Jurnal Presipitasi
Media Komunikasi dan Pengembangan Teknik Lingkungan
e-ISSN: 2550-0023

Vol 19, No 2, 2022, 316-329
Article available at homepage presipitasi

Research Article

Depth Profiles of Dissolved Oxygen (DO) and Hydrogen Sulfide (H_2S) Concentration in a Tropical Freshwater Reservoir

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Abstract

This study aims to determine the profile of dissolved oxygen and H2S based on depth in the Jatiluhur Reservoir related to fish culture in floating net cages. The scope of this research is focused on the location of floating net cage cultivation. Dissolved oxygen distribution is classified as a positive heterograde type where dissolved oxygen levels higher in the metalimnion layer due to the photosynthesis process that occurs effectively by aquatic plants and phytoplankton. Jatiluhur Reservoir shows signs of organic pollution, with BOD5 and COD levels exceeding the quality standard. This organic substance comes from the waste of floating net cages. BOD5 and COD values that exceed the quality standard result in increased oxygen consumption during the decomposition process; therefore, a hypoxic layer occurs. This occurrence can cause water conditions to become anoxic, producing H2S gas. The H2S value in the Jatiluhur Reservoir was observed to exceed 0.002 mg/L and showed an increase in the metalimnion layer.

Keywords: Floating net cages; positive heterograde; Jatiluhur reservoir

1. Introduction

Ir. H. Djuanda Reservoir, or Jatiluhur Reservoir, is one of three cascade reservoirs in West Java Province. This reservoir was completed in 1967 and is located in Jatiluhur District, Purwakarta Regency. That reservoir is the first multipurpose reservoir in Indonesia that serves to meet the irrigation needs of rice fields of around 242,000 ha. A supply of raw drinking water for the Province of the Special Capital Region of Jakarta and its surroundings. A power plant with an installed capacity of 187.5 MW, flood control, water supply for industry, city flushing tourism, and water sports are used as floating net cage (KJA) cultivation in the reservoir area (Perum Jasa Tirta II, 2022).

Using the Jatiluhur Reservoir as KJA contributes to improving welfare and opening up job opportunities for the community. The economic benefits from these activities encourage the community to continue building and developing KJA. In 1988 the number of KJA was 15 plots. In 2020, it reached 42.413 plots, with 7.112 plots within the area and 35.301 plots outside the area. Based on the Decree of the Governor of West Java No. 660.31/Kep.923.DKP/2019, the number of floating net cages in Cirata, Saguling, and Jatiluhur Reservoirs that meet the environmental carrying capacity is limited to 11,306 KJA plots (for Jatiluhur Reservoir). That indicates that the number of floating net cages operating in the Jatiluhur Reservoir has exceeded the specified number.

The increase in floating net cages not following the carrying capacity causes the trophic status in the Jatiluhur Reservoir to change from oligotrophic to eutrophic-super eutrophic (hypertrophic), which is characterized by a decrease in brightness, an increase in the concentration of phosphorus (0.061–0.359 mg/L) and nitrogen (0.212–0.867 mg/L) and blooming water hyacinth (Eichhornia crassipes) (Sari et al., 2015). The status of water quality of Jatiluhur Reservoir using the IP method is categorized as lightly polluted by organic substances. Wardhani and Sugiarti (2021) reported the decline in water quality in Jatiluhur Reservoir is caused by organic waste originating from KJA waste. Uneaten feed residues and fish metabolism wastes contribute to increasing organic matter levels; thus, the BOD5 and COD value was high (Bhavsar et al., 2016; Dewantara, 2020; Sari et al., 2020).

The increase in organic matter in the water affects the amount of dissolved oxygen demand in the decomposition process. In addition, it also has the potential to reduce dissolved oxygen levels; thus, the waters are in anaerobic conditions. Anaerobic water conditions will produce H2S and NH3 gases due to anaerobic decomposition (Winton et al., 2019). Based on the problems, research is needed regarding the profile of dissolved oxygen and H2S based on depth in the Jatiluhur Reservoir related to fish culture in floating net cages. The scope of this research is focused on the location of floating net cage cultivation. The same research has been carried out by previous researchers such as the analysis of the water quality of the Saguling Reservoir, which determines the pollutant index of the reservoir water in several monitoring locations (Wardhani et al., 2018). Profile of temperature, pH, and dissolved oxygen in Pergau Reservoir, Malaysia (Effendi et al., 2020). Effect of pH, dissolved oxygen, and temperature on organic compounds (BOD5 and COD) based on depth stratification in Lake Maninjau (Komala et al., 2019). Vertical distribution of temperature, pH, conductivity, ammonia, nitrite, nitrate, phosphate, and dissolved oxygen in Padaviya Reservoir, Sri Lanka (Siriwardana et al., 2019). The vertical profile of dissolved oxygen, the depth of hypoxia at the floating net cage location, and the effect of temperature on the decomposition rate of organic matter (k) in the Jatiluhur Reservoir (Astuti et al., 2014). Water quality parameters compared to quality standards following government regulation no 22 of 2021 (PP 22/2021) concerning the Implementation of Environmental Protection and Management.

