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Water Quality Assessment and Pollution Status Using the STORET Method in the Welang, Gembong, and Rejoso Rivers, Pasuruan, East Java

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ABSTRACT

High levels of anthropogenic activity along river basins are a major cause of declining water quality. The Welang, Gembong, and Rejoso are three large rivers in East Java, Indonesia, located in industrial and densely populated areas, and are currently experiencing pollution and water quality degradation. This study aimed to assess water quality and to determine the pollution status of these rivers. A descriptive survey method was employed from August to October 2024, and pollution levels were evaluated using the STORET method. The results showed that water quality parameters during the study period were as follows: temperature 28.1– 30.5°C, current velocity 0.10– 0.43m/ s, TSS 125– 137.5mg/ L, DO 4.88–5.98mg/ L, pH 7.05–7.35, nitrate 0.151– 0.215mg/ L, orthophosphate 0.115–0.237mg/ L, COD 29.33– 53.15mg/ L, TOM 15.8– 25.8mg/ L, and Pb 0.46–1.44 mg/L. Several parameters—TSS, orthophosphate, COD, TOM, and Pb—exceeded the Class III water quality standards established in Government Regulation Number 22 of 2021. Based on the STORET method, pollution levels in the Welang, Gembong, and Rejoso Rivers were categorized as severe, with scores of –43, –43, and –35, respectively. Thus, the pollution status of all three rivers is classified as severely polluted. These findings highlight the urgent need for waste management strategies to reduce pollution from anthropogenic activities surrounding the Welang, Gembong, and Rejoso River Basins.

INTRODUCTION

The Welang, Gembong, and Rejoso are three major rivers that flow through Pasuruan Regency and City. These rivers have generally experienced a decline in water quality, as indicated by their brownish color and unpleasant odor. According to the **Ministry of Environment (2007)**, water quality in the upper reaches of the Pasuruan River remains relatively good. However, in the middle and lower reaches, water quality declines due to land use along the rivers for rice fields, settlements, and industrial activities. The estuarine areas are also utilized for fish farming in cages and ponds.

The high level of pollution in the Pasuruan River is closely linked to the industrial zone of Pasuruan, which is also a densely populated area. These rivers are reported to carry a heavy load of pollutants, particularly heavy metals such as lead (Pb), which have exceeded the quality standards for Class III water quality as stipulated in Government Regulation Number 22 of 2021.

Rivers play a crucial role in supporting aquatic biota. The aquatic environment is influenced by physical, chemical, and biological parameters that maintain ecological balance and homeostasis. Declining river water quality can render the environment unsuitable as a habitat, leading to reduced productivity, lower biodiversity, and a decrease in species abundance **(Salaah *et al*., 2018; Elhaddad *et al*., 2022; Lestari *et al*., 2023)**. Anthropogenic activities are the primary source of river pollution and are a major driver of water quality deterioration, which ultimately impacts aquatic biota **(Salaah *et al*., 2022; Kadim & Pasisingi, 2024)**.

Exceeding water quality standards negatively affects biodiversity, particularly fish. Physicochemical parameters such as temperature and dissolved oxygen are critical for fish growth, survival, and distribution. Fish are highly sensitive to water quality changes, and alterations in these parameters can lead to contamination, migration, or even the risk of extinction **(Rosette *et al*., 2020)**.

One approach to pollution control in aquatic ecosystems is regular water quality monitoring. The STORET method is widely used to assess water quality status. This method works by comparing measurement results with water quality standards based on their designated use, as outlined in the 2003 Ministerial Decree on the Environment **(Firmahaya & Piranti, 2022)**. Assessing water quality using the STORET method provides a valuable reference for monitoring and managing water systems **(Kadim & Pasisingi, 2024)**.

The purpose of this study was to assess water quality and to identify pollution levels in the Welang, Gembong, and Rejoso River Basins in Pasuruan Regency, East Java. The parameters observed included temperature, current velocity, total suspended solids (TSS), dissolved oxygen (DO), pH, nitrate, orthophosphate, chemical oxygen demand (COD), total organic matter (TOM), and lead (Pb).

