5 and COD at the monitoring location of the Jatiluhur Reservoir did not meet the quality standards. The concentrations of DO, BOD_5 and COD respectively 1.00-3.99 mg/L; 3.10-17.00 mg/L; and 28.00-59.00 mg/L. These three parameters contribute to the decline in water quality. The status of water quality using the IP method is categorized as lightly polluted so that it affects the utilization of this reservoir, especially as raw water for drinking water. The highest level of contamination was at the floating net cages sampling location at a depth of 8 m. The decline in water quality in the Jatiluhur Reservoir is caused by organic substances originating from floating net cages waste.

Keywords: Jatiluhur; floating net cages; pollution organic

1. Introduction

Jatiluhur Dam (Ir. H. Djuanda) is a multipurpose dam that dams the Citarum River, previously dammed by two reservoirs, namely Saguling and Cirata. According to Teck-Yee Ling (2017), the construction of dams with a cascade system harms hydrology, biological and chemical processes from upstream to downstream of the dam, resulting in a decrease in water quality. The decline in water quality in the cascade reservoir also occurred in Bakun Reservoir, Malaysia, due to the accumulation of organic matter from the upstream of the dam (Teck-Yee Ling et al., 2017). In addition to the Bakun Reservoir, the water system of the Cantareira Reservoir, Brazil, which consists of five interconnected reservoirs, has experienced a decline in water quality due to the accumulation of nutrients (N and P) and sediment, which is a source of organic matter (Pompêo, 2017).

The water quality of the Citarum River is still poor, even though many water quality restoration programs have been carried out. In addition to organic parameters, several heavy metals have been detected in this river water (Desriyan and Wardhani, 2015; Rachmaningrum et al., 2015). The impact of water pollution on the Citarum River is the damage to the ecosystem of the three reservoirs that block it. First, the Saguling Reservoir, which experienced heavy pollution, detected several heavy metals in the water and sediment (Arinda and Wardhani, 2018; Wardhani et al., 2018). This reservoir's water and sediment conditions have been contaminated with heavy metals Cd, Cr, Cu, and Pb with heavy levels of pollution (Wardhani et al., 2014; Wardhani et al., 2017a; Wardhani et al., 2017b). The second reservoir that dams the Citarum River is Cirata, where the water quality is not much different from the first reservoir. In addition to the supply of poor quality water from the dammed river, the pollutant load from the reservoir's catchment area causes water quality to deteriorate (Prasiwi and Wardhani, 2018). Jatiluhur Reservoir is the third reservoir to dam the Citarum River. The pollutant load from the Citarum River has been set aside in the previous two reservoirs. There is a pollution of domestic, industrial, agricultural, and livestock wastewater from water catchment areas, so water quality has decreased. The indicator of the occurrence of pollution is indicated by the high level of eutrophication in the reservoir waters (Hamzah et al., 2016). The water quality status of Jatiluhur Reservoir using the Store method is categorized as heavily polluted by organic waste. High levels of organic waste can cause a decrease in dissolved oxygen levels in water and the appearance of toxic gases such as H_2S and can affect the life and development of fish (Purnamaningtyas, 2014).

The problem of decreasing reservoir water quality can disrupt the function of the reservoir, especially raw water for drinking water. There are two problems related to this, namely external and internal factors. External factors are wastewater pollution originating from the Citarum watershed and the catchment area of the reservoir. The internal factor comes from the activity of floating net cages (KJA) for fish cultivation in 4 zones with 34,474 KJA plots (Perum Jasa Tirta II, 2020). According to Dewantara (2020), fish farming activities in the KJA in the Jatiluhur Reservoir have exceeded the carrying capacity of the reservoir waters, resulting in a decrease in aquaculture productivity and mass fish deaths. Citarum River pollution has been overcome with the Citarum Harum program, which involves various stakeholders who contribute to the pollution. KJA cultivation contributes to the production of organic waste from feed residues and fish waste. According to Hamzah (2016), KJA in Jatiluhur Reservoir consumes around 276,000 tons/year of fish feed. Fish feed rich in N and P, only 15-30% will be retained in the meat, and the rest will be wasted in the environment (Pembayun et al., 2015). Organic waste originating from feed residues, fish faeces, and the remains of fish metabolism will settle to the bottom of the reservoir to lead to siltation because sediments are formed which are rich in sources of organic substances (Prinajati, 2019). This condition can threaten and negatively impact reservoir infrastructure, vital businesses, the availability of drinking water and irrigation water, and threaten another aquatic biota (Hamzah et al., 2016).

Various efforts to improve the water quality of Jatiluhur Reservoir have been carried out and yielded results where several parameters have met the required quality standards. Considering the very heavy pollutant load entering this reservoir from various activities in the water catchment area, key water pollution parameters are still not up to standard, so it is not suitable for drinking water as raw water. Based on the problems that occur, research is needed regarding the current description of the water quality of the Jatiluhur Reservoir. Several studies on water quality in Jatiluhur Reservoir have been conducted (Anas et al., 2017; Hamzah et al., 2016; Prinajati, 2019). However, water quality must be described in detail, considering that different biogeochemical reactions occur at each of those depths. This study aimed to determine and analyze the water quality of the Jatiluhur Reservoir at a certain depth. Water quality compared to quality standards following government regulation no. 22 of 2021 (PP 22/2021) concerning the Implementation of Environmental Protection and Management. Steps to facilitate understanding the water quality description are calculated by using the Pollution Index (IP) method. The determination of the IP value refers to the Decree of the Minister of the Environment No. 115 of 2003 (Kepmen LH No. 115/2003) concerning Guidelines for Determining the Status of Water Quality.

