Depik Jurnal Ilmu-Ilmu Perairan, Pesisir dan Perikanan (2023) 12(2): 229-235

DEPIK
Jurnal Ilmu-Ilmu Perairan, Pesisir dan Perikanan
Journal homepage: www.jurnal.usk.ac.id/depik

The assessment of status of Sibam River and Air Hitam River Pekanbaru city Riau Province using pollution index

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ARTICLE INFO

Keywords:
Pollution Index
Water Quality
Sibam River
Air Hitam River

DOI: 10.13170/depik.12.2.29001

ABSTRACT

The quality of the Siak River is gradually deteriorating with the rapid socio-economic development in its tributary watersheds. S. Sibam and Air Hitam are part of the Siak tributaries in the Siak tributary sub-region in Pekanbaru City. The quality of the Sibam and Air Hitam tributaries in the Siak Watershed of Pekanbaru City has been studied to determine the relative pollution level of water quality standards. Water quality measurements were carried out from January to August 2022 at the upstream, middle, and confluence with the Siak River. The pollution level of the Sibam River and Air Hitam River was measured using the pollution index method. The quality of the Sibam River and Air Hitam waters is compared to the quality standards according to The Regulation of Government of the Republic of Indonesia (RGRI) Number 22/2021 Class III. The water quality parameter measured consisted of dissolved oxygen, TSS, pH, BOD, COD, nitrate, nitrite, ammonia, and total phosphate. Pollution index calculations for the Sibam and Air Hitam rivers show light pollution, with index values ranging from 1.75 to 3.57. Nitrite and ammonia concentrations in the Sibam River do not meet quality standards. Whereas in the Air Hitam River, the BOD, nitrite, and ammonia level exceeds the quality standards (RGRI Number 22/2021 Class III). The highest pollution index is in the middle of the river, with settlements on both rivers.

Introduction

Sibam River and Air Hitam River are Siak Sub-Watersheds (DAS) (Nadia *et al.,* 2016). These rivers function as primary drainage channels in the western part of Pekanbaru Cit and empty into the Siak River. The Sibam and Air Hitam watersheds are peat swamp areas. However, the development of Pekanbaru City caused the Sibam and Air Hitam watersheds to change their functions into oil palm plantations, residential areas, and warehousing industries. Peatland degradation and conversion to plantations significantly affect river water quality, leading to dissolved organic carbon fluxes and oxygen levels (Abrams *et al.,* 2015). In addition, increased activity in the Sibam and Air Hitam watersheds puts pressure on the Sibam and Air Hitam Rivers, causing the rivers to become silted and water quality to decrease as the Siak sub-watershed, the Sibam and Air Hitam Rivers impact the decline in the water quality of the Siak River due to pollution. According to Indonesia's environmental and forestry statistics 2019, the Siak River is in a mild to heavily polluted condition (Ministry of Environment and Forestry of Indonesia, 2019).

According to the Indonesian Public Works Department (IPWD) (2005), 60% of Siak River pollution comes from domestic waste. Research proves that the water quality of the Siak River has been polluted by household waste, especially from its tributaries in the Pekanbaru City area (Yuliati *et al.,* 2018; Rixen *et al.,* 2010). This waste causes the water quality of the Siak River to continue to decline. Pollution that enters the river affects river species and reduces river function (Gurjar and Vinod 2019).

Moreover, pollutants will worsen water quality, making it unsafe for humans. Meanwhile, the Siak River, the source of fresh drinking water, can be disrupted. Accurately measuring changes in water quality in rivers is very important for formulating environmental protection and river pollution control policies. In this case, it is necessary to use a water quality assessment method to determine river water

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p-ISSN 2089-7790; e-ISSN 2502-6194
Received 15 November 2022; Received in revised form 16 January 2023; Accepted 9 August 2023
Available online 31 August 2023

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quality status. Determining the status of a river can be done using the pollution index because it is a simple and easy assessment method for assessing water pollution. This approach resulted in a value indicating the relative pollution levels against the water quality standard (Suriadikusumah *et al.,* 2020). A pollution index has been applied to evaluate water quality in Indonesian rivers such as Ciliwung, Jakarta (Sabila *et al.,* 2017), Citarum (Marselina *et al.,* 2022) and Cimanuk (Nurrohman *et al.,* 2019) (Bandung). However, the determination of the quality status of Siak tributaries is rarely reported. For this reason, it is necessary to determine the quality status of the tributaries as the basis for controlling the pollution of the Siak River.

