

Pollutant Load Analysis of the Barito River Based on Seasonal Scenarios

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Abstract

The Barito River is one of the major rivers in Kalimantan Island that plays a strategic role in supporting the social, economic, and environmental aspects of the surrounding communities. However, based on water quality monitoring conducted by the Environmental Agency of Central Kalimantan Province during the years 2021 to 2022 at seven points along the Barito River, it was found that the Water Quality Index indicated a “lightly polluted” status. Residential activities near the river contribute to the pollutant load through direct flow of domestic wastewater into the river. Similarly, the presence of coal stockpiles around the river is also believed to increase the pollution burden. This study aims to predict the water quality conditions resulting from land use activities—particularly residential areas and coal stockpiles—along the Barito River using the Water Quality Analysis Simulation Program (WASP) model. River water quality data was collected at four sampling points. Although the pollutant load carrying capacity from in each segment of the Barito River has not yet been exceeded by the actual pollutant load, the results of the modeling indicate that the concentrations of TSS, BOD, and COD in river water during both the dry and wet seasons have exceeded the water quality standards, with TSS values over 50 mg/L, BOD values above 3 mg/L, and COD concentrations greater than 25 mg/L. Therefore, a strategic management plan for pollution load control is urgently needed to maintain the water quality of the Barito River in accordance with Class II river classification.

Keywords: *barito river, pollutant load, water quality, wasp*

Abstrak

Sungai Barito merupakan salah satu sungai utama di Pulau Kalimantan yang memiliki peran strategis dalam mendukung kehidupan sosial, ekonomi, dan lingkungan masyarakat. Namun berdasarkan hasil pemantauan kualitas air yang dilakukan oleh Dinas Lingkungan Hidup Provinsi Kalimantan Tengah pada tahun 2021 sampai 2022 di tujuh titik sepanjang Sungai Barito, diketahui bahwa indeks kualitas air menunjukkan kategori status mutu cemaran ringan. Aktivitas permukiman di sekitar Sungai Barito berkontribusi terhadap beban pencemar melalui aliran limbah domestik ke sungai. Begitu pula dengan keberadaan stockpile batubara di sekitar sungai dianggap turut memberikan dampak terhadap peningkatan beban pencemar. Penelitian ini bertujuan untuk memprediksi kualitas air sungai akibat adanya penggunaan lahan berupa aktivitas permukiman dan stockpile batubara di sekitar perairan Sungai Barito menggunakan perangkat lunak WASP (Water Quality Analysis Simulation Program). Pengumpulan data kualitas air sungai dilakukan pada empat titik pengambilan sampel. Meskipun daya tampung beban pencemar di setiap segmen Sungai Barito belum melebihi beban pencemaran aktual, namun dari hasil pemodelan menunjukkan konsentrasi TSS, BOD dan COD pada air sungai di musim kemarau dan musim hujan melebihi baku mutu di kedua musim dengan nilai lebih dari 50 mg/L untuk TSS, lebih dari 3 mg/L untuk BOD, dan lebih dari 25 mg/L untuk COD. Sehingga perlu adanya rencana strategis untuk pengelolaan beban pencemar untuk menjaga kualitas air Sungai Barito sebagai sungai kategori Kelas II.

Kata Kunci: *sungai barito, beban pencemar, kualitas air, wasp*

1. Introduction

The Barito River plays a vital role in supporting the social, economic, and environmental livelihood of communities, particularly in Central Kalimantan Province. In addition to serving as a primary transportation route, the river also functions as a water source for domestic use, fisheries, as well as industrial and mining activities in the surrounding areas. However, alongside increasing anthropogenic pressures, the water quality of the Barito River has significantly deteriorated. According to water quality monitoring conducted by the Environmental Agency of Central Kalimantan Province in 2021–2022, the Water Quality Index of the Barito River indicated a “lightly polluted” status. The dominant sources of pollution along the river corridor are residential settlements and coal stockpile activities. These activities have the potential to cause erosion and

sedimentation, leading to elevated levels of Total Suspended Solids (TSS), as well as other parameters such as Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD), which indicate the presence of organic matter and chemical contaminants in the water. The water quality in several parts of the Barito River has already exceeded the Class II water quality standards as stipulated in Government Regulation No. 22 of 2021, Annex VI.

This study utilizes the Water Quality Analysis Simulation Program (WASP) to predict the impact of land use—particularly residential areas and coal stockpiles—on the water quality of the Barito River. The model allows for the simulation of various scenarios to evaluate how different water quality parameters, such as pollutant concentrations, may change over time and space. The results of this analysis are essential for developing appropriate management strategies to ensure that the water quality of the Barito River complies with the Class II standards set by the government.

