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Research Paper

Assessment of Changes in Water Quality of Enim River, Muara Enim, South Sumatera, Indonesia to Determine Environmental Designations

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Abstract

Enim river flows within several sub-districts in Muara Enim Regency, including Semendo Darat Laut, Semendo Darat Tengah, Semendo Darat Ulu, Tanjung Agung, Lawang Kidul, and Muara Enim. This study examines changes in the water quality of the Enim River due to domestic wastewater discharges and the presence of the coal mining industry and household industries. Water samples were taken from 4 sampling stations along the Enim River in 2018 and 2023. Data consisted of results of physical, chemical, and microbiological parameters. The status of river water quality was assessed from the pollution index. The results of Enim River surface water quality measurements showed that the parameters of total suspended solids, Dissolved Oxygen, iron (Fe), copper (Cu), oil, and grease concentrations had breached the criteria set for Class II water quality, referring to Government Regulation of the Republic of Indonesia Number 82 of 2001. The results showed that there has been a change in the water quality status of Enim River from 2018 to 2023. The river water pollution index was (1.43-2.47) in 2018 and (1.49-3.85) in 2023 (lightly polluted). Comprehensive water treatment and preventive measures are necessary to manage and mitigate additional pollution in the Enim River.

Keywords

Water Quality, Enim River, Pollution Index

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1. INTRODUCTION

Muara Enim Regency and the Enim River highlight some important aspects as part of South Sumatra Province, Indonesia (Tampubolon et al., 2022). Muara Enim Regency is known for the Enim River, which has significant historical and sustainability value. The river passes through several sub-districts in the district, such as Semendo Darat Laut, Semendo Darat Tengah, Semendo Darat Ulu, Tanjung Agung, Lawang Kidul, dan Muara Enim, reinforcing its role as a major artery for the local community. The Enim River has geographical characteristics that affect the daily lives of the surrounding communities. With a length of 19 km and a watershed area of 39 km^2, the river is not only a water source but also plays an important role in the local ecosystem. Its spring water, which originates from Gemuhak Lake in Semendo Darat Ulu Subdistrict and empties into the Lematang River, marks the diverse ecosystems of the Enim River. The community's utilization of the Enim River has been going on for a long time and has a significant impact on daily life. From irrigation of rice fields to water supply for household needs and the industrial sector, the Enim River has become vital in fulfilling life needs and local economic development. However, it should be noted that this use of the river also raises challenges related to environmental maintenance and ecosystem balance. The role of rivers in supporting human activities is crucial to understanding the complex relationship between humans and the environment. Rivers are a water source for daily human needs and provide energy, tourism, and transport sectors. However, with development and population growth, rivers often experience changes in function to become waste disposal sites from various human activities, especially in urban areas (UNESCO, 2021; Anderson et al., 2019). Increased sewage discharge into rivers can cause serious pollution, threatening the sustainability of the environment and public health (Bashir et al., 2020). Pollutants that enter the river will be carried to the sea or lake, worsening the condition of the aquatic ecosystem and potentially creating new problems. If the river's capacity for pollution has reached its limit, river pollution will occur, impacting various aspects of life (Bhat et al., 2018).

The difficulty of obtaining a clean water supply has become a significant concern. The leading cause of this problem is water pollution caused by waste from industries, households, and agriculture (Plessis, 2022; Lin et al., 2022). As the primary water source for many communities, river water has become where waste from various human activities accumulates (Duncan et al., 2019). The impaired quality of river water, mainly due to the water's high physicochemical and biological parameters, demands treatment processes before use, as direct use can harm human health (Anh et al., 2023). This is regulated in the Regulation of the Governor of South Sumatra No. 16 of 2005 concerning Water Quality Treatment and the Regulation of the Ministry of Health of the Republic of Indonesia No. 2 of 2023 concerning Clean Water Requirements. In the face of these challenges, special attention needs to be paid to ensuring a safe and clean water supply for people. These efforts must involve multi-sectoral cooperation and effective policy implementation to safeguard water quality and public health. Land use is an essential factor influencing river water quality (Datta et al., 2021). To minimize the degradation of river water quality, the existing natural capacity of river water to resist pollution needs to be maintained (Dewata and Adri, 2018). Land use along the Enim River can affect water quality, including agriculture, settlements, and industry (Ingrao et al., 2023). Agricultural activities involving annual crops that use fertilizers and pesticides are expected to affect river water quality through discharges from agricultural land into water bodies (Uddin and Jeong, 2021; Kumar et al., 2021). In addition, people's activities that produce domestic wastewater discharges (Arum et al., 2019), as well as those of the coal mining industry and household industries that discharge their wastewater into the Enim River, will affect water quality. Water quality is maintained through water pollution control efforts, which is done by keeping water functions so that water quality meets quality standards (Omer, 2020; Ding et al., 2015).

