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Bongso River Water Quality Status Due to Traditional Oil Mining Activities Using the Pollution Index Method

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Abstract. Wonocolo traditional petroleum mining activities in Kedewan District, Bojonegoro Regency, have a positive impact on the local community's economy but also have a negative impact, namely environmental pollution, especially surface water. This research aims to determine the water quality of the Bongso River in the Wonocolo traditional petroleum mining area based on physical and chemical parameters (Temperature, pH, DO, TSS, TDS, COD, phenol, nitrate, and Salinity) and analyze the level of river water pollution using the pollution index method. The Bongso River water quality analysis results show several parameters that exceed quality standards, namely, station SB 1 COD and Phenol. Station SB 2 TDS, TSS, COD, and phenol. Station SB 3 TDS, TSS, COD, and phenol. Station SB 4 TDS, TSS, COD, phenol, and DO levels do not meet the minimum quality standards of 3.4 mg / L. Station SB 5 TDS, COD, and Phenol. Station SB 6 TDS, COD, and Phenol. Station SB 7 TDS, TSS and Phenol. Meanwhile, the salinity of the Bongso River increased from upstream (SB1) to middle (SB2), from 0 ppt to 4 ppt (rainy season). Water quality status using the IP method shows that SB 1 and SB 5 stations are categorized as Lightly Polluted. Meanwhile, stations SB 2, SB 3, SB 4, SB 6, and SB 7 are categorized as Moderately Polluted.

***Keywords**:* Wonocolo Old Well, Water Quality Evaluation, Water Quality Status, Pollution Index Method

I. INTRODUCTION

Old oil wells, totaling 137, in the Wonocolo area of Kedewan District, Bojonegoro Regency, East Java Province, are a legacy of the Dutch East Indies colonial government and are currently managed by PT Bojonegoro Bangun Sarana (BBS). After the end of the colonial period, the management of the oil mine transitioned into the hands of the people of Wonocolo Village. Over time, Wonocolo's traditional oil mining activities reached their peak in the 2000s, with a total of 730 wells opened for exploitation, some of which are still operating today [1].

On the other hand, traditional petroleum exploitation carried out by the Wonocolo community has a positive impact in the form of increased oil production and community economic growth on a national scale [2]. However, this activity also has a negative impact in the form of environmental pollution, including surface water pollution. The adverse impact of water pollution is a threat to human health, and damage to ecosystems will worsen [3]. Because oil processing from these wells is still carried out traditionally, including in the stage of separating crude oil and produced water, still using simple equipment [2]. The use of simple equipment with non-standard procedures in crude oil extraction activities can increase the risk of spills that have the potential to contaminate soil and surface water [4].

In addition to producing crude oil in the process of petroleum exploitation, a large amount of wastewater is produced due to old oil wells. This is generally due to the high-value water cut in old oil wells, which account for more than 90% [5]. By the magnitude of the value of the water cut, this is likely to cause crude oil spills around the well.

Apart from that, the local community manages the oil mine traditionally using simple technology, namely in the form of an iron pipe, which is pulled back and forth with a cable and with the help of a used car engine. The oil is lifted with an iron pipe. To the ground surface, then flowed directly into the reservoir without going through channels. Specifically, the remaining water carried with the oil is directly channeled into the river without any prior processing [6] such conditions are often considered to pollute the surrounding environment, including rivers, and the non-optimal separation process between water and oil causes produced water discharged into rivers to have a level of contamination that exceeds the specified quality standards.

Therefore, to maintain the function of environmental conservation, it is necessary to take control measures against businesses and activities that have the potential to cause pollution and damage environmental ecosystems. Based on this description, the assessment of the level of water pollution of the Bongso River in the Wonocolo traditional oil mining area can be determined using a combination of physical and chemical parameters. Physical parameters include Temperature, Total dissolved solids (TDS), and Total Suspended Solid (TSS). Then, the chemical parameters consist of dissolved oxygen (DO), pH, chemical oxygen demand (COD), phenol, and nitrate (NO_3).

