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Analysis of Water Pollution Index in The Tributary of Kusan River, South Kalimantan

Fatma Nurkhaerani[1*], Wilma Nurrul Adzillah[2], Gina Lova Sari[2], Eka Nugroho Oktariyanto[3]

[1] Civil Engineering, Engineering Faculty, Universitas Singaperbangsa Karawang, Karawang, Indonesia
[2] Environmental Engineering, Engineering Faculty, Universitas Singaperbangsa Karawang, Karawang, Indonesia
[3] Water Resources Engineering Research Group, Civil and Environmental Engineering Faculty, Bandung Institute of Technology, Bandung, Indonesia

* Corespondent Author: fatma.nurkhaerani@ft.unsika.ac.id

Abstract: Domestic wastewater discharge remains a major factor contributing to the deterioration of river water quality, as untreated effluents are still commonly released directly into river systems. This concern is particularly evident in the downstream segment of the Kusan River tributary, situated in the villages of Sungai Lembu and Beringin. The intensifying expansion of residential settlements in the area has been identified as a key driver of pollution in the Kusan River, with its scale increasing annually. Environmental degradation arises when the pollutant load exceeds the assimilative capacity of the aquatic ecosystem. Under such conditions, the natural recovery process becomes protracted and increasingly ineffective, resulting in persistent contamination. This research is designed to assess the influence of surrounding anthropogenic activities on the water pollution index and the ecological condition of the Kusan River tributary in the aforementioned villages, within Tanah Bumbu Regency, South Kalimantan Province, employing the Water Pollution Index (WPI) methodology. Based on laboratory analyses, Total Suspended Solids (TSS) concentrations in the lower reaches of the tributary exceed 50 mg/L, thus surpassing the threshold set by Government Regulation No. 22 of 2021 concerning Water Quality Management and Pollution Control. Moreover, findings from the pollution index evaluation indicate that water quality in the study area ranges from good to lightly polluted, with index scores varying between 0.33 and 1.73.

Keywords: Kusan River; pollution index; TSS; water quality

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1. Introduction

Population growth in Indonesia continues to increase yearly, impacting settlement growth. The decline in river water quality is caused by several factors, including the increasing number of settlements that discharge domestic wastewater directly into rivers without treatment. The increased wastewater will undoubtedly increase pollution, especially for Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), oil, and fat parameters. Physical, chemical, and biological conditions of water quality can affect the availability of clean water for humans, recreation, industry, and agriculture [1]. The rapid pace of urbanization has led to significant city expansion and a surge in population migration to urban areas. This growth has resulted in increased discharge of domestic sewage and industrial wastewater into city rivers. Consequently, these issues have degraded urban aquatic ecosystems and contributed to the continuous decline in water quality [2].

The Kusan River has an estuary located in Tanah Bumbu Regency, which is dominated by fish farming activities, loading and unloading of fishery products, and domestic activities (settlements) along the river. These activities certainly affect changes in the quality of the Kusan River, both physically, chemically, and biologically, because, from these parameters, the level of pollution in the seas can be known [2]. One of the sources of pollution in the Kusan River is residential activities, which have increased every year. Pollution and damage are caused by the load of pollutants that enter beyond the environmental capacity. If the pollutant load is too large, the environment needs time to repair itself, and repairs will be difficult, so environmental pollution will occur [3]. Domestic wastewater contains suspended and dissolved organic materials (protein, carbohydrates, and fat) and inorganic materials (granules, images, and metals) [4]. At various monitoring sites in Banjar Regency, South Kalimantan, total coliform concentrations in the river ranged from 5,050 to 52,833.335 CFU/100 mL. These results show that the river water quality fails to comply with government standards [5].