Previous research on the water quality of the Enim River has been conducted. The decrease in the water discharge of Enim River is related to the destruction of the ecosystem around the watershed, which causes a reduction in water sources. The high level of sedimentation in the watershed also causes the turbidity level in the Enim River to be high, so this river cannot be utilized optimally for household activities (Pramilus et al., 2024). Mass balance was used, which was analyzed using an ANOVA test with data management using the SPSS program. The high level of sedimentation in the watershed also causes the turbidity level in the Enim River to be high, so this river cannot be optimally utilized for household activities. The entry of household and industrial waste into the river is expected to deteriorate river water quality further. Based on this statement, a study was conducted to analyze river water quality physico-chemically and biologically. This study aims to analyze the water quality of the Enim River and its impact on its biota.

2. EXPERIMENTAL SECTION

2.1 Description of Study Area

The research was conducted in the Enim River, the main river in the watershed area of Muara Enim Regency (Figure 1). Enim River has a length of 19 km with a watershed area of 39 km^2, and its spring water comes from Gemuhak Lake in Semendo Darat Ulu sub-district and empties into Lematang River. Laboratory analysis was conducted at the Laboratory Centre of the Ministry of Health of the Republic of Indonesia, South Sumatra Province, and the Laboratory of PT. Bukit Asam, Tbk.

2.2 Data Collection for Water Ecology and Quality

Data collection for the study of water ecology and quality involved the collection of water samples from the Enim River during two periods: January to June 2018 and January to March 2023. Four sampling sites along the river were selected; their coordinates can be seen in Table 1. Samples were taken from one-liter plastic bottles before use. Before use, the bottles were thoroughly cleaned and conditioned, and sampling was conducted by submerging the sample holes. The samples were then stored in a cool box and transported to the analysis site. National standards were used to conduct analytical methods and compare the results with national and international surface water quality standards.

The analysis involved the evaluation of various aspects of ecology and water quality. Assessing aquatic ecosystems involves observing key markers such as total ammonium, nitrite, nitrate, and phosphate levels. Furthermore, measurements related to physical, chemical, and microbiological factors are included in the water quality parameter category. Temperature, total dissolved solids (TDS), and total suspended solids (TSS) are examples of physical indicators. Chemical indicators include oil and fat, detergent, pH, COD, BOD, DO, and the presence of chemical compounds and heavy metals that meet quality standards. The number of feces and total coliforms is the main focus of microbiological assessment. Republic of Indonesia Government Regulation 82 of 2001 concerning Water Quality Management and Water Pollution Control was consulted to compare the results, focusing on Class II standards.

2.3 Determination of Sampling Points

The selection of water sampling sites was conducted using the random sampling method, which divides the study area into segments or points representing the entire study population. The selection of sampling points to assess river water quality was influenced by several factors, such as accessibility, cost-effectiveness, and time constraints associated with the study. The following list outlines six sampling locations along the Enim River.