MATERIALS AND METHODS

Time and location of research

This research was conducted over a three-month period, namely from August to October 2024, in three main rivers in the Pasuruan area, East Java, namely the Welang River, Gembong River, and Rejoso River (Fig. 1).

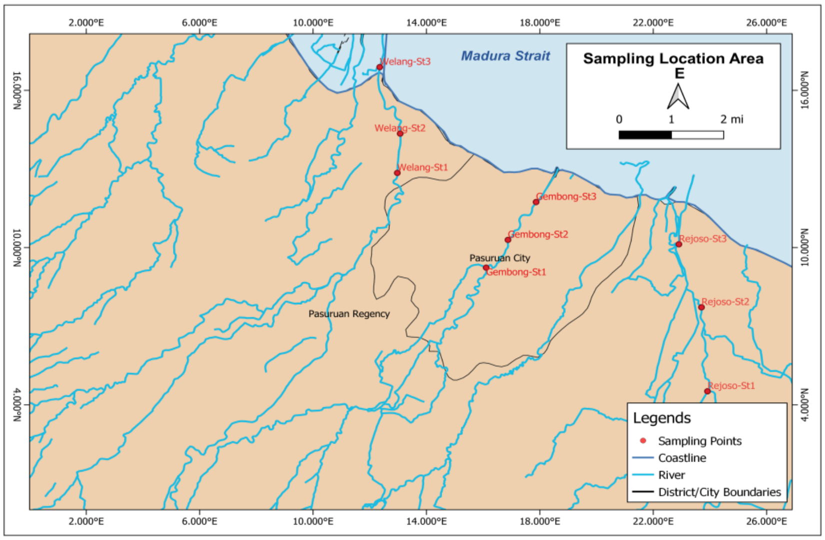

Fig. 1. Research areas of the Welang, Gembong, and Rejoso rivers

Research methods

This study employed a survey approach with descriptive data analysis. Sampling locations were determined using purposive sampling, based on the presence of anthropogenic activities with the potential to contribute pollutants to the river. Water samples were collected from three observation stations along each river.

The water quality parameters analyzed included temperature, current velocity, total suspended solids (TSS), dissolved oxygen (DO), pH, nitrate, orthophosphate, chemical oxygen demand (COD), total organic matter (TOM), and lead (Pb). Measurements were conducted using two approaches: *in situ* and *ex situ*. *In situ* measurements were performed directly at the sampling sites, while *ex situ* measurements involved collecting water samples with a 3-liter water sampler. Samples were stored in bottles, placed in a cold box, and subsequently analyzed in the laboratory.

The level of pollution was determined using the STORET method, which compares the results of water quality measurements with Class III water quality standards as stipulated in Government Regulation Number 22 of 2021.

Data analysis

Water quality data were analyzed using the STORET method **(KEPMENLH, 2003)** to assess the pollution level of each river. The analysis was carried out by comparing measured parameter values against the Class III water quality standards outlined in Government Regulation Number 22 of 2021 **(Saraswati *et al*., 2014)**.

In the STORET system, parameters that comply with quality standards are given a score of 0, while those exceeding the standard are assigned penalty scores according to the provisions in Table (1). The cumulative score determines the water quality status, which is classified into four categories based on the United States Environmental Protection Agency (USEPA):

- **Class A (very good)**: score = 0, water meets all quality standards
- **Class B (good)**: score –1 to –10, lightly polluted
- **Class C (moderate)**: score –11 to –30, moderately polluted
- **Class D (poor)**: score ≤ –31, heavily polluted

Table 1. Value system for parameters and quality standards of the STORET method (Decree of the Minister of Environment of Republic Indonesia No. 115/2003)

Number of samples	Value	Parameter		
		Physics	Chemistry	Biology
< 10	Maximum	-1	-2	-3
	Minimum	-1	-2	-3
	Average	-3	-6	-9
> 10	Maximum	-2	-4	-6
	Minimum	-2	-4	-6
	Average	-6	-12	-9

RESULTS

Water quality analysis

Temperature

Temperature is a key factor influencing the distribution of species in river ecosystems **(Rahat *et al*., 2022)**. Variations in temperature across stations are affected by sunlight intensity, with the level of exposure and the density of riparian vegetation playing important roles in regulating water temperature **(Sinulingga *et al*., 2023)**. In this study, temperatures across the three rivers ranged from 28.1 to 30.5°C, with the highest value recorded at Station 1 of the Gembong River and the lowest at Station 1 of the Rejoso River (Fig. 2).

