



Assessment of Water Quality and Pollution Load Capacity of Walesi River, Papua Mountains

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ABSTRACT

The Walesi River serves as a vital water source for the community in Jayawijaya Regency, Papua Mountains, but its quality is increasingly impacted by human activities and inadequate sanitation systems. This research aims to evaluate the water quality and pollution load capacity of the Walesi River using the Pollution Index (IP) and Mass Balance methods, focusing on physical, chemical, and microbiological parameters in accordance with Government Regulation (PP) No. 22 of 2021. The research involved water quality testing and flow rate measurements at four sampling locations to calculate pollution load capacities. Results from the Pollution Index (IP) method indicated that the water quality at all sites is categorized as "Good." However, phosphate levels were found to have reached the maximum allowable threshold of 0.20 mg/L, signaling no additional capacity for this pollutant. Other parameters, including TDS (52,682.62 ml/day), Ammonia (75.74 ml/day), and Total Coliform (2,797.14 ml/day), were within tolerable limits based on the Mass Balance analysis. The findings emphasize the need for enhanced sanitation infrastructure and monitoring to maintain and improve water quality. This research not only provides baseline data for the sustainable management of the Walesi River but also serves as a methodological reference for evaluating water quality and pollution load capacities in other regions of Papua and Indonesia, contributing to broader efforts in sustainable water resource management.

Keywords: Water Quality, IP, Mass Balance, Walesi River.

INTRODUCTION

Water quality issues are a major concern in water resources management, as changes in water quality can have a significant impact on the environment and the sustainability of ecosystems (Sukristiyono et al., 2021). Water quality describes the suitability of water for various purposes, such as drinking water, fisheries, irrigation, industry, recreation, and so on (Setyowati, 2016). Understanding and maintaining water quality is an important step to ensure its safe and sustainable use. Water quality can be evaluated through thorough physical, chemical and biological testing (Harianti & Nurasia, 2016).

Globally, water quality challenges are increasingly complex due to population growth, urbanization, and climate change resulting in water pollution and reduced clean water resources. (Makbul et al., 2023). The World Health Organization (WHO) notes that more than 2 billion people worldwide still face limited access to clean water, while water quality degradation has a direct impact on human and ecosystem health (Organization, 2016). Therefore, monitoring and managing water quality is a very urgent issue to ensure the sustainability of water resources in the future.

In Indonesia, water quality issues are one of the main challenges, especially in rapidly developing regions such as Papua. Papua Province, which recently expanded into three new provinces-South Papua, Central Papua, and Papua Pegunungan-faces challenges in natural resource management, including water quality. Papua Pegunungan, located in the highland region of Papua, administratively consists of eight districts and has a unique ecosystem. The division of this region, as stipulated in the Law on New Autonomous Region (DOB) of Papua on June 30, 2022, aims to accelerate development and improve public services (Nasir & Syahuri, 2023).

Jayawijaya Regency, which is one of the administrative regions of Mountainous Papua, has special challenges related to clean water needs. The local population largely relies on natural water sources such as rivers to fulfill their drinking and clean water needs. One of the most important rivers in the region is the Walesi River, which is the main source of water for the local community. However, abundant water availability does not always guarantee good water quality. Various human activities, including settlements, agriculture and land use change, can affect the water quality of Walesi River.

Research on water quality in Papua is limited, but some previous studies provide important insights. For example, research by (Pradana et al., 2019) showed that anthropogenic activities have a significant impact on river water quality in Indonesia, including pollution by domestic and agricultural waste. Another research by (Kaihena et al., 2024) underlined the importance of physical, chemical and biological analysis in comprehensively evaluating water quality. However, to date, research on the pollution load capacity of rivers in the highland region of Papua, such as the Walesi River, has been minimal.

The urgency of this research lies in the need to provide scientific data that can support sustainable water quality management in the Papua Mountains region. With unique geographical conditions and great natural resource potential, it is important to understand the water quality conditions of the Walesi River in depth to ensure its continued use for community needs. This research is not only important from a scientific perspective but also has strategic value to support sustainable regional development in Papua.