2. Methods

Water sampling was carried out from September to December 2020. The surface water sampling method was based on SNI 6989.57:2008 regarding the surface water sampling method. Dissolved oxygen parameters were measured directly in the field (on-site) using a calibrated Horiba water quality checker. Meanwhile, the BOD5, COD, and H2S parameters were analyzed at the Water Laboratory of Perum Jasa Tirta II, which has implemented quality control and quality assurance (Table 1). Water sampling uses the grab sample method and refers to the same SNI. The water samples were put into polyethene bottles and a Winkler for BOD5. Water samples based on depth were taken using a vertical type depth water sampler; this tool has a capacity of 2.2 L. Sample preservation was carried out in the laboratory with a maximum time limit of 12 hours for sample delivery. Water sampling used the grab sample method, a single sample taken directly from a particular place or water monitored over a short period. Water sampling was carried out at Karamba station at coordinates 6°33'10.4" Latitude and 107° 23'41.7" Longitude. This station is a legal floating net cage cultivation area classified as dense with a depth of 31–100 m. Vertical observations were carried out at four depths, i.e., 0 m, 2 m, 4 m, and 8 m, with a metalimnion or thermocline layer at a depth of 2–4 m. The location of Karamba station can be seen in Figure 1.

Table 1. Method and preservation of sample analysis

No	Parameters	Test Method/Equipment	Required Preservation
		On-Site	
1	DO	Water Quality Checker	No preservation
		Laboratory	
2	Sulfida (H_2S)	Methylene Blue	0–6°C
3	BOD_5	*Winkler* Titration	H_2SO_4 pH < 2
4	COD	Close Reflux titremetric	NaOH pH > 9

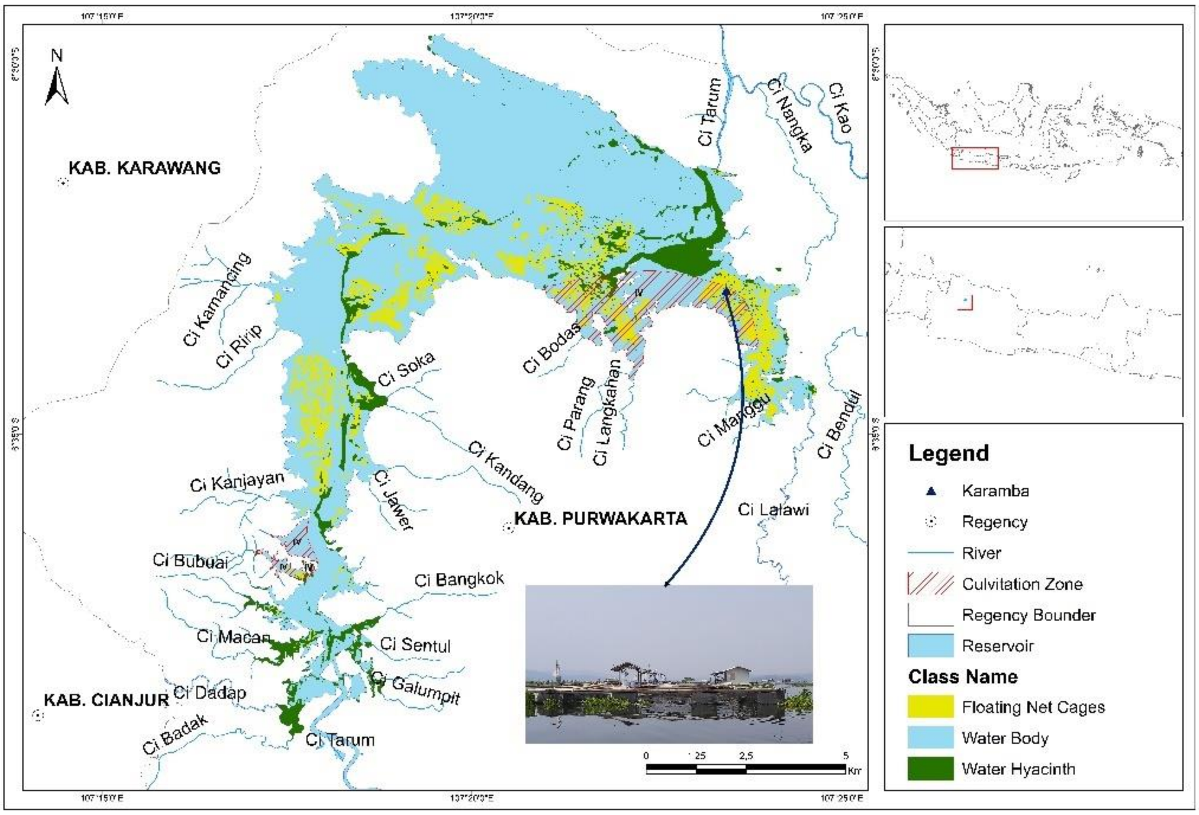

Figure 1. Karamba station location

3. Result and Discussion

Kampong The variation of dissolved oxygen (DO) at the location at the Karamba station during the study is shown in Table 2 and Figure 2. Dissolved oxygen levels at the surface in the dry season (July and August) and the rainy season (January, November, and December) were generally higher (≥ 4.00 mg/L) than at the bottom depth. In the rainy season, dissolved oxygen levels are high due to hydrodynamic forces; thus, the exchange of atmospheric oxygen, especially from the turbulence of water masses and waves (Effendi, 2003). The difference in dissolved oxygen levels, which is not significant during these months, indicates that seasonal changes do not affect dissolved oxygen levels on the surface of the tropical reservoir. That was because the process of photosynthesis by aquatic plants (algae) and phytoplankton continues (Effendi et al., 2020; Welch, 1952). Boyd & Lichtkoppler (1979) stated that the process of photosynthesis is the primary source of dissolved oxygen in waters which can produce 5–20 mg/L. Therefore, dissolved oxygen levels are high in the surface layer (epilimnion). This condition is similar to the results of research by Kumar et al. (2017), Ling et al. (2018), and Woldeab et al. (2018), which show dissolved oxygen levels in the dry and rainy seasons ≥ 4.00 mg/L in tropical reservoirs.