Materials and Methods

Location and time of research

This river is located in Pekanbaru Regency, the Capital of Riau Province (Figure 1). This research was carried out in January–Agustus 2022 at the Sibam River and Air Hitam River. Each river consists of three research stations. Station 1 is upstream of the river, station 2 is in the middle, and station 3 is the downstream part of the river where it confluences the Siak River. The coordinates of the research stations for the two rivers are presented in Table 1.

Table 1. Position of three stations on Sibam and Air Hitam River.

Station	Sibam River	Air Hitam River
	Positions	
St 1	08o54’34.81”S 116o17’51.35”E	00˚32'31.5”S 101˚23'38.0”E
St 2	08o54’35.34”S E 116o17’52.53”E	00˚32'46.5”S 101˚23'43.9”E
St 3	08o54’35.69”S 116o17’53.65”E	00˚32'53.4”S 101˚23'45.1”E

Sample collection

Samples were analyzed for eight parameters, i.e., Temperature, Total Suspended Solids (TSS), Dissolved Oxygen (DO), pH, Biochemical Oxygen Demand (BOD5), Chemical Oxygen Demand (COD), Nitrate, Nitrite, Ammonia, and Total Phosphate and river hydrodynamics, namely Velocity and water discharge. Velocity is measured using a flow watch FL-03. Discharge calculation is obtained by multiplying the current rate and the cross-sectional area of the river (Sosrodarsono, 1993).

A Van Dor Water Sampler takes one liter of water at a depth of 0-20 cm. The water sample is put into a polyethylene bottle and stored in a cool box at 4^0 C. The procedure for preserving river water samples is carried out according to Indonesian National Standard (INS) 2008. Temperature (mercury thermometer) and pH were measured in situ using a portable tools analysis pH-meter (Hanna HI 98107). Dissolved oxygen measure with Winkler methods.

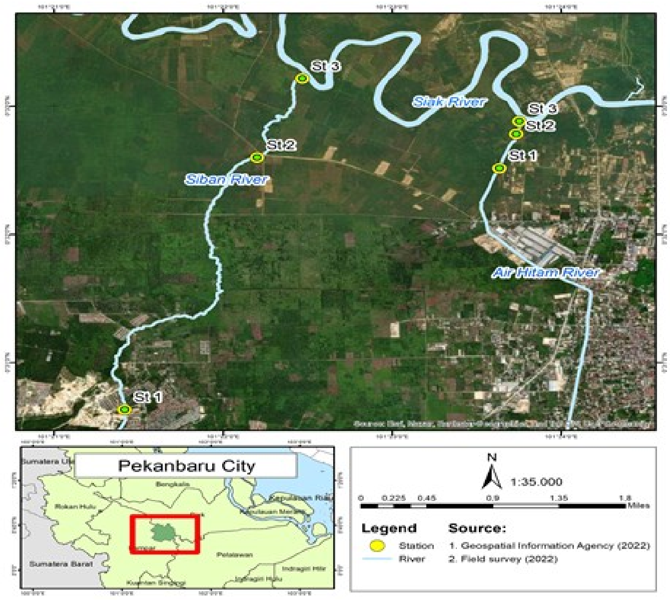

Figure 1. Study Location in Sibam River and Air Hitam River Pekanbaru City

Data analysis

Analysis of the water quality status of the Sibam River and Air Hitam River uses a pollution index as stated by the Decree of the Minister of the Environment Indonesia (MEI) Number 115 of 2003. According to Regulation of Government of the Republic of Indonesia (RGRI) Number 22/2021 *(Class III)*, the water quality standard used Class III because these rivers are designated to cultivate freshwater fish. Determining river water quality of status with pollution index can be seen as follows:

$$PI_j = \sqrt{\frac{\left(\frac{C_i}{L_{ij}}\right)_M^2 + \left(\frac{C_i}{L_{ij}}\right)_R^2}{2}} \quad (1)$$