This range remains within the Class III water quality standards set by Government Regulation Number 22 of 2021, which allows a maximum deviation of 3°C from natural conditions. Furthermore, the observed temperatures fall within the tolerance limits for aquatic life, including fish, as reported by **Komberem *et al.* (2022)**, who noted that aquatic organisms generally tolerate temperatures between 28 and 32°C.

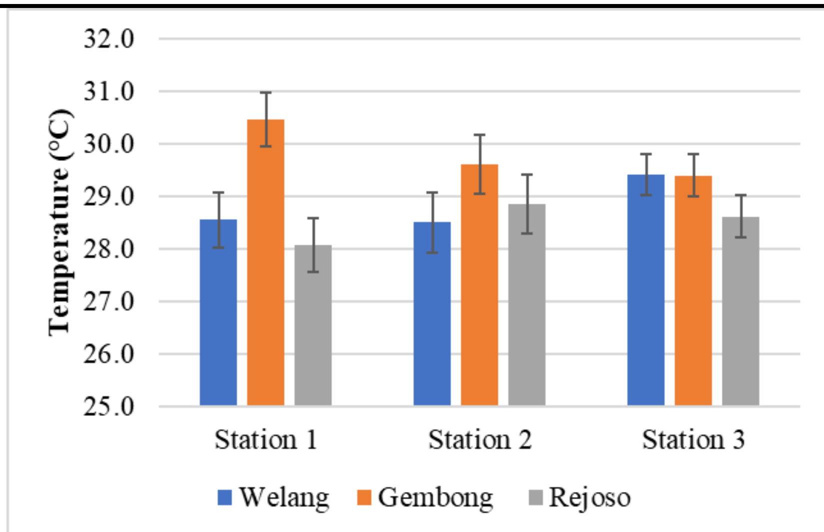

Fig. 2. Temperature of water samples collected from August during October 2024

Current speed

Current plays an important role in water circulation; besides serving as a transport medium for dissolved and suspended substances, it also influences oxygen solubility in water **(Affan, 2012)**. In this study, current speeds in the three rivers ranged from 0.10 to 0.43m/ s. The highest current speed was recorded at Station 1 of the Welang River, while the lowest was observed at Station 1 of the Rejoso River (Fig. 3).

Overall, the Welang, Gembong, and Rejoso Rivers are classified as having slow currents. According to **Syahrul *et al*. (2021)**, waters with current speeds above 1m/ s are categorized as very fast, those between 0.5 and 1m/ s as fast, between 0.25 and 0.5m/ s as slow, and below 0.1m/ s as very slow.

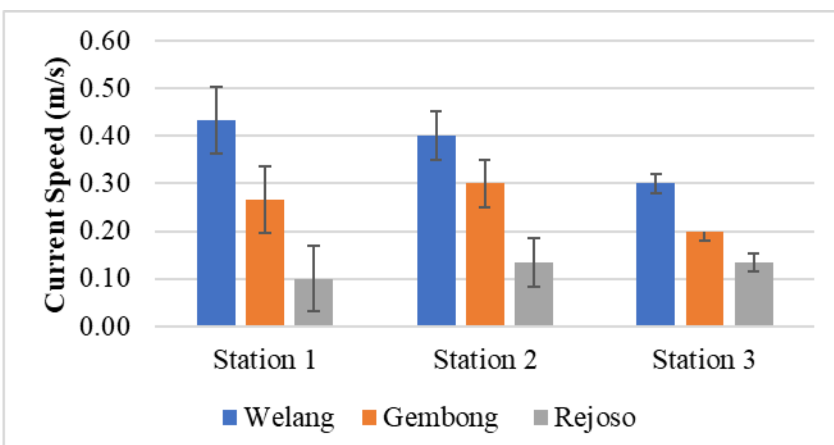

Fig. 3. Current Speed of water samples collected from August during October 2024

Total suspended solids (TSS)