Table 2. Measurement result of DO

Month	Water Quality Standard of Class II (mg/L)	Level of DO (mg/L)			
		Depth (m)			
		0	2	4	8
January		4.20	4.10	**3.10**	**3.60**
February		**1.00**	**1.00**	**1.00**	**1.20**
March		**1.00**	**2.00**	**2.00**	**1.00**
April		**3.70**	**3.40**	**2.60**	**2.60**
May		**2.98**	**3.30**	**3.10**	**3.20**
June	Signaled by	**3.97**	**3.80**	**3.20**	**2.90**
July	≥ 4.00	5.00	5.00	**3.30**	5.00
August		5.00	4.40	**3.80**	**3.90**
September		**2.90**	**1.00**	5.00	**2.96**
October		**1.00**	6.00	**3.80**	5.00
November		6.00	6.00	**3.70**	**3.80**
December		5.00	6.00	6.00	6.00
Average		**3.48**	**3.83**	**3.38**	**3.43**
Stdev		1.74	1.80	1.29	1.48

At a depth of 2 m and further, oxygen levels decreased. That was because, at a depth of 2m, the ability of phytoplankton and algae to carry out photosynthesis is more significant than at a depth of 4 and 8 m. Furthermore, Leidonald et al. (2019) stated that decreased dissolved oxygen levels with increasing depth were thought to be due to the decreased diffusion process. According to Lukman et al. (2013), the photosynthesis process will take place optimally at a depth of 0–4 m, related to the depth of the euphotic zone and the profile of chlorophyll abundance tends to decrease with increasing depth. Jatiluhur Reservoir has a euphotic zone at a depth of 0–4.83 m (Pratiwi, 2009), while at a depth of 4m, the intensity of sunlight has begun to decrease. Therefore at depths of 4 and 8 m, oxygen tends to be obtained from the distribution of the layer above it. Furthermore, Arinda & Wardhani (2018) stated that the decrease in light intensity is also caused by suspended and dissolved substances and water hyacinth plants, which could reflect and absorb light. Therefore, the rate of oxygen production by phytoplankton decreases with increasing depth (Boyd & Lichtkoppler, 1979).

The decrease in dissolved oxygen levels at depths of 4 and 8 m was also caused by the input load of organic matter (food residue and fish faeces) and waste from floating net cages. In addition, the decomposition of organic matter such as dead plankton and the respiration process by aquatic biota can also reduce dissolved oxygen levels (Welch, 1952). The respiration process by plankton and fish causes a loss of dissolved oxygen of 5.00–15.00 mg/L and 2.00–6.00 mg/L (Astuti et al., 2014; Boyd & Lichtkoppler, 1979; Devi et al., 2017; Welch, 1952). The low dissolved oxygen is also influenced by the slow mixing speed and stagnant water in the water-sediment layer; thus, it forms a thick layer and inhibits the oxygen diffusion process in the bottom layer (Siriwardana et al., 2019). This condition is similar to the results of research by Noori et al. (2018), which explains the difference between dissolved oxygen levels in the epilimnion layer and the lower layer indicating the possibility of limited mixing.

In February-May, September, and October, dissolved oxygen levels in the epilimnion layer were low (≥ 4.00 mg/L), especially in February, March, and October in an anoxic state (< 2.00 mg/L) and did not show a stratification pattern (Preece et al., 2019). According to Effendi (2003) and Lukman et al. (2013), these conditions were related to the relatively homogeneous temperature along the water column; thus, the mass-circulation of water will take place throughout the water column (holomictic), which will distribute anoxic conditions from the inside to the surface of the water. That followed the results of temperature measurements which were relatively homogeneous (31–33°C) at each depth. In October, a significant increase in dissolved oxygen levels of 9.00 mg/L at a depth of 2 m in metalimnion or thermocline layer. The increased dissolved oxygen levels at a depth of 2 m were thought to be due to internal waves in the thermocline layer due to surface reaeration by powerful winds (Henderson-Seller & Markland (1987).

The low level of dissolved oxygen in the KJA area was due to the high organic matter originating from feed residues, fish metabolism residues (faeces), and marine cage waste. The presence of suspended and dissolved substances and water hyacinth plants covering the water's surface can reduce the light intensity; therefore, the photosynthesis process does not run optimally (Arinda & Wardhani, 2018) due to the oxygen source being reduced. The decomposition activity of organic matter and the respiration process of plankton and fish also caused the availability of dissolved oxygen to be low and even anoxic; thus, the waters were in anaerobic conditions. Furthermore, according to Winton et al. 2019, anoxic water conditions produce H2S and NH3 gases. The deaeration process also caused a decrease in dissolved oxygen levels, inflow from groundwater, iron oxidation, and reactions by other gases such as the nitrification process (Astuti et al., 2014; Boyd & Lichtkoppler, 1979; Devi et al., 2017; Welch, 1952). According to Woldeab et al. (2018), dissolved oxygen levels below 2 mg/L can cause fish death.