The novelty of this research lies in its approach that integrates the analysis of water quality and pollution load capacity in the Walesi River, which is one of the main rivers in the highlands of Papua. This approach provides a holistic picture of the river's condition, ranging from physical,

chemical, to biological parameters, while evaluating the river's ability to tolerate pollution without compromising its water quality.

Based on the above background, the purpose of this research is to evaluate the water quality of the Walesi River and determine its pollution load capacity. This research is expected to provide valid and accurate data on the condition of river water quality and the acceptable pollution load tolerance limit. This research has several benefits, both scientifically and practically. Scientifically, this research will enrich the literature on water quality in the Papua region, especially in highland areas. Practically, the results of this research can be used as a reference for local governments, non-governmental organizations and communities in managing water resources in a sustainable manner.

RESEARCH METHOD

River water quality is a qualitative condition that can be measured based on certain parameters and certain methods that are in accordance with applicable government regulations (Siregar, 2023). River water quality can be expressed by physical, chemical and microbiological parameters that describe how the water quality is. Water quality based on Government Regulation of the Republic of Indonesia No.22 of 2021 concerning the Implementation of Environmental Protection and Management in appendix VI concerning River Water Quality Standards and the like (Leonard, 2023).

Measurement of river flow velocity is carried out by counting the number of turns in a predetermined time, which is then correlated with the table and will get the velocity at that point. The distribution of velocity (v) in the vertical state is a parabolic distribution, so to obtain the vertical average velocity at a point, measurements were taken at 2 points, namely at a depth of $0.20 H$ and $0.80 H$ (H = depth of river water). Based on the flow velocity data obtained from these points, the calculation of the velocity (v) at each cross section is then carried out. The amount of flow in each cross section is the result of multiplying the average velocity in the cross section with the relevant measured cross-sectional area.

Pollution Index Method

Based on the Decree of the Minister of Environment No. 115 of 2003 concerning Guidelines for Determining Water Quality Status and Government Regulation No. 22 of 2021 concerning the Implementation of Environmental Protection and Management, water quality analysis can be carried out using the Pollution Index (IP) method (Simangunsong et al., 2024). IP method using the formula:

$$IP = \frac{\sqrt{\frac{C^2}{BM}max - \frac{C}{BM}rerata}}{2}$$

Description:

IP : Pollution Index

Ci : Concentration of water quality parameter i

BM : Concentration of water quality parameter i in the Quality Standard

The class levels in this method are used to determine whether a particular use is suitable or unsuitable with certain parameter values. The pollution class levels are:

Table 1. Pollution value class

<i>IP Value</i>	<i>Water Quality</i>
0 - 1,0	Good Condition
1,0 - 5,0	Lightly polluted
5,0 - 10,0	Moderately Polluted
>10	Severely polluted

Source: Minister of Environment Decree No. 115 of 2003

Mass Balance Method

The Mass Balance method is used to determine the average concentration of down stream from point sources or non-point sources (Mujib et al., 2022). This method can be used as a presentation of changes in flow rate or pollutant load in water flow. The analysis carried out is by formula:

$$CR = \frac{\sum CiQi}{\sum Qi} = \frac{\sum Mi}{\sum Qi}$$

where:

CR : average concentration of constituents in the combined flow

Ci : constituent concentration at the i-th stream

Qi. : flow rate of the i-th stream

Mi : mass of the constituent in the i-th stream

Calculating Pollution Load

Analysis on the pollution load is carried out as follows:

1) Measured pollution load

Pollution load from a river during existing conditions, with the following formula:

$$BPA = QxCMxf$$

where:

BPA : actual pollution load (kg/day)

Q. : measured discharge (m³/s)

CM : measured concentration (mg/ltr)

$$\text{Conversion Factor (f)} = \frac{1kg}{1000} = \frac{(1000ltr)x^2}{1m^3} \times \frac{84.600 \text{ detik}}{1 \text{ hari}} = 84,6 \frac{kg.ltr.dtk}{mg.m3.hari}$$

2) Maximum pollution load

Load from a pollution that is only allowed in a river based on its designation. In this calculation to determine the initial conditions in a river without any input from pollutant sources to the river body, with the following formula:

$$BPA = QxCBMxf$$

Description:

BPM : maximum pollution load (kg/day)

Q. : measured river discharge (m³/s)

CBM : quality standard concentration (mg/ltr)

$$\text{Conversion Factor (f)} = \frac{1\text{kg}}{1000} = \frac{(1000\text{ltr})x^2}{1\text{m}^3} \times \frac{84.600\text{ detik}}{1\text{ hari}} = 84,6 \frac{\text{kg.ltr.dtk}}{\text{mg.m3.hari}}$$

Pollution load capacity is an ability of waters to accept the entry of pollution load without causing pollution to the source. Pollution load capacity can be analyzed by Mass Balance, namely:

$$\text{DTBP} = \text{BPM} - \text{BPA}$$

Description:

DTBP : Pollution load carrying capacity (kg/day)

BPM : Pollution load according to quality standards (kg/day)

BPA : Measured pollution load (kg/day)

RESULT AND DISCUSSION

This research was conducted in June 2024 in Jayawijaya Regency of Papua Mountain Province. The planning research area is located in Jayawijaya Regency which is one of the eight regencies in the Papua Pegunungan Province located at 3o 30'0"- 4o 00'0" South latitude and between 138o 30'0"-139o 00'0" East longitude, as shown in Figure 1.

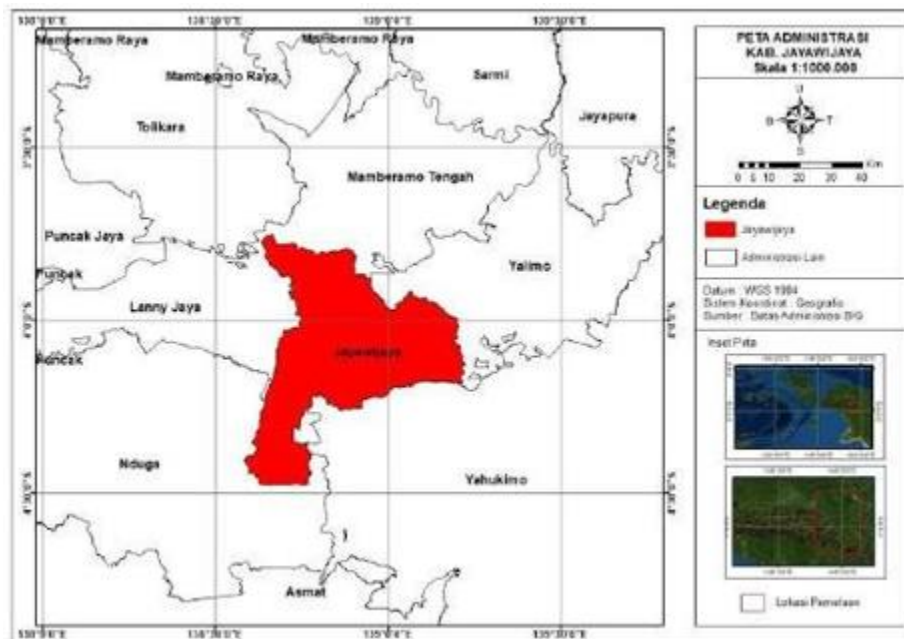


Figure 1. Map of research location Jayawijaya Regency Papua Mountains

The catchment boundary is determined based on the topography of the Walesi watershed, which is 16.647 km². In addition, the ability of the river to obtain continuous availability is based

on the land cover in the watershed area. The results of the catchment area boundary determination for the Walesi River are shown in Figure 2.



Figure 2. Jayawijaya Walesi watershed map

The topography of Jayawijaya Regency is generally a mountainous area with most of it at an altitude ranging from 1500 meters above sea level to 2200 meters above sea level. Land use in Jayawijaya Regency is a protected forest area, residential area, nature reserve area (KSA), and nature conservation area (KPA). The dominance of land use in the Walesi watershed, namely Asolokobal District and Walesi District is: forest covering an area of 8,490.44 Ha, this is because the Jayawijaya Regency area is a forest area whose topographic conditions are mountains with an altitude of 700-4,700 meters above sea level, while the smallest land use for settlements is 11.62 Ha. For more details about the area of each type of land use is tabulated in Table 1.

