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Water quality and degradation rate analysis: Assessing pollution and environmental impact for effective management

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ABSTRACT

Background: Situ Pengarengan is polluted by various types of waste from community activities and industrial sources along its shorelines. This study aims to assess the lake's degradation rate by analyzing water quality parameters and pollution sources. **Method:** The research was conducted from February to July 2022, with water samples collected from six sampling points. Laboratory tests measured temperature, TSS, turbidity, pH, DO, BOD, COD, nitrate, phosphate, and *E. coli*. The results were compared to Class 2 water quality standards under Government Regulation No. 22 of 2021. **Findings:** Based on IKA-NSF calculations, Situ Pengarengan's water quality is categorized as moderately polluted, with an average score of 65.04. The degradation rate coefficients for each segment are 2.21 per day, -1.07 per day, and -3.04 per day. **Conclusion:** The findings indicate moderate pollution levels in Situ Pengarengan, highlighting the need for improved environmental management and pollution control measures. **Novelty/Originality of this Study:** This study provides a quantitative assessment of Situ Pengarengan's degradation rate using IKA-NSF calculations and degradation rate coefficients, offering a scientific basis for targeted pollution mitigation strategies.

KEYWORDS: water quality; degradation rate; Situ Pengarengan.

1. Introduction

The ponds (*situ*) in Depok offer various benefits to the surrounding communities, such as water supply, agricultural irrigation, flood control, tourism activities, fisheries, provision of raw water for industries, peat mining for organic fertilizer, and as tourist attractions. In general, ponds are useful for flood control, providing clean water, and meeting various needs, such as drinking water, irrigation, industry, and fish farming. These benefits can be maximized if the ponds are well-managed.

The utilization of the pond by various sectors and community activities around the area has led to environmental pressure on the water of the lake. As a result, the functions and benefits of the lake have continued to decline. The presence of physical development, such as small and large settlements, poses a threat to the preservation and existence of the ponds in Depok because it degrades the surface area and volume capacity of the pond. As a result, the pond's ability to slow down water flow is reduced, leading to flooding issues. Moreover, the pond has been used as a dumping ground for waste and garbage, causing pollution.

One of the ponds in Depok is Situ Pengarengan. Situ Pengarengan is located in the Cisalak Village, Sukmajaya District, Depok, West Java. With an area of 7 hectares, it stretches

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from north to south, bordered by Juanda Street to the north, fields and bushes to the south, vacant land to the east, and housing to the west. Pollution has occurred in this pond due to the accumulation of garbage and waste, resulting in sedimentation. Therefore, it is necessary to conduct research on the water quality and pollution load capacity of Situ Pengarengan in order to assess the quality of its water. The aim of this study is to calculate the pollution load capacity of Situ Pengarengan.

1.1 Situ Pengarengan

According to data from Central Bureau of Statistics of Depok City (2020), Depok City is astronomically located between 6°19' - 6°28' South latitude and 106°43' - 106°55' East longitude. Depok is a lowland area with an altitude of between 77 to 150 meters above sea level, characterized by lowlands to hills that are slightly undulating. The total area of Depok is 200.29 km^2. Geographically, Depok is located in the southern part of West Java Province, bordering the Special Capital Region of Jakarta. Its administrative boundaries are as follows: Depok is bordered on the north by DKI Jakarta; on the south by Bogor Regency; on the west by South Tangerang City; and on the east by Bogor Regency. Depok is divided into 11 sub-districts: Sawangan, Bojongsari, Pancoran Mas, Cipayung, Sukmajaya, Cilodong, Cimanggis, Tapos, Beji, Limo, and Cinere.

Situ Pengarengan is one of the lakes located in Depok, West Java. It is located in Cisalak Village, Sukmajaya Subdistrict, at coordinates 6°22'52.68" South latitude and 106°51'27.70" East longitude. The area of Sukmajaya Sub-district is 17.35 km^2, with the following administrative boundaries: to the north is bordered by Mekarsari Village and Tugu Village; to the south is bordered by Abadijaya Village; to the east is bordered by Curug Village; and to the west is bordered by Bakti Jaya Village. The population of Sukmajaya Sub-district from 2016 to 2020 showed dynamic changes.

According to Central Bureau of Statistics of Depok City (2019), Situ Pangarengan is a natural lake covering an area of 7 hectares with an average depth of 1.5 meters. High sedimentation levels have caused the lake to become shallow. The primary water source for Situ Pangarengan is Kali Jantung, while its outlet flows into Kali Laya. Situ Pangarengan serves multiple purposes, including water storage, flood control, fishing, and recreational activities. However, severe environmental degradation has diminished its tourism potential over time.

1.2 Definition and characteristics

Based on the Regulation of the Minister of Environment Number 28 of 2009 concerning Water Pollution Load Bearing Capacity of Lakes and/or Reservoirs Article 1 Paragraph 3, Lake is a water container and its ecosystem formed naturally including situ and similar water containers with local terms. PP RI No 22 of 2021 states that lakes, both natural and artificial, are places where surface water runoff or groundwater flows that gather at a point that is relatively lower than the surrounding area. Situ/lakes are waters that do not have a direct flow with the ocean. Depending on its origin, a lake can occur anywhere within a watershed. Upstream lakes do not have a single river but have inflows from many small tributaries, by direct surface rainfall and groundwater. Such lakes almost always have a single outlet river. Further downstream in the watershed, a situ/lake has a river as the main input and one main output, with the water balance from input to output varying as a function of additional water sources (Bhateria & Jain, 2016).

In addition, the site and/or lake is a source of water, disposal of surface water and groundwater, flood control, water reserve reservoir and maintenance of river flow, recreation and education facilities, fish and wildlife rearing places, etc. The function of the lake for people's lives is as a source of water that can be used directly by the community, the location of inland fisheries development, the place where the life cycle of several important endemic biota takes place, means of inland water transportation, as a producer of electrical energy, recreational facilities and tourism objects. Muhtadi et al. (2017) stated that lake characteristics can be divided into two, namely surface characteristics and bottom surface characteristics. In surface characteristics, there are several important parameters that need to be considered. First, the maximum length (Lmax) measured from the farthest distance at the edge of the lake in meters. Second, the effective maximum length (Le), which is measured at the edge of the lake surface without passing through the island if any. Third, the maximum width (Wmax), which is the furthest distance at the edge of the lake surface perpendicular to Lmax. Furthermore, the effective maximum width (We) is obtained by measuring the furthest distance perpendicular to Le. Surface area was calculated from maps using the polygon method with the help of the ArcView program and expressed in km^2, m^2, or hectares. The shoreline length (SL) is the perimeter of the lake, while the average width is obtained from the ratio between the lake surface area and Lmax. The shoreline development index (SDI) shows the relationship between SL and surface area, giving an idea of the complexity of the lake shoreline.

In addition, on the lake bottom surface characteristics, there are ten parameters to consider. Mean depth is calculated from the ratio of lake volume to surface area and is expressed in meters. Maximum depth (Zmax) is measured by two methods, directly using an echosounder or indirectly through contour interpretation on bathymetric maps. Relative depth (Zr) is the ratio between Zmax and the average diameter of the lake surface. Mean slope (S) describes the shallow area in percentage terms, indicating how sloping or steep the lake bed is. The development of the lake volume provides information about the overall shape of the lake bed. Morpho edaphic index is used to predict the potential yield of electrical power in a body of water. Lastly, the compensation depth indicates the depth at which the light intensity reaches only 1% of the intensity at the surface, which is important in understanding the photosynthetic zone within the lake.