The vertical profile of dissolved oxygen (Figure 2) shows that dissolved oxygen levels fluctuate with increasing depth; thus, it does not show a stratification pattern between the surface and bottom layers. According to Goldman & Horne (1983) and Hutchinson & Edmondson (1957), the type of dissolved oxygen distribution (Figure 2) obtained from the observations included a positive heterograde type. This condition occurs, presumably because phytoplankton carries out photosynthetic activities effectively in the metalimnion layer. Therefore dissolved oxygen levels are higher than oxygen levels on the surface and bottom. Goldman & Horne (1983) and Hutchinson & Edmondson (1957) stated that a positive heterograde type could occur if the water column is transparent for photosynthesis and the number of aquatic plants and phytoplankton large in the metalimnion layer. This type describes the type of eutrophic waters. The research is in contrast to the results of Siriwardana et al. (2019) in Padaviya Reservoir, Sri Lanka, which is classified as a clinograde type where the oxygen content at the surface is more significant than at the bottom depth.

The average dissolved oxygen level at 0 m depth is lower than 4.00 mg/L (Figure 2), the minimum limit for fishing activities. Kumar (2017) states that the optimal dissolved oxygen level for fish culture activities is > 4.00 mg/L. This number indicates that the waters of the Jatiluhur Reservoir have a hypoxic depth starting at 0 m. The research results of Astuti et al. (2014) stated that the depth of hypoxia at the KJA location in Jatiluhur Reservoir in 2013 started at a depth of 3 m and below. This change in the depth of hypoxia occurred due to an increase in oxygen consumption by the continuous decomposition of organic matter. Waters with oxygen levels below 4.00 mg/L caused fish to be on the surface to take oxygen directly from the atmosphere. Thus, fish experience gasping (Nastiti et al., 2018). The BOD_5 value on the surface at the Karamba station throughout 2020 had exceeded the specified quality standard (3.00 mg/L). The high BOD_5 level was a direct impact on KJA activity. The relative BOD_5 vertical distribution had a monthly different pattern/trend (**Table 3**).

Table 3. Measurement result of BOD_5

Month	Water Quality Standard of Class II (mg/L)	Level of BOD_5 (mg/L)			
		Depth (m)			
		0	2	4	8
January	3	**6.30**	**7.00**	**8.00**	**13.00**
February		**7.00**	**11.00**	2.60	2.80
March		**6.40**	2.00	**7.00**	**5.00**
April		**5.00**	**4.00**	2.80	**4.00**
May		**6.20**	**6.40**	**6.40**	**7.00**
June		**8.00**	**9.00**	**8.00**	**5.00**
July		**4.00**	**5.00**	**4.00**	2.80
August		**8.00**	**5.90**	**4.00**	**5.80**
September		**6.50**	**12.00**	**4.00**	**7.00**
October		**12.00**	**21.00**	**8.00**	**13.00**
November		**7.00**	**5.70**	**5.00**	**5.00**
December		**13.00**	2.60	**12.00**	**4.00**
Average		**7.45**	**7.63**	**5.98**	**6.20**
Stdev		**2.62**	**5.19**	**2.76**	**3.45**

In January and May, the BOD5 value increased with increasing depth. BOD5 levels will increase when the temperature value decreases with increasing depth (Komala et al., 2019). Feeding is done three times a day with a pump system, resulting in much-wasted feed and accumulated at the bottom of the water; thus, the BOD5 value was high. The observations showed an increased value of BOD5 at a depth of 8 m by 13.00 mg/L in January and 7.00 mg/L in May. The cultured fish did not entirely consume the feed; some of the feed was wasted in the waters, while the feed consumed by the fish will be excreted as faeces. Fish feed is rich in N and P; 15–30% is retained in the flesh, and the rest will be wasted in the environment (Pembayun et al., 2015). In double cages or double layers, the amount of feed wasted in the waters is 10% (Karunia & Marinasari, 2015). The accumulated feed residue will settle at the bottom of the water and cause siltation due to a 10 cm thickening of the sediment, a source of organic matter (BP2KSDI, 2016).

Waste generated from marine cages, fish metabolism residues, and the decay of aquatic plants such as water hyacinth and animals contribute to increasing organic matter levels. The accumulation of organic matter will increase the availability of nutrients that stimulate the growth of water hyacinth and phytoplankton; thus, eutrophication and algae blooms occur (Bhavsar et al., 2016; Sari et al., 2020). Sari et al. (2015) reported that nitrate and orthophosphate levels in Jatiluhur Reservoir ranged between 0.212–0.867 mg/L and 0.061–0.359 mg/L nitrate levels of more than 0.2 mg/L result in eutrophication and encouraged rapid algae growth (blooming). Furthermore, Pakusina et al. (2018) described high organic matter content indicating high biological productivity or eutrophication. That is proven by the trophic status of the Jatiluhur Reservoir, which is classified as hypertrophic (BP2KSDI, 2016; Sari et al., 2015) and is characterized by water hyacinth blooms. The increase in organic matter in the hypolimnion layer can reduce dissolved oxygen levels because oxygen levels are used for the decomposition process of organic matter. Furthermore, Effendi (2003) and Likens (2010) stated that the hypolimnion layer is the site of the decomposition process; therefore, dissolved oxygen levels are low. Low dissolved oxygen levels in January and May (Table 2).