2. Methodology

The study was carried out in September 2020, representing the dry season at 16 monitoring points, as presented in Table 1. The depth of the intake points varied, namely 0, 2, 4, and 8 meters, depending on the depth of the reservoir. A sampling of water refers to SNI 6989.57-2008 regarding the method of sampling surface water. The waters of the Jatiluhur Reservoir have an average depth of 37.6 m and a maximum depth of 90 m (Perum Jasa Tirta II, 2020) so that water sampling is adjusted to the depth of the monitoring location. In waters with a depth of less than 10 m, water samples were taken at 2 points, namely the surface and the bottom, such as the Parung Kalong monitoring point. Waters with a depth of 10-30 m, water samples were taken at 3 points, namely the surface, the thermocline layer and the bottom, as was done in Sodong, Bojong, Jaramas, Kerenceng, PDAM, Taroko and Baras Barat. The thermocline layer in the Jatiluhur Reservoir is at a depth of 2-4 m. In the reservoir section with a depth of 31-100 m, samples were taken at 4 points: the surface, the thermocline layer, above the hypolimnion layer, and the bottom, as was done in Karamba and DAM.

The distribution of water quality monitoring locations refers to the same SNI where four locations must be monitored, namely (1) where the river enters the reservoir at 5 locations, namely Parung Kalong, Sodong, Bojong, Jamaras and Cilalawi; (2) in the middle of the reservoir in 3 locations namely Kerenceng, Pasir Astana and Pasir Kole; (3) locations for tapping water for utilization are carried out at intake locations (PDAM and Taroko), tourism and water sports locations (DAM and Baras Barat), as well as cultivation locations (Karamba and Tajur Sindang); (4) the reservoir water outlet is carried out at the Tailrace and hydropower inlet. The distribution and description of the location of the sampling points are presented in Figure 1.

Sampling is done instantaneously (grab sample) with the direct measurement method in the field using a tool (water quality checker). The tool is useful for measuring temperature, pH, and dissolved oxygen levels in the water. Parameters of dissolved residues, fluoride, nitrate, sulfate, BOD5, and COD were analyzed at the Water Laboratory of Perum Jasa Tirta II. A sampling at a depth of 2 to 8 meters using a tool called a depth water sampler. The sample preservation is based on SNI 6989.57-2008 regarding the method of sampling surface water. The laboratory analysis results are compared with water quality standards based on PP 22/2021 class II water designation. Table 2 presents the parameters, quality standards, test methods, and tools used in the research.

Table 1. Location, coordinate point, and depth of sampling point

Num	Monitoring Point	Geodetic Coordinates		Depth (m)			
		Latitude	Longtitude	0	2	4	8
1.	Parung Kalong	6°40'25,3"	107° 19'23,2"	√	√		
2.	Sodong	6°38'51,9"	107° 17'53,6"	√	√	√	
3.	Bojong	6°37'45,2"	107° 18'10,2"	√	√	√	
4.	Jaramas	6°35'44,7"	107° 18'3,7"	√	√	√	
5.	Kerenceng	6°32'52,6"	107° 18'30,5"	√	√	√	
6.	Karamba	6°33'10,4"	107° 23'41,7"	√	√	√	√
7.	Cilalawi	6°34'20,9"	107° 24'9,6"	√			
8.	PDAM	6°33'35,0"	107° 24'5,2"	√	√	√	
9.	Taroko	6°33'6,7"	107° 24'7,8"	√	√	√	
10.	Baras Barat	6°31'51,1"	107° 22'35,9"	√	√	√	
11.	Tailrace	6°31'18,3"	107° 23'21,9"	√			
12.	DAM	6°31'28,2"	107° 23'7,2"	√	√	√	√
13.	Pasir Astana	6°30'41,1"	107° 19'47,9"	√			
14.	Pasir Kole	6°31'29,6"	107° 21'6,4"	√			
15.	Tajur Sindang	6°33'39,3"	107° 22'4,0"	√			
16.	*Inlet* PLTA Ir. H. Djuanda	6°31'29,2"	107° 23'17,8"	√			

Source: Research Results, 2020 based on the location of water quality monitoring conducted by Perum Jasa Tirta II