1.3 Water quality

Water quality degradation is an important concern in water resources management due to its significant impact on environmental and human health (Islam et al., 2022). Therefore, research on water pollution load carrying capacity is needed to determine the river's capacity to accept pollutant loads without causing significant degradation of water quality (Ali et al., 2013). In this context, water quality monitoring is a crucial step in efforts to control pollution in river water. Pradana et al. (2019) emphasized the importance of water quality monitoring as one of the main considerations in water pollution management.

Bhateria & Jain (2016) explained that water quality testing is very important before water is used for various purposes such as drinking, domestic needs, agriculture, and industry. This is because water naturally contains various types of impurities, both floating, dissolved, suspended, and microbiological. To accurately determine water quality, it is necessary to test several parameters which are divided into physical, chemical, and biological properties. Physical parameters include temperature, turbidity, Total Dissolved Solids (TDS), and Total Suspended Solids (TSS) (Tanjung et al., 2019). Chemical parameters include pH, Biological Oxygen Demand (BOD), Dissolved Oxygen (DO), phosphate, nitrate, and other chemical compounds (Abdullahi et al., 2021). Meanwhile, biological parameters include the presence of fecal coliform and total coliform, as regulated in Government Regulation No. 22 of 2021.

In addition, water quality is largely determined by its physical, chemical, and biological composition (Nailah et al., 2021). The chemical composition of water is influenced by substances such as heavy metals, pesticides, detergents, and petroleum. Meanwhile, turbidity, color, and temperature are part of the physical composition of water. On the other hand, biological composition is determined by the presence of pigments and plankton in water (Muarif, 2016). The combination of these compositions will give an overall picture of the water quality in an area.

The water quality status of a water body is determined based on the level of water quality conditions that indicate whether the water is in a polluted condition or in good condition at a certain period. This is regulated in Article 1 Paragraph 7 of the Regulation of the Minister of Environment Number 28 of 2009 concerning Water Pollution Load Bearing Capacity of Lakes and/or Reservoirs. The status of water quality is then compared with water quality standards or water classes that have been determined to determine the level of pollution (Rahman et al., 2021).

Based on PP No. 22 of 2021 concerning the Implementation of Environmental Management, water quality in Indonesia is classified into four classes, namely Class I, II, III, and IV (Machiriyah & Slamet, 2020). Class I is used for raw drinking water or other uses that require the same water quality as drinking water. Class II is used for water recreation infrastructure, freshwater fish farming, animal husbandry, and agricultural irrigation. Class III is intended for freshwater fish farming, animal husbandry, and agricultural irrigation with lower quality requirements than Class II. Meanwhile, Class IV is intended for agricultural irrigation and other uses that require the same water quality. This classification provides clear guidelines in determining the use of water that is safe and in accordance with its quality (Tofani, 2019). With this classification, environmental management can be carried out more effectively and sustainably, so that water resources can still be utilized optimally without neglecting aspects of health and environmental sustainability.

2. Methods

The implementation of the water quality and pollution load research was conducted at Situ Pengarengan, located in Cisalak Village, Sukmajaya District, Depok City, West Java, from February to July 2022. Water sampling was carried out using the grab sampling method, referring to SNI 6989.57:2008 on Surface Water Sampling Methods. The researcher used a water sampler that had been rinsed with situ water beforehand and tied with a raffia string, then placed into the pond at a specific depth. At each point, two samples were taken to minimize errors during sample collection. The samples were placed into 1.5-liter jerry cans, labeled, and stored in a cooler box to reduce the rate of chemical reactions and prevent changes in the parameter contents. The samples were then tested at the laboratory of Trisakti University.

This study used three parameters: biological, physical, and chemical, which were tested based on methods according to national standards (SNI). These three parameters were used to calculate the water quality index by applying the IKA-NSF method. The National Sanitation Foundation Water Quality (NSF-WQI) or Water Quality Index was determined to evaluate the quality level of water from a specific water body location. The index was adjusted based on nine parameters: BOD, DO, Nitrate, Total Phosphate, Temperature, Turbidity, Total Solids, pH, and Total Coliform. The water quality of the pond was tested with both in-situ analysis at the sampling points and ex-situ laboratory analysis.

Table 1. Method of analysis for water quality parameters in Situ

Number	Parameter	Unit	Analysis method
Physics			
1	Temperature	°C	SNI 06-6989.23-2005
2	TSS	mg/L	SNI 06-6989.3-2004
3	Turbidity	NTU	SNI 06-6989.23-2005
Chemistry			
1	pH	-	SNI 06-6989.11-2004
2	DO	mg/L	SNI 6989.57:2008
3	BOD_5	mg/L	SNI 6989.72:2009
4	COD	mg/L	SNI 6989.73:2019
5	Nitrate	mg/L	SNI 6989.79:2011
6	Phosphate	mg/L	SNI 06-6989.31-2005
Biology			
1	*E. coli*	MPN/100	SNI 06-6858-2002

After obtaining the water quality data from the laboratory tests, the data was compared with the quality standards as outlined in Appendix VI of Government Regulation No. 22 of

2021, which applies to Class 2 water. This class of water refers to bodies of water that serve functions such as freshwater fish farming, recreation, livestock watering, irrigation, and several other functions that are in line with the quality of the water. The comparison results were then presented in the form of tables and diagrams for descriptive interpretation. The analysis results are presented in the following Table 1.

2.1 Water quality index – national sanitation foundation (IKA-NSF)

To evaluate the water quality level, the water quality index must be determined. The steps for calculating water quality using the IKA-NSF method are as follows: (1) The concentration of each parameter is measured. (2) The subindex value for each parameter on the curve (Ii) must be determined. This curve is obtained from the individual parameter curves based on Ott (1978). (3) The importance value for each parameter (Wi) is determined. The following table presents the importance values for each parameter.

Table 2. Parameter importance value IKA-NSF

Number	Parameter	Parameter importance value
1	Temperature	0.10
2	Turbidity	0.08
3	Total suspended solid (TSS)	0.08
4	pH	0.12
5	Dissolved oxygen (DO)	0.17
6	Biological oxygen demand (BOD_5)	0.10
7	Nitrate	0.10
8	Phosphate	0.10
9	*E. coli*	0.15

$$IKA - NSF = niIi \times Wi \quad \text{(Eq. 1)}$$

Next, the water quality index is calculated using the Equation 1. Where Ii represents the subindex value of each parameter derived from the curve, and Wi denotes the importance value assigned to each parameter. By summing the products of each parameter's subindex and its corresponding importance value, a single composite value is obtained. This value serves as an indicator of the overall water quality, allowing the classification of the water condition as either good or poor. The categorization of water quality based on the resulting index values is presented in Table 3.

Table 3. Water quality index

Quality	Range of value	Color
Very poor	0-25	Red
Poor	26-50	Orange
Moderate	51-70	Yellow
Good	71-90	Green
Very good	91-100	Blue

2.3 Pollutant degradation rate

To calculate the degradation rate, the parameter used is only BOD5, which is an organic compound. The formula used to calculate the degradation rate (Davis and Cornwell, 2013) is as equation 2. The explanation of the variables used is as follows: Ct refers to the final concentration measured in milligrams per liter (mg/L), while Co represents the initial concentration, also in milligrams per liter (mg/L).

$$Ct = Co \times e\,(-kt) \quad \text{(Eq. 2)}$$

t denotes the hydraulic residence time, expressed in days, which indicates the average time the water remains in the treatment system. *K* is the degradation rate coefficient, expressed per day (/day), reflecting the rate at which the contaminant concentration decreases over time. Next, the calculation using the Equation 2.

3. Results and Discussion

3.1 Water quality and water status

Water quality testing was conducted to determine whether the water body is experiencing heavy, moderate, or light pollution (Hamakonda et al., 2019). The parameters measured in Situ Pengarengan include physical, chemical, and biological parameters. The physical parameters measured are temperature, TSS, and turbidity. The chemical parameters include pH, DO, BOD5, COD, Nitrate, and Phosphate, while the biological parameter measured is E. coli. Water sampling was carried out three times, in March, May, and June 2022, to ensure the results are valid and accurate.