Meanwhile, the BOD5 profile vertically in February, March, April, and June-December fluctuated with increasing depth; thus, it does not show a stratification pattern. This condition seemed to be related to a relatively homogeneous temperature indicating the possibility of holomictic mixing. Therefore there is no tendency to accumulate organic matter in the water column (Komala et al., 2019). Furthermore, Arinda & Wardhani (2018) explained that stirring and water mass transfer influenced the random and fluctuating concentration differences at each station and depth. In addition, the higher organic matter content on the surface (0 m depth) is thought to be caused by organic matter originating from surface plankton organisms (Harlina, 2021). That is related to the euphotic zone (0–4.83 m), the zone of oxygen and organic matter production (Effendi, 2003; Samal et al., 2014). A high BOD5 value will reduce the availability of dissolved oxygen in the water because it is used in the oxidation process of organic matter, which is broken down by microorganisms. The higher the organic matter in the waters, the more oxygen is needed; thus, dissolved oxygen levels decrease and become anoxic. This condition occurred in February and March when dissolved oxygen levels were at 8 m < 2 mg/L (Table 2). Suppose dissolved oxygen levels are low in the water. In that case, anaerobic bacteria will break down the organic matter and produce methane gas (CH4) and release inorganic sulfur in the form of hydrogen sulfide (H2S) (Bertrand et al., 2015).

Furthermore, Kumar (2017) stated that low dissolved oxygen levels and BOD above 5 mg/L indicate the presence of organic matter contamination. The decreased dissolved oxygen levels in water can interfere with fish survival and metabolic processes (Astuti et al., 2014). However, in July, October, and December, this phenomenon did not occur even though the BOD5 value was relatively high though the dissolved oxygen level was also high, i.e., 5.00–6.00 mg/L. This condition indicated that the dissolved oxygen resulting from photosynthesis in these waters was more significant than the oxygen requirement for the organic matter decomposition process. In addition, the decrease in dissolved oxygen due to the decomposition process also depends on the amount and distribution of organic matter, water temperature, and water volume in the hypolimnion layer (Astuti et al., 2014; Boyd & Lichtkoppler, 1979; Devi et al., 2017; Welch, 1952).

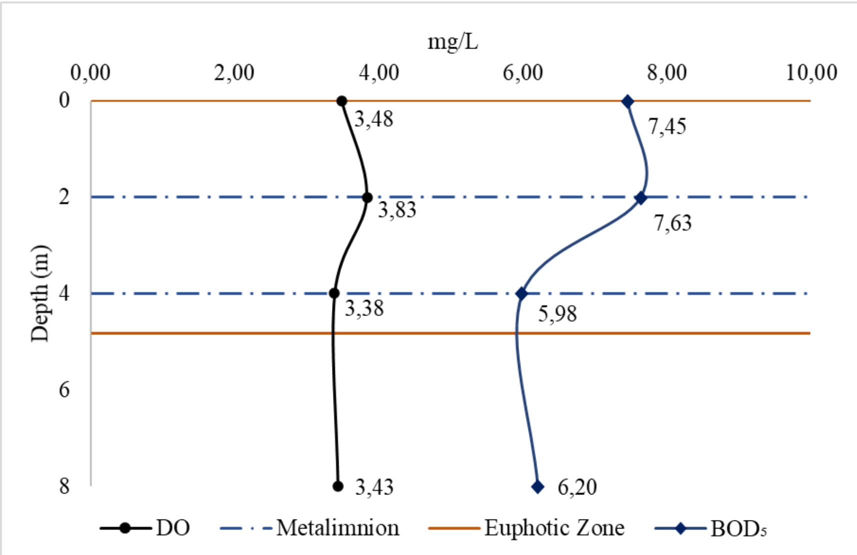

Figure 2. Profile of DO and BOD_5 vertically in 2020

Overall, the BOD5 profile fluctuated vertically with increasing depth and formed a maximum pattern at a depth of 2 m and did not show a stratification pattern between the surface layer and the bottom depth. This condition was similar to Ling et al. (2017) research in Bakun Reservoir, Malaysia, where the average BOD5 level at the surface was relatively more significant than the bottom depth. The results are different from Komala et al. (2019) research in Maninjau Lake, where BOD5 levels at the Cage station increased with increasing depth. The higher organic matter content on the surface was caused by organic matter originating from surface plankton organisms (Harlina, 2021). In addition, the difference in BOD5 values at each depth was also influenced by stirring and water mass transfer (Arinda

& Wardhani, 2018). The maximum BOD5 level at a depth of 2 m indicated high biological productivity. Furthermore, Pakusina et al. (2018) stated that the high levels of BOD5 in the waters and high levels of dissolved oxygen indicated that the reservoir was eutrophication. That was following the results of observations where the average dissolved oxygen level at a depth of 2 m was 3.64 mg/L which was the maximum level.