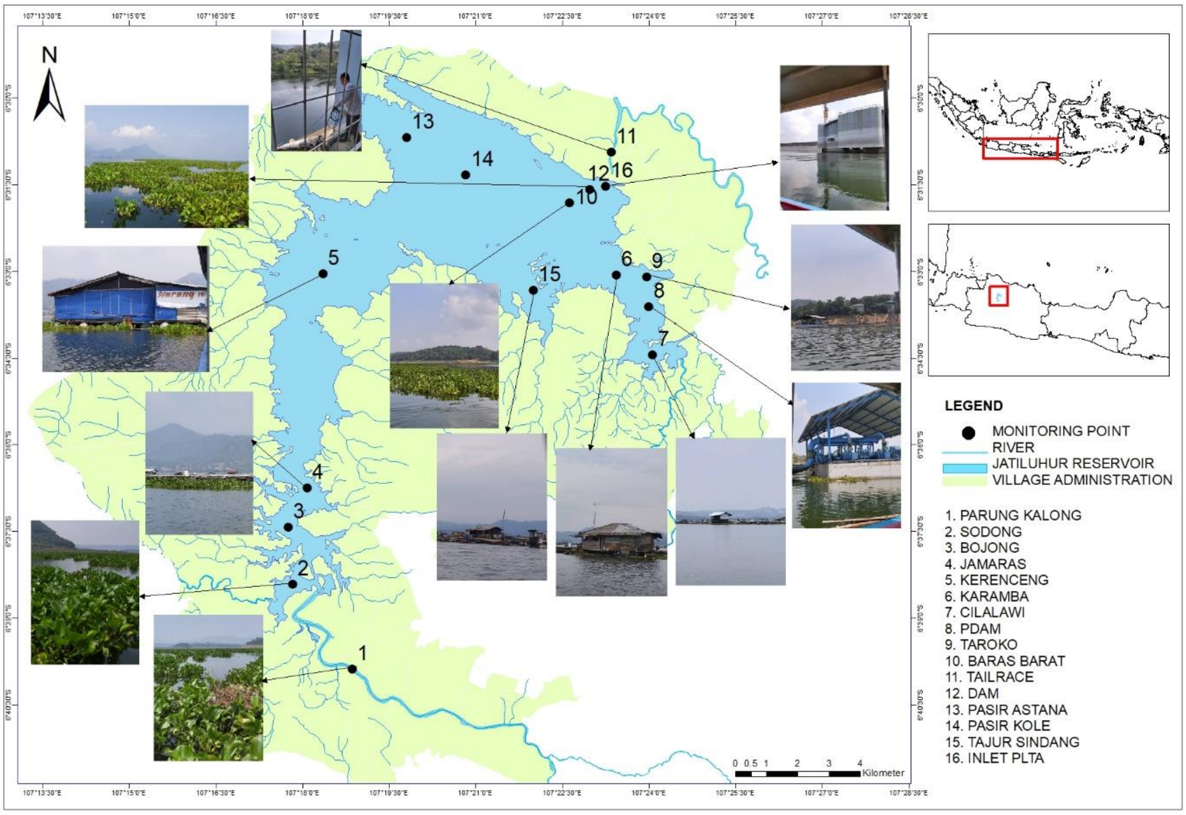

Figure 1. Distribution of water sampling points

Table 2. Parameters, quality standards, test methods and tools used in research

Num	Parameter	Unit	PP No. 22/2021 Kelas II	Test Method/Equipment
	Physics			
1.	Temperature	°C	Deviation ± 3	*Water Quality Checker*
2.	Dissolved Residue (TDS)	mg/L	1,000	APHA 23rd Ed.2540.C
	Chemicals			
3.	pH		6-9	*Water Quality Checker*
4.	Dissolved Oxygen (DO)	mg/L	Required > 4	*Water Quality Checker*
5.	Fluoride (F^-)	mg/L	1.5	SNI 06-6989.29-2005
6.	Nitrate (NO_3^-N)	mg/L	-	APHA 23rd Ed.4500-NO3.E
7.	Sulfate (SO_4^{2-})	mg/L	300	SNI 06-6989.20-2009
8.	BOD_5	mg/L	3	SNI 6989.72: 2009
9.	COD	mg/L	25	APHA 23rd Ed.5220.C
	Microbiology			
10.	*Escherichia coli*	Amount/100 ml	1,000	APHA 23rd Ed.9223

3. Result and Discussion

Jatiluhur Reservoir gets its water supply from the Cilalawi River, Cisomang, and the Citarum River outlet of the Cirata Reservoir. Based on the trophic status (nitrate and orthophosphate), the water of the Jatiluhur Reservoir is classified as oligotrophic and eutrophic-super eutrophic (hypertrophic) (Sri et al., 2015). The catchment area of Jatiluhur Reservoir is 4,500 km2 with various population activities, namely domestic, industrial, agricultural, mining etc. The diversity of these activities affects the water quality of the reservoir. Based on the study results, there are three parameters, namely DO, BOD_5, and COD, that do not meet the quality standards, which will be discussed in detail.

Class II quality standard minimum concentration of DO in water must be greater than 4 mg/L. The presence of dissolved oxygen in the water of more than 4 mg/L will ensure optimal water life. If the DO concentration is less than required, anaerobic conditions will occur in the water. Figure 2 presents the distribution of sampling points with DO values that meet/exceed the quality standard.