According to the Environmental Agency of Depok City (2019), Situ Pengarengan is a conserved pond, used for recreational activities and fish maintenance. Therefore, the water quality data was compared with the quality standards as outlined in Appendix VI of Government Regulation No. 22 of 2021, which applies to Class 2 water. This class refers to water bodies used for freshwater fish farming, recreation, livestock watering, irrigation, and other functions aligned with the quality of the water.

Table 4. Results of water quality measurement of Situ Pengarengan in March-June 2022 (sampling I)

Parameter	Unit	Quality standards	Sampling point						Max	Min	Avg
			1	2	3	4	5	6			
Period I (March 2022)											
Physic											
Temperature	C	Deviation 3	30.2	29.5	32.1	32	30.5	30.3	32.1	29.5	30.77
TSS	mg/L	50	0.018	0.13	0.02	0.05	0.02	0.06	0.13	0.02	0.05
Turbidity	NTU	-	10.32	12.93	9.49	7.72	9.40	5.15	12.93	5.15	9.17
Chemistry											
pH	-	6-9	6.40	6.11	6.34	6.32	6.61	6.24	6.61	6.11	6.33
DO	mg/L	4	4.46	5.66	5.37	6.19	5.19	6.18	6.19	4.46	5.50
BOD5	mg/L	3	11.70	14.60	4.78	8.38	7.88	14.60	14.60	4.78	10.32
COD	mg/L	25	38.40	86.40	54.40	78.40	78.40	75.20	86.40	38.40	68.53
Nitrate	mg/L	10	0.15	0.04	0.08	0.06	0.07	0.03	0.15	0.04	0.07
Phosphate	mg/L	0.03	0.07	0.05	0.09	0.05	0.05	0.04	0.09	0.04	0.06
Biology											
E. coli	MPN/ 100ml	1000	34500	34500	22100	14700	9200	5400	34500	5400	20067
Period II (May 2022)											
Physic											
Temperature	C	Deviation 3	29.7	29.7	30	30	30.2	30.5	30.5	29.7	30.02
TSS	mg/L	50	0.02	0.15	0.02	0.02	0.01	0.13	0.15	0.01	0.06
Turbidity	NTU	-	11.955	15.265	9.42	7.31	8.63	10.07	15.27	7.31	10.44
Chemistry											
pH	-	6-9	6.60	7.30	7.20	7.20	7.20	7.40	7.40	6.60	7.15
DO	mg/L	4	4.39	5.04	5.48	6.63	6.82	4.19	6.82	4.19	5.42
BOD5	mg/L	3	5.79	3.86	3.01	3.91	2.07	11.90	11.90	2.07	5.09
COD	mg/L	25	27.15	62.30	27.35	28.40	25.45	43.20	62	25.45	35.64
Nitrate	mg/L	10	0.20	0.08	0.07	0.17	0.16	0.08	0.20	0.07	0.13
Phosphate	mg/L	0.03	0.33	0.37	0.32	0.34	0.32	0.37	0.29	0.29	0.33
Biology											
E. coli	MPN/ 100ml	1000	29500	10700	9200	20500	20000	1660	29500	9200	17750

Period III (June 2022)											
Physic											
Temperature	C	Deviation 3	29.8	29.3	29.4	29.5	29.5	29.6	29.8	29.3	29.52
TSS	mg/L	50	0.009	0.010	0.015	0.011	0.011	0.024	0.02	0.01	0.01
Turbidity	NTU	-	9.57	9.65	9.2	7.6	9.215	8.23	9.65	7.60	8.91
Chemistry											
pH	-	6-9	7.40	7.60	7.50	7.50	7.60	7.70	7.70	7.40	7.55
DO	mg/L	4	14.25	19.04	14.40	11.63	10.76	10.62	19.04	10.62	13.45
BOD5	mg/L	3	6.29	4.18	1.35	0.81	2.92	4.26	6.29	0.81	3.30
COD	mg/L	25	32.00	56.00	48.00	56.00	56.00	48.00	56.00	32.00	49.33
Nitrate	mg/L	10	0.06	0.13	0.08	0.09	0.10	0.11	0.13	0.06	0.09
Phosphate	mg/L	0.03	0.23	0.17	0.17	0.17	0.13	0.19	0.23	0.13	0.18
Biology											
E. coli	MPN/ 100ml	1000	3550	1025	380	470	920	1860	3550	380	1367.5

(Quality Standards of Government Regulation No. 22 Class 2, 2021)

3.1.1 Temperature

Temperature is one of the environmental factors that plays a significant role in controlling the ecosystem of a water body (Elvince, 2021). According to Boyd (2015), solar radiation, air temperature, weather, and climate affect the temperature in water. The temperature during the day is higher compared to that in the morning and evening, indicating the influence of solar radiation. The penetration of sunlight causes the temperature to rise significantly in shallow ponds. The results of water temperature measurements at Situ Pengarengan showed varying outcomes.

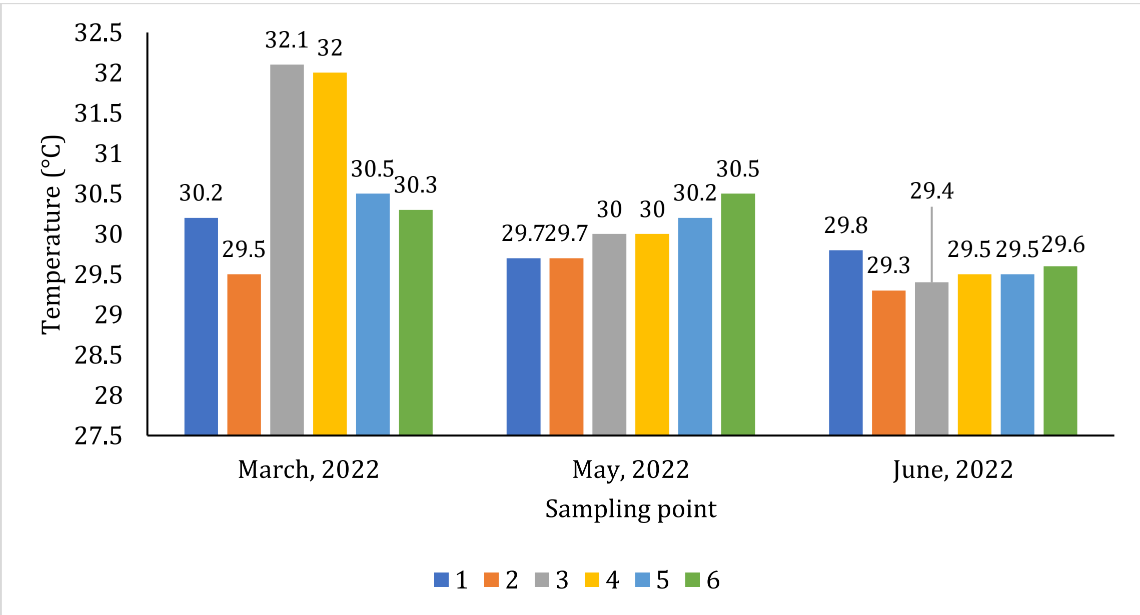

Fig. 1. Water temperature graph of Situ Pengarengan

The temperature measurements showed that the water temperature at Situ Pengarengan, recorded over three sampling occasions, ranged from 29.3 to 32.1 °C. The average value obtained from the three sampling points was 30.1 °C. From the graph, it can be observed that the highest temperature was recorded at Point 3 in March. This was due to the fact that this area was free from surrounding trees, allowing direct exposure to sunlight, and the water sample was taken during the day when there were no cloud cover. The lowest temperature was recorded at Point 2 in June. This was because there were many trees around this area, preventing the water from direct sunlight exposure. In addition, the water sample at Point 2 was taken in the afternoon.