Research related to the Wonocolo traditional oil mining area has been carried out by several researchers, including: [2] Conduct river water analysis research on wastewater receipts from traditional oil mining activities on the Kragsaan and Bungsu Rivers by taking river water samples at 3 points in each river. the river water quality in the upstream section is still in good condition, while in the downstream section, there are several parameters whose values exceed class II water quality standards. Furthermore, research conducted by [1] conducted research on the study of the quality of petroleum-produced water and its impact on the water pollution of the Dong Rumpit River in the Wonocolo Village petroleum well area by sampling 5 points of Dong Rumpit Wonocolo River water, representing upstream, middle, and downstream, However, the entire Dong Rumpit river section has exceeded class 3 water quality standards. However, in this research, there were additional sampling points for Bongso River water, namely seven points based on the density of traditional oil wells. By adding the water sampling point, we can find changes in the water quality of the Bongso River gradually from the middle upstream to downstream.

In this study, the salinity parameter was added because previous research, according to [7] stated that there were indications that the Bongso River has a higher salinity content than freshwater rivers, and no research has proven this high salinity content. Therefore, this study aims to evaluate the water quality of the Bongso River in the Wonocolo traditional oil mining area based on national water quality standards in Government Regulation No. 22 of 2021 Annex VI, measure the salinity value of river water, and determine the status of water quality based on the Pollution Index (IP) referring to the guidelines of the Minister of Environment Decree Number 115 of 2003.

II. METHODS

This research uses a descriptive-quantitative method that aims to analyze the water quality of the Bogso River and evaluate the status of its water quality. Sampling uses the grab sample method, which refers to SNI 03-7016-2004 – Sampling Procedures for monitoring water quality in a watershed. The water sampling station refers to the SNI 6989.57:2008 surface water sampling methods. The research and data analysis period is November 2023 - January 2024. The research was conducted in the traditional petroleum mining area of Wonocolo, Kedewan, Bojonegoro.

Water Quality Measurement

Parameters used to measure river water quality include physical parameters such as temperature, Total Suspended Solids (TSS), and Total Dissolved Solids (TDS), as well as chemical parameters such as pH, Dissolved Oxygen (DO), Chemical Oxygen Demand (COD), Phenol, Nitrate, and Salinity. Then, water quality testing is divided into two, namely direct measurements in the field (in situ) and laboratory tests (ex-situ) at PPSDM Cepu Migas for analysis according to APHA provisions and Indonesian National Standards (SNI), which are presented in Table 1.

Table 1. River Water Quality Parameters and Test Methods Used

Parameters	Unit	Test Method
Temperature	°C	*In situ*
Ph	-	*in situ*
TDS	mg/L	*in situ*
DO	mg/L	*in situ*
TSS	mg/L	SNI 6989.3:2019
COD	mg/L	SNI 6989.73:2019*
Phenol	mg/L	SNI 06-6989.21-2004*
NO3 as N	mg/L	APHA 4500-NO3-.23rd ED 2017*

Sampling location

The Bongso River water sampling location in the Wonocolo traditional oil mining area consists of seven stations representing various river conditions, namely Station SB 1 (Upstream - Natural Source), Station SB 2 (Central - Source of Pollution), Station SB 3 (Central - Source Pollution), station SB 4 (Central - Source of Pollution), station SB 5 (Downstream - Middle of Forest), SB Station 6 (Downstream - Middle of Forest) and station SB 7 (Downstream - Middle of Forest). Coordinates for

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taking Bongso River water samples using Google Earth. There are seven station points representing river flow in the Wonocolo traditional oil mining area starting from Upstream (SB 1), Middle (SB 2, SB 3, and SB 4), and Downstream (SB 5, SB 6, and SB 7), as shown in Figure 1.