Based on research conducted by BP2KSDI (2016) and Sari et al. (2015) shows that the trophic status of waters in Jatiluhur Reservoir has changed from oligotrophic to hypertrophic characterized by decreased brightness, increased phosphorus and nitrogen, and blooms of water hyacinth plants (Figure 1). These uncontrolled conditions can increase siltation, organic matter, and evapotranspiration, cause oxygen depletion in the deep layers of water and interfere with water transportation (BP2KSDI, 2016). Furthermore, at a depth of 4 m, the level of BOD5 decreased due to the decomposition process of organic matter; thus, the dissolved oxygen level at that depth decreased. The hypolimnion layer is where the decomposition occurs; therefore, it has low dissolved oxygen (Effendi, 2003; Likens, 2010). At a depth of 8 m, there was an increase in BOD5 levels, indicating an accumulation of organic matter. The organic matter increased from the rest of the feed that settled on the bottom of waters and sediments (BP2KSDI, 2016).

The observed BOD5 value above the standard quality value indicates that the activity of decomposition of organic matter by microorganisms at the KJA location was very high. The organic matter came from feed residues, fish metabolism, and marine cage waste. Furthermore, Putra et al. (2015) reported that waters with KJA had higher organic matter than waters without KJA and areas covered with water hyacinth. The high decomposition activity of organic matter and respiration by plankton and fish caused the availability of dissolved oxygen to become lower and even depleted (anoxic). In this study, it seems that the dissolved oxygen level was still above 2.00 mg/L; thus, it was not in an anoxic condition but a hypoxic condition (< 4.00 mg/L), i.e., oxygen is below the minimum level required to maintain animal life (Liu et al., 2020).

In contrast to BOD5, COD values exceeded the quality standard (25.00 mg/L) found in the surface layer in June, August, October, and December (Table 4). The high value of COD in the waters indicated the presence of organic matter that can be degraded biologically (biodegradable) or difficult to degrade biologically (non-biodegradable) (Effendi, 2003). The organic matter resulted from waste from the fish culture in cages, i.e., wasted feed residue, fish metabolism residue, and KJA guard waste. Furthermore, Utami (2016) and Dmitry (2013) explained that feeding could increase organic matter as wasted feed and significantly increase BOD5 and COD levels in the water. This condition was by the study results of BOD5 levels that exceeded the quality standard.

Table 4. Measurement result of COD

Month	Water Quality Standard of Class II (mg/L)	Level of COD (mg/L) Depth (m)			
		0	2	4	8
January	25	20.00	26.00	27.00	**42.00**
February		21.00	31.00	7.00	10.40
March		22.00	22.00	22.00	18.00
April		14.00	11.00	7.00	13.00
May		20.00	21.00	22.00	24.70
June		28.00	29.00	28.00	16.00
July		14.00	19.00	15.00	9.00
August		26.00	18.00	12.00	17.00
September		22.00	40.00	12.00	22.00
October		40.00	76.00	25.00	45.00

Month	Water Quality Standard of Class II (mg/L)	Level of COD (mg/L) Depth (m)			
		0	2	4	8
November		21.00	18.00	17.00	17.00
December		46.00	7.00	36.00	12.00
Average		24.50	26.50	19.17	20.51
Stdev		9.61	17.92	9.01	11.66

The vertical distribution of COD levels has a different pattern each month. In January and May, the COD value increased with increasing depth, indicating a tendency for an accumulation of organic matter in the hypolimnion layer. Furthermore, Silaen et al. (2017) explained that organic waste would settle and accumulate at the bottom of the water; thus, organic matter increases. The slow speed of water flow makes organic matter settle and accumulate on the bottom of the water (Irawan, 2022). The bottom layer or hypolimnion is the place for decomposing organic matter (Komala et al., 2019), which does not experience mixing and has low dissolved oxygen levels. High levels of COD due to organic matter from feed residues, fish metabolism, and marine cage waste increase the decomposition process in the water column. This high organic matter decomposition activity causes the availability of dissolved oxygen to decrease with increasing depth to form a hypoxic pattern. That seen from the dissolved oxygen level at a depth of 8 m has reached a hypoxic condition (Table 2).

Furthermore, the vertical COD profile fluctuated with increasing depth in February, March, April, and June-December. Generally, the COD level at the surface was relatively higher than the bottom depth. This condition is caused by organic matter originating from surface plankton organisms (Harlina, 2021). Furthermore, Arinda & Wardhani (2018) stated that the concentration differences, which were random and fluctuated at each depth, were influenced by stirring and water mass transfer. The temperature value was relatively homogeneous along the water column. No metalimnion layer barrier allows the water mass circulation to occur throughout the water column (holomictic). There was no tendency for an accumulation of COD at the bottom of the water column (Komala et al., 2019).

Similar to BOD5, the vertical distribution of COD at Karamba station also fluctuated and formed a maximum pattern at a depth of 2 m. There was a slight increase in organic matter at the bottom depth. The results differed from Komala et al. (2019) in Maninjau Lake, where COD levels at the cultivation site increased with increasing depth. The more excellent COD value in the epilimnion layer seemed to be related to organic matter originating from surface plankton organisms (Harlina, 2021) and the effect of stirring and water mass transfer (Arinda & Wardhani, 2018). Organic matter content in the waters will continue to increase along with the number of KJA. The number of KJA units in the waters of the Jatiluhur Reservoir had increased from 21,579 plots (2014) to 42.413 plots in 2020. An increase in the number of KJA will increase the waiting waste of KJA, the amount of feed, and the biomass of fish being cultured, which in turn can increase the number of pollutants in the form of wasted leftover feed and fish faeces. Furthermore, Prinajati (2019) reported that increasing pollution in the Jatiluhur Reservoir was dominated by organic waste from fish culture activities in the KJA.