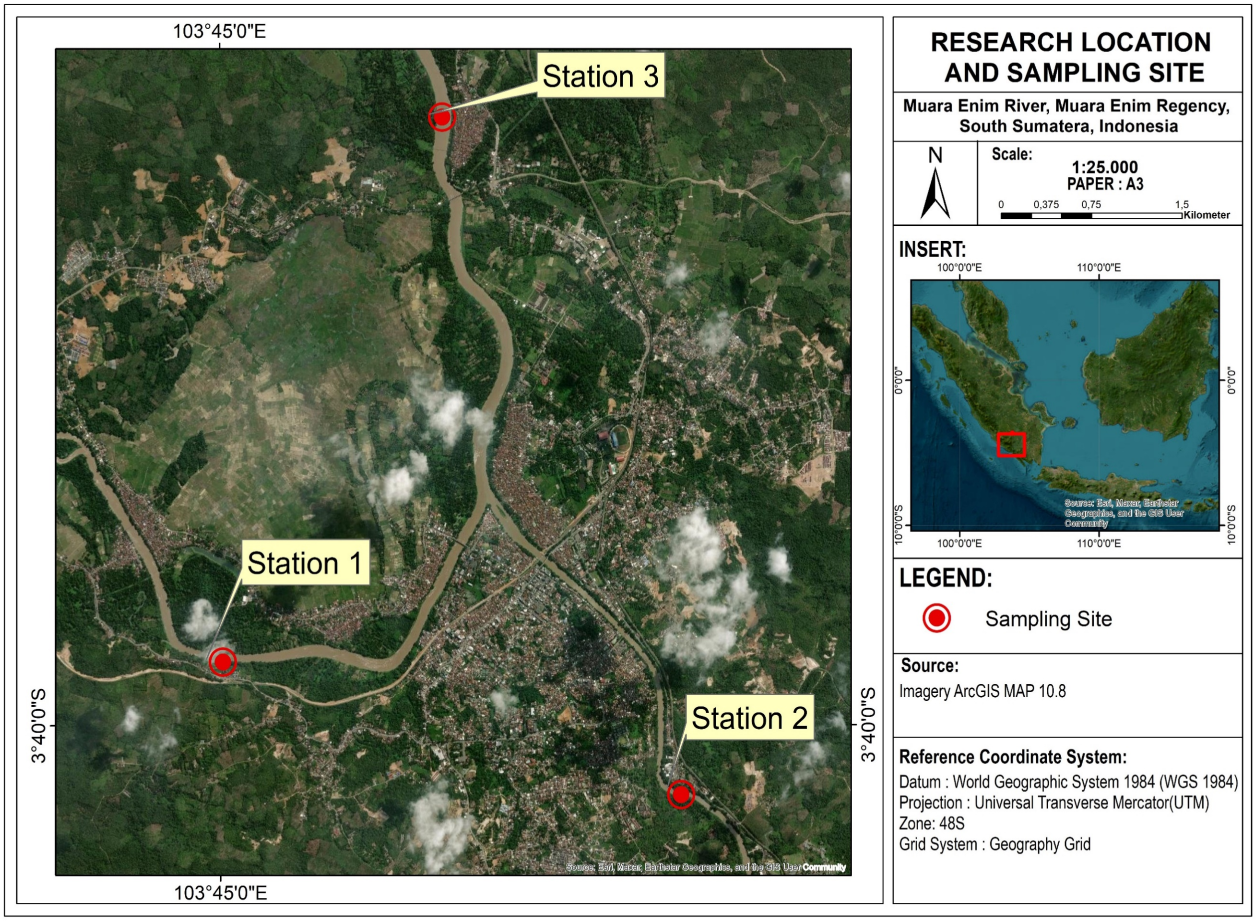

Figure 1. Location of Study Area in the Enim River

Table 1. The Sampling Points for Assessing Surface Water Quality within the Enim River

Location for Sampling Near the Enim River	Coordinate	
	Latitude	Longitude
Station 1	3°66'20.8"S	103°75'02.3"E
Station 2	3°67'17.0"S	103°78'44.6"E
Station 3	3°62'27.6"S	103°76'66.6"E
Station 4	3°77'08.5"S	103°78'65.8"E

2.4 Pollution Index

The analysis utilized the Pollution Index (PI) method to assess the water quality status of the Enim River. This method, as outlined in Decree No. 115 of 2003 by the Minister of the Environment, aims to indicate pollution levels for Class II water. Criteria are established based on scores: good ($0 \leq PI_j \leq 1.0$), lightly polluted ($1.0 < PI_j \leq 5.0$), moderately polluted ($5.0 < PI_j \leq 10.0$), and heavily polluted ($PI_j \geq 10$). The Pollution Index is computed using Equation (1).

$$PI_i = \sqrt{\frac{(C_i l_{ij})^2_M + (C_i l_{ij})^2_R}{2}} \quad (1)$$

In this case, the concentration of water quality parameter (i) is indicated by L_{ij}, according to the quality standard (j). C_i, on the other hand, stands for the concentration of water quality parameter (i) as determined by examining water samples collected at Enim River sampling locations. The Pollution Index values are then classified into various water quality ranges, as outlined in Table 2.

