Water quality conditions and pollution status of the Belawan River, North Sumatra Province

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Abstract. The Belawan River is located in North Sumatra, Indonesia. This river crosses Medan City and Deli Serdang Regency. This research will be conducted from June to July 2024, encompassing sampling, measurement of water physicochemical parameters, laboratory testing and analysis of samples, and data analysis. The location of sampling and measurement of environmental parameters was carried out in the Belawan River, Pancur Batu District, Deli Serdang Regency. Sampling was carried out at 15 stations using a purposive sampling method. Determination of pollution status using the Pollution Index, CCME, and NSF-WQI methods. The characteristics of the physical parameters obtained were temperature (23.0-32.3°C), turbidity (1.19 NTU - 11.7 NTU), TSS (1 mg/L - 25 mg/L), and TDS (4.9 mg/L - 198.2 mg/L). The chemical parameter characteristics are DO (6.2 mg/L - 9.3 mg/L), pH (6.6 - 9.7), BOD (3.5 mg/L - 23.8 mg/L), COD (9.1 mg/L - 50.5 mg/L), nitrate (0.4 mg/L - 4.1 mg/L), and phosphate (0.2 mg/L - 2 mg/L), and the biological parameter characteristics are faecal coliform (20 MPN - 1400 MPN). The pollution status of the Belawan River shows light to good pollution. Polluted conditions are found in the downstream, and good conditions are found in the upstream

1 Introduction

The main problem encountered in relation to water resources was the quantity of water, which was no longer able to meet the increasing demand, and the quality of water, which had progressively declined. This condition could lead to disturbances, degradation, and hazards for living organisms that depended on water resources, including humans. The decline in water quality was not only caused by industrial waste but was also attributed to domestic waste and agricultural activities [1,2]. The Belawan River and its catchment area were among the rivers in North Sumatra that played an important role in maintaining water availability in Medan City and its surrounding areas [3].

The Belawan watershed (DAS Belawan) covered an area of approximately 38,029.30 ha, equivalent to 92.23%, with its headwaters located at the foot of Mount Sibayak (Karo Regency) and its outlet in Belawan (Medan). The upper part of the Belawan watershed was dominated by mountainous areas (70.58%), hills (35.15%), and slopes (20.28%). Meanwhile, land use in the Belawan watershed consisted of 56.45% dryland agriculture, 10.39%

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plantations, and 9.66% settlements. Consequently, various land use activities in the Belawan watershed affected the condition of riverbanks and river ecosystems, including disruption of watershed hydrology, which resulted in erosion, landslides, flooding, and sedimentation in the downstream areas of the river [3]. In addition, these activities had an impact on water quality degradation, namely the pollution of the river [1].

Research on water quality analysis in the Belawan River had previously been conducted [4], particularly in the downstream section of the river [5]. However, the study carried out by Miranda in 2021 [4] only examined BOD and COD parameters and was not able to determine the overall pollution status of the Belawan watershed from upstream to downstream. Reports on pollution status in the Belawan watershed were most frequently recorded in the downstream area, particularly in the northern part of Medan City, which indicated the occurrence of organic pollution, heavy metals, and, more recently, microplastics [5,6]. Therefore, this study was intended to identify and report the current status of water quality in the Belawan River and its tributaries.

2 Method

2.1 Time and Location of the Study

The study was conducted from June to July 2024 in the Belawan watershed (DAS Belawan), covering 15 observation sites. These sites represented the downstream (3 points), middle stream (4 points), upstream (3 points), and tributaries (5 points).