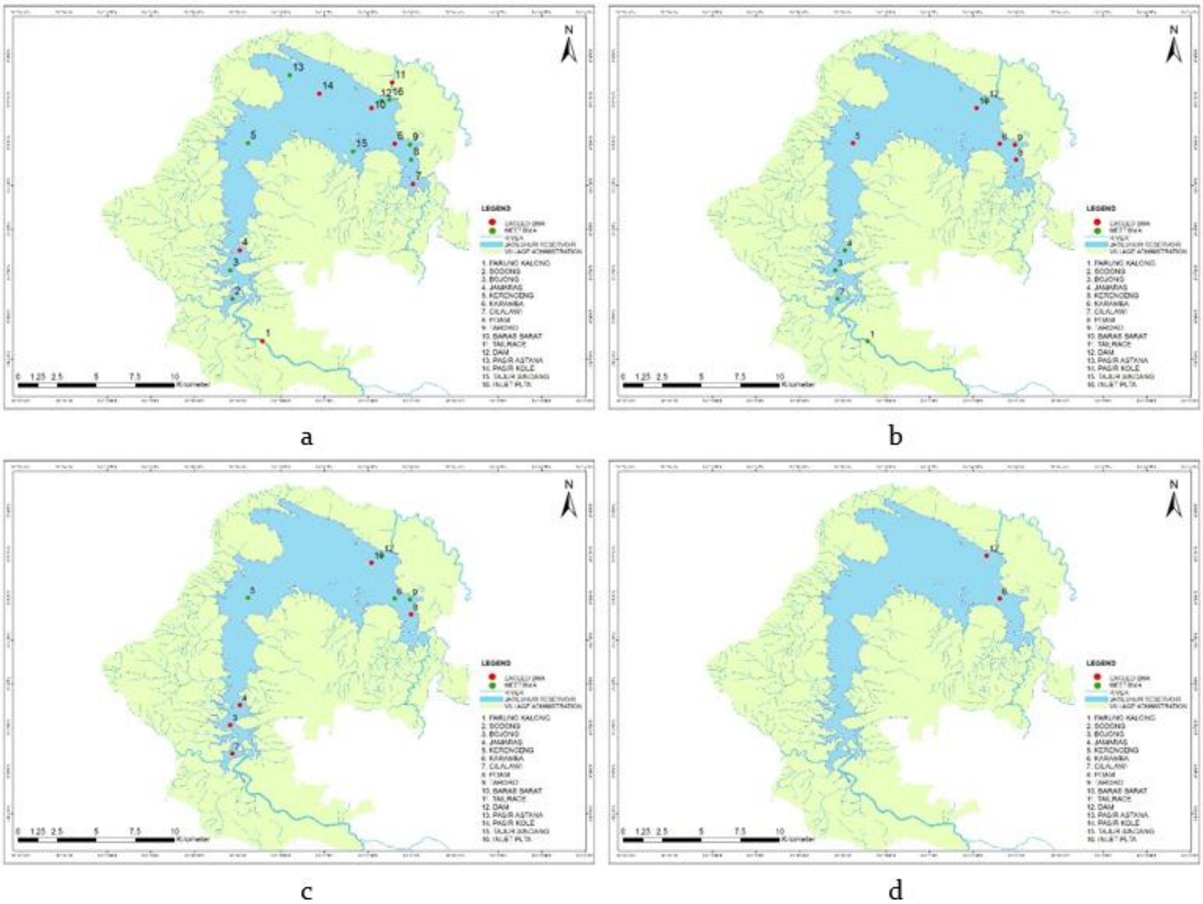

Figure 2. Distribution of DO per depth (a) 0 m (b) 2 m (c) 4 m (d) 8 m

The results of monitoring the DO concentration in Jatiluhur Reservoir on the surface at several monitoring locations show that DO is already low (< 4 mg/L), even in Parung Kalong and Cilalawi, the DO concentration is very critical (1 mg/L). At the bottom of the water, the lowest oxygen concentration is in Karamba (2.96 mg/L), and the highest is in DAM (3.96 mg/L). This condition is similar to the results of the study in Maninjau Lake, where the DO concentration was very critical (< 1 mg/L) (Lukman, 2013).

The DO distribution vertically in September 2020 does not show a stratification pattern between the surface and bottom layers. According to Lukman (2013), this condition is related to the relatively homogeneous temperature along the water column. There is no metalimnion layer barrier so that the mass circulation of water takes place throughout the water column. This is following the results of the measurement of temperature parameters per depth in the waters of the Jatiluhur Reservoir, which showed homogeneous results (32-35°C). In contrast to the DO conditions in Bakun Reservoir and Qiandaohu Lake, China, the dissolved oxygen concentration decreases with increasing depth (Teck-Yee Ling et al., 2017; Zhang, 2015). According to Leidonald (2019), in stagnant waters such as reservoirs or lakes, dissolved oxygen concentration generally decreases with increasing depth. This happens because the oxygen supply from photosynthesis and diffusion processes decreases (Sinaga et al., 2016 in

Leidonald et al., 2019). Lacerda (2018) states that stratification in waters can cause the formation of oxycline, which reduces the concentration of dissolved oxygen in the hypolimnion layer. Weak water mass mixing causes low DO concentrations in the bottom water column, oxygen use for organic matter decomposition, and sediment and rainfall also contribute to the depletion of dissolved oxygen concentrations (Noori et al., 2018).