Table 1. Land Utilization Condition of Asolokobal District and Walesi District Area

No.	District	Land Area (Ha)									
		PKM	HTN	SB	PK	SW	TGL	Water	KSNG	PTH	JML
1	Asolokobal	6,92	3.368,31	98,90	653,00	13,98	-	43,13	-	-	4.184,23
2	Walesi	4,70	5.122,13	507,84	345,29	-	167,51	1,82	3.711,89	-	9.861,15
	Total	11,62	8.490,44	606,74	998,29	13,98	167,51	44,95	3.711,89	-	14.045,38

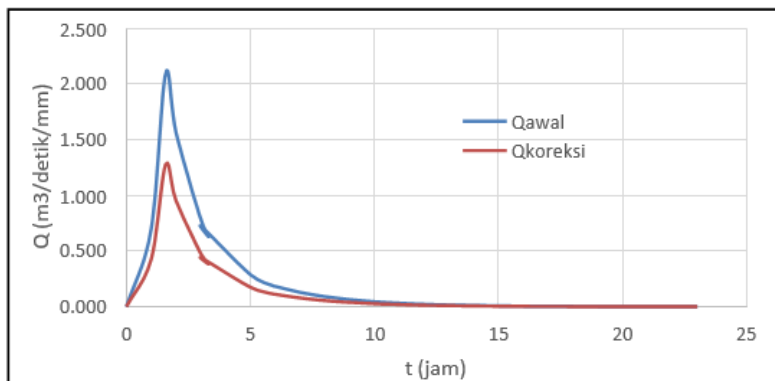


Figure 3. Nakayasu HSS of Walesi River Jayawijaya

The results of the recapitulation of flow discharge measurements, the dimensions of the river cross section are as follows:

Table 2: Recapitulation of Walesi River Flow Discharge

River Flow	Discharge (m ³ / sec)
Point I	0,887
Point II	0,773
Point III	0,616
Point IV	0,577

Figure 4. Walesi River water quality sampling location

Source: 2024 measurement results

Walesi River with the main river length is 11, 049 KM, with water quality sampling locations are Location I, II, III and IV. Water sampling is carried out in a moment (grab sample) at four predetermined locations. Based on SNI 06-2421- 2991, the location of water sampling in rivers is strongly influenced by the speed of water flow, so that for discharge < 5 m3 / s, water sampling is carried out in rivers at 0.5 x depth from the water surface. With the reference standard of PP No. 22 of 2021 concerning the Implementation of Environmental Protection and Management (Alanda, 2023) Class II, the results of the Walesi River water quality examination were obtained at 4 location points as in Table 3. Testing was carried out at the Regional Health Laboratory (Labkesda Papua Province) quality standard class two (II). The parameters tested were physical (temperature, color), chemical (pH, TDS, NO₂-N (nitrite), NO₃-N (Nitrate) and PO₄-P (Phosphate) and total coliform.

Table 3. Water quality examination results

No.	Parameters	Unit	Quality Standard	Laboratory Test Results				Method Specifications
				Jayawijaya Regency				
				Walesi I	Walesi II	Walesi III	Walesi IV	
1	Temperature	°C	Deviation 3	17	29,1	29.0	18	
2	Color	tcu	15	10,0	4,0	13.0	12,0	SNI 6989.80.2011
3	Turbidity	ntu	5	5,0	6,10	6,0	6,0	SNI 06-6989.25-2005
4	Dissolved Solids (TDS)	mg/L	1000	233,0	54,0	103,0	177,0	SNI 06-2413-1991
5	pH	.	6.0 9.0	7,80	7,20	7,30	7,90	
6	Ammonia (NH ₃ -N) as	mg/L	1,5	0,31	0,23	0,22	0,32	USEPA Method 8038
7	Total hardness (CaCO ₃)	mg/L	500	182,0	250,0	270,0	164,0	Standard Method 2012, Section 2340.C
8	Nitrate (NO ₃ -N) as	mg/L	50	0,50	2,20	1,60	0,70	Standard Method 2012, Section 4500-NO ₃ .E