The Pollution Index (PI) serves as a fundamental instrument in evaluating aquatic environmental conditions, particularly for determining the status of river water quality [6] . In response to growing concerns over water resource sustainability, European nations have implemented integrated watershed management practices under the framework of the Water Framework Directive (WFD) [7]. The classification of water quality status is guided by river water quality benchmarks established in Government Regulation No. 82 of 2001, where an index range of 0.728 to 0.892 signifies water of good [8]. A decline in water quality not only reflects environmental degradation but also presents significant threats to human health and the well-being of other organisms. Furthermore, such deterioration compromises the utility, efficiency, ecological resilience, and overall capacity of freshwater resources, contributing to their progressive depletion [9]. This research aims to assess the extent to which anthropogenic activities influence the water pollution index in the Kusan River tributaries, specifically in the villages of Sungai Lembu and Beringin, within Tanah Bumbu Regency, South Kalimantan Province.

2. Methods

2.1. Time and Location of Research

This research was executed in the tributaries of the Kusan River located in Sungai Lembu and Beringin Villages, Kusan Hilir District, Tanah Bumbu Regency, in September 14 2023. Meanwhile, surface water sample tests were conducted at the Laboratory of the Tanah Bumbu Regency Environmental Service. The sampling points analyzed were located in two tributaries of the Kusan River which for each location collected for three samples. This research used the grab sampling method, in which water samples were collected directly from the river at specific points and times using sterile containers. The locations that can be seen in **Figure 1** and spesicific coordinates in **Table 1.**