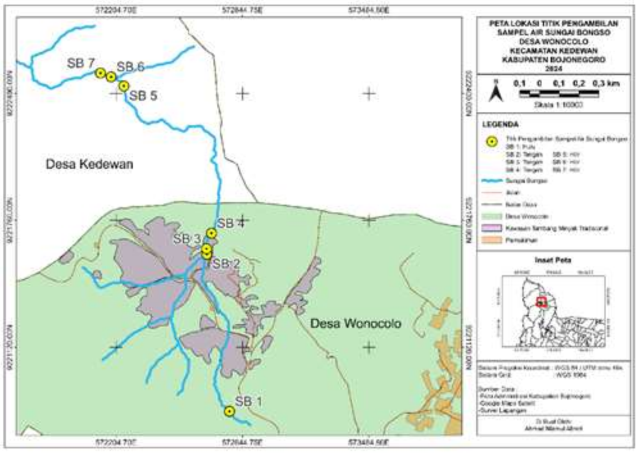

Figure 1. Map of Bongso River Water Sampling Station

Tools and materials

The tools used are a pH meter, thermometer, TDS meter, DO meter, Salinometer, Global Positioning System (GPS), QGIS 3.24 software, Google Earth, and Microsoft Excel. Meanwhile, the materials used include river water samples and distilled water.

A. *Pollution Index (IP)*

Evaluation of river water quality conditions is carried out by the provisions contained in Government Regulation No. 22 of 2021 concerning the Implementation of Environmental Protection and Management Annex VI. The level of river water pollution is determined based on the Pollution Index Method (IP) by Minister of Environment Decree No. 115 of 2003 Appendix 2 concerning determining water quality status. The results of IP calculations to determine water quality status are presented in Table 2. The Pollution Index (IP) calculation formula [8] used to determine the level of water quality pollution is based on the calculation results from equations 1 to equation 4 below:

$$\boldsymbol{IP_j} = \sqrt{\frac{\left(\frac{c_i}{L_{ij}}\right)_M^2 + \left(\frac{c_i}{L_{ij}}\right)_R^2}{2}} \quad (1)$$

With:
J = water allocation standards
Ip_j = Pollution index for designation j
C_i = concentration of water quality parameters
L_{ij} = the concentration of water quality parameter i is listed in water quality standard j
M = Maximum
R = Average

Information:
Lij = concentration of water quality parameters included in the quality standards of water use (j)
C_i = concentration of water quality parameters (i) obtained from the results of water analysis at a data collection location
Waters
IPj = pollution index for designation (j) which is a Ci/Lij function
If the parameter concentration value decreases, the pollution level increases, Ci/Lij (measurement results) replaced with Ci/Lij, the calculation results are:

$$(C_i/L_{ij})_{baru} = \frac{C_{im} - C_i(hasil\ pengukuran)}{C_{im} - L_{ij}} \quad (2)$$

If the quality standard value (Lij) has a range

- For $C_i < L_{ij}$ avg

$$(C_i/L_{ij})_{baru} = \frac{[C_{im} - (L_{ij})_{rata-rata}]}{\{(L_{ij})_{minimum} - (L_{ij})_{rata-rata}\}} \quad (3)$$

-For average $C_i > L_{ij}$ avg

$$(C_i/L_{ij})_{baru} = \frac{[C_i - (L_{ij})_{rata-rata}]}{\{(L_{ij})_{minimum} - (L_{ij})_{rata-rata}\}} \quad (4)$$

If two values (Ci/Lij) are close to the reference value of 1.0, or the difference is very large, this causes damage to water bodies that are difficult to determine, so the following solutions are used:

- Use the value (Ci/Lij) from the measurement results (obtained value < 1.0)
- Use the new value (Ci/Lij). If the new value (Ci/Lij) = 1.0 + P.log (Ci/Lij), then the P measurement result is constant, and the value is determined freely and adjusted to the results of environmental observations or existing requirements set (usually used 5)

Determine the average value and maximum value of the total Ci/Lij

The relationship of IP values to water quality status is presented in Table 2.