2. Research Methodology

2.1 Research Location

The research location is situated along a river segment between the coordinates 2° 6'31.11"S and 114°51'36.21"E to 2° 2'38.71"S and 114°52'43.37"E, covering a length of approximately 12 kilometers. Administratively, the study area is located in Teluk Timbau Village, Dusun Hilir Subdistrict, South Barito Regency, Central Kalimantan Province. The research location is shown in **Figure 1** below.

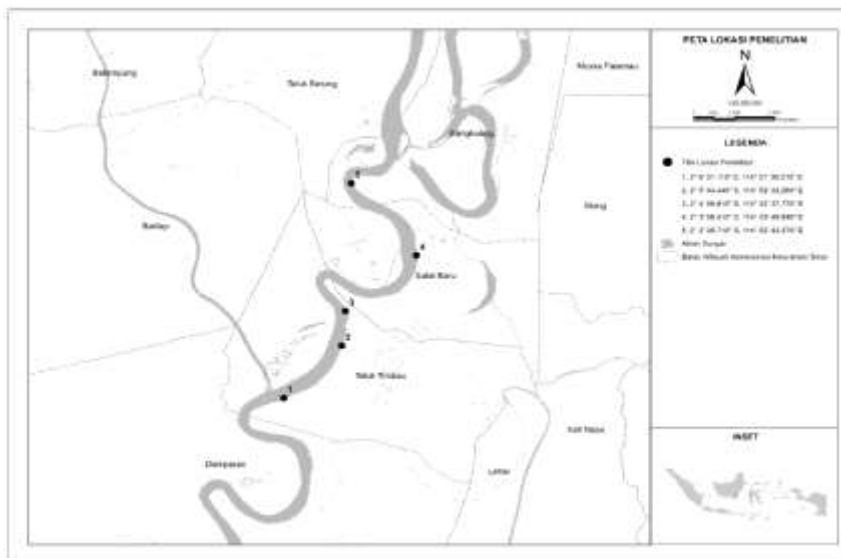


Figure 1. Research Location Map
Source: Analysis Results, 2025

2.2 Research Methods

The research began with a literature review to examine and analyze various relevant scientific references. Subsequently, the river was divided into segments based on identified pollution sources. The study was conducted along a 12-kilometer stretch of the Barito River, which was divided into four segments. The primary pollution sources in these segments include domestic activities from residential areas and the operations related to coal stockpiles. The segmentation of the study area is illustrated in **Figure 2** below.

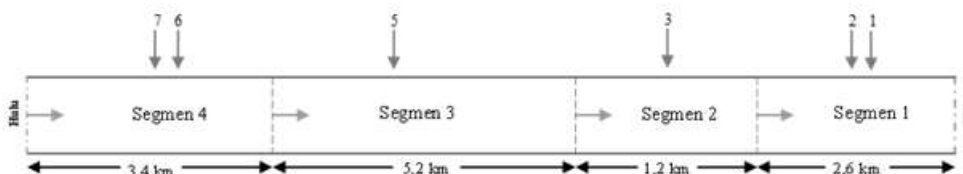


Figure 2. Segmentation of the Barito River
Source: Analysis Results, 2025

The distribution of land use and anthropogenic activities in each segment provides an initial picture of the distribution of pollutant loads entering the Barito River. This information is an important basis for water

quality modeling, especially for calculating pollutant load estimation entering the river from each source point. The sources of pollutants in each segment are shown in **Table 1** below.

Table 1. Potential Sources of Pollution

Segment	Source of Pollution	Land area	Total population
1	Coal Stockpile	29,324 Ha	-
	Settlement	-	1013 people
2	Coal Stockpile	4,840 Ha	-
3	Coal Stockpile	19,326 Ha	-
4	Coal Stockpile	5,904 Ha	-
	Settlement	-	431 people

Source: Analysis Results, 2025

Then, primary data collection was carried out in the form of river water quality data collection at four predetermined sampling points referring to SNI 6989.59:2008 concerning Surface Water Sampling Methods. While secondary data was in the form of river profile and characteristic data, hydrological data, climatological data, and existing activity data to determine the source of pollution. Based on the data above, the potential pollutant load that affects the water quality of the Barito River can be analyzed through modeling using WASP. The results of this modeling will be presented in the form of a graph with information on the concentration of each parameter (BOD, COD, and TSS). Model validation was carried out by calculating the Root Mean Square Error (RMSE) value from the modeling data and field monitoring data. Based on this simulation, the capacity status in each segment will be known.