3. RESULT AND DISCUSSION

3.1 Water Quality Outcomes

The results of the Enim River water quality assessment conducted every four years in 2018 and 2023 are presented in Table 3. Variations in each parameter were observed at

Table 2. Categorizes the Status of Water Quality as Per the Pollution Index Method

Pollution Index (PI)	Level of pollution
$PI_j > 10$	Severely polluted
$5 \leq PI_j \leq 10$	Moderately pollutes
$1 \leq PI_j \leq 5$	Lightly polluted
$0 \leq PI_j \leq 1$	Good

four sampling points, covering upstream, midstream, and downstream locations. Water temperature in the Enim River fluctuated between 29.6 and 32.5°C, indicating tropical conditions conducive to aquatic organisms (Buwono et al., 2021). The temperature is impacted by land cover conditions, particularly the reduction of vegetation along the Enim River. This river's rise in water temperature impacts aquatic creatures since it is linked to oxygen concentrations. The trend in total dissolved solids (TDS) values between 2018 and 2023 is similar. Throughout both periods, TDS levels remained within acceptable quality norms.

On the other hand, the concentration of total suspended solids (TSS) at nearly all sampling points in both 2018 and 2023 surpasses the established quality standard (exceeding 50 mg/L). Elevated TSS levels in water can elevate temperatures and diminish dissolved oxygen (DO) levels (Maulud et al., 2021). The suspended sediment leads to water cloudiness, impacting aquatic life by disrupting habitats and breeding grounds for fish and invertebrates (Malik et al., 2020). Additionally, certain pathogens find refuge in sediment, evading water treatment and potentially amplifying disease transmission through water (Kelley et al., 2014). The elevated levels of total suspended solids (TSS) are impacted by industrial waste discharged from industries near the Enim River. These industries span various categories, including rubber and small-scale local food processing. The escalation in TSS is also linked to diminished land coverage surrounding the Enim River, leading to soil erosion and subsequent sediment runoff into the river. Additionally, construction activities for housing in the region contribute to the heightened concentrations of TSS.

3.2 Parameters of Chemical

The findings from the chemical analysis of Enim River water quality in 2018 and 2023 are presented in Table 2 and Table 3. The assessment of water quality around areas influenced by mining industry activities reveals that both copper (Cu) and oil and Fat parameters at the Enim River's upstream, midstream, and downstream sections have surpassed the established quality standards. Specifically, the copper (Cu), iron (Fe), and oil and fat levels of the Enim River exceed the quality standards stipulated in South Sumatra Governor Regulation Number 16 of 2005 concerning Water Quality Treatment and Minister of Health Regulations. Republic of Indonesia Number 2 of 2023 concerning Clean Water Requirements Relating to Water Quality Management and Class II Water Pollution Control. Over time, large-scale pollution of aquatic ecosystems is expected to cause changes to the fauna and flora of affected wetlands (Datta et al., 2021).