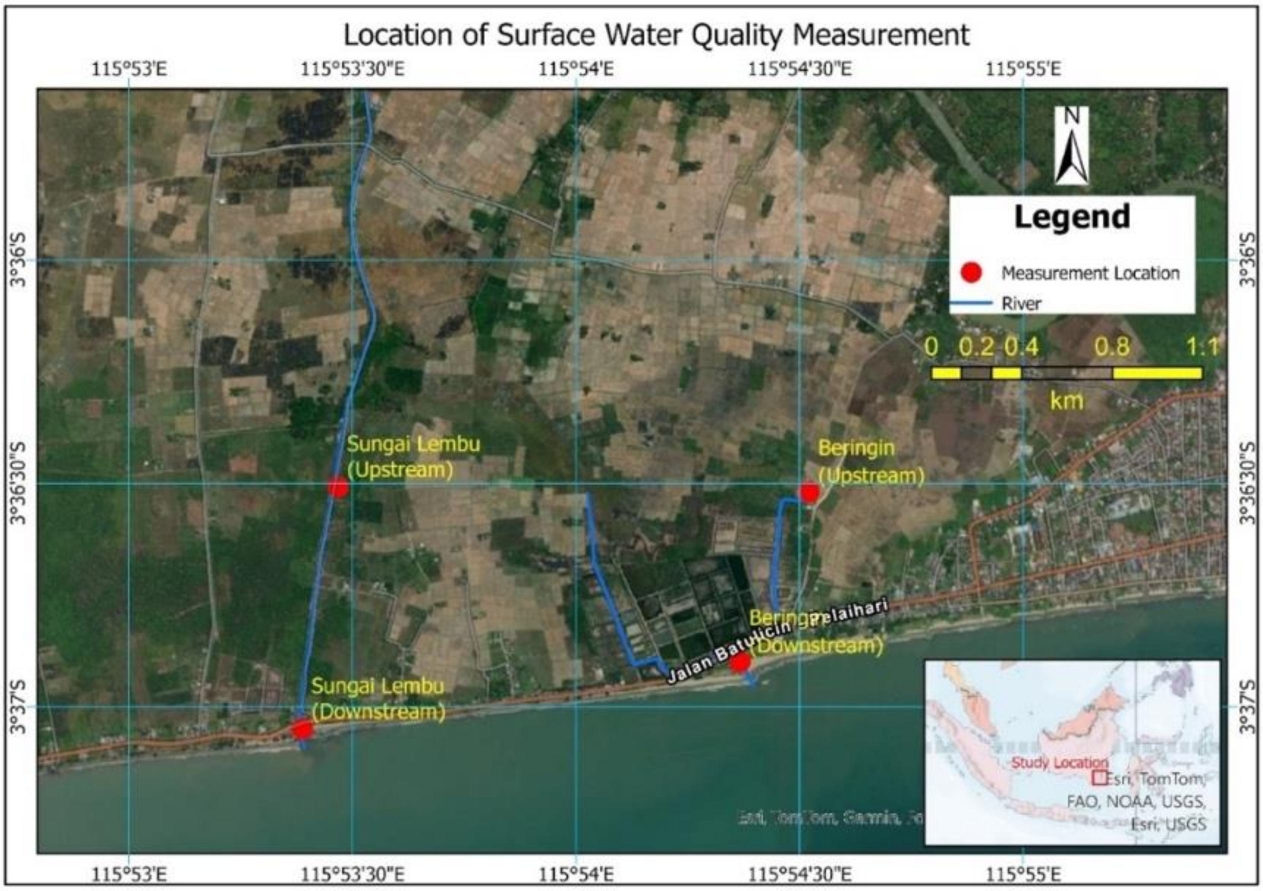

Figure 1. Study location

Table 1. Coordinates of surface water quality measurement locations

No.	Location	Village	Coordinate
1.	Tributary of Kusan River (Upstream)	Sungai Lembu	3°36’30.47”S – 115°53’28.10”E
2.	Tributary of Kusan River (Downstream)	Sungai Lembu	3°37’2.93”S – 115°53’23.31”E
3.	Tributary of Kusan River (Upstream)	Beringin	3°36’31.13”S – 115°54’31.34”E
4.	Tributary of Kusan River (Downstream)	Beringin	3°36’53.94”S – 115°54’22.03”E

2.2. Research Procedures

This research employed a surface water sampling procedure in accordance with the Indonesian National Standard (SNI) 6989.57:2008, which outlines standardized methodologies for surface water sample collection. The selection of water quality parameters was guided by the regulatory framework established under Government Regulation of the Republic of Indonesia No. 22 of 2021 concerning the Implementation of Environmental Protection and Management, specifically referencing the river water quality standards stipulated in Annex VI.I for Class II water bodies. Accordingly, the parameters utilized in the water quality assessment for this study are presented in **Table 2.**

Table 2. Key parameters and specifications of the tested sample method

No	Parameter	Unit	Quality Standards	Method Specification
A	**Physics**			
1	Temperature	°C	Dev-3	SNI 06-6989.23-2005
2	TSS	mg/L	50	SNI 6989.3-2019
B	**Chemicals**			
1	pH		6-9	SNI 6989.11.2019
2	BOD_5	mg/L	3	SNI 6989.72:2009
3	COD	mg/L	25	SNI 6989.2-2019
4	Dissolved Oxygen (DO)	mg/L	4	TB-IK W-008 (Elektrometri)
5	Nitrat (NO_3-N)	mg/L	10	SNI 6989.79:2011
6	Nitrit (NO_2-N)	mg/L	0.06	SNI 06-6989.9-2004
7	Oil and Fat	mg/L	1.00	TB-IK W-060 (FTIR)
C	**Microbiology**			
1	Total Coliform	MPN/100 mL	5,000	APHA 99221 MPN 2017

(Source:[9])

Water quality testing was carried out at the Environmental Laboratory of the Tanah Bumbu Regency Environmental Service using the testing method in Table 2. The research used a descriptive method with a quantitative approach.

2.3. Pollution Index Calculation

Subsequent to the water quality testing, the Pollution Index (PI) value was determined using a methodology aligned with the provisions set forth in the Decree of the State Minister for the Environment No. 115 of 2003, Attachment II, which provides guidelines for assessing water quality status. The calculation was performed using the following formula (1). Furthermore, **Table 3** evaluates the results of the pollution index on water quality.

$$Pij = \sqrt{\frac{(\frac{C_i}{L_{ij}})_{2M} + (\frac{C_i}{L_{ij}})_{2R}}{2}} \quad (1)$$