Where

- PIj: Pollution Index for designation (j), which is a function of Ci/Lij
- Ci: Concentration water quality parameters (i) obtained from the analysis of water samples on a location for taking samples from a river channel (unit?),
- Lij: State the concentration of the listed water quality parameters in the Quality Standard of a Water Designation (j),
- M: Maximum value of Ci/Lij

- R: Average value of Ci/Lij

The results of this PIj calculation show the level of water pollution based on the standard of water pollution status according to Regulation of Government of the Republic of Indonesia (RGRI) Number 22/2021 *Class III,* concerning the implementation and protection of the environment. The PIj grade may be determined by:

- It selected parameters that, if the parameter grade is the low point, the water quality shall upgrade.
- Choose the concentration of quality standard parameters that do not possess a range.
- Evaluate the Ci/Lij value for every parameter at every sampling location.
- Decide the maximum grade or theoretical value of Cim (e.g., for DO, then Cim is a saturated DO value). In this example, the Ci/Lij rate of the calculation results is exchanged for the calculated Ci/Lij value, specifically:

$$\left(\frac{C_i}{L_{ij}}\right)_{\text{new}} = \frac{C_{im} - C_{i\,(measurements\ results)}}{C_{im} - L_{ij}} \quad (2)$$

If the standard Lij value has a range

- for $C_i \leq L_{ij}$ average

$$\left(\frac{C_i}{L_{ij}}\right)_{\text{new}} = \frac{\left[C_i - (L_{ij})_{average}\right]}{\left\{(L_{ij})_{maksimum} - (L_{ij})_{average}\right\}} \quad (3)$$

- for $C_i > L_{ij}$ average

$$\left(\frac{C_i}{L_{ij}}\right)_{\text{new}} = \frac{\left[C_i - (L_{ij})_{average}\right]}{\left\{(L_{ij})_{maksimum} - (L_{ij})_{average}\right\}} \quad (4)$$

Hesitation appears if two values Ci/Lij is nearby the reference value of 1.0, for example, C1/Lij= 0.9 and C2/L2j = 1.1, or huge differences exist, for illustration, C3/L3j = 5.0 and C4/L4j = 10.0. In this example, the level of water body damage is difficult to determine. An approach to overcome this case is:

- The value (Ci/Lij) of the calculation results is used if this value is less than 1.0.
- The new value (Ci/Lij) is used if the calculated value (Ci/Lij) is higher than 1.0.

$$\left(\frac{C_i}{L_{ij}}\right)_{\text{New}} = 1{,}0 + P.\log\left(\frac{C_j}{L_{ij}}\right)_{measurements\ results} \quad (5)$$

The pollutant index value will be categorized into several water quality ranges. The level of water pollution is divided into four classes, namely: Meets the quality standard if the value $0 \leq PI_j \leq 1.0$; Lightly polluted = $1.0 < PI_j \leq 5.0$; Moderately polluted $= 5.0 < PI_j \leq 10$; Heavily polluted, If the value $PI_j > 10$.

Results

Water Quality

The water quality characteristics of the Sibam and Air Hitam Rivers are shown in Table 2 and Table 3. The temperature in the Sibam River ranges from 28-30 ºC and slightly lower in the Air Hitam River (28-31 ºC). However, the temperatures in the two rivers are generally relatively similar. The TSS values for the Sibam River and Air Hitam range from 4 to 6 mg/l and 14 to 58 mg/l, respectively. It can be seen from Table 2 and Table 3 that TSS levels in the Sibam River are lower than in the Air Hitam River. The highest TSS value in the Sibam River and Air Hitam is at station (St) 3, where this station meets the Siak River.

The Sibam and Air Hitam rivers fluctuate upstream to downstream. The dissolved oxygen (DO) in the Sibam River ranged from 4.12-5.52, with the highest value at St 1 of the second sampling (5.56 mg/l) (Table 2 and Table 3). The highest oxygen in the Air Hitam River was observed at St 2, with a 4.8 mg/l. Oxygen concentration in each river still meets the quality standard according to RGRI no 22 of 2022 class III of 3 mg/l.