2.2.1 Calculation of Point Source Pollutant Flow Rate

Domestic wastewater flow rate is the volume of wastewater originating from household activities (such as bathing, washing, cooking, and defecating) in a unit of time. Calculation of domestic wastewater flow rate uses the following formula (SPALDT, 2018):

$$\text{Wastewater flow rate} = 80\% \times \text{Amount of water usage} \times \text{Peak factor} \quad (1)$$

$$\text{Peak factor} = 1.2 \text{ from } Q_{\text{average users}}$$

2.2.2 Calculation of Non-Point Source Pollutant Flow Rate

The flow rate or rate of surface water runoff uses the surface water runoff calculation method (peak runoff) in the water catchment area (DTA) using the Rational method (Hardjosuprpto, 1998) using the following formula:

$$Q = f \cdot C \cdot I \cdot A \quad (2)$$

Description :

Q = Peak flow rate

f = conversion factor (f = 1/360 for Q in m³/sec)

A = Runoff coefficient

I = Rain intensity (mm/hour)

The rainfall intensity value is determined through the hydrological analysis stage by calculating the maximum planned daily rainfall using several probabilistic distribution methods including the Normal Distribution Method, Gumbel, and Log Pearson Type III. To determine the most appropriate distribution, a suitability test is carried out using the Chi-Square method (Suripin, 2004).

a) Gumbel Method

The Gumbel method is a calculation of rainfall for a particular PUH based on the extreme price distribution or normal distribution which is widely used in Indonesia. The Gumbel method can be calculated using the equation:

$$R_T = R_K + \frac{SD}{S_n} (Y_T - Y_n) \quad (3)$$

Description:

R_T = Maximum daily rainfall PUH t year

R_K = Confidence range (mm/hr)

SD = Standard deviation of rainfall data

S_n = Reduced standard deviation

Y_T = Reduced varied for PUH t years

Y_n = Reduced mean

The confidence range value (R_k) in the Gumbel method needs to be calculated before determining the maximum daily rainfall value using the equation:

$$Rk = \pm t(a)Se \quad (4)$$

$$Se = b \frac{SD}{\sqrt{n}} \quad (5)$$

$$b = \sqrt{1 + 1,3k + 1,1k^2} \quad (6)$$

Description:

Rk = Confidence range (mm/24 hours)

Se = Probability error (deviation)

$t(a)$ = Function a = 90%, $t(a)$ 1,640

SD = Standard deviation

b) Metode *Log Pearson* Tipe III

This method is based on changing existing data into logarithmic form. By arranging rainfall data from largest to smallest first:

$$\text{Log } R = \text{Log } (R_i) \quad (7)$$

$$\overline{\text{Log } R} = \frac{\text{Jumlah } R}{n} \quad (8)$$

$$\tau_x = \sqrt{\frac{\sum(R_i - \bar{R})^2}{n-1}} \quad (9)$$

$$C_s = \frac{n \sum(R_i - \bar{R})^3}{(n-1)(n-2)(SD)^3} \quad (10)$$

$$X_t = \bar{X} + K_x SD \quad (11)$$

$$R_T = 10^{X_t} \quad (12)$$

c) Normal Distribution Method

$$X_T = \bar{X} + K_T SD \quad (13)$$

Where:

X_T = Estimated expected value with anniversary period

\bar{X} = Average value of variance

SD = Standard deviation of variance values

K_T = Frequency factor

d) Compatibility Test

The goodness-of-fit test using Chi-Square is carried out by comparing the Chi-Square value (X^2) which is calculated using the following equation..

$$X^2 = \frac{\sum(O_i - E_i)^2}{E_i} \quad (14)$$

Where:

X^2 = Chi-Square Parameters

O_i = Number of observation values in subgroups

E_i = The sum of theoretical values in subgroups

e) Rainfall Intensity

$$I = \frac{(54 \times R) + (0,07 \times R^2)}{t + (0,31 \times R)} \quad (15)$$

Where:

I = Rainfall Intensity

t = Concentration time (minutes)

R = Maximum daily rainfall (mm/24 hours)

2.2.3 Pollutant Load Calculation

Domestic household wastewater can also be generally categorized into two categories, namely point sources calculated using the direct method if it has been processed into a centralized wastewater treatment plant and domestic pollutant loads calculated using the indirect method using emission factors if it does not go through processing in the IPAL, can use septic tanks or be directly flow rate into water bodies. The formula used to calculate the potential pollution load from household sources (Water Environment Center, Research and Development Center for SDA, Ministry of Public Works, 2004) is as follows:

$$PBP = \text{Total population} \times \text{Emission Factor} \times \text{Equivalence ratio} \times \alpha \quad (16)$$

Where:

PBP : Potential Pollutant Load

1) Population emission factors:

- BOD = 40 gr/people/day
- COD = 55 gr/ people/day
- TSS = 38 gr/ people/day

2) City equivalent ratio (flow rate load):

- City = 1
- Suburbs = 0,8125
- Interior = 0,625

3) Alpha (α) : Load transfer coefficient (delivery load)

Value $\alpha = 1$, used for areas that are located between 0 and 100 meters from the river

Value $\alpha = 0,85$ or locations between 100-500 meters from the rive

Value $\alpha = 0,3$ for locations that are more than 500 meters from the river

The equation for calculating the potential water pollution load originating from coal stockpiles or built-up land is as follow.

$$\text{PNPS} = \text{Land area} \times \text{Emission factor} \times 1\% \quad (17)$$

Description :

PNPS = Potential non-point source pollution load

Emission factor BOD = 15,34 kg/ha/day

2.2.4 WASP Model Analysis

In this study, a prediction analysis was conducted using WASP software to simulate the impact of surface activities and coal stockpiles on water quality under two-season conditions, namely the dry season and the wet season. The steps taken are to set up the hydrodynamic model through the hydrodynamic model configuration stage with water flow pattern data, river depth and profile data, water flow velocity data, and other hydrological conditions and to configure the water quality model with water quality parameter data (USEPA, 2000).

2.2.5 Validation of Model Simulation Results

Model validation is carried out with historical data to ensure that the model can replicate actual conditions. Calibration in modeling is carried out to determine the suitability between the modeling results and the existing research results or also known as the model fit test (goodness of fit). According to Wool et al. (2020), calibration is used to adjust parameters so that the parameters entered have a closer match between the modeling results and the observed data. Calibration in this study uses statistical analysis with the RMSE (root mean square error) method with the following equation.

$$\text{RMSE} = \sqrt{\frac{\sum(Co - Cs)^2}{n}} \quad (18)$$

Description

Cs = modeling results

Co = observation results

n = lots of data

A smaller RMSE value indicates that the model has better performance in representing actual conditions in the field. In the context of Barito River water quality modeling, the use of RMSE is used to assess the extent to which water quality simulations (e.g. TSS, BOD, COD parameters) are able to approach field measurement results.

2.2.3 Determination of Carrying Capacity and Load Capacity

Pollutant load capacity (TLC) is used to determine the assessment of water quality and quantity standards from the maximum amount of pollutants. The river TLC is determined from the results of the WASP model simulation of minimum and maximum flow rate variations and modifications of the addition and reduction of pollutant loads calculated using the following mass balance equation (Imtyas, 2023).

$$\text{DTBP} = \text{Pollutant Load According to BMA} - \text{Potential Pollutant Load} \quad (19)$$

3. Results and Discussion

3.1 Pollutant Load Estimation

Pollutants produced from residential activities are domestic wastewater from household activities (such as bathing, washing, cooking, and defecating) in a unit of time. The amount of wastewater flow rate produced from domestic residential activities can be seen in **Table 2** below.

Table 2. Point Source Pollutant Flow rate (Residential Activities)

Location	Source of Pollution	Total population (people)	Waste water flow rate	
			(m ³ /sec)	(m ³ /day)
Segment 1	Settlement 1	1013	0,0014	116,70
Segment 4	Settlement 4	431	0,0006	49,65

Source: Calculation Results, 2025

Determination of pollutant flow rate from non-point sources in this case coal stockpile dock activities is carried out using the surface runoff approach. Before calculating the runoff flow rate, it is necessary to conduct a rainfall analysis first. This is done to obtain the planned rainfall intensity value used as the basis for calculating the runoff flow rate. Maximum rainfall data for 10 years from the Central Statistics Agency. Several probabilistic distribution methods used in this analysis include Normal Distribution, Log-Normal, Gumbel, and Log Pearson Type III with the result are shown in **Table 3**.

Table 3. Recapitulation of Maximum Daily Rainfall

PUH	CHHM (mm/24 hours)		
	Gumbel	Log Pearson	Distribusi Normal
2	16,95	431,42	427,62
5	147,40	501,01	498,20
10	237,68	534,14	535,18
20	323,86	566,17	555,34
25	352,80	584,96	565,43
50	438,49	600,50	599,88
100	523,68	600,50	623,41

Source: Calculation Results, 2025

After obtaining the maximum daily rainfall value from each method, a Chi-Square goodness-of-fit test was carried out and the results were obtained as shown in **Table 4**.