The pH value is a crucial indicator that signifies the water quality condition. It impacts the solubility of substances in water and the availability of nutrients essential for organisms (Aydin et al., 2021; Nienie et al., 2017). According to the evaluation carried out in 2018 and 2023, the pH levels observed at the sampling sites fell within the range of 6.5 to 7.4, adhering to the standards for favorable water quality and providing a conducive environment for aquatic organisms (optimal pH range: 6.5–9). As with Class II water quality criteria, the Biochemical Oxygen Demand (BOD) value for river water should not exceed 3 $mg.L^{-1}$. Across four water sampling stations, the BOD values were within acceptable limits, ranging from 0.5 to 1.9 in 2018 and 0.7 to 1.5 in 2023. The presence of organic pollutants influences the BOD concentration in water and directly affects the Dissolved Oxygen (DO) levels. High BOD concentrations lead to decreased DO levels in water (Ding et al., 2015). Elevated levels of Biochemical Oxygen Demand (BOD) in water can reduce Dissolved Oxygen (DO) levels. This decrease in DO levels is due to the microbial decomposition process that occurs during BOD assessment. Microbes use dissolved oxygen to decompose the organic matter in a water sample. The amount of oxygen used is directly related to the amount of organic matter present, as assessed by the BOD test (Alam et al., 2021). If persistently high BOD and low DO values are allowed, it can disrupt the stability of aquatic biota, ultimately leading to their demise. In addition, Chemical Oxygen Demand (COD) concentrations at all sampling points along the Enim River ranged from 3.1 to 13.4 $mg.L^{-1}$. There is an increasing trend in COD values from 2018 to 2023. However, the COD values are still within the safe threshold by Indonesian water quality standards for Class II, which is less than 25 $mg.L^{-1}$. In general, less valuable COD suggests lower levels of water contamination. Dissolved Oxygen value at the Enim River sampling points in 2018 and 2023 exceeded 4 $mg.L^{-1}$. These DO values align with acceptable Class II water quality standards in Indonesian rivers.

From the data presented in Table 3 and Table 4, the analysis results for nitrate and manganese indicated that their concentrations were within safe limits. Nevertheless, the assessment of sulfur content, represented as H_2S, in the Enim River indicated that two sampling sites in 2023 had surpassed the designated threshold value. This elevated sulfur content may be attributed to nearby industrial activities near the Enim River. Similarly, elevated metal content, particularly Copper (Cu) and other metals, was detected at five sampling points in 2018 and 2023. However, it seemed that the concentrations of other metals were beneath the established quality standard.

Table 3. Results of the Surface Water Quality Assessment Conducted in 2018

Parameters	Unit	Result Sampling Point 1	2	3	4	Quality Standards
Physics						
Temperature	°C	32	32.6	30.8	29.5	±3
TDS	$mg.L^{-1}$	146	110	119	178	1.000
TSS	$mg.L^{-1}$	68	57	98	124	50
Chemistry						
pH	-	7.4	7	6.5	7.2	6 – 9
BOD_5	$mg.L^{-1}$	0.5	0.5	1.9	0.9	3
COD	$mg.L^{-1}$	5	13.4	3.1	3.2	25
DO	$mg.L^{-1}$	6.2	6.0	5.5	8.5	min 4
Total phosphate as P	$mg.L^{-1}$	0.1	0.1	0.1	0.1	0.2
Nitrate (NO_3)	$mg.L^{-1}$	1.8	6.8	4.4	4.5	10
Arsen (As)	$mg.L^{-1}$	< 0.011	< 0.011	< 0.052	< 0.061	1
Cobalt (CO)	$mg.L^{-1}$	< 0.025	< 0.025	< 0.025	< 0.025	0.2
Cadmium (Cd)	$mg.L^{-1}$	0.004	0.004	0.004	0.004	0.01
Copper (Cu)	$mg.L^{-1}$	0.040	0.032	0.049	0.035	0.02
Iron (Fe)	$mg.L^{-1}$	0.762	0.581	0.684	0.680	0.3
Lead (Pb)	$mg.L^{-1}$	0.001	0.001	0.001	0.001	0.03
Manganese (Mn)	$mg.L^{-1}$	0.075	0.083	0.103	0.068	0.1
Mercury (Hg)	$mg.L^{-1}$	0.0001	0.0001	0.0001	0.0001	0.002
Zing (Zn)	$mg.L^{-1}$	0.032	0.028	0.045	0.027	0.05
Chloride (Cl^-)	$mg.L^{-1}$	23.8	17.6	30.7	20.4	600
Cyanide (CN)	$mg.L^{-1}$	< 0.003	< 0.003	< 0.003	< 0.003	0.02
Flouride (F)	$mg.L^{-1}$	0.65	0.87	0.17	0.53	1.5
Nitrite (NO_2)	$mg.L^{-1}$	0.002	0.003	0.003	0.002	0.06
Sulfur as H_2S	$mg.L^{-1}$	0.018	0.012	0.026	0.017	0.002
Oil and fat	$\mu g.L^{-1}$	10.600	10.000	10.000	12.000	1.000
Detergent	$\mu g.L^{-1}$	15.6	23.6	35.4	13.5	200
Microbiology						
Fecal Coliform	$100.mL^{-1}$	430	400	380	300	1.000
Total Coliform	$100.mL^{-1}$	1.300	3.500	3.000	1.200	5.000