3.1.2 Total suspended solids

Total Suspended Solids (TSS) are materials suspended in water with a diameter > 1 µm. These materials do not pass through a 0.45 µm pore size Millipore filter. Fine sand and microorganisms are included in this group of materials. These substances are found in water because the water body carries the erosion or abrasion of sand. High TSS concentrations block the entry of light into the water, thus disrupting photosynthesis. The photosynthesis activity of aquatic plants also decreases, leading to a reduction in oxygen, which eventually causes fish deaths (Jiyah et al., 2017). From the measurements, it was found that the TSS levels at all points were below the quality standard set at 50 mg/L. The results of the TSS measurements are shown in Figure 2 below.

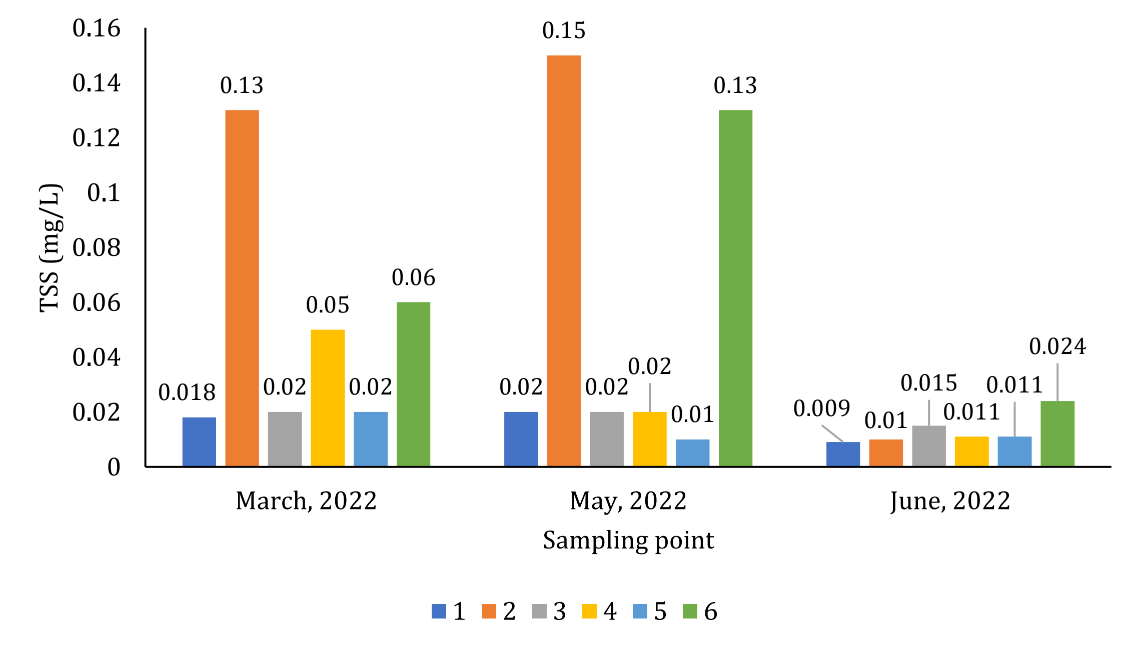

Fig. 2. TSS levels graph of Situ Pengarengan

The TSS measurements showed that the TSS levels at Situ Pengarengan, recorded over three sampling occasions, ranged from 0.01 to 0.15 mg/L. The average value obtained from the three sampling points was 0.04 mg/L. From the graph, it can be observed that the highest TSS concentration was recorded at Point 2 in May. This was due to the fact that this point is located near the wastewater discharge from nearby residential areas, causing sedimentation due to suspended particles from organic waste. Additionally, there was a lot of trash in the area. On the other hand, the lowest TSS concentration was recorded at Point 5 in each month. The low TSS content in the water of Situ Pengarengan was because, during the water sample collection, the rainfall was relatively low, and the water discharge was small, which prevented sediment at the riverbed from being stirred up.

3.1.3 Turbidity

The measurement results showed that the turbidity of Situ Pengarengan ranged from 5.15 to 15.27 NTU. From the three sampling points, the lowest turbidity value was found at Point 6 in March, which is the outlet of Situ Pengarengan. This occurred because, during the water sampling at Point 6 in March, the area had already been cleaned by the personnel assigned to remove the trash and mud from the area. The highest turbidity value was recorded at Point 2 in May. The high turbidity at Point 2 was caused by the presence of a wastewater discharge from the surrounding settlement, which resulted in turbidity due to suspended particles, making it more difficult for sunlight to penetrate the water. In addition, this point is an area that collects runoff from open land.

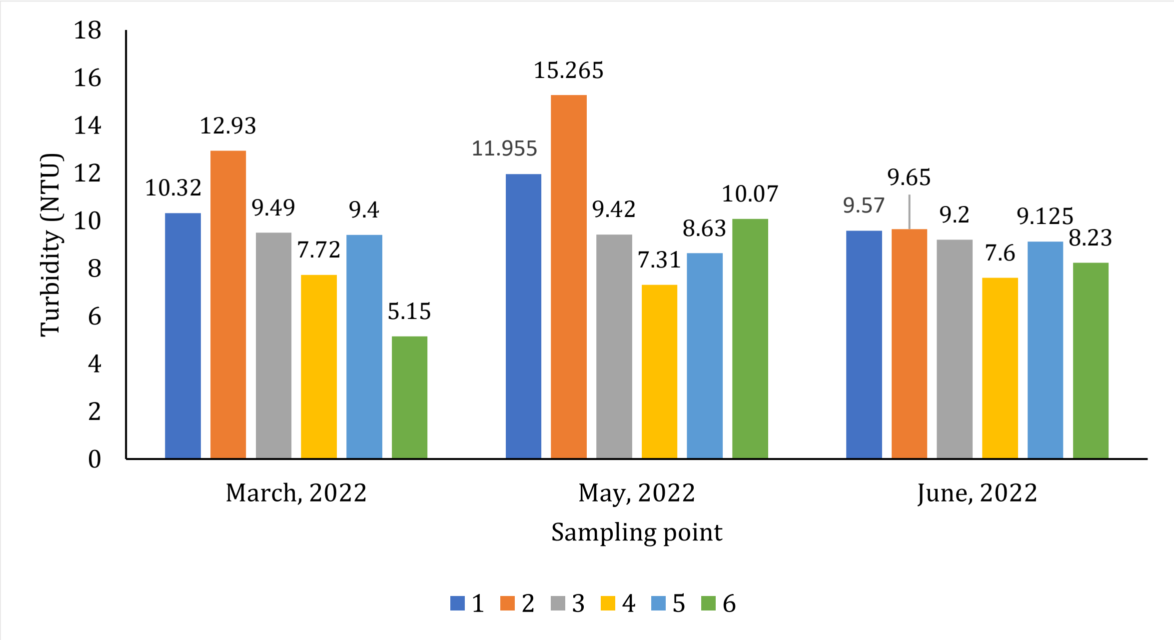

Fig. 3. Turbidity graph of Situ Pengarengan

3.1.4 pH

The measured pH values of Situ Pengarengan ranged from 6.11 to 7.70. The average value from the three sampling occasions was 7.01. As seen from the graph, the lowest pH value occurred at Point 2 in March. The low pH at this point was likely due to the high concentration of $CO2$ caused by the accumulation of trash at this location, which could have interfered with the penetration of light into the water, preventing the aquatic plants from performing photosynthesis. Additionally, this could have been influenced by the fact that March is the rainy season, with relatively high rainfall and runoff from the surrounding roads, as well as the presence of organic acids produced through the decomposition of organic materials. On the other hand, the highest pH value was recorded at Point 6 in June. The high pH at this point was likely due to the fact that, during the water sampling, there was not much trash because the area had been cleaned by the staff.