Table 4. Recapitulation of Chi-Square Test Results

No	Method	X ² Nilai	Nilai	X ² Table	Description
1	Gumbel	4,00	<		Accepted
2	Log Pearson	7,00	>	5,99	Rejected
3	Normal Distribution	1,00	<		Accepted

Source: Calculation Results, 2025

The results of the suitability test using the Chi-Square Method for each maximum rainfall analysis method state that the Gumbel Method and the Normal Distribution Method are acceptable because the X² value from the calculation results is smaller when compared to the X² value in the table. However, it is still necessary to choose one of the best methods. The test results show that using the Normal Distribution Method is the most appropriate distribution for rainfall data at the location, with a test statistic value of 1.00, which is the smallest Chi-Square value when compared to Chi-Square in the Gumbel and Log Pearson Type III methods. So that the planned rainfall value used in calculating rainfall intensity is the planned rainfall from the Normal Distribution Method calculation.

Furthermore, the planned rainfall is calculated for various return periods, such as 2 years, 5 years, 10 years, 20 years, 25 years, 50 years and 100 years. Based on these calculations, the planned rainfall value is 555.34 mm/24 hours for a return period of 20 years. The selection of the planned rainfall value for a 20-year return period is based on the return period often used in hydrological analysis for technical planning of infrastructure development such as drainage channels, flood control. According to Chow et al. (1988), the greater the impact or risk of damage due to hydrological system failure, such as flooding or excessive runoff, the greater the return period value used. From the results of the hydrological analysis, the calculation results are obtained as in **Table 5** below.

Table 5. Results of Rainfall Intensity Calculation

PUH (Year)	Maximum Daily Rainfall (R) (mm/24 hours)	Rain Duration Time (t) (minutes)	Rainfall Intensity (mm/hour)
20	555,34	301,77	67,83

Source: Calculation Results, 2025

The runoff coefficient (C) plays a very crucial role in calculating the runoff flow rate from the disposal of coal stockpile wastewater into rivers. The runoff coefficient value describes the proportion of rainfall that flows as surface runoff after falling on an area that cannot be absorbed by soil or vegetation. In the case of coal stockpiles, this coefficient value is used to estimate how much rainwater will flow directly into drainage channels or rivers. Coal stockpile areas generally have hard surfaces that cannot absorb water efficiently, such as concrete or soil layers, so the C value in this area tends to be high, ranging from 0.5 to 0.8, indicating that almost all rainfall will flow as surface runoff. The amount of runoff flow rate generated from each coal stockpile activity can be seen in **Table 6** below.

Table 6. Non-Point Source Pollutant Flow rate (Stockpile Activities)

Location	Zone	Stockpile area	Coefficient Runoff	Rainfall Intensity	Runoff Flowrate (Q)	
		Ha		(mm/hour)	(m ³ /sec)	m ³ /day
Segment 1	Stockpile 1	29,3243	0,7	67,83	3,8678	334174,33
Segment 2	Stockpile 2	4,84			0,6384	55155,75
Segment 3	Stockpile 3	19,326058			2,5490	220236,20
Segment 4	Stockpile 4	5,9036			0,7787	67276,34

Source: Calculation Results, 2025

The potential pollutant load in the research area in the Barito River along approximately 12 km comes from 2 residential sectors and the presence of coal stockpile dock activities. Domestic pollutant loads are estimated by calculation using an indirect method using emission factors assuming treatment using septic tanks or being flow rate directly into water bodies. For household pollutant loads, they are estimated by multiplying the number of residents per mapping unit multiplied by the emission factor of certain pollutant parameters per person per day and the load transfer coefficient. The emission factor is the potential emission of pollutant sources while the transfer coefficient is an estimated figure that shows the percentage of the amount of pollutant load that enters the water source. Meanwhile, the potential water pollutant load from coal stockpile dock activities is obtained based on data on the area of land used for these activities. The total potential pollutant load received in the Barito River area along approximately 12 km is 56.04 kg BOD/day, 78.19 kg COD/day, and 152,317.15 kg TSS/day. The following are the results of the calculation of potential pollutant loads in the Barito River flow presented in **Table 7**.

Table 7. Results of Calculation of Potential Pollutant Load

Segment	Source of Pollution	Pollutant Load (kg/day)			Total Pollutant Load (kg/day)		
		BOD	COD	TSS	BOD	COD	TSS
1	Stockpile 1	4,50	6,75	6.2558,11	37,42	52,02	62.589,89
	Settlement 1	32,92	45,27	31,28			
2	Stockpile 2	0,74	1,11	4.868,22	0,74	1,11	4.868,22
3	Stockpile 3	2,96	4,45	77.603,71	2,96	4,45	77.603,71
4	Stockpile 4	0,91	1,36	7.242,52	14,81	20,62	7.255,83
	Settlement 4	14,01	19,26	13,31			