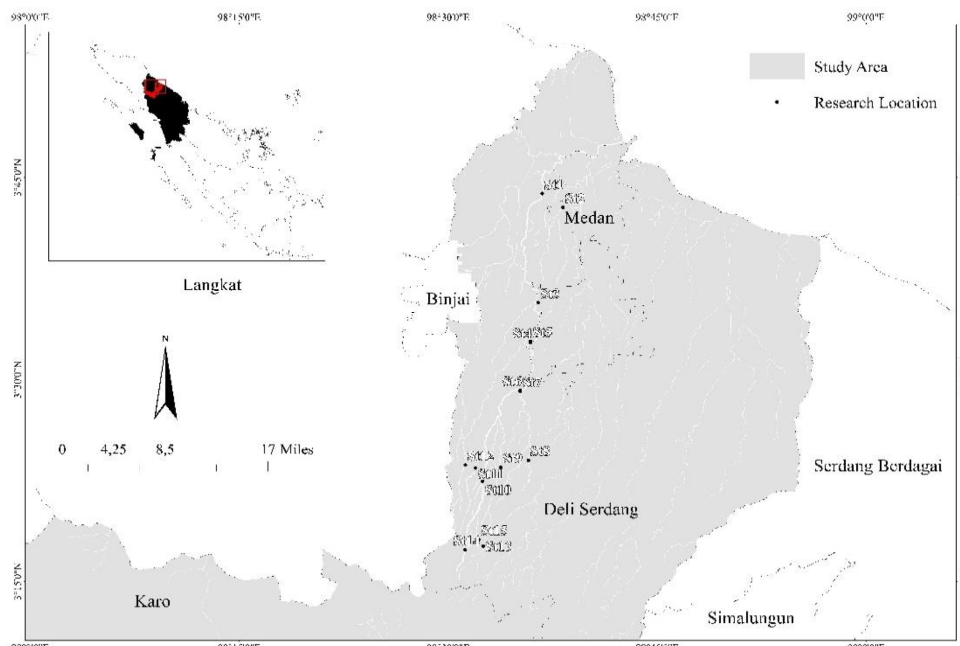

Figure 2. Location of the Belawan River

2.2 Water Measurement and Sampling

The water quality parameters measured consisted of six physical, four chemical, and one biological parameter. Some parameters were measured directly in the field, while others were analysed in the laboratory. The sampling and laboratory analysis methods referred to the standard procedures of APHA [7].

2.3 Data Analysis

The analysis of water quality data was carried out descriptively and compared with other nearby and relevant rivers or watersheds. The determination of water quality status employed the Pollution Index (PI) method, the National Sanitation Foundation – Water Quality Index (NSF/WQI), and the Canadian Council of Ministers of the Environment (CCME) Water Quality Index [2].

3 Result

3.1 Characteristics of Water Quality

The temperature measurements at 15 stations within the Belawan watershed ranged from 23.0 to 32.3 °C. As was generally observed, the middle and downstream sections recorded warmer ranges (29.0–32.3 °C) compared with the cooler upstream section (23.0–23.8 °C) (Table 1). This condition was attributed to the higher geographical elevation of the upstream area, where cooler ambient temperatures influenced the water temperature [1]. Cooler temperatures and rocky substrates (Table 1) were characteristic features of upstream river segments, which were also typically associated with stronger currents [2]. Similar conditions were also reported in various rivers across North Sumatra and surrounding areas, including the upstream section of the Wampu River, the upstream section of the Deli River [1], the upstream section of the Batangtoru River, and even the Alas-Singkil River, where upstream temperatures were recorded as low as 18 °C [2].

The upstream river segment was characterised by high oxygen concentrations (> 8.0 mg/L) and low turbidity levels (Table 1). Turbidity in the upstream section did not exceed 2 NTU, whereas in the middle and downstream sections it reached up to 11.07 NTU. The low turbidity in the upstream section was due to the rocky substrate, which resulted in minimal suspended particles, while the downstream areas with muddy or sandy substrates were more prone to resuspension [2]. This condition was also supported by lower TSS values in the upstream section (1–3 mg/L) compared with the downstream section (10–25 mg/L).

The concentrations of TDS measured in the Belawan watershed ranged between 4.9 and 198.2 mg/L. In general, TDS was higher in the downstream section compared with the upstream section, except at station 13. The elevated TDS levels in the downstream section were caused by the accumulation of dissolved substances entering the waters, particularly from domestic and household activities. Similar conditions were also observed in the Batangtoru River, the Alas-Singkil River [2], and the Deli River [1]. The high TDS values at station 13 were presumed to be associated with pollutant inputs from detergents and soaps derived from bathing activities by visitors around the station. Typically, elevated TDS levels occurred due to the presence of abundant dissolved solids, either naturally or as a result of human activities [2].

The in situ pH concentrations in the Belawan watershed ranged between 6.6 and 9.7. Overall, these pH values were within the normal range, except at station 13, where the pH reached 9.7. This relatively high value was presumed to have been caused by the presence of detergents and soaps originating from bathing activities around station 13.