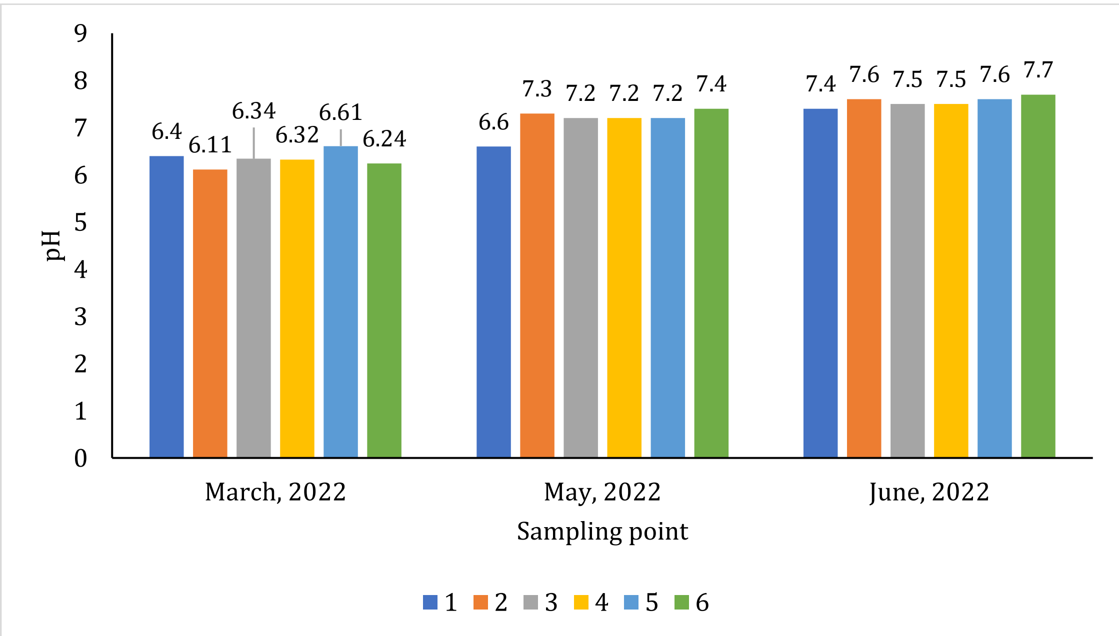

Fig. 4. pH Graph of Situ Pengarengan

3.1.5 Dissolved oxygen (DO)

The amount of oxygen dissolved in water is indicated by the dissolved oxygen parameter. This content plays an essential role in ensuring the sustainability of aquatic organisms. On the other hand, if organic and domestic waste is abundant and exceeds the river's purification capacity, along with the presence of chemicals that can be oxidized by oxygen, the oxygen levels will decrease (Gazali et al., 2014). From the DO concentration measurement results, all sampling points had DO concentrations exceeding the established quality standard of 4 mg/L. The higher the DO concentration, the better the water quality. If the DO is too low, the water will produce an unpleasant odor due to potential anaerobic degradation. The DO concentration graph for Situ Pengarengan can be seen in Figure 5 below.

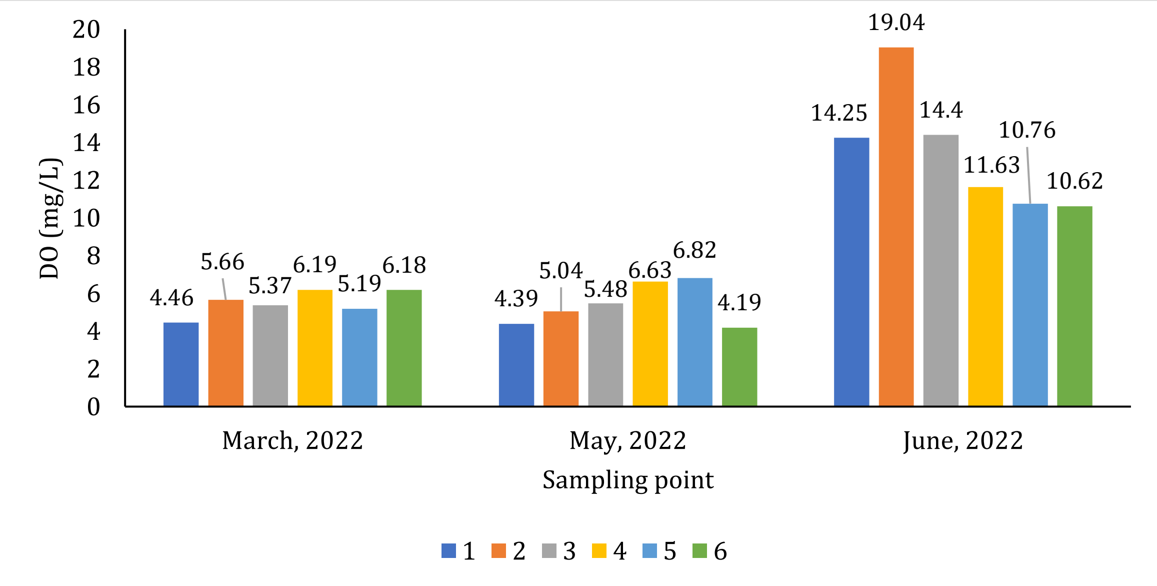

Fig. 5. DO concentration graph of Situ Pengarengan

The measured DO concentrations at Situ Pengarengan ranged from 4.11 to 6.82 mg/L. The average value from the three sampling points was 5.24 mg/L. At Point 1, the DO concentration was generally lower than that at the other points. This was because Point 1 receives input from the inlet of Situ Pengarengan, namely Kali Jantung, where there is waste from activities such as tofu production and livestock farming (cows and goats). According to Zharifa et al. (2019), the DO concentration can decrease if there is input from organic materials from domestic waste. The low DO concentration indicates that the oxygen demand for microorganisms to decompose organic materials is quite high.

3.1.6 Biochemical Oxygen Demand (BOD)

Biochemical Oxygen Demand (BOD) is the amount of oxygen required to eliminate organic waste in water during decomposition by aerobic bacteria (Andara et al., 2014). BOD reflects the oxygen needed by bacteria and other microorganisms when decomposing organic materials under aerobic conditions (Elvince, 2021). From the results obtained, it is observed that more points exceeded the quality standard set at 3 mg/L. The BOD5 measurement results can be seen in Figure 6 below.

The measured BOD5 concentrations at Situ Pengarengan ranged from 0.81 to 14.60 mg/L. The average value from the three sampling occasions was 6.11 mg/L. The BOD5 concentrations were relatively high at Points 1 and 2. This was due to the input from the inlet, which carries wastewater from livestock pens and tofu production, as well as the presence of many domestic wastewater channels at Point 2. At Points 3, 4, and 5, which are located in the central area of Situ Pengarengan, degradation processes occurred, causing the

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BOD5 concentrations at these points to decrease. However, at the outlet of Situ Pengarengan, the concentrations tended to rise again due to the accumulation of trash carried by the water flow and collected at the outlet of the pond.