The pH values in the Air Hitam and Sibam Rivers are five. This value indicates that the two rivers are acidic. There is no difference in the pH value in the Sibam River and the Air Hitam River based on the observation and sampling St that have been carried out. According to RGRI 22 of 2021, the pH value of river water is standard if it is around 6-9, except for rivers that are affected by peat swamps. Therefore, the pH of the Sibam River and Air Hitam is categorized as fulfilling the quality standard even though the value is low because it is less than six.

In the Sibam River, BOD levels are lower than in the Air Hitam River. Concentrations of BOD in the Sibam River were relatively similar (3-4 mg/l), while Air Hitam ranged from 9-18 mg/l. The high BOD content at all observation stations in the Air Hitam River has exceeded the class III quality standard according to RGRI 22 of 2021 (6 mg/l).

Table 4 shows COD concentrations in the Sibam River in sampling 1 to 3 were 13.3-21.5, 10.00-20.8 mg/l, and 10.80-18.5 mg/l, respectively. The COD in the observation of sampling 1 is higher than that of sampling 2 and 3. There is a tendency for the COD to increase to the lower reaches of the river, especially at St 3 (confluence with the Siak River). The range of COD in the Air Hitam River observations will be seen in Table 3.

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Table 2. Characteristics of the water quality of the Sibam River

No	Parameter	Unit	Quality Standard *	Sampling 1 January			Sampling 2 March			Sampling 3 August		
				St 1	St 2	St 3	St 1	St 2	St 3	St 1	St 2	St 3
1	Temperature	^0C		29	30	28	28	29	28	28	30	29
2	TSS	mg/l	100	4	4	6	4	4	6	4	5	5
3	pH**		-	5	5	5	5	5	5	5	5	5
4	DO	mg/l	3	5.48	8.24	8.32	4.12	5.56	8.24	4.12	5.77	8.37
5	BOD	mg/l	6	3.50	1.44	4.12	1.85	4.12	3.29	4.12	5.15	4.12
6	COD	mg/l	40	13.3	14.8	21.5	10	16.8	20.8	10.8	17.2	18.5
7	Nitrate	mg/l	20	0.07	0.08	0.06	0.07	0.09	0.07	0.07	0.07	0.11
8	Nitrite	mg/l	0.06	0.08	0.09	0.07	0.09	0.1	0.08	0.09	0.09	0.11
9	Ammonia	mg/l	0.5	0.06	0.07	0.06	0.07	0.08	0.07	0.07	0.07	0.09
10	TP	mg/l	1	0.05	0.05	0.06	0.04	0.05	0.07	0.04	0.05	0.07
11	River Depth	m	-	0.34	0.33	0.95	0.42	0.41	0.9	0.38	0.36	0.93
12	River Widht	m	-	6	4	14	6	5	14	6	5	14
13	Water Debit	m^3/s	-	0.20	0.49	2.66	0.51	0.20	1.26	0.68	0.36	2.60
14	Velocity	m/s	-	0.10	0.30	0.10	0.20	0.10	0.10	0.30	0.20	0.10

** Peat swamp river

Table 3. Characteristics of the water quality of the Air Hitam River

No	Parameter	Unit	Quality Standard*	Sampling 1 January			Sampling 2 March			Sampling 3 August		
				St 1	St 2	St 3	St 1	St 2	St3	St 1	St 2	St 3
1	Temperature	^0C		28	30	31	29	28	30	29	29	30
2	TSS	mg/l	100	14	22	58	20	22	26	29	34	41
3	pH**		-	5	5	5	5	5	5	5	5	5
4	DO	mg/l	3	3.60	3.60	4	3.60	4.80	4	3.20	3.60	4
5	BOD	mg/l	6	10	9	10	18	18	16	16	12	12
6	COD	mg/l	40	32.11	24.26	20.65	26.08	22.25	19.65	27.08	26.83	21.15
7	Nitrate	mg/l	20	0.28	0.37	0.37	0.60	0.51	0.42	0.47	0.47	0.42
8	Nitrite	mg/l	0.06	0.24	0.31	0.28	0.52	0.42	0.38	0.38	0.38	0.35
9	Ammonia	mg/l	0.5	0.37	0.37	0.13	0.25	0.18	0.14	0.30	0.16	0.14
10	TP	mg/l	1	0.90	0.35	0.34	0.49	0.53	0.41	0.67	0.44	0.38
11	River Depth	m	-	1.40	2.00	4.00	1.50	1.70	3.60	1.40	1.70	4.00
12	River Widths	m	-	8	12	20	8	12	20	8	12	20
13	Water Debit	m^3/s	-	1.12	3.60	12	1.80	3.06	10.8	1.68	2.04	8
14	Velocity	m/s	-	0.10	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.10