Additionally, the concentration of oil and fat in the Enim River has remained consistently high and has shown an upward trend. This is evident from the oil and grease concentrations measured at four sampling points, which ranged from 0.032 to 0.339 $\mu g.L^{-1}$ (Cu metal) and 0.31 to 0.892 $\mu g.L^{-1}$ (Fe metal), significantly exceeding the threshold value set for Class II water quality standards (1000 $\mu g.L^{-1}$) stipulated in Government Regulation of the Republic of Indonesia No. 82 of 2005 on Water Quality and Government Regulation of the Republic of Indonesia No. 82 of 2001 on Water Quality Management and Water Pollution Control. These findings indicate that the daily activities of individuals residing along the Enim River contribute to these issues.

3.3 Microbiological Parameters

Fecal and total coliform levels are critical indicators of the Enim River's water quality, especially in 2018 and 2023. Tables 2 and 3 show that the values of these parameters have increased. However, the fecal and total coliform concentrations at the four test stations remained under the statutory limits for class II river water quality (less than 1000/100 mL and 5000/100 mL). However, if suitable handling and preventive measures are not adopted, these levels may surpass the threshold, particularly at sampling point 2. The prevalence of feces and total coliform in the Enim River is attributable to adjacent people's activities.

3.4 Water Quality Status

The analysis provides an overview of the surface water quality evaluation derived from testing employing the Pollution

Table 4. Results of Surface Water Quality Measurements in 2023

Parameters	Unit	Result Sampling Point 1	2	3	4	Quality Standards
Physics						
Temperature	°C	32.5	33.5	31.8	33.3	±3
TDS	$mg.L^{-1}$	155.0	108.0	136.0	108.0	1.000
TSS	$mg.L^{-1}$	90.0	78.0	59.0	81.0	50
Chemistry						
pH	-	7.10	7.22	7.30	7.40	6 – 9
BOD_5	$mg.L^{-1}$	0.9	0.7	1.5	0.7	3
COD	$mg.L^{-1}$	4.8	12.0	6.9	5.6	25
DO	$mg.L^{-1}$	5.2	6.0	7.8	5.0	min 4
Total phosphate as P	$mg.L^{-1}$	< 0.04	< 0.04	< 0.04	< 0.04	0.2
Nitrate (NO_3-N)	$mg.L^{-1}$	1.9	7.5	5.6	3.7	10
Arsen (As)	$mg.L^{-1}$	< 0.003	< 0.003	< 0.003	< 0.003	1
Cobalt (CO)	$mg.L^{-1}$	< 0.037	< 0.037	< 0.037	< 0.037	0.2
Cadmium (Cd)	$mg.L^{-1}$	< 0.0025	< 0.0025	< 0.0025	< 0.0025	0.01
Copper (Cu)	$mg.L^{-1}$	0.084	0.042	0.135	0.339	0.02
Iron (Fe)	$mg.L^{-1}$	0.892	0.840	0.310	0.802	0.3
Lead (Pb)	$mg.L^{-1}$	0.002	0.001	0.001	0.001	0.03
Manganese (Mn)	$mg.L^{-1}$	0.0373	0.0023	0.0031	0.0037	0.1
Mercury (Hg)	$mg.L^{-1}$	< 0.003	< 0.003	< 0.003	< 0.003	0.002
Zing (Zn)	$mg.L^{-1}$	0.029	0.0223	0.0415	0.002	0.05
Chloride (Cl^-)	$mg.L^{-1}$	13.0	15.8	32.8	21.5	600
Cyanide (CN)	$mg.L^{-1}$	0.005	0.005	0.005	0.005	0.02
Flouride (F)	$mg.L^{-1}$	0.74	1.15	0.27	0.18	0.5
Nitrite (NO_2-N)	$mg.L^{-1}$	0.023	0.011	0.082	0.003	10
Sulfur as H_2S	$mg.L^{-1}$	0.017	0.035	0.036	0.018	0.002
Oil and fat	$\mu g.L^{-1}$	20.300	22.000	40.000	20.000	1.000
Detergent	$\mu g.L^{-1}$	18.9	35.9	18.5	12.8	200
Microbiology						
Fecal Coliform	$100.mL^{-1}$	500	720	230	200	1.000
Total Coliform	$100.mL^{-1}$	2.000	3.000	2.000	1.000	5.000