TSS levels in the three rivers ranged from 125 to 137.5mg/ L, with the highest value recorded at Station 3 of the Welang River and the lowest at Station 1 of the Rejoso River (Fig. 4). These values fall into the high category and exceed the Class III water quality standard set by Government Regulation Number 22 of 2021, which specifies a maximum limit of 100mg/ L.

Elevated TSS concentrations are often associated with increased human activity along rivers **(Tanjung *et al*., 2022)**. Contributing factors include natural processes such as sedimentation from upstream areas and pollutant inputs from domestic waste. High TSS levels can increase turbidity, reduce water transparency, and limit light penetration into the water column, ultimately affecting aquatic ecosystems **(Salaah *et al*., 2018; Walukow *et al*., 2021)**.

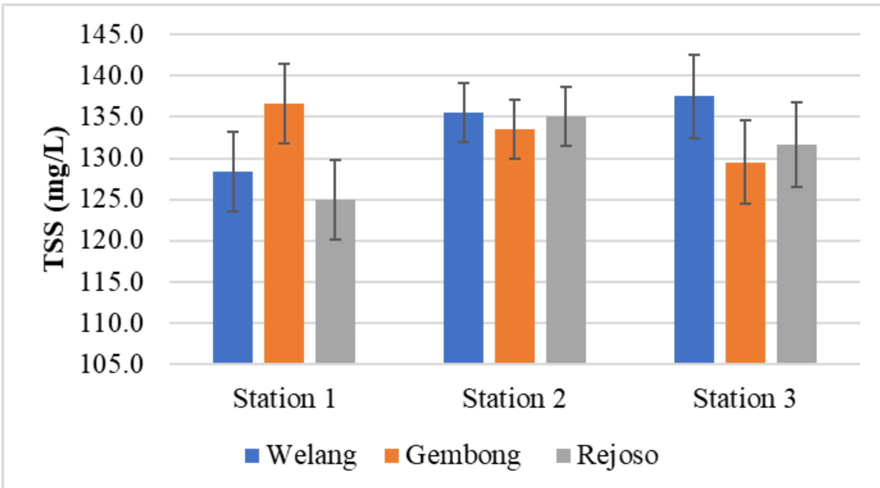

Fig. 4. TSS of water samples collected from August during October 2024

Dissolved oxygen (DO)

DO levels in the three rivers ranged from 4.88 to 5.98mg/ L, with the highest value recorded at Station 3 of the Welang River and the lowest at Station 3 of the Gembong River (Fig. 5). These values remain within the Class III water quality standards established by Government Regulation Number 22 of 2021, which sets a minimum DO threshold of 3mg/ L.

The observed DO concentrations are generally suitable for supporting aquatic life. The minimum DO level required to sustain freshwater fish in tropical regions is approximately 5mg/ L **(Sugianti & Astuti, 2018)**. However, values near the lower range in this study suggest potential stress for aquatic organisms. Low oxygen levels can impair fish health, increase susceptibility to disease, and potentially reduce fish populations in river ecosystems **(Istiqomah *et al*., 2023)**.