The increase in the number of marine cages that produce marine cage waste, accumulation of feed residues, and domestic waste disposal around the Jatiluhur Reservoir lake contribute to reducing dissolved oxygen concentrations. The KJA waste load that comes from feed (artificial feed in the form of pellets) and fish faeces is rich in nutrients and organic matter. The rest of the feed is a source of organic matter that can cause the concentration of BOD to increase and decrease the concentration of DO. The available oxygen concentration will be consumed for the respiration process and remineralization of organic matter and nitrification (Lukman, 2013). Sari (2020) stated that fish farming activities in cages lead to the accumulation of leftover feed, reducing water quality.

Based on the research results conducted by Prinajati (2019), as much as 4,200 kg of fish feed is not eaten and settles every day. The results of Hamzah's research (2016) stated that the waters of the Jatiluhur Reservoir consume around 276,000 tons/year of fish feed. Fish feed rich in N and P, only 15-30% will be retained in the meat, and the rest will be wasted in the environment (Pembayun et al., 2015). Increased nutrients (phosphate and nitrate) and excess organic matter encourage eutrophication and algae blooms. This condition occurs at the Karamba monitoring point, which water hyacinth plants have covered. Figure 1. Deficient dissolved oxygen levels make it easier for nutrients from fish feed and sediment to be dissolved. Sri (2015) reported that the trophic status of the waters of the Jatiluhur Reservoir is classified as oligotrophic and eutrophic-super eutrophic (hypertrophic), which indicates nitrogen and phosphorus pollution has occurred.

Low DO concentrations can inhibit the photosynthesis process of living things and are threatened with death. The DO parameter describes the oxygen content available and needed by living things for photosynthesis (Prinajati, 2019). A DO concentration of 1.00 mg/L in the surface layer at Parung Kalong, and Cilalawi indicates that the quality around the location based on the DO parameter has a heavy pollution level and indicates the possibility of anoxic conditions. The low dissolved oxygen concentration at Parung Kalong and Cilalawi points can reduce the self-purification process of waters. In addition, the condition of calm water flow in the waters of the Jatiluhur Reservoir causes the self-purification process to be not optimal. According to Agustiningsih (2012) in Purwati et al. (2019), the self-purification process was not optimal due to the precise flow pattern and the absence of turbulence, so that the reaeration process was reduced. Further, A. Niu et al. (2019) reported that low water flow velocity causes the self-purification process to decrease, so contaminants settle to the bottom of the water.

The results of the BOD5 parameter test showed that 15 sampling locations exceeded the class II water quality standard of 3 mg/L. The BOD5 concentration value in the surface layer ranged from 2.70-17.00 mg/L. Results This is similar to the research conducted by Sari (2020). The concentration of BOD5 in the surface layer of the Jatiluhur Reservoir is higher than the BOD5 concentration in the Bakun Reservoir at 4.30 mg/L (Teck-Yee Ling et al., 2017). The lowest concentration of BOD5 in the bottom waters was in DAM (5.00 mg/L), and the highest was found in Karamba (7.00 mg/L). To see the distribution of BOD5 levels, it is presented in Figure 3.

The average vertical BOD5 concentration does not show a stratification pattern between the surface and bottom depths. This condition is similar to the results of research conducted in Lake Maninjau (Lukman, 2013). This is because the temperature value is relatively homogeneous along the water column. There is no metalimnion layer barrier so that the mass circulation of water takes place throughout the water column (Lukman, 2013). Furthermore, Arinda and Wardhani (2018) reported random and fluctuating concentration differences at each station and the depth were affected by stirring and water mass transfer.