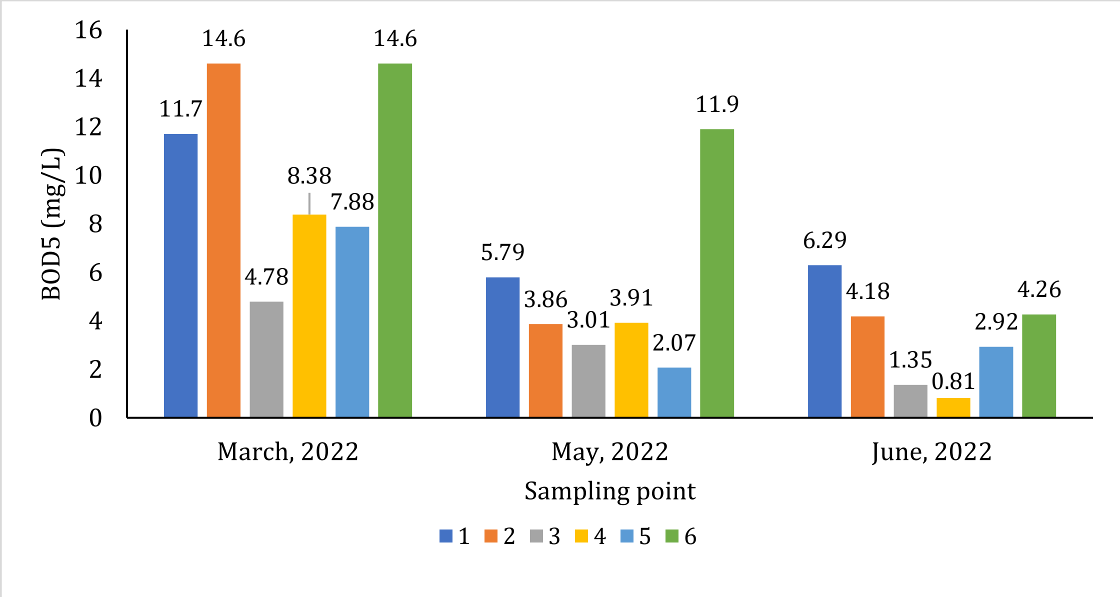

Fig. 6. BOD concentration graph of Situ Pengarengan

3.1.7 Chemical Oxygen Demand (BOD)

Chemical Oxygen Demand (COD) is the amount of oxygen required to oxidize the waste materials in water through a chemical reaction, including those that can be biologically degraded and those that are difficult to degrade (Marlina et al., 2017). From the results obtained, it is observed that more points exceeded the quality standard set at 25 mg/L. The COD measurement results can be seen in Figure 7 below.

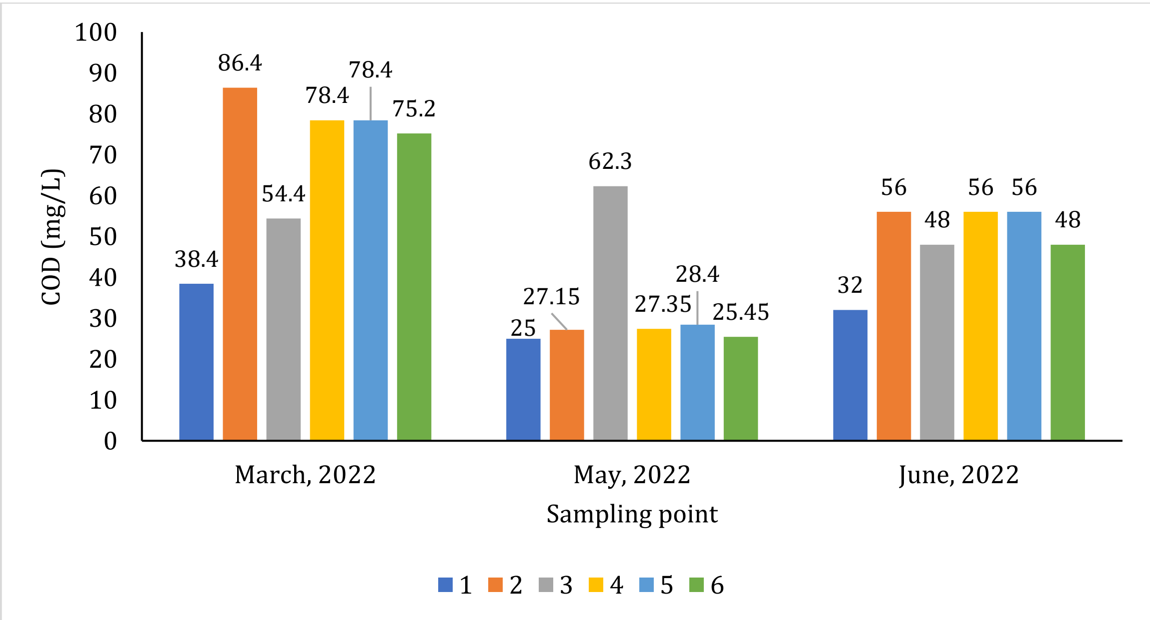

Fig. 7. COD concentration graph of Situ Pengarengan

The measured COD concentrations at Situ Pengarengan ranged from 25.45 to 86.40 mg/L. The average value from the three sampling occasions was 51.17 mg/L. The highest COD concentration was found at Point 2 in March, while the lowest concentration was found at Point 5 in May. Household and industrial waste are the main sources of organic waste and the primary cause of the high COD concentration. Additionally, waste from livestock pens (cows and goats) also contributes to the high COD levels.

3.1.8 Nitrate

Nitrate can be produced naturally or from human activities. The natural source of nitrate is the nitrogen cycle, while the human-induced sources include the use of nitrogen fertilizers, industrial waste, and human organic waste (Setiowati et al., 2016). The main sources of nitrate are household waste and agricultural activities, including animal and human waste (Putri et al., 2019). The nitrate concentration graph for Situ Pengarengan can be seen in Figure 8 below.