Source: Calculation Results, 2025

Based on the calculation results above, it shows that the COD and BOD concentrations are higher from domestic activities compared to coal stockpile activities. This is estimated because domestic waste from residential or household activities generally contains high organic loads from food scraps, detergents, kitchen waste, and wastewater (Trisyani et al., 2021). These organic compounds are easily decomposed by microorganisms, increasing the BOD and COD values. COD reflects the total oxygen requirement to oxidize all organic materials, while BOD reflects the oxygen requirement of microorganisms to decompose easily degradable organic materials. Therefore, the pollutant load from COD and BOD is higher from domestic activities in residential areas. Meanwhile, the results of the pollutant load calculation in Table 7 show that the TSS concentration tends to be higher in coal stockpile activities. This can be caused by rainwater runoff that carries fine particles of coal or other materials into water bodies (Hendrawan et al., 2017). These particles contribute to increased turbidity and suspended solids content in rivers. Although coal also contains chemical

compounds, such as heavy metals and aromatic compounds, most of the pollutants from stockpiles are inorganic or difficult to degrade, so they contribute more dominantly to TSS parameters than BOD or COD.

3.2 WASP Analysis

The results of the modeling using WASP software are presented in graphical form. The model inputs used are river water flow rate in the wet season and dry season, flow rate from each pollutant source, pollutant load value, and climatological data such as air temperature and wind speed. Modeling using different flow rates (dry season and wet season flow rate) is carried out considering that river flow rate in the wet season tends to be high due to increased rainfall and surface runoff which can carry pollutants in the form of material from the catchment area, one of which is due to the activities of coal stockpile. By using flow rate from both seasons for modeling the water quality of the Barito River, it is expected to be able to describe the worst conditions of the river system. The magnitude of the Barito River flow rate during the wet season is 349.85 m³/sec and 69.17 m³/sec for the dry season which is used as input for WASP modeling for wet season conditions. The following **Tables 8** are the results of WASP modeling of the Barito River water quality during the wet season and dry season, respectively.

Table 8. WASP Modelling Results of Barito River Water Quality During the Wet and Dry Season

Segment	Distance from Downstream	TSS (mg/l)		COD (mg/l)		BOD (mg/l)	
		Wet	Dry	Wet	Dry	Wet	Dry
1	0	94,37	34,38	32,15	6,74	12,63	2,52
2	2,6	97,60	45,42	34,11	12,94	13,73	4,92
3	3,8	98,86	56,01	34,66	16,61	14,13	6,43
4	8,9	101,09	89,00	36,60	31,74	15,77	13,05

Source: Calculation Results, 2025

The water quality conditions of the Barito River in the dry season and wet season based on the TSS, BOD, COD parameters are shown in **Figure 3** below.

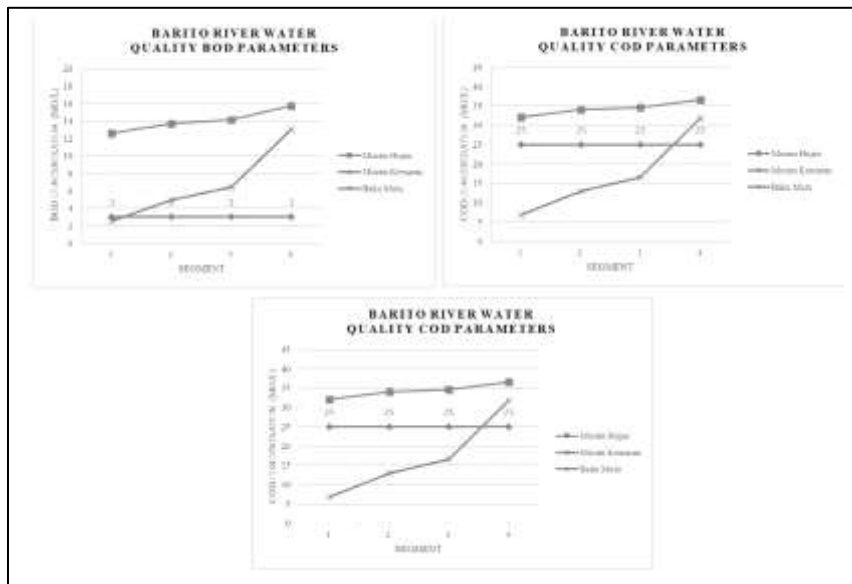


Figure 3. WASP Modeling Results of Barito River Water Quality in Wet Season and Dry Season

Source: Calculation Results, 2025

Based on the graph in **Figure 3** above, it can be seen that water quality parameters such as TSS, COD, BOD, and DO show variations in concentration in four river segments. All pollutant concentrations show higher values during the wet season. The high TSS value during the wet season is caused by the high rate of surface flow that carries suspended material from activities on land to water bodies (Effendi, 2003). When compared to the class II water quality standard based on PP 22 of 2021, the TSS parameter threshold is 50 mg/L, so that the TSS concentration value in each segment in the Barito River has exceeded the quality standard threshold.