Table 2.
Pollution Index Score

No.	Pollution Index (IP) Score	Water Quality
1.	$0 \le Pij \le 1.0$	Good Conditions
2.	$1.0 < Pij \le 5.0$	Lightly polluted
3.	$5.0 < Pij \le 10$	Moderately polluted
4.	$Pij \ge 10$	Heavily polluted

III. RESULTS AND DISCUSSION

River Water Quality Based on Physico-Chemical Parameters

The parameters and quality standards used in the analysis of Bongso River water quality refer to Government Regulation Number 22 of 2021 concerning the Implementation of Environmental Protection and Management, Annex VI concerning National Water Quality Standards. Parameters are set based on indications of polluting sources from petroleum mining activities. Meanwhile, water quality standards cannot be set specifically for the Bongso River, so class II water quality standards are used as guidelines. This criterion refers to water that can be used for water recreation infrastructure/facilities, freshwater fish farming, animal husbandry, water to irrigate crops, and other designations similar to these uses. The results of the analysis of the water quality of the Bongso River at different stations are presented in Table 3.

Table 3.
Results of Bongso River Water Quality Analysis

No	Parameters	Unit	River Water Quality Standard Class (2)	Location						
				SB 1	SB 2	SB 3	SB 4	SB 5	SB 6	SB 7
1	pH	-	6-9	7.8	8.3	8.3	8.3	8.5	8.5	8.5
2	Temperature	(°C)	22-28	25.9	34.3	34.3	34.8	30.2	29.6	29.8
3	DO	(mg/L)	4	4	5.2	5.5	3.4	4.6	6.9	6.6
4	TDS	(mg/L)	1000	526	1010	1190	1450	1310	1400	1230
5	TSS	(mg/L)	50	27.60	93.60	1778	1019	42.4	32.4	54.80
6	COD	(mg/L)	25	47.1	94.0	84.7	28.2	103.5	65.9	0.66
7	Nitrate NO3	(mg/L)	10	0.57	0.67	0.69	0.76	0.62	0.66	0.72
8	Phenol	(mg/L)	0.005	0.196	0.552	0.747	0.632	0.364	0.585	0.556

Temperature

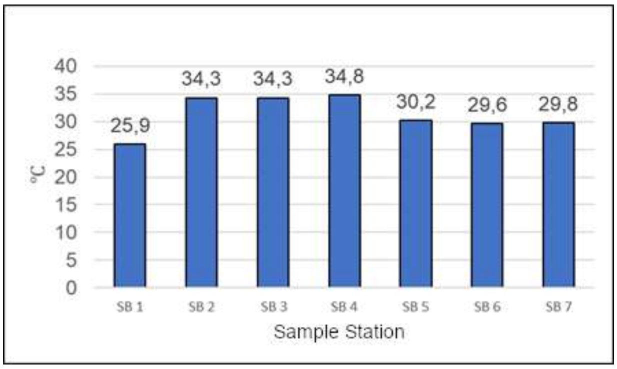

Figure 2. Water Temperature Value of Bongso River

Based on the temperature parameter measurement result presented in Figure 2, the average ranges from 25 °C to 34 °C. This is related to measurement time, location height, and vegetation cover differences. The temperature measurement at SB 1 (upstream) was 25.9°C; this was because the temperature measurement was carried out in the morning and was at a natural source, so the temperature was still normal. Then, at stations SB 2, SB 3, and SB 4, in the middle of a traditional oil mining area, the temperature increased drastically from 25°C to 34°C. This is closely related to the source of pollution from traditional oil mining, namely waste directly from water separation. and oil flows into the Bongso River; however, downstream of the Bongso River at stations SB 5, SB 6, and SB 7, it gradually drops to 29°C. This is related to the condition of the area, which is far from sources of pollution and the large amount of vegetation cover. Sinambela and Sipayung (2105) state that water temperature can fluctuate depending on air temperature patterns, sunlight intensity, geographical location, vegetation cover, and water conditions [9]. High-temperature values can also be associated with active oil mining activities and can be influenced by ambient air temperature and the intensity of sun exposure to water bodies, heat exchange between water and surrounding air [10], because water temperature is also a limiter for aquatic organisms.