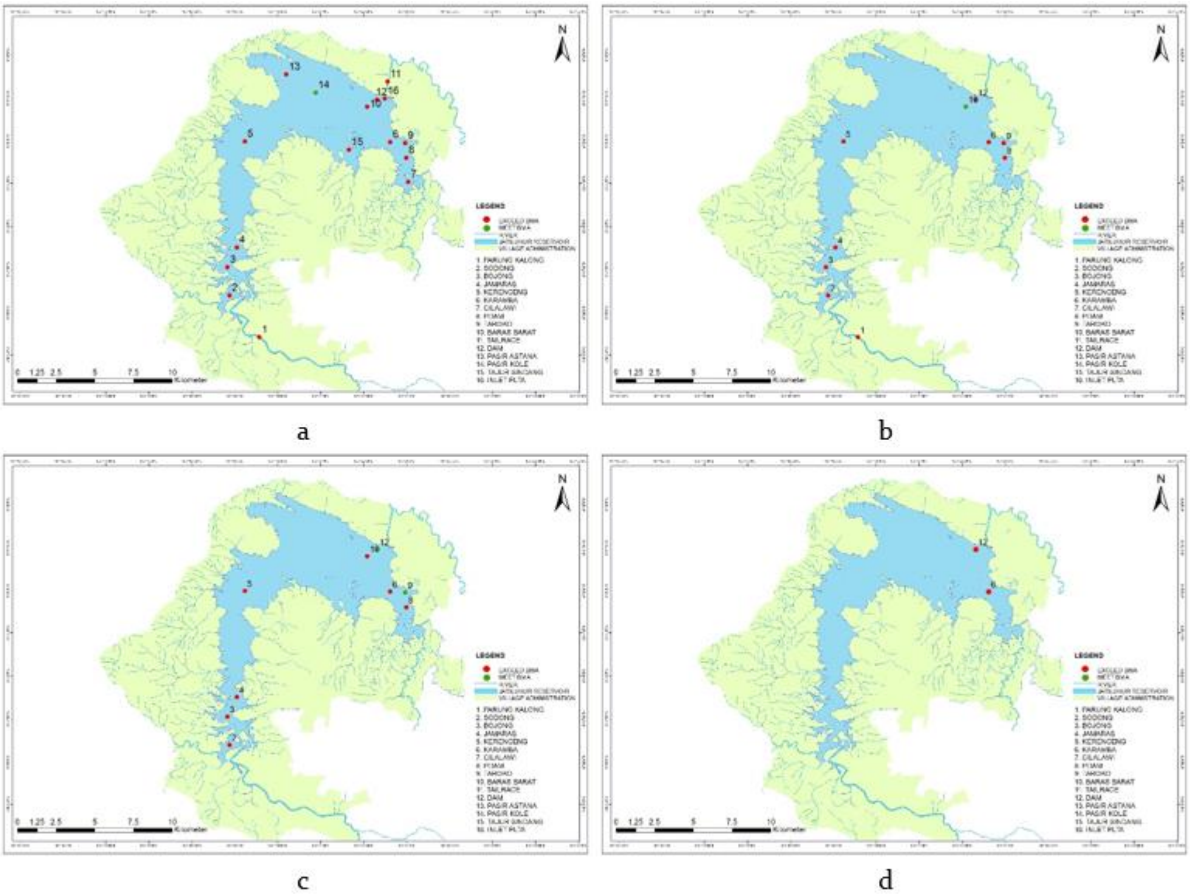

Figure 3. Distribution of BOD5 per depth (a) 0 m (b) 2 m (c) 4 m (d) 8 m

The high concentration of BOD5 in the waters of the Jatiluhur Reservoir is caused by fish culture waste in cages (KJA) originating from feed (feed pellets) and fish faeces. Gina (2020) reported that the accumulation of fish feed caused the BOD condition in Jatiluhur Reservoir water. An increase in the concentration of BOD5 in lake waters indicates a high accumulation of organic matter (Teck-Yee Ling et al., 2017). Furthermore, Panjaitan in Silaen (2017), organic waste in relatively stagnant waters will settle and accumulate at the bottom of the water so that organic matter or BOD5 increases. The covering of the waters of the Jatiluhur Reservoir with water hyacinth plants (Eichhornia crassipes) contributes to increasing organic matter. Water plants and fish that have died will rot and settle to the bottom of the water (Azizah, 2017). The accumulated feed will settle and cause siltation in the reservoir because sediments with a thickness of 10 cm are formed where the sediment is a source of organic substances (Astuti et al., 2016). High levels of organic substances and high nutrient content can increase the growth of water hyacinth (Eichhornia crassipes), resulting in eutrophication (Bhavsar, 2016; Gina et al., 2020). Covering the waters of the Jatiluhur Reservoir by water hyacinth can reduce the concentration of dissolved oxygen, increase siltation, and reduce the amount of water (Astuti et al., 2016). In addition, the high value of BOD5 in the waters can come from agricultural and residential waste originating from bathing, washing, and latrine activities that produce organic matter (Nurrohman et al., 2019).

Similar to BOD5, the COD parameter also shows a value that exceeds the Class II quality standard of 25 mg/L. The test results for COD parameters in the surface layer ranged from < 7.00-59.00 mg/L. These results are similar to the research conducted by Gina (2020). The lowest COD concentration in the bottom waters was in DAM (15.00 mg/L), and the highest was found in Karamba (22.00 mg/L). Figure 4 presents the distribution of COD values that meet/exceed the quality standard.