**Peat swamp river

Nitrate levels fluctuate in the Air Hitam River. On the contrary, the Sibam River tends to be similar along the river flow. The range of nitrate is 0.28-0.60 mg/l (Air Hitam River) (Table 3) and 0.07-0.11 mg/l (Sibam River). Nitrate grades in the Air Hitam River were higher than in the Sibam River. However, the groups met the class III quality standard (20 mg/l).

The output of nitrite measurements during the study in the Sibam River is illustrated in Table 2. The average content of nitrite ranges from 0.09 to 0.10 mg/L. Nitrite concentration in the Sibam is relatively similar. However, the nitrite at St 2 (0.10 mg/L) tends to be higher than at St 1 and 3 (0.09 mg/L). The nitrite content in the Air Hitam River is higher, ranging from 0.24-0.52 mg/l. This value exceeded the quality standard, 0.06 mg/l (Class III, RGRI 22/2021). The high nitrite in Air Hitam was observed at St 1 (0.52 mg/l).

Ammonia measured during the Sibam and Air Hitam River studies is presented in Table 2 and Table 3 with a range of 0.06-0.09 mg/l and 0.14-0.37 mg/l, respectively. The ammonia content in the Air Hitam River is higher, especially at St 1 (0.52 mg/l), already exceeding the quality standard of 0.05 mg/l.

Table 3 shows that the TP content of the Sibam River increased slightly downstream. In contrast to the Air Hitam, the TP concentration fluctuates along the river's course.

The average depth of the Sibam River ranges from 0.36 - 0.92 m. The most profound river depth is at St 3 (0.92 m), while the lowest is at St 2 (0.36 m). Sibam River discharge fluctuates in the range of 0.35 – 2.17 m^3/s. The Sibam River discharge tends to fluctuate. The highest Sibam river discharge is at St 3 (2.17 m^3/s), while the lowest is at St 2 (0.35 m^3/s)

Water quality status

In sampling 1 and 2, the PI value in the Sibam River ranges from 2.50 to 2.95. In contrast, the third sampling varies from 2.50 to 3.15, with an average of 2.79, indicating that the river quality status is lightly polluted (Table 4). The PI values for the Air Hitam River for all research stations are presented in Table 5, ranging from 1.70 to 3.57. Although the PI value is higher than Sibam River, it is still considered lightly polluted.

Table 4. Pollution Index (PI) of Sibam River

Sampling	Sibam River					
	St 1		St 2		St 3	
	PI	Category	PI	Category	PI	Category
1	2.51	Lightly polluted	2.74	Lightly polluted	2.50	Lightly polluted
2	2.74	Lightly polluted	2.95	Lightly polluted	2.74	Lightly polluted
3	2.74	Lightly polluted	2.75	Lightly polluted	3.15	Lightly polluted

Table 5. Pollution Index (PI) of Air Hitam River

Sampling	Air Hitam River					
	St 1		St 2		St 3	
	PI	Category	PI	Category	PI	Category
1	1.70	Lightly polluted	3.41	Lightly polluted	3.25	Lightly polluted
2	1.71	Lightly polluted	3.71	Lightly polluted	3.57	Lightly polluted
3	2.06	Lightly polluted	3.50	Lightly polluted	3.42	Lightly polluted