Table 5. Water Quality Status Assessment of Enim River Based on the PI Technique

Sampling Points towards the Enim River	Pollution Index 2018	Pollution Index 2023	Quality Status 2018	Quality Status 2023
Station 1	1.83	3.43	Lightly polluted	Lightly polluted
Station 2	2.04	2.60	Lightly polluted	Lightly polluted
Station 3	2.47	3.85	Lightly polluted	Lightly polluted
Station 4	2.39	1.49	Lightly polluted	Lightly polluted

Index (IP) method. The pollution classification of the Enim River at individual sampling points in 2018 and 2023 is outlined in Table 4. The water quality status of the Enim River was evaluated using the pollution index method, indicating lightly polluted conditions (with values ranging from 1.43 to 2.47) in 2018 and (ranging from 1.49 to 3.85) in 2023 (Table 5). Anticipated activities surrounding the Enim River are expected to exacerbate its water quality by increasing the volume, type, and contaminants in wastewater annually. Without significant treatment efforts, the current lightly polluted status of the Enim River could escalate to moderately polluted in a relatively short timeframe.

While the water pollution level in Indonesia's Enim River currently meets drinking water quality standards, indications of contamination with Copper (Cu), Iron (Fe), and Oils and Fats are evident, primarily due to the influence of the mining industry, rapid urban development, and dense population in the region. Over recent decades, the absence of a broader regional watershed perspective and concentration solely on a particular location may have led to ineffective river management practices in the study area (Ding et al., 2015). Our research shows that urban development and mining activities significantly impact the water quality of the Enim River, highlighting the urgent need for restoration or management efforts in this area. Various management strategies are recommended to improve water quality. The preservation of forested land in the catchment, especially non-waterproof areas, should be limited, given priority, and regulated. In addition, the importance of riparian vegetation in urban areas is crucial, as this vegetation plays an important role in filtering sediment and sediment-borne pollutants transported by surface runoff, thus affecting water quality effectively (Siemek et al., 2023; Swanson et al., 2017). In addition, our findings show that urban areas along the Enim River experience high levels of nutrient pollution. The main sources of pollutants are domestic and industrial effluents (Bhosale et al., 2019). Illegal dumping activities, sewer system leaks, and septic system failures are significant and ongoing contributors to this pollution of the Enim River. Therefore, developing efficient water and sewage treatment plants and waste management systems in the region is essential and effective. Limiting nutrients' discharge to the Enim River's lower reaches through the reduction of point source effluents, especially during periods of low flow in the dry season, is essential.

4. CONCLUSIONS

Results from surface water quality measurements conducted in the Enim River in 2018 and 2023 showed that several parameters, including Total Suspended Solids (TSS), Copper (Cu), Iron (Fe), and Oils and Fats, exceeded the quality standards set by Indonesian Government Regulations. Although the water in the Enim River meets Class II water quality standards intended for transport, fish farming, and crop irrigation, certain parameters exceed these limits. Considerable water treatment is required to improve the suitability of the Enim River for domestic use. The pollution index of the Enim River ranges from 1.43 to 2.47 in 2018 and 1.49 to 3.85 in 2023, indicating lightly polluted conditions. The highest pollution index was observed at sampling point 3 of Enim River. Technical and non-technical measures are required to mitigate further pollution escalation.

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