Table 1. Water Quality in the Belawan Watershed

Parameters	Water Quality Standard*	Sampling Station														
		1	**2**	**3**	**4**	**5**	**6**	**7**	**11**	**8**	**9**	**10**	**12**	**13**	**14**	**15**
River Segment	**-**	**Down stream**				**Middle stream**				**Tributary**				**Upstream**		
Dissolved Oxygen/ DO (mg/l)	4	7.3	6.3	6.3	6.2	6.5	6.6	7.1	7.8	7.0	7.7	7.4	8.0	8.4	9.3	8.6
Temperature (°C)	22-28	29	30.7	32.3	32.2	30.8	29.3	29.1	29.1	29.5	28.1	29.1	29.0	23.8	23.1	23.0
pH	6-9	8.6	6.6	7.8	6.8	7.6	8.3	8.5	7.5	8.3	8.3	8.1	7.6	9.7	7.5	8.3
Turbidity (NTU)	50	3.16	11.07	3.93	2.55	2.55	2.07	3.51	2.41	2	1.99	2.84	1.61	3.25	1.19	1.21
Total Suspended Solid/TSS (mg/l)	50	10	16	25	11	12	3	5	2	2	1	3	1	2	3	1
Total Dissolved Solid/TDS (mg/l)	1000	66.1	135	66.7	57.5	57.4	54.3	53.7	39.9	58.8	4.9	47.7	39	198.2	82.2	48
Biological Oxyen Demand/BOD (mg/l)	3	5.7	10.7	5.8	5	4	4.3	4.7	7.3	4.5	4.2	23.8	6.4	6.3	6.4	3.5
Chemical Oxygen Demand/COD (mg/l)	25	12.2	20.4	12.2	10.7	10.3	9.2	10.4	15.8	9.5	9.1	50.5	14.1	13.6	13.7	11.6
Nitrate (mg/l)	10	4.1	0.4	2.9	1.5	0.4	1	0.4	0.7	0.8	0.4	0.4	0.6	0.4	1.2	0.6
Phosphate (mg/l)	0.2	0.25	2	0.26	0.2	0.19	0.43	0.26	0.17	0.3	0.15	0.29	0.14	0.08	0.11	0.03
Fecal coliform (MPN/100 ml)	1000	210.0	56.0	83.0	220	1400.0	330.0	490.0	330.0	470.0	340.0	220.0	470.0	330.0	260.0	20
Substrate	-	Sandy mud				Sand and gravel				Gravel and cobbles/rocks				Cobbles		

*[8]

The analysis of organic matter in the Belawan River watershed showed that COD concentrations ranged from 9.1 to 50.5 mg/L, while BOD values ranged from 3.2 to 23.8 mg/L. These results indicated that COD values were consistently higher than BOD values, demonstrating that COD was always greater due to the oxidation of inorganic compounds as well [2]. The nitrate analysis in the Belawan River showed concentrations between 0.4 and 4.1 mg/L. The highest nitrate concentration was observed at station 1, reaching 4.1 mg/L. This condition was likely due to the presence of fishing activities, residential settlements, and discharges of domestic wastewater in the area.

The highest phosphate concentration measured was 0.43 mg/L. This finding indicated the presence of organic waste materials in the river water. That discharges of organic waste such as detergents and the degradation of organic matter generated phosphates. One of the main factors contributing to elevated phosphate levels in water was the input of domestic waste, including detergents . Based on the investigation conducted in the Belawan River, phosphate concentrations were found to range between 0.2 and 2 mg/L. These values suggested that the phosphate content in the Belawan River exceeded the water quality standard, with both inorganic and organic forms present in solution, dust, and within the bodies of aquatic organisms [8].

Based on the investigation conducted in the Belawan River, the highest *Faecal coliform* concentration was recorded at 1,400 CFU/100 mL at Station 5. This result indicated that the river water at Station 5 experienced contamination. The presence of faecal coliform in river water tended to increase as a result of poor household sanitation. Furthermore, urbanisation and industrialisation had a significant influence on the occurrence of faecal coliform bacteria in aquatic environments [9].

3.2 Water Quality Status

Based on the results of calculations using various indices, the water quality status in the Belawan watershed was categorised as ranging from lightly polluted to good (Table 2). A good quality status was observed in the upstream section (CCME), particularly at Station 15 (Pollution Index). In contrast, the downstream section, especially at Station 2, exhibited the highest Pollution Index value, approaching a moderate status. This was attributed to the station's location, which was directly adjacent to densely populated residential areas, and the fact that Station 2 represented a tributary/canal whose water supply originated directly from urban areas. A similar condition was reported in the Deli watershed, where tributaries and canals located within the city centre displayed the poorest water quality, with some segments even classified as moderately polluted [1]. Community activities in settlements along the riverbanks, such as bathing and washing in the river, contributed significantly to river pollution due to the direct discharge of domestic wastewater into the aquatic environment [1,2].