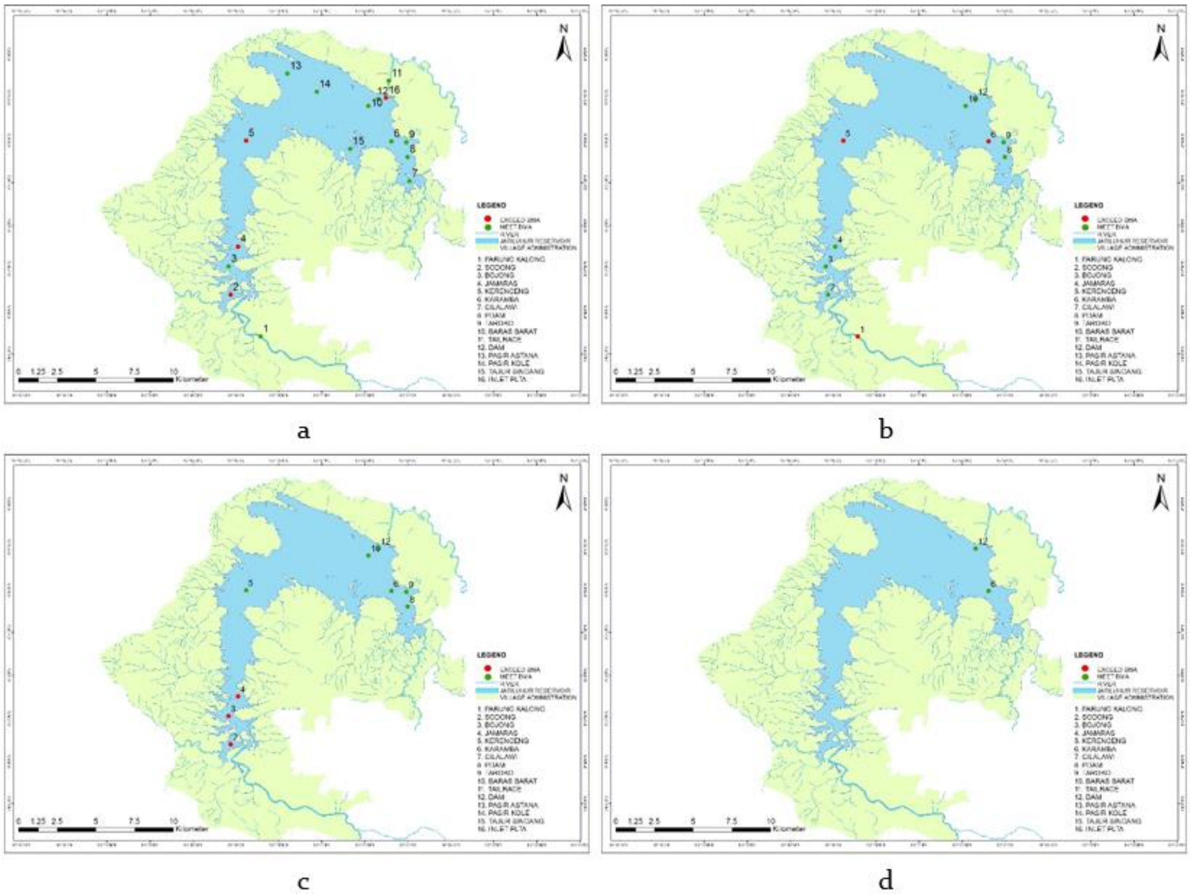

Figure 4. Distribution of COD per depth (a) 0 m (b) 2 m (c) 4 m (d) 8 m

The magnitude of the COD value in the waters of the Jatiluhur Reservoir is due to a large amount of deposition and accumulation of organic waste originating from fish farming activities in cages. KJA waste in fish feed, excretion products, and the remains of fish metabolism contribute to increasing organic matter. The accumulation of fish feed will settle and cause siltation in the reservoir, forming sediment thicknesses of 10 cm (Astuti et al., 2016). Andara (2014) stated that the high concentration of COD indicates a high level of water pollution by organic matter. The COD value in unpolluted waters is usually less than 20 mg/L, while polluted waters can be more than 200 mg/L (Effendi, 2003). The high and low COD values indicate that the area contains a lot of organic substances consisting of hydrocarbon components with small amounts of oxygen, nitrogen, sulfur and phosphorus, which can increase the growth of water hyacinth (Eichhornia crassipes) so that eutrophication occurs (Bhavsar, 2016; Fajri & Kasry, 2013; Gina et al., 2020).

Determination of the water quality status of the Jatiluhur Reservoir is carried out after analyzing the water quality of the reservoir. The water quality status method used is the IP method. The pollution index is used to determine the level of pollution relative to water quality parameters. This index relates to significant pollutant compounds for a designation developed for several uses for all parts of a water body or part of it (Yuliastuti, 2011).

Quality status is determined at each sampling depth by comparing the measured parameter values with the established quality standards. The water quality standard used is based on PP 22/2021 Class II. The results of the calculation of the quality status can be seen in Figure 5.