Total Dissolved Solids **(TDS)**

Based on the analysis of TDS concentration in Figure 3, it shows that in its natural condition SB 1 station which is the upper reaches of the Bongso River before receiving the impact of mining activities, TDS concentration is still below class II water quality standards of 526 mg / L. while the concentration at SB 2 station is 1010 mg / L, SB 3 1190 mg / L, SB 4 1450 mg / L, SB 5 1310 mg/L, SB 6 1400 mg/L and SB 7 1230 mg/L, TDS concentrations at the station have exceeded class II river water quality standards of 1000 mg/L in Government Regulation Number 22 of 2021 Appendix VI. This happens because there is an excessive amount of dissolved materials resulting from the separation process between water and oil, which will cause a layer of oil on the surface of the water, which can increase turbidity, which in turn will inhibit the penetration of sunlight into the water so that it can affect the photosynthesis process.

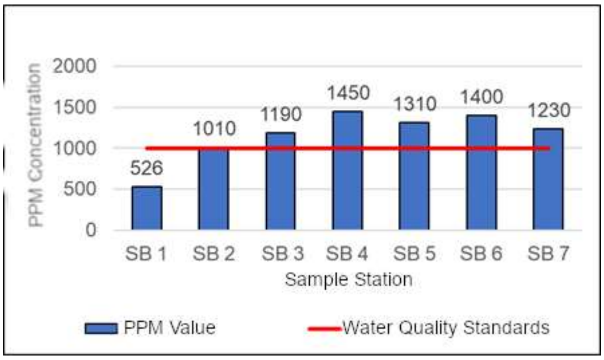

Figure 3. TDS Value of Bongso River Water

Apart from that, it is also influenced by the relatively small size of the river so that it is unable to effectively break down the concentration of pollutants [2]. According to [11] Total dissolved solids refer to dissolved substances and colloids in water that are chemical compounds, such as inorganic materials consisting of ions that can generally be found in aquatic environments.

***Total Suspended Solids* (TSS)**

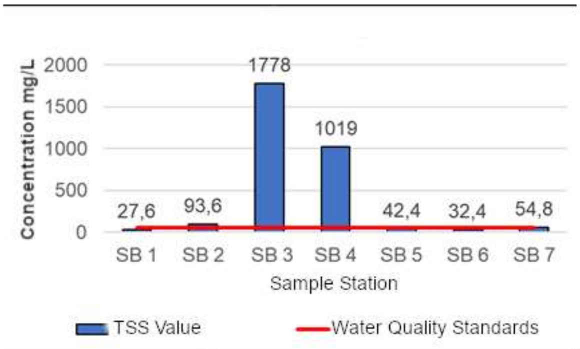

Figure 4. TSS Value of Bongso River Water

The results of the concentration analysis Total Suspended Solid (TSS) in Figure 4 shows that the TSS concentration at SB 1 station is 27.6 mg / L, so it still meets the criteria for class 2 water quality standards because the station is in a natural source, then at SB 2 station it is 93.6 mg / L, SB 3 is 1778 mg / L and SB 4 is 1019 mg / L because the station is at the location of pollution sources from traditional old petroleum well mining, so that the TSS content exceeds class II water quality standards in PP Number 22 of 2021. This is because waste from petroleum mining activities is directly flowed into rivers. So that the large content of TSS also causes an increase in the turbidity level of water [12]. High levels of TSS are also caused by erosion or soil erosion that dissolves into rivers due to the absence of vegetation along the river flow.

According to [13] The increase in TSS value is also caused by suspended particles originating from land and carried by river currents.

pH

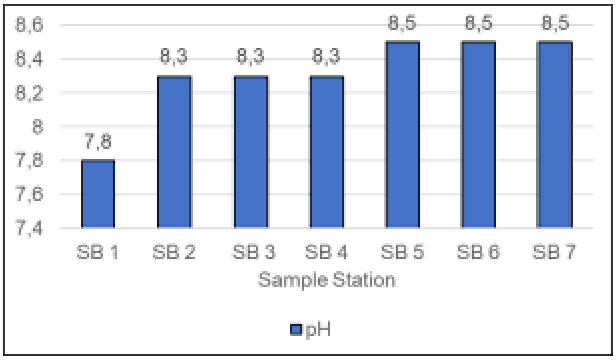

Figure 5. pH Value of Bongso River Water

Based on the pH measurement results in Figure 5 shows that the average pH concentration value of Bongso River water is 7.8 to 8.5. So that it still meets class II water quality standards, namely (pH values 6-9). However, at stations SB 5, SB 6, and SB 7, there was an increase in pH to 8.5. This is because the station is located in the downstream part of the Bongso River, where there is a lot of organic material, such as fallen leaf litter, which causes it to rot and settle, which can affect the level of pH alkalinity. in river waters [14].