High COD concentrations reflect high organic and inorganic pollutant loads, where pollutants come not only from domestic waste, but most likely from other activities such as industry. The COD concentration in

each segment shows a value that exceeds the class II water quality standard based on PP 22 of 2021, where the COD threshold is 25 mg/L. In line with COD, the BOD concentration in each segment in the research area has also exceeded the quality standard, which is more than 3 mg/L for class II rivers. High BOD indicates that more organic materials must be decomposed by microorganisms, which has the potential to reduce oxygen levels in the water if not balanced with sufficient dissolved oxygen.

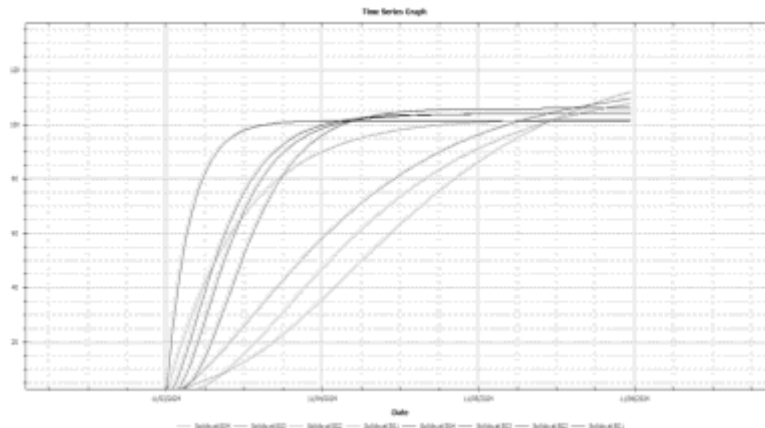


Figure 4. WASP Model Results of Barito River Water Quality in Wet and Dry Seasons
 Source: Analysis Results, 2025

Based on the results of the WASP modeling that has been carried out, higher pollutant concentrations are shown in the wet season compared to the dry season. This is a phenomenon that is considered common in tropical water bodies and is closely related to changes in hydrological patterns, especially increased water flow rate and surface runoff. In the wet season, high rainfall causes a significant increase in river flow rate. This increase in flow rate accelerates river flow and increases the volume of water flowing from the catchment area to the main water body. This flow carries various types of pollutants from the land surface, such as suspended solids, organic matter, household waste, agricultural waste, to heavy metals, especially from areas with open land cover, dense settlements, or intensive agricultural areas (Effendi, 2003; Chapra, 2008). In addition, high flow rates during the wet season also have the potential to increase erosion around river flows and riverbeds which causes an increase in TSS. Solids that also carry bound pollutants, such as organic matter that increases BOD and COD.

While in the dry season, the water flow rate is relatively low so that not much material is carried by surface runoff into the river. Although the volume of water decreases and the flow tends to be stagnant, the amount of pollutants entering is also reduced. Therefore, although the risk of concentration increases due to low water volume, the amount of pollutant load entering the water body is relatively small, so that in general the concentration of water quality parameters is often lower than in the wet season. Thus, the difference in pollutant concentration between the wet and dry seasons is greatly influenced by river flow rate, runoff intensity, and land use characteristics in the catchment area.

However, from the results of river water quality modeling using WASP as shown in **Figure 4**, as one example of pollutant TSS shows differences in pollutant distribution characteristics between the wet season and the dry season in the Barito River flow, shows that in the wet season the concentration of pollutants in each segment tends to increase rapidly and reaches a stable condition in a relatively short time. This is different from the dry season conditions shown by the colored lines on the graph, where the increase in TSS concentration tends to be slower and occurs gradually until it approaches equilibrium conditions.

This difference can be scientifically explained through variations in river flow rate in both seasons. In the wet season, river flow rate increases significantly due to high rainfall and high volume of surface runoff, which causes an increase in river flow velocity and volume. This condition supports a more efficient dilution process and accelerates the horizontal transport of pollutants along the water column, so that the distribution of pollutants is more evenly distributed and reaches stability (Ambrose, 2006). Meanwhile, in the dry season, river flow tends to decrease, which causes the dilution capacity to decrease and the residence time of pollutants in the water column to be longer. As a result, the mixing process takes place more slowly and causes water quality stability to be achieved over a longer period of time. Overall, the results of this modeling show that water quality dynamics are influenced by seasonal hydrological conditions (Wool et al., 2020).