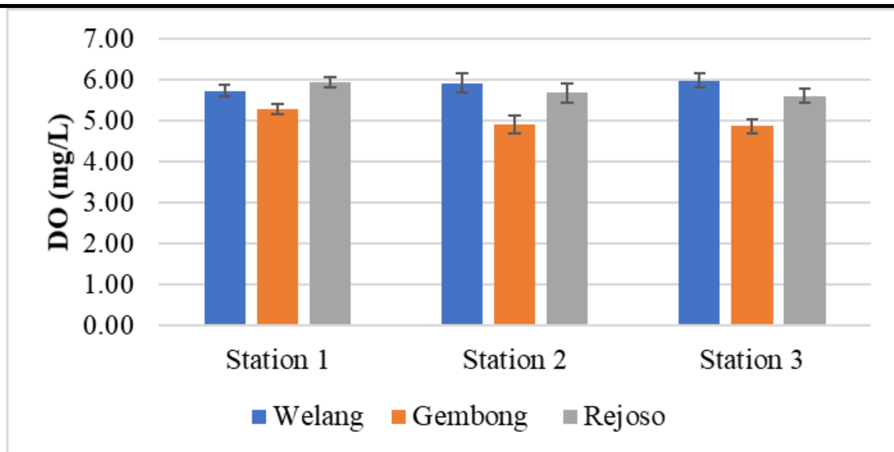

Fig. 5. DO of water samples collected from August during October 2024

pH

pH levels in the three rivers ranged from 7.05 to 7.35, with the highest value recorded at Station 1 of the Gembong River and the lowest at Station 3 of the Gembong River (Fig. 6). These values fall within the Class III water quality standards set by Government Regulation Number 22 of 2021, which requires a pH range of 6–9.

The observed pH levels are considered optimal for supporting fish growth, as the ideal range for aquatic organisms is between 6.5 and 8.5 **(Ibrahim *et al*., 2023)**. However, extreme pH values can be harmful; water with a pH above 10 or below 5 may endanger fish survival **(Shrestha *et al*., 2023)**. Both highly acidic and highly alkaline conditions can disrupt fish health and growth, potentially leading to stress or mortality **(Istiqomah *et al*., 2023)**.

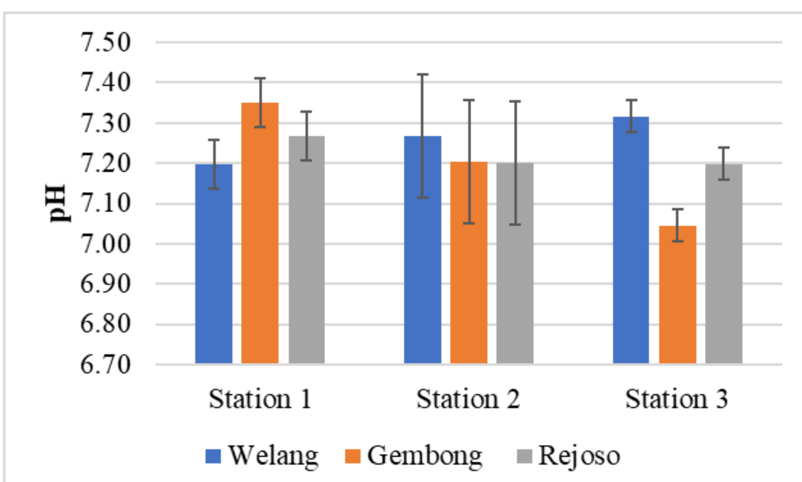

Fig. 6. pH of water samples collected from August during October 2024

Nitrate

Nitrate is a compound formed through the complete oxidation of nitrogen compounds in water **(Ihsan *et al.*, 2023)**. It plays an essential role in aquatic ecosystems, particularly as a nutrient supporting photosynthesis and phytoplankton growth.

In this study, nitrate levels ranged from 0.151 to 0.215 mg/L, with the highest concentration recorded at Station 3 of the Gembong River and the lowest at Station 3 of the Rejoso River (Fig. 7). These values remain well within the Class III water quality standard established by Government Regulation Number 22 of 2021, which sets a maximum limit of 20mg/ L.

Although nitrate is vital for primary productivity, excessive concentrations can negatively impact aquatic organisms by triggering eutrophication, leading to uncontrolled algal blooms **(Guntur *et al*., 2017)**.