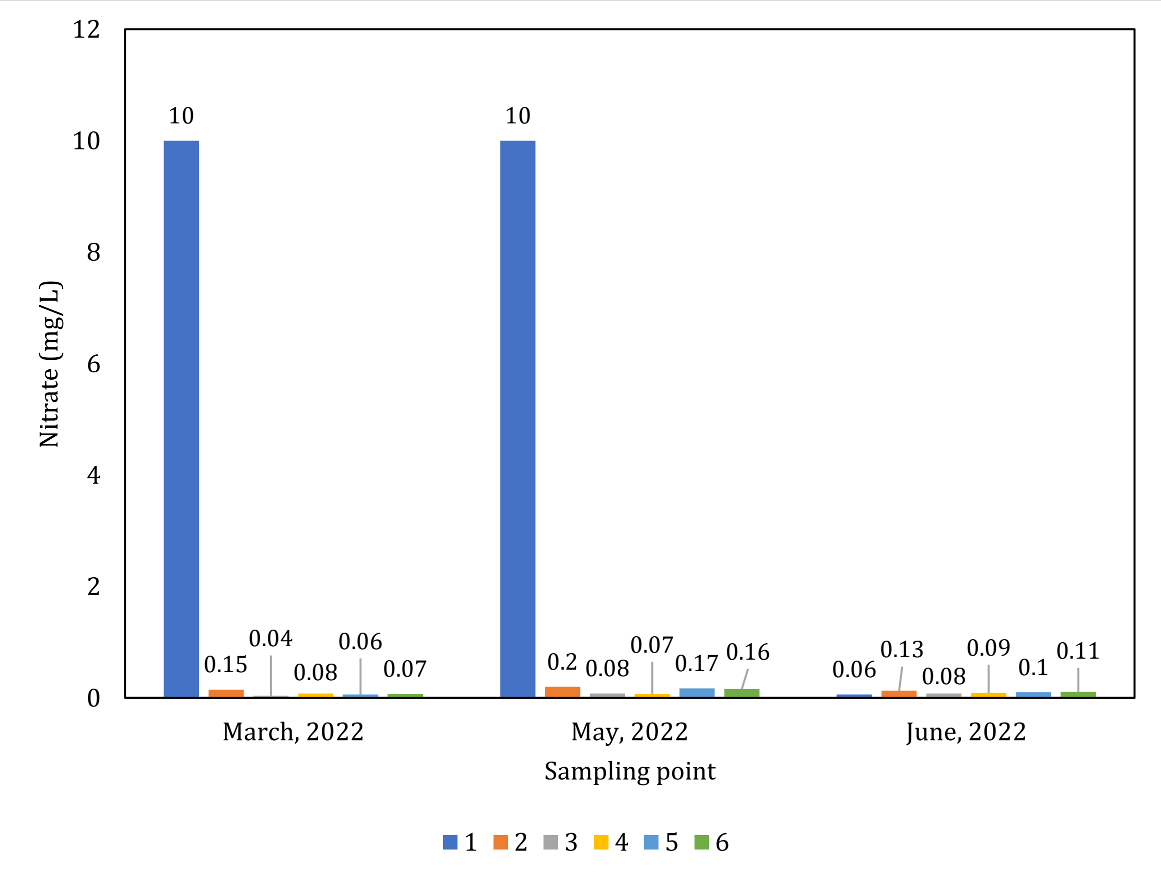

Fig. 8. Nitrate concentration graph of Situ Pengarengan

The measured nitrate concentrations at Situ Pengarengan ranged from 0.03 to 0.20 mg/L. The average value from the three sampling occasions was 0.10 mg/L. The lowest nitrate concentration was recorded at Point 6 in March, while the highest concentration was found at Point 1 in May. The high nitrate levels at Point 1 were influenced by activities from the nearby cow and goat pens, wastewater from surrounding residential areas and local shops, as well as runoff from the surrounding farms.

3.1.9 Phosphate

The weathering of mineral rocks and the decomposition of organic materials, combined with the increased discharge of detergent waste, are natural sources of phosphorus (Widiyanti et al., 2018). While phosphorus is naturally needed by aquatic biota for their survival, excessive amounts can lead to eutrophication, resulting in excessive algal growth.

This phenomenon, known as algal blooming, can reduce the entry of oxygen and sunlight into the water, leading to a decrease in dissolved oxygen levels (Herliwati et al., 2021).

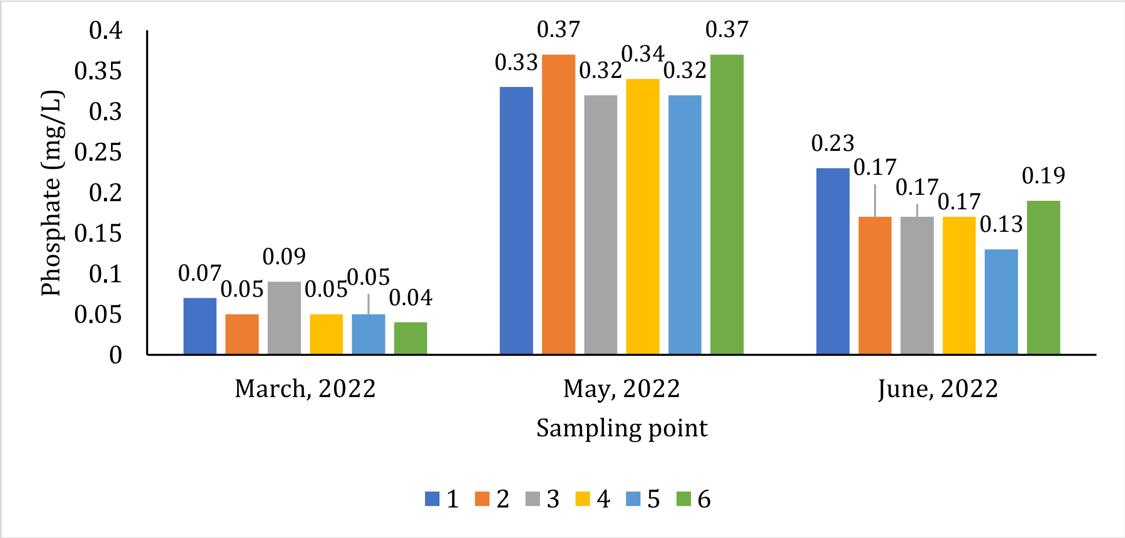

Fig. 9. Phosphate concentration graph of Situ Pengarengan

From the results obtained, it is evident that the phosphate concentrations at all sampling points exceeded the established quality standard of 0.03 mg/L. The phosphate concentration measurement results can be seen in Figure 9 below. The measured phosphate concentrations at Situ Pengarengan ranged from 0.04 to 0.37 mg/L. The average value from the three sampling occasions was 0.19 mg/L. The highest phosphate concentration was found at Point 2 in May. The high phosphate concentration at this point was caused by the influence of activities from the surrounding community, such as local shops, workshops, and farming activities, where pollutants containing phosphates (e.g., detergents or runoff from agricultural areas with fertilizer) may have contributed. The lowest phosphate concentration was recorded at Point 6 in March.

3.1.10 Escherichia coli

The coliform bacteria group is an indicator of domestic wastewater contamination in water. Several diseases, particularly gastrointestinal diseases such as typhoid, cholera, and dysentery, can be transmitted through coliform bacteria in water (Chapra, 2008). The E. coli concentration graph for Situ Pengarengan can be seen in Figure 10 below.

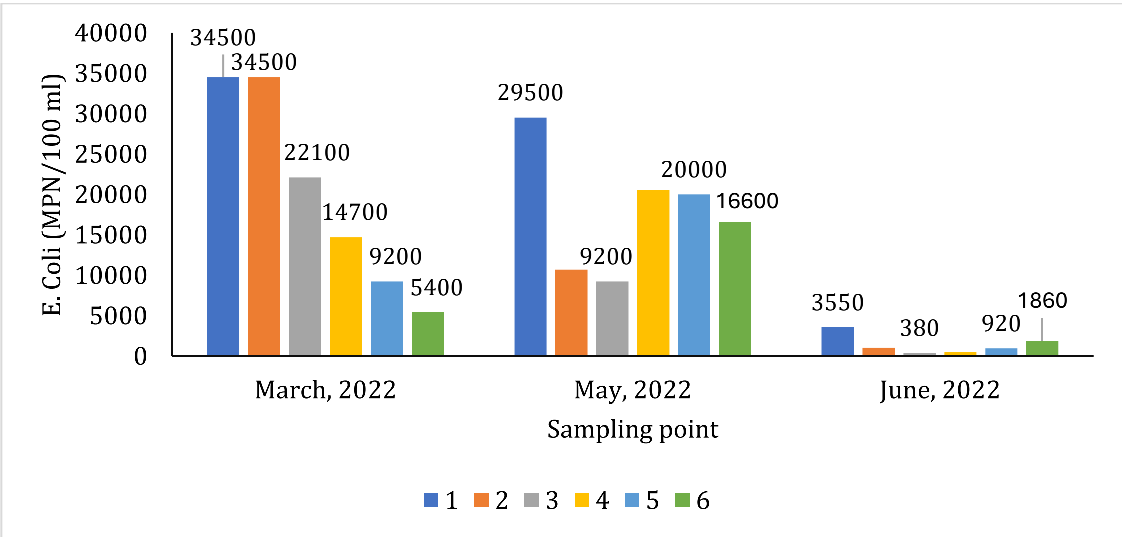

Fig. 10. E. coli concentration graph of Situ Pengarengan

The measured E. coli concentrations at Situ Pengarengan ranged from 380 to 34,500 MPN/100 mL. In the first and second sampling events, the E. coli levels at all points exceeded the quality standard of 1,000 MPN/100 mL. However, in the third sampling, all points were below the established quality standard threshold. The highest E. coli concentrations were found at Points 1 and 2 in March, while the lowest concentration was recorded at Point 3 in June. The high E. coli values at Points 1 and 2 were caused by the entry of animal waste from the cow and goat pens near the inlet of Situ Pengarengan.