Lij = Concentration of water quality parameters listed in the water quality standards (J)
Ci = Concentration of water quality parameters in the field
Pij = Pollution index for use (J)
(Ci/Lij)M = Value, maximum Ci/Lij
(Ci/Lij)R = Value, average Ci/Lij

Table 3. Classification of water quality based on Pollution Index

No.	Pollution Index	Water Quality
1.	0<Pij<1.0	Good condition
2.	1.0<Pij<5.0	Lightly pollution
3.	5.0<Pij<10	Medium pollution
4.	Pij>10	Heavily pollution

(Source: [10])

3. Results and Discussion

3.1. Water Quality of Kusan River Tributaries

The laboratory tests for 4 (four) surface water samples taken from the Kusan River tributary in Sungai Lembu and Beringin Villages showed that 3 (three) of the 10 (ten) surface water quality parameters whose concentrations were close to or slightly exceeded the environmental quality standards set for class II designation were TSS, BOD5, and oil and fat. **Table 4** shows more complete results.

Table 4. Water Quality Laboratory Analysis Results

No.	Parameter	Unit	Quality Standards	Test Results			
			Class II	1	2	3	4
A	**Physics**						
1	Temperature	°C	31±3	29.00	27.00	29.00	28.00
2	TSS	mg/L	50.00	67.70	69.00	84.00	20.30
B	**Chemicals**						
1	pH	-	6.00-9.00	8.00	7.80	7.20	7.50
2	BOD_5	mg/L	3.00	2.90	2.00	2.20	2.40
3	COD	mg/L	25.00	8.50	8.50	8.30	8.30
4	Dissolved Oxygen (DO)	mg/L	4.00	6.80	6.70	6.40	6.40
5	Nitrat (NO_3-N)	mg/L	10.00	0.09	0.02	0.04	0.16
6	Nitrit (NO_2-N)	mg/L	0.06	<0.004	0.04	<0.004	<0.004
7	Oil and Fat	mg/L	1.00	<0.145	1.01	1.02	<0.145
C	**Microbiology**						
1	Total Coliform	MPN/100 mL	5,000	930	210	930	930

As presented in **Table 4**, the parameters exceeding the Class II water quality thresholds include Total Suspended Solids (TSS) as well as oil and grease. Among the sampling sites, only the downstream location of the Kusan River in Beringin Village recorded a TSS concentration of 20.30 mg/L, which falls within the acceptable limit of 50.00 mg/L.

In contrast, the remaining three locations—comprising the upstream and downstream segments in Sungai Lembu Village and the upstream point in Beringin Village—exhibited TSS concentrations of 67.70 mg/L, 69.00 mg/L, and 84.00 mg/L, respectively, all of which surpass the stipulated standard. These elevated levels are likely attributable to significant sediment transport and deposition occurring in the downstream sections, influenced by soil erosion from upstream areas of the Kusan River. Supporting findings have been documented by [11], where TSS concentrations in the Way Kuripan River were observed at an average of 115.0 mg/L, with a range between 40.0 and 270.0 mg/L—values still within the maximum permissible limit of 400 mg/L.

The relatively low TSS concentrations observed in this study may be due to the timing of the sampling, which did not coincide with the rainy season; consequently, sediment loads were likely dominated by localized domestic activities rather than runoff-induced erosion. TSS represents the concentration of suspended particles in the water, which typically includes silt and microorganisms. These solids are primarily introduced into river systems through soil erosion [12]. In the upstream section, there are still rice fields and gardens where the potential for erosion in the river is more significant. In addition, compounds that usually become suspended solids because they are insoluble are amino acids or proteins often found in domestic liquid waste. Bacteria that are pathogenic or not can become suspended solids with other solids, where these bacteria usually form flocs that spread quickly and settle. Some bacteria will die, causing fragments of cell walls and fibers and potentially increasing the TSS value in liquid waste [13].