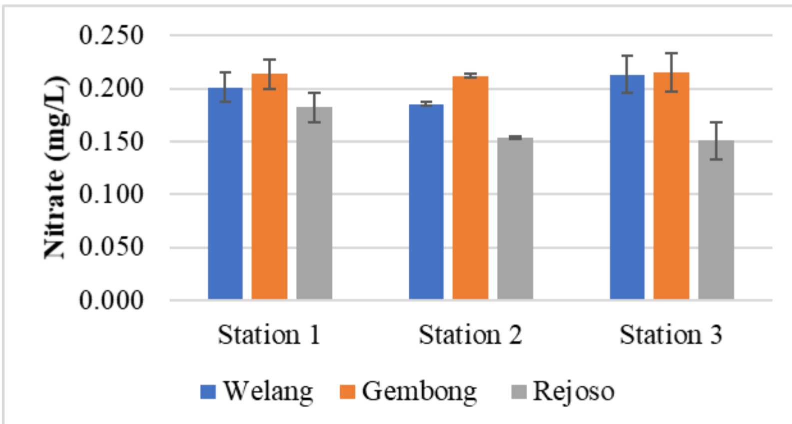

Fig. 7. Nitrate of water samples collected from August during October 2024

Orthophosphate

Phosphorus is an important indicator of organic pollution originating from domestic and industrial activities **(Sunardi *et al*., 2012)**. Excess phosphate in aquatic systems can increase nutrient loads, thereby accelerating the eutrophication process. Phosphate concentrations are strongly influenced by the inflow of organic matter carried by rivers **(Rizal *et al*., 2017)**.

In this study, orthophosphate levels ranged from 0.115 to 0.237 mg/L, with the highest value recorded at Station 2 of the Rejoso River and the lowest at Station 3 of the Welang River (Fig. 8). These concentrations are categorized as high and they exceed the Class III water quality standard specified in Government Regulation No. 22 of 2021, which sets a maximum limit of 0.015mg/ L.

The elevated orthophosphate values indicate that the rivers have been polluted by phosphate inputs. High phosphate concentrations can affect the distribution of aquatic organisms, particularly fish, and contribute to reduced water quality. Excessive phosphate can also decrease biodiversity, as only a limited number of species are able to tolerate polluted conditions. In contrast, diverse aquatic biota are more likely to thrive in environments with good water quality **(Priyono, 2012)**.

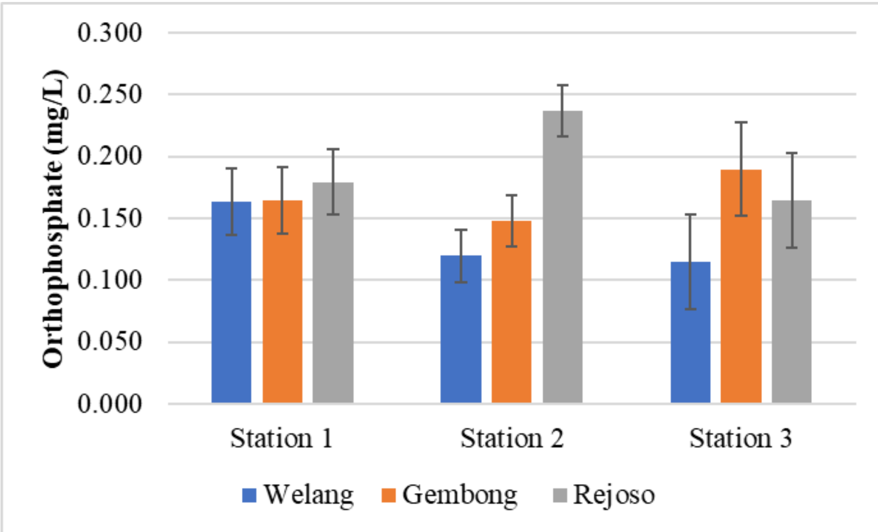

Fig. 8. Orthophosphate of water samples collected from August during October 2024

Chemical oxygen demand (COD)

COD levels ranged from 29.33 to 53.15mg/ L, with the highest value recorded at Station 3 of the Welang River and the lowest at Station 1 of the Rejoso River (Fig. 9). These values indicate relatively high organic pollution, with several stations exceeding the Class III water quality standard of 40mg/ L as stipulated in Government Regulation Number 22 of 2021.