Discussion

Human activities significantly influence the quality of river waters in general. Pollution levels in the Sibam and Air Hitam Rivers are increasing in the river's lower reaches due to increasing human activities, such as settlements, industry, and agriculture. According to Kotti *et al.,* (2005), river water pollution increases from upstream to downstream due to human activities along the banks of the river. Residential activities and oil palm plantations in watersheds have decreased the water quality of the Sibam River and Air Hitam River. The decline in river water quality is characterized by nitrite and ammonia parameters (Sibam River and Air Hitam River), and BOD (Air Hitam River) does not meet quality standards. Following the statement Abbott (2018) that agricultural activities and urbanization on the banks of the river increase nitrogen levels in the waters. Agricultural activities in the Sibam and Air Hitam watersheds are oil palm plantations. Peat swamps in watersheds are converted to oil palms. Additionally, the remnants of fertilizer are carried with rain runoff into the river, increasing nitrogen concentration in river water (Comte *et al.,* 2012). Additionally, the remnants of fertilizer are carried with rain runoff into the river, increasing nitrogen levels in river water.

Anthropogenic activities on the riverbanks have increased the BOD concentration in the Sibam and Air Hitam rivers. Furthermore, runoff water can transport eroded soil particles from areas to water bodies. Suspended particles contribute significantly to water turbidity, which impairs photosynthesis, degrades light penetration, alters oxygen levels, and reduces the food supply for aquatic organisms (Bilotta and Brazier, 2008). Moreover, sediment plug streams, reducing their water-holding capacity, and can cover spawning beds, killing populations of fish (Kemp *et al.,* 2011)

Anthropogenic activities on the riverbanks have increased the BOD content in the Sibam and Air Hitam Rivers. A higher BOD content usually indicates the presence of organic pollutants from untreated domestic and industrial wastes (Saifullah *et al.,* 2016). Surface water has a BOD tolerance limit of 5 mg/L for aquatic life and reflects the amount of organic matter in water bodies (Loucif *et al.,* 2020).

The results of the calculation of the Sibam and Air Hitam River pollution indexes describe the quality status of the river in a lightly polluted condition. However, the pollution index value of the Air Hitam River is higher than that of the Sibam River. This higher pollution index value indicates that the quality of the Air Hitam River is worse than the Sibam River.

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The Air Hitam River's poor quality is caused by the nitrite and ammonia parameters exceeding the quality standard and high BOD levels. The high levels of BOD in the Air Hitam River originate from domestic waste. The Air Hitam River flows in a densely populated area. Residential settlements produce domestic liquid waste with a high organic matter content (Vane *et al.,* 2022). Pollution in water can result from several factors, including the direct removal of waste or rain, as well as shipments of pollutants from other areas and farming activities (Silva *et al.,* 2001).

The higher pollution index in the Air Hitam River is also due to the low current velocity. Suradikusumah *et al.,* (2020) state that the pollution index rate was influenced not only by the quantity of waste input but also by the flow velocity. The slow flow rate causes effective contact between the microorganism and the substrate. In contrast, the fast flow rate causes a connection between the substrate and the bacteria. In addition, the slow flow rate causes the aeration process in the water to be lower, thereby reducing the self-purification of the river and causing a high level of water pollution.

At Air Hitam River, station 2 shows the highest pollution index value. Station 2 is the middle part of the river. The watershed contains residential areas, the tofu processing industry, and the warehousing industry, which discharges waste into the river, reducing river water quality. In Indonesia, domestic and tofu processing waste is not treated before being discharged into the river. Industrialization and urbanization have generated large amounts of wastewater, which have increased pollution and caused environmental damage to river water (Xu *et al.,* 2022)

Conclusion

The quality status of the Sibam River and Air Hitam is categorized as lightly polluted, with pollution index values ranging from 2.51-3.15 and 1.57-3.57, respectively. The nitrite and ammonia levels in each river have exceeded the quality standard (RGRI 22/2021, class III)

Acknowledgments

The authors thank the University of Riau, especially the Institute for Research and Community Service (LPPM), which has funded this research. Acknowledgments are also given to the students involved and helped in this research.

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How to cite this paper:
Yuliati, E. Sumiarsih, Efawani, I. Mulyani, N.E. Fajri. 2023. The assessment of status of Sibam River and Air Hitam River Pekanbaru city Riau Province using pollution index. Depik Jurnal Ilmu-Ilmu Perairan, Pesisir dan Perikanan, 12(2): 179-186.