In a study conducted by [15], stated that most aquatic organisms are prone to fluctuations in pH because the ideal pH value of water is 7 - 8.5. Where very acidic water conditions or alkaline can interfere with the metabolic and respiration processes of these aquatic organisms [16].

***Dissolved Oxygen* (DO)**

Figure 6 shows the value of the DO concentration of the Bongso River, which ranges from 3.4 – 6.9 mg / L. The dissolved oxygen condition at all stations reflects that SB 4 station has the lowest DO level, 34 m.g / L, below the river water quality standard of 4 mg / L. This condition is caused by the impact of pollution derived from traditional petroleum mining activities. The entire station's power dissolved oxygen (DO) still relatively meets the minimum DO level limit. According to [17], oxygen plays an important role as an indicator of water quality because

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dissolved oxygen plays a role in the oxidation and reduction of organic and inorganic matter. Low DO values also occur due to the low process of photosynthesis by phytoplankton at the bottom of the river so that dissolved oxygen levels in the water become low. This can affect the performance and survival of biotic communities [18].

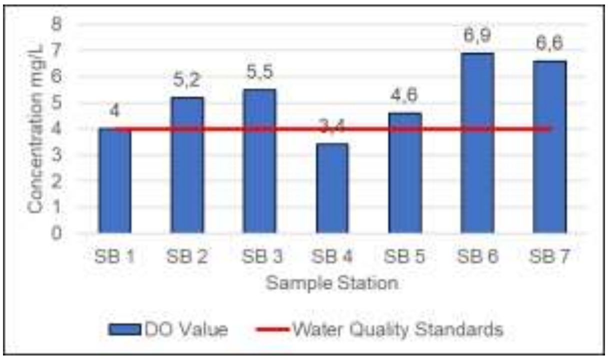

Figure 6. DO Value of Bongso River Water

Chemical Oxygen Demand (COD)

Based on the results of COD measurements in Figure 6, it shows that the COD concentration value has exceeded the established quality standards, namely < 25 mg / L (PP No. 22 of 2021 concerning the Implementation of Environmental Protection and Management, Class II) located at SB 1, SB 2, SB 3, SB 4, SB 5 and SB 6 stations. The possibility of high-value Chemical Oxygen Demand (COD) exceeds quality standards due to the proximity to water sources produced from old wells and petroleum processing plants along the river banks. This is in line with research [4], which states that the increasing level of COD value can be interpreted as an increase in the need for oxygen to dissolve chemicals, which also increases due to the entry of pollutants by petroleum industry activities. According to [19], oxygen consumption in a chemical reaction process known as Chemical Oxygen Demand (COD) reflects the high content of organic matter pollution in the aquatic environment. The high content of organic compounds in river water can cause health problems for the surrounding ecosystem if consumed directly.

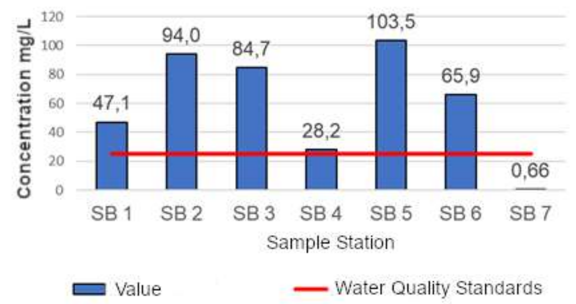

Figure 6. COD Value of Bongso River Water

Nevertheless, the value of Chemical Oxygen Demand (COD) at the SB 7 observation station has decreased to below-quality standards. This decrease is due to the winding characteristics of the river, which causes mixing between surface water and the riverbed to increase the Dissolved Oxygen (DO) content. This increase in DO levels impacts decreasing COD levels in river water [1].