In addition to TSS and oil-fat content, other measured parameters such as Biochemical Oxygen Demand (BOD_5), Chemical Oxygen Demand (COD), and total coliform remained within the permissible thresholds established for Class II water quality standards. BOD_5 concentrations across the four monitoring locations ranged from 2.00 to 2.90 mg/L, remaining below the regulatory limit of 3.00 mg/L. Notably, the highest BOD_5 value of 2.90 mg/L was recorded in the upstream segment of the Kusan River, approaching the maximum allowable concentration. For oil and grease, concentrations observed in the upstream region of the Kusan River at Sungai Lembu Village and in the downstream portion at Beringin Village were both below 0.145 mg/L—well within the acceptable limit of 1.00 mg/L for Class II water. Conversely, samples collected from the downstream area of Sungai Lembu Village and the upstream site at Beringin Village exceeded the standard, registering values of 1.01 mg/L and 1.02 mg/L, respectively.

The presence of oil and grease in these waters is predominantly attributed to domestic wastewater discharge from residential zones. Detergent concentrations serve as a critical indicator of water quality, primarily due to the surfactants they contain—chemically active agents capable of disrupting aquatic ecosystems. These compounds produce persistent foam that impedes oxygen diffusion into the water column, thereby threatening the survival of aquatic organisms [14].

Fatty oils are categorized as persistent organic pollutants that exhibit low biodegradability due to their resistance to microbial decomposition. These substances possess a specific gravity lower than that of water, which causes them to accumulate as a thin film on the water's surface [15]. This surface layer significantly impairs the diffusion of atmospheric oxygen into the water, thereby reducing dissolved oxygen levels. Furthermore, the presence of this oil layer obstructs sunlight penetration, which is essential for photosynthesis, ultimately leading to disruptions in aquatic food web dynamics. Due to their chemical stability and low degradability, oil and grease persist in aquatic environments and pose a long-term threat to ecosystem health [11].

3.2. Water Pollution Level Analysis

The findings from the water quality assessment are utilized to evaluate the current condition of river water in the Kusan River tributaries. To determine the water quality status, the Pollution Index (PI) method is employed, as it quantifies the degree of contamination in relation to established water quality thresholds [12]. The analysis of the pollution index was conducted using surface water quality test results and was guided by the Minister of Environment Decree No. 115 of 2003, which outlines the procedure for assessing water quality status through the Pollution Index approach. The outcomes of this analysis are presented in **Tables 5 and 6**.

Table 5. Analysis of River Water Pollution Levels in the Kusan River Tributaries in Sungai Lembu Village

No	Parameter	Unit	Water Quality (Ci)	Quality Standards (Li)	C_i/L_i
Water Quality Status of Kusan River Tributaries in Sungai Lembu Village (Upstream)					
1	TSS	mg/L	67.70	50.00	1.35
2	BOD	mg/L	2.90	3.00	0.97
3	COD	mg/L	8.50	25.00	0.34
4	Oil and Fat	mg/L	0.145	1.00	0.15

No	Parameter	Unit	Water Quality (Ci)	Quality Standards (Li)	C_i/L_i
5	Total Coliform	MPN/100 mL	930	5,000	0.19
Category		Lightly Pollution		C_i/L_i max	1.35
				C_i/L_i average	0.60
				IP	1.10
					1.05
Water Quality Status of Kusan River Tributaries in Sungai Lembu Village (Downstream)					
1	TSS	mg/L	69.00	50.00	1.38
2	BOD	mg/L	2.00	3.00	0.67
3	COD	mg/L	8.50	25.00	0.34
4	Oil and Fat	mg/L	1.01	1.00	1.01
5	Total Coliform	MPN/100 mL	210	5,000	0.04
Category		Lightly Pollution		C_i/L_i max	1.35
				C_i/L_i average	0.60
				IP	1.10
					1.05

Tabel 6. Analysis of River Water Pollution Levels in the Kusan River Tributaries in Beringin Village