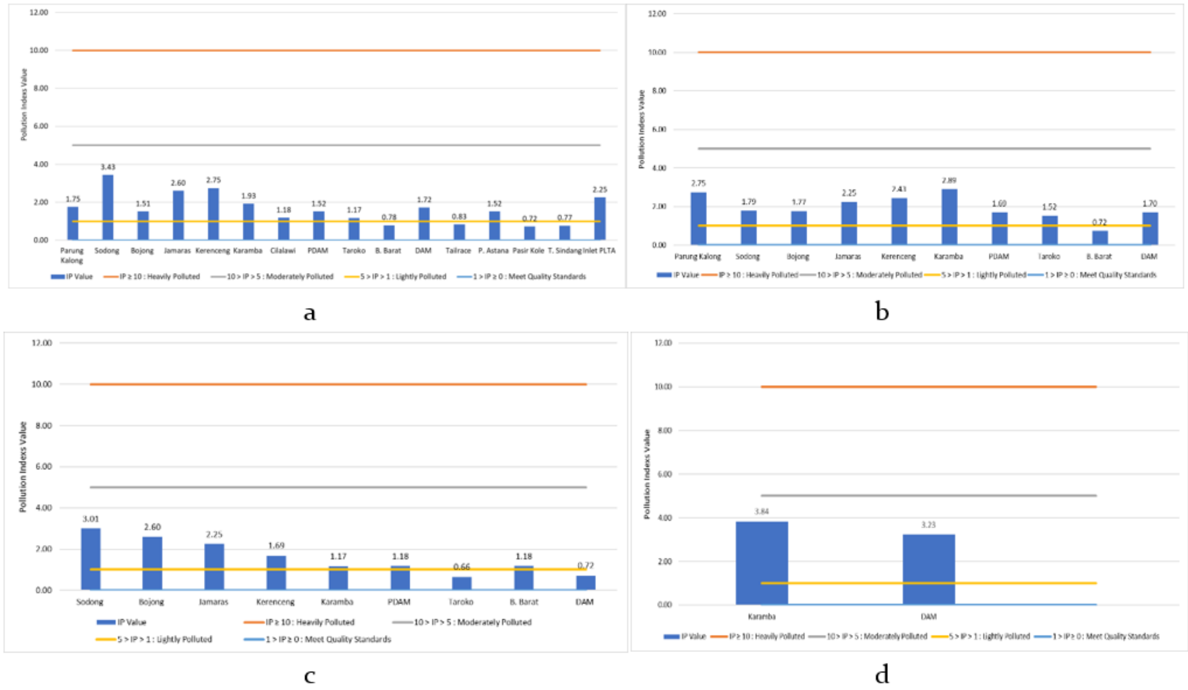

Figure 5. Water quality status of Jatiluhur Reservoir per depth (a) 0 m (b) 2 m (c) 4 m (d) 8 m

Based on the results of the calculation of the pollution index at 16 monitoring points, it can be concluded that the quality of the waters of the Jatiluhur Reservoir in September 2020 on average is lightly polluted. Pollution of the waters of the Jatiluhur Reservoir occurs due to the DO, BOD5 and COD content that has exceeded the predetermined threshold. The highest pollution index value was at the Karamba monitoring point of 3.84 at a depth of 8 m. Karamba is a monitoring location in a fish farming location Figure 1.

KJA units also function as residences and stalls, thus generating domestic waste from bathing, washing, latrines and garbage activities. The results showed that the water quality status of the Jatiluhur reservoir based on "US-EPA" was moderately polluted, almost heavily polluted, with a value of -30 class C (Anas et al., 2017). Furthermore, Prinajati (2019) reported that fish farming activities in cages reduced water quality and increased the water pollution load by 512.89 mg/second. If this condition is allowed to continue, the pollution load will continue to increase so that the water quality of the Jatiluhur Reservoir will deteriorate, and siltation can occur, resulting in a decreasing reservoir volume. In addition, there will be damage to aquatic ecosystems due to excessive sedimentation. Hamzah (2016) reported that the sedimentation entering the waters of the Jatiluhur Reservoir was 7,000,000 M3. The decline in water quality of the Jatiluhur Reservoir also impacts the health conditions of the people in the outlet area who use the reservoir water for daily activities.

Based on the research results, efforts are needed to reduce the burden of organic pollution. The source of this pollutant comes from KJA activities in the waters of the Jatiluhur Reservoir and domestic, industrial, agricultural and livestock activities in the catchment area of the Jatiluhur Reservoir and Citarum Watershed. A comprehensive effort is needed by involving various stakeholders to reduce organic matter entering the reservoir waters successfully. The calculation of the pollutant load of KJA feed waste has been carried out by many studies where the results must be applied immediately. The pollutant load of KJA feed waste plays a significant role in determining organic pollutants in the Jatiluhur Reservoir, so further research must be carried out, namely calculating its contribution to pollution during different seasons and knowing the level of decline in the carrying capacity of the reservoir environment.

4. Conclusion

After measuring and analyzing the water quality of the Jatiluhur Reservoir based on the test parameters, it was found that the concentrations of DO, BOD5, and COD at the monitoring location of the Jatiluhur Reservoir did not meet the quality standards. The concentrations of DO, BOD5, and COD were 1.00-3.99 mg/L, respectively; 3.10-17.00 mg/L; and 28.00-59.00 mg/L. The water quality of Jatiluhur Reservoir based on the assessment of the water quality status with the IP method on average has entered the category of lightly polluted so that it affects the utilization of this reservoir, especially as raw water for drinking water. The highest level of contamination was at the KJA sampling location at a depth of 8 m. The decline in water quality in the Jatiluhur Reservoir is caused by organic substances originating from KJA waste. These results indicate the need for reservoir management to prevent further deterioration of water quality. Therefore, it is necessary to carry out further research to calculate the pollutant load of KJA waste during different seasons and determine the level of decline in the carrying capacity of the reservoir environment.

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