No.	Parameters	Unit	Quality Standard	Laboratory Test Results				Method Specifications
				Jayawijaya Regency				
				Walesi I	Walesi II	Walesi III	Walesi IV	
9	Nitrite as (NO ₂ -N)	mg/L	3	0,003	0,012	0,009	0,003	Standard Method 2012, Section 4500-NO ₂ .B
10	Phosphate as (PO ₄ -P)	mg/L	0,2	0,2	0,2	0,2	0,2	USEPA Method 8051
11	Manganese (Mn)	mg/L	0,1	0,020	0,030	0,030	0,027	USEPA Method 8149
12	Lead (Pb)	mg/L	0,01	0,002	0,003	0,003	0,005	SNI 6989.8.2009
13	Total Coliform	MPN/100 l	5000	50	29	55	50	PK/BLKDP-8.01 (Double Tube)

Source: Primary Data 2024

The Pollution Index (IP) can be used to make decisions to improve water quality if there is a decrease with the entry of pollutants into water bodies (Yuniarti & Biyatmoko, 2019).. The IP calculation is carried out at 6 location points in the Walesi River, each location point includes several physical, chemical and microbiological parameters, with the calculation stages, namely calculating the value of the difference between the concentration value and the quality standard. $(\frac{C}{BM})$ The difference between the concentration value and the quality standard. The results of these calculations if $(C / BM) > 1$, then the calculation is carried out = $1 + \log(\frac{C}{BM})$ to obtain a new value. $(\frac{C}{BM})$ value. The value of $(\frac{C}{BM}) < 1$ then the value will remain the same. Temperature and pH parameters are calculated by the formula:

$$\frac{C}{BM} = \frac{C_{ukur} - BM_{rerata}}{BM_{min} - BM_{rerata}}$$

This is further shown in Table.

Table 4. Calculation results of new C/BM and C/BM values Location I

No.	Parameters	C	BM	C/BM	New C/BM
1	Temperature	17	29	0,59	0,59
2	Dissolved Solids (TDS)	233,0	1000	0,23	0,23
3	pH	7,80	7,5	1,04	1,09
4	Ammonia as (NH ₃ -N)	0,31	1,5	0,21	0,21
5	Total hardness (CaCO ₃)	182,0	500	0,36	0,36
6	Nitrate as (NO ₃ -N)	0,50	50	0,01	0,01
7	Nitrite as (NO ₂ -N)	0,003	3	0,001	0,001
8	Phosphate as (PO ₄ -P)	0,2	0,2	1,00	1,00
9	Manganese (Mn)	0,020	0,1	0,20	0,20
10	Lead (Pb)	0,002	0,01	0,20	0,20
11	Total Coliform	50	5000	0,01	0,01

No.	Parameters	C	BM	C/BM	New C/BM
		Total			3,90
		Ci/Bi average			0,35
		Maximum Ci/Bi			1,09

Source: 2024 analysis results

The results of the recapitulation of the calculation of the Pollution Index (IP) for the Walesi River water quality status are as follows:

Table 5. Results of IP calculation and Water Quality Status of Walesi River

No.	IP Value	Water quality status
1	0,646	Good condition
2	0,561	Good condition
3	0,554	Good condition
4	0,634	Good condition

Source: 2024 Analysis Results

The IP value of Walesi River shows that the water quality condition is still in the good condition category. No pollution has occurred in the Walesi River because there is no industry, settlements are still relatively far apart, garden land without using fertilizers or pesticides and other pollutant sources are not found.

Walesi River Pollution Load Analysis

Determination of the pollution capacity of the Walesi River in Wamena is carried out in several stages of calculation, starting from measuring the speed and flow rate with a currentmeter measuring instrument, then calculating the capacity of the pollution load using the Mass Balance method.