Pembayun et al. (2015) explained that only 15–30% of fish feed would be digested, and the rest would be wasted. The feed accumulated to the bottom of the water in the double layer KJA system used in the Jatiluhur Reservoir is 10%. KJA farmers' feed for one plot is 4,000 kg/plot/year (Karunia & Marinasari, 2015). The number of KJA plots in Jatiluhur Reservoir in 2020 was 42,413; thus, the amount of feed released was 42,413 plots x 4,000 kg/plot/year = 169,652,000 kg/year. If multiplied by 10% of the remaining feed that is wasted and settles at the bottom of the reservoir, then 10% x 169,652,000 kg/year = 16,965,200 kg/year of uneaten feed settles annually. That shows that a fairly large amount of the remaining feed becomes pollutant material. This excess pollution load will increase the turbidity and water nutrients such as N, P, H_2S, NH_3, and CH_4 due to decomposition (BP2KSDI, 2016; Dewantara, 2020). The amount of dissolved oxygen needed to decompose the total organic matter in the water column is illustrated by high levels of COD.

Bhavsar et al. (2016) and Sari et al. (2020) explained that wasted feed residue could be used as nutrients that stimulate the growth of water hyacinth and phytoplankton, resulting in eutrophication and algae blooms. Based on the results of trophic status measurements carried out by BP2KSDI (2016) and Sari et al. (2015), the trophic status of the Jatiluhur Reservoir waters was classified as hypertrophic, which was characterized by decreased brightness, increased phosphorus and nitrogen, and blooms of water hyacinth plants. Dewantara (2020) reported that most of the distribution of water hyacinth was around floating net cages with an area of about 441.65 Ha in 2019. Furthermore, BP2KSDI (2016) stated that the presence of water hyacinth plants that covered the waters could increase siltation, organic matter, and evapotranspiration, causing oxygen depletion in the deep layers of water as well as interfering with water transport. Based on **Table 5**, the vertical distribution of H_2S levels had a different pattern in each month, and in February, May, and July, the H_2S levels on the surface were > 0.002 mg/L. The high levels of H_2S were due to low dissolved oxygen levels (< 4.00 mg/L).

Table 5. Measurement result of H_2S

Month	**Water Quality Standard of Class II (mg/L)**	**Level of H_2S (mg/L)**			
		Depth (m)			
		0	**2**	**4**	**8**
January	0.002	0.000	0.000	0.010	0.010
February		0.020	0.020	0.031	0.010
March		0.000	0.000	0.000	0.000
April		0.000	0.000	0.000	0.000
May		0.050	0.034	0.034	0.027
June		0.000	0.000	0.006	0.000
July		0.004	0.005	0.000	0.000
August		0.000	0.000	0.000	0.040
September		0.000	0.000	0.000	0.000
October		0.000	0.000	0.005	0.007
November		0.000	0.000	0.000	0.000
December		0.000	0.006	0.004	0.000
Average		**0.006**	**0.005**	**0.008**	**0.008**
Stdev		**0.015**	**0.011**	**0.012**	**0.013**

Anaerobic decomposition of feed or organic matter will contribute to H2S and CO2, which will flow into the water surface layer (Dmitry, 2013). Decomposition or mineralization of organic matter associated with the death of living organisms will release inorganic sulfur in the form of H2S (Bertrand et al., 2015). In addition, the presence of H2S in the waters also came from rocks and sediments (Bertrand et al., 2015). In February, May, and July, the H2S level at the surface was relatively higher than the bottom depth. That was thought to be due to the reaction of sulfide with iron (II) to form ferrous sulfide or iron (II) sulfide (FeS) minerals (equation (1) and (2)) (Henny & Nomosatryo, 2012).

$$SO_4^{2-} \rightarrow S^{2-} \tag{1}$$
$$Fe_3(PO_4)_2 + 3\,S^{2-} \rightarrow 3\,FeS + 2\,PO_4^{3-} \tag{2}$$

Meanwhile, in January, June, August, October, and December, H2S levels tended to increase with increasing depth because organic matter decomposition occurred at the bottom of the waters (hypolimnion layer) (Effendi, 2003). The decomposition process of organic matter requires a high amount of oxygen. That causes conditions at the bottom of the water to become anaerobic; thus, dissolved oxygen levels decrease. That observed that dissolved oxygen levels decreased in January, June, and August (Figure 2). However, the decrease in dissolved oxygen levels in December did not occur (Table 2). High H2S levels and not accompanied by low dissolved oxygen are considered suitable for fish culture activities. According to Dmitry (2013), H2S will be oxidized to harmless sulfate in toxic or aerobic waters. Henny & Nomosatryo (2012) stated that the sulfide oxidation process would cause the oxygen content in the water to run out < 1.00 ppm.