Nitrate (NO3)

Figure 8 shows nitrate values in the Bongso River at all stations, showing that nitrate concentrations are still far below class II river water quality standards (10 mg / L). This can be connected with the morphological characteristics of the Bongso River, which has a winding contour, causing changes in river flow patterns from laminar to turbulent. This situation has an impact on increasing the effectiveness of the process of Self-purification against pollutants of river water pollution [1]. According to [20] Nitrates are present in the natural environment as a result of natural processes and also as an impact of human activities. Nitrates naturally come from the nitrogen cycle, while human-derived sources include the utilization of nitrogen fertilizers, industrial wastes, and organic waste. If humans dump their waste into water, it can increase the concentration of nitrates.

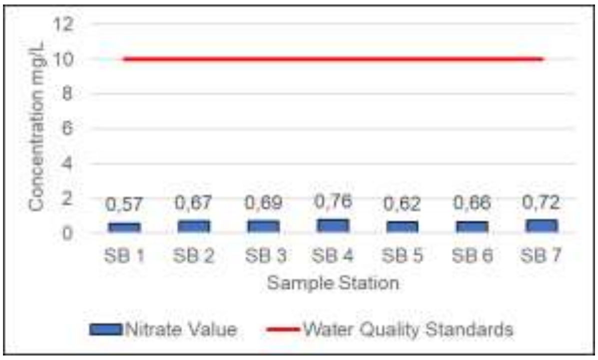

Figure 8. Nitrate Value of Bongso River Water

Phenol

Figure 9 shows that the phenol concentrations of all SB 1 to SB 7 stations far exceed those above class II river water quality standards (0.005 mg/L). Because the presence of phenol as a pollutant in the river is related to the presence of oil on the surface of the river water. Phenol concentration levels that exceed quality standards can come from oil residues dissolved in wastewater discharged into rivers [21]. So, if waste containing phenol is thrown into the environment, it will endanger the lives of living creatures around it. Phenolic compounds are dangerous because they are carcinogenic and degrade slowly by sunlight. Phenol is a very toxic organic compound that has a very sharp taste and odor [22].

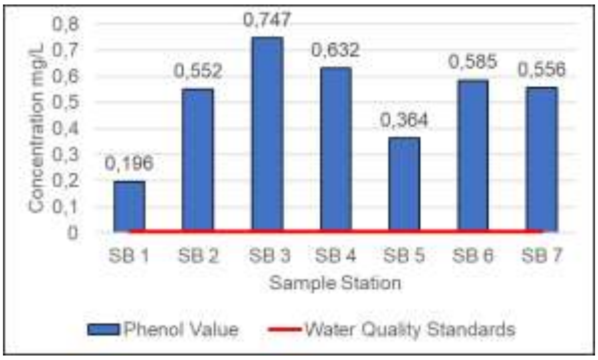

Figure 9. Phenol Value of Bongso River Water

Salinity

Testing of salinity parameters in Figure 10 shows that the concentration of salinity value of Bongso River water has increased from upstream (SB 1) to the middle (SB 2), from 0 ppt to 4 ppt, because when salinity measurements are carried out the rainy season, therefore the salinity level increases and at SB 2 station is also affected by the pollution source from the traditional oil mine. At the station (SB 3), it is 2 ppt, (SB 4) 2 ppt, (SB 5) 1 ppt, (SB 6) 2 ppt and (SB 7) 2 ppt. All of these stations still meet the criteria for freshwater quality standards. Since the salinity value of water for fresh waters usually ranges from 0-5 ppt, brackish waters range from 6-30 ppt (salinity of brackish water), and salinity of marine waters > 30 ppt [23]. Previous studies based on biological parameters according to [24] explained the indication of high salinity in the water of the Bongso River, which affects the low macrozoobentic organisms because not all freshwater organisms can survive in river water conditions with high salinity. Therefore, this salinity parameter is added to prove directly by testing, and the results still meet the criteria of freshwater quality standards.