Table 6. Recapitulation of Walesi River Pollution Load Capacity

Location	Parameters	Quality Standard Pollutant Load (number/day)	River Pollution Load (Amount/day)	Load Bearing Capacity Pollutants (number/day)
Jayawijaya Walesi River	TDS	61.624,80	8.942,18	52.682,62
	Ammonia	92,44	16,70	75,74
	CaCO3	30.812,40	13.297,65	17.514,75
	Nitrate	3.081,24	76,33	3.004,91
	Nitrite	184,87	2,22	182,65
	Phosphates	12,32	12,32	-
	Manganese (Mn)	6,162	1,62	4,54
	Total Coliform	308.124,00	305.326,86	2.797,14

Source: 2024 Analysis Results

The value (-) indicates that pollution occurs, so that control efforts are needed, phosphates are found as pollutants that can cause eutrophication in these river waters. Eutrophication will

cause uncontrolled algae growth, resulting in a decrease in oxygen concentration and will disrupt the river water ecosystem.

Laboratory test results showed that several parameters exceeded the water quality standards based on PP No. 22 of 2021 Class II, which is intended for clean water needs. The prominent physical parameters are turbidity at points II, III, and IV with values of 6.10 NTU, 6.0 NTU, and 6.0 NTU, respectively. In addition, the phosphate content at all four measurement locations had the same value of 0.2 mg/L. Total coliform bacteria contamination was also significant, with a level of 55.0 MPN/100 ml, which was caused by the poor sanitation system in the area. Some communities still use the river as a dumping ground for household waste and animal waste (including pigs).

The results of this research can be compared to research in similar areas in Papua, such as in Mimika or Nabire districts, which also face challenges related to water quality due to domestic activities and lack of sanitation infrastructure. For example, research by (Siahaan & Sawir, 2021) found high coliform levels due to the utilization of the river as a source of clean water as well as a waste disposal site. Outside Papua, a research in Citarum District, West Java, also showed a similar pattern of pollution, where poor domestic waste management was the main contributor to river water pollution (Ismaya et al., 2023). This comparison emphasizes the importance of implementing better waste management systems in various regions.

The high level of turbidity at the measurement points can be explained by soil erosion that is carried into the river, especially in areas with minimal land cover or uncontrolled land clearing activities (Santoso et al., 2017). The uniform phosphate content across all sites indicates a consistent source of contaminants, most likely from domestic sewage or fertilizer use around the area. Meanwhile, the high coliform reflects biological pollution due to direct disposal of human and animal waste without prior treatment.

Based on the results of this research, the Jayawijaya local government should prioritize the development of communal sanitation systems, such as integrated septic tanks or domestic sewage treatment plants, to reduce direct discharges to the river. In addition, public education on the importance of keeping rivers clean and the impact of pollution on health should be improved, especially in communities that still use rivers as a source of clean water. Watershed management through reforestation and erosion control programs are also important steps to reduce water turbidity. The government should strengthen supervision of domestic and industrial waste disposal, along with strict enforcement of regulations. Collaboration with local communities, non-governmental organizations and the private sector is also needed to create sustainable solutions and support water quality improvement in the region.

CONCLUSION

The conclusion in this research shows the results of research that assesses the water quality and pollution load capacity of the Walesi River in Jayawijaya Regency, Papua, using the Pollution

Index (IP) and Mass Balance methods, several conclusions can be drawn. The water quality status of the Walesi River in four locations (I, II, III, and IV) calculated using the Pollution Index (IP) method is classified as “Good”. However, the analysis of pollution load carrying capacity using the Mass Balance Method shows that of the eight water quality parameters, one parameter, phosphate (PO₄-P), has reached the maximum allowable value of 0.20 mg/L, equivalent to the Quality Standard limit. Other parameters, such as TDS (Total Dissolved Solid) at 52,682.62 ml/day, Ammonia (NH₃-N) at 75.74 ml/day, and Total Coliform at 2,797.14 ml/day, were still within the allowable threshold limit, indicating the ability of the river system to accommodate a certain level of pollution without exceeding the set threshold.

This research contributes to understanding the current status of water quality and pollution load dynamics in the Walesi River and provides important data for environmental management in the region. The findings highlight the urgency of monitoring phosphate levels, as they indicate a high risk of breaching acceptable limits if pollution continues. In the future, this research serves as a basis for evaluating the impacts of human activities and environmental policies on water quality over time. The research also provides a methodological framework for assessing water quality and pollution load capacity in other rivers in Papua and Indonesia, ensuring sustainable water resources management in regions facing similar environmental challenges.

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