Elevated COD concentrations reflect a high load of organic and inorganic pollutants that require oxygen for decomposition. This condition can lead to a reduction in dissolved oxygen levels, thereby lowering water quality. Decreased oxygen availability directly affects the survival of aquatic biota, as oxygen is essential for respiration, growth, and reproduction **(Supardiono *et al*., 2023)**.

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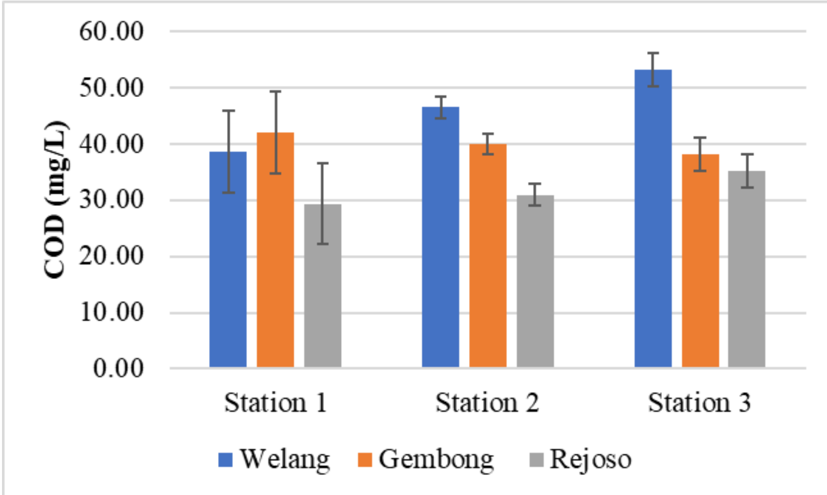

Fig. 9. COD of water samples collected from August during October 2024

Total organic matter (TOM)

TOM levels ranged from 15.8 to 25.8mg/ L, with the highest value recorded at Station 2 of the Rejoso River and the lowest at Station 1 of the Rejoso River (Fig. 10). These values place TOM in the high category, exceeding the Class III water quality standard set by Government Regulation Number 22 of 2021, which specifies a maximum limit of 3 mg/L.

Excessive total organic matter can negatively affect aquatic organisms **(Suriyadin *et al*., 2023)**. High concentrations of organic matter increase the production of toxic gases such as carbon dioxide (CO_2) and ammonia (NH_3) during decomposition processes **(Liu *et al*., 2017)**. Elevated CO_2 levels are particularly harmful to fish, as they interfere with the respiratory process and can cause stress or mortality **(Aida *et al*., 2022)**.

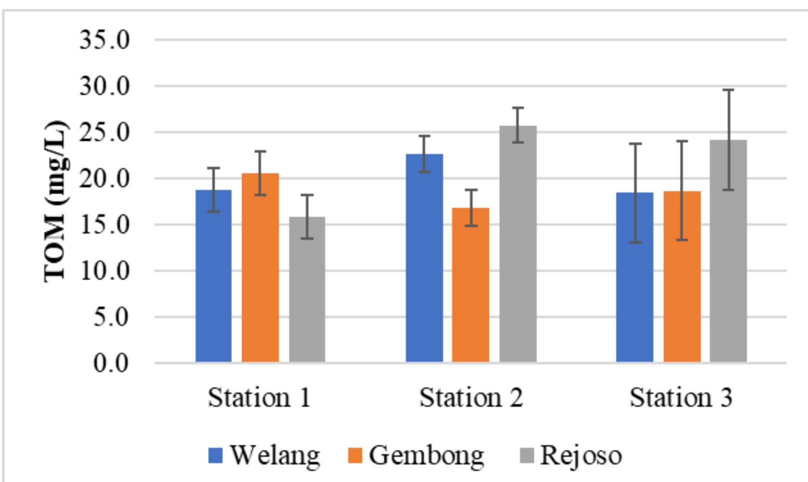

Fig. 10. TOM of water samples collected from August during October 2024

Lead (Pb)

Pb concentrations ranged from 0.46 to 1.44mg/ L, with the highest value recorded at Station 3 of the Welang River and the lowest at Station 1 of the Gembong River (Fig.