3.2 KA-NSF value

The water quality analysis using the IKA-NSF method demonstrates the status of water quality at Situ Pengarengan. In the IKA-NSF method, water quality is categorized into 5 classes: very good, good, moderate, poor, and very poor, each with specific value ranges. From the results obtained, it is known that, overall, Situ Pengarengan is classified as moderately polluted, with an average status value of 64.94. The IKA-NSF value data for Situ Pengarengan in each sampling can be seen in Table 7 below.

Table 5. IKA-NSF value of Situ Pengarengan

	Value of IKA					
Point	Sampling I	Note	Sampling II	Note	Sampling III	Note
1	53.35	Medium	54.60	Medium	61.70	Medium
2	57.94	Medium	57.59	Medium	69.86	Medium
3	66.95	Medium	69.14	Medium	70.13	Medium
4	66.08	Medium	68.79	Medium	79.94	Good
5	65.01	Medium	70.01	Medium	79.67	Good
6	50.09	Bad	56.06	Medium	72.10	Good
Present status	59.90	Medium	62.70	Medium	72.23	Good

Based on the results obtained, during the first sampling, Situ Pengarengan was classified as moderately polluted with an average value of 59.90. In the second sampling, the average value was 62.70, which also falls within the moderate category. In the third sampling, the average value was 72.23, which falls under the good category. From the three samplings, it can be observed that there was an improvement from the first to the second sampling and from the second to the third sampling. This indicates that the water quality of Situ Pengarengan is improving.

The lowest IKA-NSF value in the first sampling was found at Point 6, with a value of 50.09, categorized as poor. The highest IKA-NSF value was found at Point 3, with a value of 66.95, categorized as moderately polluted. In the second sampling, the lowest IKA-NSF value was found at Point 1, with a value of 54.60, categorized as moderately polluted. The highest IKA-NSF value was found at Point 5, with a value of 70.01, categorized as moderately polluted. In the third sampling, the lowest IKA-NSF value was again at Point 1, with a value of 61.70, categorized as moderately polluted. The highest IKA-NSF value was found at Point 4, with a value of 79.94, categorized as good. From the three samplings, the average water quality value for Situ Pengarengan was 65.04, which falls into the moderate pollution category. This is due to the parameters such as BOD, COD, Phosphate, and E. coli exceeding the established quality standards.

Based on research from the Environmental Agency in 2019, the water quality index values were then used to calculate the pollution index status, which indicated that in 2019, the water quality status of Situ Pengarengan was classified as heavily polluted with an average pollution index (IP) value of 10.890. In 2022, the water quality status of Situ Pengarengan, based on IKA-NSF, showed that the water condition was moderately polluted with an average value of 65.04. This indicates that from 2019 to 2022, the water quality of Situ Pengarengan improved from heavily polluted to moderately polluted.

3.3 Pollutant degradation rate

Situ Pengarengan is divided into three segments: Segment A, B, and C. To determine the degradation rate, the flow rate must first be calculated. The calculation results for the area, flow velocity, volume, and discharge in each segment of Situ Pengarengan are shown in Table 6 below. From the calculations, it is found that Segment B has the largest area among the other segments, with an area of 177.51 m^2 and a volume of 35,464.12 m^3. Segment A has an area of 135.51 m^2 and a volume of 23,582.11 m^3, while Segment C has an area of 119.32 m^2 and a volume of 13,356.12 m^3. The size of the volume in each segment is influenced by the area and average depth of each segment. The discharge at Situ Pengarengan varies. The largest discharge is found in Segment C (1.99 m^3/second), while the smallest is in Segment B (0.99 m^3/second).

Table 6. Area, flow velocity, volume, and discharge of each segment in Situ Pengarengan

Segment	Average width (m)	Average depth (m)	Average velocity (m/second)	Distance between segments (m)	Surface area (m^2)	Volume (m^3)	Discharge (m^3/second)
A (*Inlet*)	193.58	0.70	0.01	174.03	135.51	23582.11	1.51
B (Middle)	146.7	1.21	0.01	199.79	177.51	35464.12	0.99
C (*Outlet*)	121.75	0.98	0.02	111.94	119.32	13356.12	1.99

Segment A has a discharge of 1.51 m^3/second. The variations in discharge are due to the average width, depth, and flow velocity of each segment.vTo calculate the degradation rate coefficient, factors such as morphology, hydrology, and hydraulic residence time (td) affect the speed of pollutant removal or degradation (Oktaviyani et al., 2015). To calculate td for each segment, the volume and discharge of that segment are needed. The results of hydraulic residence time for each segment of Situ Pengarengan are shown in Table 7 below.

Table 7. Results of hydraulic residence time (td) calculation for each segment of Situ Pengarengan

Segment	Second (td)	td (day)
A	11755.55	0.14
B	15501.39	0.18
C	6623.43	0.08

The hydraulic residence time for the first segment is 0.14 days, for the second segment is 0.18 days, and for the third segment is 0.08 days. Hydraulic residence time is influenced by the size of the outlet discharge. The larger the outlet discharge, the shorter the hydraulic residence time. With the hydraulic residence time, the degradation rate can then be calculated (Zharifa et al., 2019). The results of the degradation rate coefficient calculation for Situ Pengarengan are shown in Table 8 below.

Table 8. Degradation rate coefficient

Segment	Mixture concentration (mg/L)	Exit concentration at each segment (mg/L)	td (day)	Degradation rate coefficient (/day)
A	7.39	5.66	0.14	2.21
B	5.66	6.86	0.18	-1.07
C	6.86	8.75	0.08	-3.04

The larger the outlet discharge, the shorter the hydraulic residence time. Hydraulic residence time shows the speed of organic material degradation in the water (Zharifa et al., 2019). The degradation rate coefficients for Segments B and C are -1.07 per day and -3.04 per day, respectively. This occurs due to incomplete degradation in these segments. Other factors that may influence incomplete degradation in Situ Pengarengan include insufficient hydraulic residence time, which means the organic material degradation process has not fully occurred. In the current condition, with Situ Pengarengan's very slow flow characteristics, the water body is considered a natural reactor with a batch system. Therefore, the concentrations in the body of water behave as a complete mix system.

4. Conclusions

Situ Pengarengan is a lake designated for conservation, recreation, and fish maintenance. Therefore, in accordance with its purpose, the water quality analysis of Situ Pengarengan will be compared with the water quality standards outlined in Government Regulation No. 22 of 2021 concerning Environmental Protection and Management, Appendix VI of Water Quality Standards for Lakes and Similar Bodies of Water, Class 2. Class 2 water quality standards apply to water used for recreational water facilities, freshwater fish farming, irrigation, animal husbandry, and/or other purposes requiring water quality of the same standard.

The parameters exceeding the quality standards include BOD, COD, Phosphates, and E. coli. The water quality of Situ Pengarengan is classified as moderately polluted, with an average value of 65.04, calculated using the IKA-NSF method. The degradation rate coefficient is determined by dividing Situ Pengarengan into three segments: Segment A, Segment B, and Segment C. The degradation rate coefficients for each segment are 2.21 per day, -1.07 per day, and -3.04 per day, respectively.

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Author Contribution

All authors contributed equally to the study's conception, data collection, analysis, and manuscript writing. Each author reviewed and approved the final version for submission.

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Conflicts of Interest

The authors declare no conflict of interest.

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