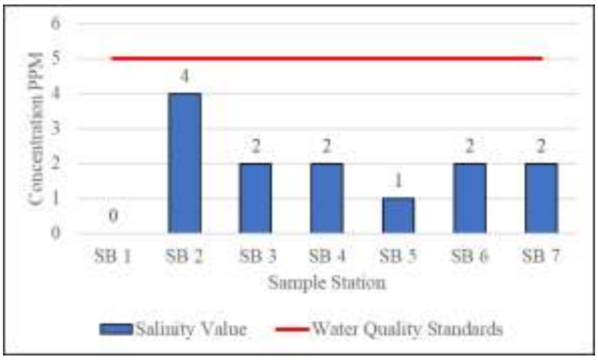

Figure 10. Water Salinity Value of Bongso River

Analysis of Pollution Index (IP) Method

Recapitulation results are in Table IV. Shows the analysis of the pollution index at seven water monitoring points of the Bongso River located in the Wonocolo traditional oil mining area. The value obtained is 4.39 upstream (SB 1), in the middle at the station (SB 2) is 5.43, station (SB 3) is 5.74, station (SB 4) is 5.48, then downstream at the station (SB 5) is 4.98, station (SB 6) is 5.53 and station (SB 7) is 5.46. Water quality status based on the Pollution Index shows the category of lightly polluted at two stations (SB 1 and SB 5), then the category that shows moderate pollution is present at five stations, namely (SB 2, SB 3, SB 4, SB 6 and SB 7). Sources of pollution are identified based on land use around sampling points, namely SB 1 points (rice fields), SB 2, SB 3, and SB 4 points (traditional oil well mining areas), and SB 5, SB 6, and SB 7 points (forests, rice fields, and vacant land). With the current state of water quality conditions, the relevant agencies must determine appropriate water resource management for conservation in the traditional mining area of Wonocolo oil wells. Because the water quality of the Bongso River has exceeded the class II water standard criteria stipulated in PP Number 22 of the Year 2021 Appendix VI. regarding National Water Quality Standards.

Table IV.
Recapitulation of Pollution Index Results

No.	Location	Pollution Index	Status
1.	SB 1	4.39	Lightly polluted
2.	SB 2	5.43	Moderately polluted
3.	SB 3	5.74	Moderately polluted
4.	SB 4	5.48	Moderately polluted
5.	SB 5	4.98	Lightly polluted
6.	SB 6	5.53	Moderately polluted
7.	SB 7	5.46	Moderately polluted

IV. CONCLUSION

Based on the study's results, it can be concluded that there are physical and chemical parameters in the Bongso River that do not meet class II water quality standards. The parameters exceeded at SB station 1 were COD (47.1 mg/L) and Phenol (0.196 mg/L); SB 2 stations are TDS (1010 mg/L), TSS (93.60 mg/L), COD (94.0 mg/L) and phenol (0.552 mg/L); SB 3 stations are TDS (1190 mg/L), TSS (1778 mg/L), COD (84.7 mg/L), and phenol (0.747); SB 4 station is TDS (1450 mg/L), TSS (1019 mg/L), COD (28.2 mg/L), phenol (0.632 mg/L) and DO levels (3.4 mg/L); SB 5 stations are TDS (1310 mg/L), COD (103.5

mg/L) and phenol (0.364 mg/L); SB 6 stations are TDS (1400 mg/L), COD (65.9 mg/L) and phenol (0.585 mg/L). SB 7 stations are TDS (1230 mg/L), TSS (54.80 mg/L) and phenol (0.556 mg/L). The salinity value of Bongso River water has increased from upstream (SB1) to middle (SB2), from 0 to 4 ppt during salinity measurements in the rainy season. Then, based on the calculation of the Pollution Index, it is known that the Bongso River is categorized as lightly polluted at SB 1 (4.39) and SB 5 (4.98) stations and moderately polluted stations SB 2 (5.43), SB 3 (5.74), SB 4 (5.48), SB 6 (5.53) and SB 7 (5.46). This shows that petroleum mining activities have traditionally been the main cause of exceeding river water quality standards in several parameters, so handling efforts are needed, especially for parameters that exceed quality standards.

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