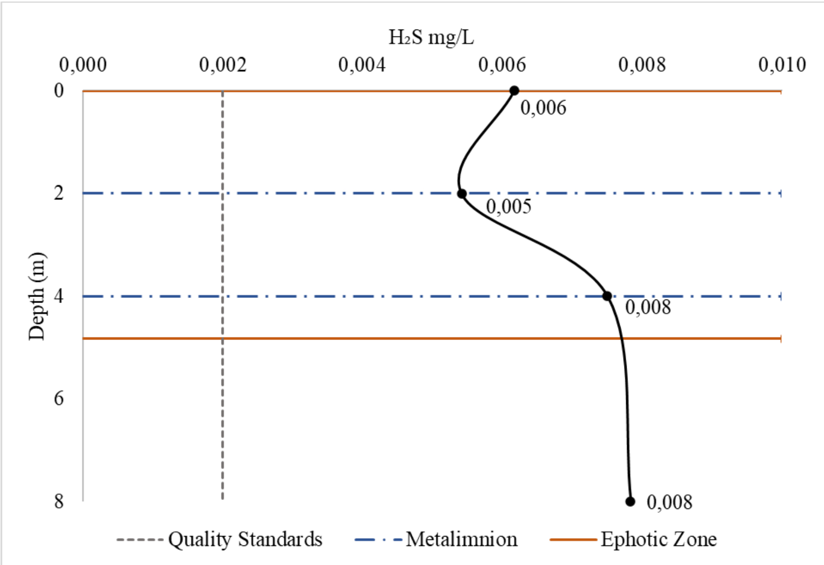

Figure 3. Profile of H_2S vertically in 2020

The average H2S content in the water column of the Jatiluhur Reservoir tends to fluctuate, and there is an increase in the metalimnion layer (Figure 3). The highest H2S levels were found at a depth of 4–8 m, i.e., 0.008 mg/L. Changes or fluctuations in H2S levels in the waters of the Jatiluhur Reservoir were thought to be due to the decomposition process of organic matter and uneaten and accumulated feed residue. An increase in H2S levels at 4 m indicates a decomposition process of organic matter that uses much oxygen, thus decreasing dissolved oxygen levels (Figure 3). High decomposition activity causes conditions at the bottom of the water to become anaerobic; thus, Desulfovibrio anaerobic bacteria will use sulfate (SO42-) as a source of oxygen in the oxidation process of organic matter (Sawyer et al., 2003), resulting in the formation of H2S as shown by equation (3) and (4).

$$SO_{4\,(aq)}^{2-} + \text{organik} \xrightarrow[\text{bakteri}]{} S^{2-} + CO_{2\,(g)} + H_2O_{(l)} \quad (3)$$

$$S^{2-} + 2H^{+}_{(aq)} \rightleftarrows H_2S_{(g)} \quad (4)$$

In addition, the sulfate ion will be reduced to sulfite ion (SO32-) in anoxic conditions, forming an equilibrium with hydrogen ions to form H2S (Wardhani et al., 2017). According to Bertrand et al. (2015), sulfate reduction activity in eutrophic waters such as in Jatiluhur Reservoir is very high; therefore, the water is saturated with sulfur. The sulfate reduction process also produces CH4 and N2, which are diffused into the surface water and atmosphere with H2S and CO2 (Dmitry, 2013). Furthermore, Henny & Nomosatryo (2012) explained that low dissolved oxygen content would accelerate H2S diffusion to the surface; thus, H2S levels are high. In general, the H2S content in the Karamba station is dangerous for the survival of fish in cages because it is more significant than 0.002 mg/L, similar to the results of measurements conducted by Sari et al. (2020) in Jatiluhur Reservoir in 2019.

The amount of organic matter from wasted feed residue and metabolic waste is one of the causes of decreased water quality. Prinajati (2019) reports that KJA activities decrease water quality in Jatiluhur Reservoir with a percentage between 2014 and 2019 of 7.87% with a pollution load level of 512.89 mg/second in 2019. The pollution load affects the amount of oxygen in the decomposition process, which can reduce oxygen levels. Thus, the water is in anaerobic conditions. The organic matter decomposition process that occurs anaerobically will produce H2S gas. The presence of H2S gas in waters can cause dissolved oxygen to run out, cause a foul odour, lose iron, release phosphate from sediments, and accumulate in the bottom of the water; therefore, it impacts eutrophication in the lake (Bertrand et al., 2015). This condition occurred in the sediment of the Saguling Reservoir, which was polluted by heavy metals and eutrophication (Wardhani et al., 2021). If one day there is a downwelling or upwelling of low oxygen levels accompanied by toxic substances such as H2S, it will be brought to the surface, causing mass death of fish. However, the level of H2S in the waters of the Jatiluhur Reservoir is still below 0.13–0.045 mg/L, which can cause fish death (Winton et al., 2019).

4. Conclusions

Dissolved oxygen distribution is classified as a positive heterograde type where dissolved oxygen levels are higher in the metalimnion layer due to the photosynthesis process that occurs effectively by aquatic plants and phytoplankton. Jatiluhur Reservoir shows signs of organic pollution, with BOD5 and COD levels exceeding the quality standard. This organic substance comes from the waste of floating net cages. BOD5 and COD values that exceed the quality standard result in increased oxygen consumption by the decomposition process; therefore, a hypoxic layer occurs. That can cause water conditions to become anoxic, producing H2S gas. The H2S value in the Jatiluhur Reservoir was observed to exceed 0.002 mg/L and showed an increase in the metalimnion layer.

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