No	Parameter	Unit	Water Quality (Ci)	Quality Standards (Li)	C_i/L_i
Water Quality Status of Kusan River Tributaries in Beringin Village (Upstream)					
1	TSS	mg/L	20.30	50.00	0.41
2	BOD	mg/L	2.20	3.00	0.73
3	COD	mg/L	8.30	25.00	0.33
4	Oil and Fat	mg/L	0.145	1.00	0.15
5	Total Coliform	MPN/100 mL	930	5,000	0.19
Category		Good condition		C_i/L_i max	0.73
				C_i/L_i average	0.36
				IP	0.33
					0.58
Water Quality Status of Kusan River Tributaries in Beringin Village (Downstream)					
1	TSS	mg/L	84,00	50.00	1.68
2	BOD	mg/L	2,40	3.00	0.80
3	COD	mg/L	8,30	25.00	0.33
4	Oil and Fat	mg/L	1,02	1.00	1.02
5	Total Coliform	MPN/100 mL	930	5,000	0.19
Category		Lightly Pollution		C_i/L_i max	1.68
				C_i/L_i average	0.80
				IP	1.73
					1.32

As presented in **Tables 5 and 6**, the symbol *Ci* represents the laboratory-measured concentration of each water quality parameter, while *Li* denotes the corresponding standard threshold values as defined by Government Regulation No. 22 of 2021, specifically for Class II water quality. The Pollution Index (PI) is calculated by comparing the observed concentrations (*Ci*) with the regulatory standards (*Lij*) for each parameter, resulting in a ratio (*Ci/Lij*) that reflects the degree of deviation from permissible limits. Based on this analysis, the pollution index values for the Kusan River tributary in Sungai Lembu Village—both upstream and downstream—exceeded 1.00, indicating that the water quality falls within the category of slightly polluted.

Meanwhile, in **Table 6**, the pollution index for the upstream segment of the Kusan River tributary in Beringin Village is recorded at 0.33, indicating that the water quality remains within a healthy and uncontaminated range. Conversely, the downstream section exhibits a pollution index of 1.73, categorizing it as lightly polluted. This elevated index is largely attributable to the high levels of Total Suspended Solids (TSS) at the river estuary, where significant sediment accumulation occurs. Such sedimentation is commonly driven by upstream land use changes. Supporting this, research by [16], reported a 17.44% expansion in open land area, accompanied by reductions in residential zones and aquaculture ponds by 0.614% and 11.069%, respectively.

These shifts imply increased runoff and erosion, ultimately raising TSS concentrations in the estuarine waters of the Banger River. Furthermore, unregulated construction along riverbanks significantly contributes to environmental degradation, particularly through the direct discharge of untreated waste, including human effluents, into the river. Ideally, communal sanitation facilities should incorporate appropriate wastewater treatment systems and septic tanks to mitigate such impacts. Additionally, riverbank washing practices—common among local residents—pose further threats to water quality and public health and should be addressed [17]. Moreover, paddy cultivation is the predominant agricultural activity along the riverbanks in the study area, and it contributes to the decline of water quality. Implementing controlled drainage practices can help minimize pollutant runoff from paddy fields and serve as an effective strategy to protect river ecosystems [18].

4. Conclusion

River water quality can be significantly affected by various anthropogenic activities, including domestic, industrial, aquacultural, and agricultural practices. In the tributaries of the Kusan River flowing through Sungai Lembu and Beringin Villages, noticeable changes in water quality have been observed, largely attributed to domestic sources. The results showed that paddy cultivation along riverbanks and domestic wastewater discharges contributed to increased pollutant loads, with Total Suspended Solids (TSS) in the lower reaches exceeding 50 mg/L—the only parameter not meeting the threshold set by Government Regulation No. 22 of 2021 concerning the Management of Water Quality and Control of Water Pollution. Moreover, pollution index evaluations conducted in these areas of Tanah Bumbu Regency, South Kalimantan Province, reveal that the water quality status ranges from good to lightly polluted, with pollution index values between 0.33 and 1.73.

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