3.3 Validation of Model Simulation Results

After modeling the water quality of the Barito River using WASP, then the results of the model concentration were compared with the values in the field by means of validation using RMSE (Root Mean Square Error). The following is a recapitulation of the model validation results seen in **Table 10**.

Table 10. Recapitulation of Validation Results with RMSE (Root Mean Square Error)

No.	Parameter	RMSE	
		Wet season	Dry season
1	TSS	8,80	39,87
2	BOD	2,41	8,48
3	COD	2,51	21,01

Source: Calculation Results, 2025

Based on the results of model validation using the RMSE (Root Mean Square Error) method, the results of the model validation show a large number in the model results using dry season flow rate. This indicates that there is a significant deviation or difference between the model prediction results and field observation data. In terms of water quality modelling using the WASP (Water Quality Analysis Simulation Program) model, a high RMSE value indicates that the model is unable to accurately represent the actual water quality conditions. This can be caused by several factors, such as errors in data input (e.g. river flow rate, pollutant load concentration, kinetic parameters), selection of inappropriate assumptions or model parameters, or limitations in the spatial and temporal data resolution used. A low RMSE value (<10–20% of the average observation data) indicates very good model results, while a high RMSE value needs to be analyzed and readjusted to improve model performance. Based on the validation results, the use of WASP to predict the water quality of the Barito River in this study is considered more accurate for modelling river water quality for the wet season.

3.4 River Pollutant Load Carrying Capacity

The calculation of the river Pollutant Load Carrying Capacity (DTBP) aims to determine the extent to which a water body is able to accept pollutant loads without causing a decrease in water quality below the established quality standards. The following are the results of the calculation of the pollutant load carrying capacity of the Barito River in **Table 11**.

Table 11. Pollutant Load Capacity of the Barito River

No	Parameter	BPS	BPA	BPA<BPS
		(kg/day)	(kg/day)	
1	Total Suspended Solid (TSS)	1.511.352	152.317,15	Qualify
2	Chemical Oxygen Demand (COD)	755.676	78,20	Qualify
3	Biochemical Oxygen Demand (BOD)	90.681,12	56,04	Qualify

Source: Calculation Results, 2025

If $BPA < BPS$, it means that the actual pollutant load (BPA) entering the water body is smaller than the pollutant load capacity (BPS) that can still be accepted by the water body without exceeding the quality standards. Scientifically, this condition shows that the assimilation capacity of the water body is still sufficient to receive and decompose the incoming pollutant load. The potential for significant pollution is still low, but monitoring and control still need to be carried out to anticipate an increase in the load in the future. Based on the results of WASP modeling and determining the pollutant load capacity, it is known that the pollutant load entering the Barito River flow from residential activities and coal stockpiles does not have a significant impact on the water quality of the Barito River. However, because the condition of the Barito River is already categorized as lightly polluted, the condition of pollutants that have exceeded the quality standards in the Barito River water still needs to be considered by planning strategic management to restore the condition of the river to comply with the quality standards of Class II rivers Government Regulation Number 22 of 2021 Annex VI.

4. Conclusion

Domestic and coal stockpile activities around the Barito River result in the emergence of pollutant loads that have the potential to cause river air pollution. Although after modeling, the pollutant load generated from each pollutant source does not have a significant impact on changes in river pollutant concentrations. Settlement or household activities has an affect on increasing BOD and COD content, while coal stockpile activities has an affect on increasing TSS concentrations in the water.

The pollutant load generated from each pollutant source does not have a significant impact on changes in river pollutant concentrations. The river water flow rate that increases significantly due to high rainfall can support a more efficient dilution process so that the distribution of pollutants is more even and stability is achieved. Meanwhile, in the dry season, the dilution capacity decreases and the residence time of pollutants in the water column becomes longer, causing higher pollutant concentrations in the wet season compared to the dry season due to the high rate of surface flow that carries suspended material from activities on land into the water. As a result, the mixing process takes place more slowly and causes water quality stability to be achieved over a longer period of time. Pollutant concentrations are higher in the wet season compared to the dry season due to the high rate of surface flow that carries suspended material from activities on land into the water.

One of the limitations of this study is the limited availability of water quality sampling data during the dry season. As a result, the model input for the dry season is less representative, leading to a higher degree of uncertainty in the simulation results for that period compared to the wet season. Therefore, interpretation of river water quality during low-flow conditions should be conducted with caution, and the model outcomes should not be solely relied upon for management decisions in the dry season. To improve the accuracy and representativeness of modeling, it is recommended that water quality modeling for the dry season be based on data that accurately reflect dry season characteristics to capture the variability of pollutant behavior under minimal flow conditions.

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