11). These concentrations are categorized as high exceeding the Class III water quality standard established in Government Regulation Number 22 of 2021, which sets a maximum allowable limit of 0.03mg/ L.

Elevated Pb levels pose serious risks to aquatic ecosystems. Lead contamination can disrupt the health and survival of aquatic organisms **(Yolanda *et al*., 2017)**. Increased Pb concentrations in water are highly toxic and may cause mortality in fish populations inhabiting contaminated rivers **(Priatna *et al*., 2016)**.

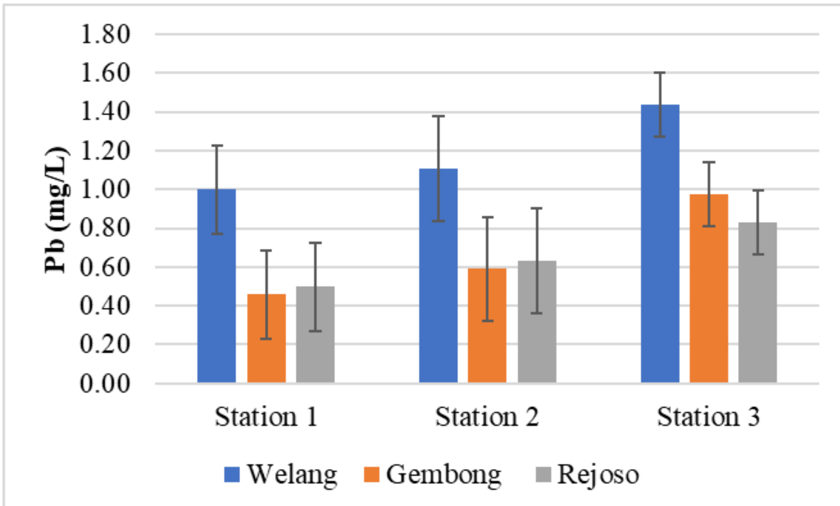

Fig. 11. Pb of water samples collected from August during October 2024

Pollution status based on STORET method

Based on the STORET analysis, the Welang River obtained a score of –43, classified as heavily polluted. The Gembong River showed the same score of –43 and was also categorized as heavily polluted, while the Rejoso River obtained a slightly higher score of –35 but remained in the heavily polluted category (Table 2).

The results indicate that all three rivers have experienced significant declines in water quality, as reflected by several parameters exceeding the established quality standards. In the Welang and Gembong rivers, the parameters that surpassed the thresholds were TSS, orthophosphate, COD, TOM, and Pb. In the Rejoso River, TSS, orthophosphate, TOM, and Pb exceeded the limits, while COD values remained within the acceptable standard.

The high pollution levels in the Welang, Gembong, and Rejoso Rivers are strongly influenced by intensive human activities in the surrounding areas. These rivers flow through Pasuruan Regency and Pasuruan City, regions characterized by dense populations and extensive industrial development, which contribute substantially to pollutant loads in the aquatic environment.

Table 2. STORET index value

No	River Name	Score	Status
1	Welang	-43	heavily polluted
2	Gembong	-43	heavily polluted
3	Rejoso	-35	heavily polluted

CONCLUSION

The pollution status of the Welang, Gembong, and Rejoso rivers was classified as poor, with a category of heavily polluted. Both the Welang and Gembong rivers obtained STORET scores of –43, with parameters exceeding quality standards including TSS, orthophosphate, COD, TOM, and Pb. The Rejoso River obtained a score of –35, with parameters exceeding the standards for TSS, orthophosphate, TOM, and Pb. In contrast, the parameters of temperature, current speed, DO, pH, and nitrate remained within the Class III water quality standards across all three rivers.

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