The calculation results between the Pollution Index method and CCME, which were averaged across parameters in the downstream, middle, and upstream categories, classified the water quality status into the lightly polluted category. This occurred because both methods were fundamentally similar, as they relied on comparison factors against the same quality standards. Previous studies conducted in various types of aquatic systems, such as the Deli watershed [1], the Belawan estuary, and Anak Laut Lake [2], demonstrated similar outcomes, with values that did not differ significantly. However, when compared with the NSF-WQI method, the results showed notable differences from those of the Pollution Index and CCME. This discrepancy was due to the different standards employed in the NSF-WQI compared with those applied in the Pollution Index and CCME. Nevertheless, if the newly established water quality index categories from the Ministry of Environment and Forestry were applied [2], the NSF-WQI values yielded results consistent with those obtained using the Pollution Index. Therefore, by adopting the new categorisation from the Ministry of

Environment and Forestry, it was concluded that the Belawan watershed ranged from lightly polluted (middle, downstream, and tributaries) to good (upstream).

In general, the condition of rivers in Indonesia did not differ significantly from that of the Belawan watershed, and in fact, their water quality status frequently indicated a heavily polluted state. Rivers with water quality status ranging from lightly to moderately polluted included the Deli River [1] and the Cisadane River [10]. The Ciliwung River in Jakarta and West Java demonstrated a moderate to heavy pollution status [11,12]. The Citarum watershed in West Java was categorised as moderately to heavily polluted [13]. Overall, river pollution in Indonesia was predominantly organic in nature, with some rivers also contaminated by heavy metals [6]. Nevertheless, it was also possible that these rivers had already been affected by microplastic pollution[14]. Evidence of such pollution was reported in Jakarta Bay, into which thirteen rivers discharged, all of which had been contaminated by microplastics [15]. Similar findings were also reported in several estuaries of major rivers flowing into other large Indonesian cities, including Belawan [5].

Table 2. Water Quality Status of the Belawan Watershed

Sampling Station	**Water Quality Index Method**		
	Pollution Index	NSF-WQI	CCME-WQI
Station 1	1.77*	70.70*	
Station 2	4.35*	68.70*	75.18*
Station 3	1.78*	79.05**	
Station 4	1.54*	76.31**	
Station 5	1.22*	71.62**	70.34*
Station 6	1.95*	77.27**	
Station 7	1.47*	76.62**	
Station 11	2.11*	79.07**	
Station 8	1.41*	77.77**	
Station 9	1.27*	77.22**	79.57*
Station 10	3.98*	72.40**	
Station 12	1.92*	75.87**	
Station 13	1.91*	68.83*	
Station 14	1.89*	75.42**	86.65**
Station 15	0.97**	84.24**	

* lightly polluted; ** good

References

1. R. Leidonald, A. Muhtadi, M. A. Ashshiddiq, V. S. P. Siahaan, and B. U. Manurung, Jurnal Pengelolaan Sumberdaya Alam Dan Lingkungan (Journal of Natural Resources and Environmental Management) **15**, 669 (2025)
2. A. Muhtadi and R. Leidonald, *Limnologi : Teori, Konsep, Dan Model Pengelolaan Perairan Darat* (PT. IPB Press, Bogor, 2025)
3. Ministry of Public Works and Public Housing, *Rencana Pengelolaan Sumberdaya Air Wilayah Sungai Belawan, Ular, Padang* (Jakarta, 2021)
4. A. Mirandha, Irvan, and H. Wahyuningsih, IOP Conf Ser Earth Environ Sci **713**, 012011 (2021)
5. A. Muhtadi, R. Leidonald, A. Rahmawati, T. D. T. Merdangga, Y. Nurhamiyah, and M. R. Cordova, Egypt J Aquat Res **51**, 163 (2025)
6. L. Sulistyowati, Y. Yolanda, and N. Andareswari, Global Journal of Environmental Science and Management **9**, 885 (2023)

7. APHA, *Standard Methods for The Examination of Water and Wastewater*, 23rd ed. (American Public Health Association, American Water Works Association, and Water Environment Federation, Washington, D.C., 2017)
8. Government of the Republic of Indonesia, *Penyelenggaraan Perlindungan Dan Pengelolaan Lingkungan Hidup.* (Peraturan Pemerintah, Republik Indonesia, 2021), p. 119
9. S. Thorndahl, J. M. Nielsen, and M. R. Rasmussen, J Environ Manage **349**, 119483 (2024)
10. S. U. Purwati, N. S. Lestari, and E. L. Nasution, IOP Conf Ser Earth Environ Sci **407**, 012009 (2019)
11. D. Ratnaningsih, E. L. Nasution, N. T. Wardhani, O. D. Pitalokasari, and R. Fauzi, IOP Conf Ser Earth Environ Sci **407**, 012006 (2019)
12. J. R. Rajagukguk and D. A. Pranoto, IOP Conf Ser Earth Environ Sci **1175**, 012013 (2023)
13. P. A. Permatasari, L. F. Amalo, R. Pangestu, and M. D. Putra, Jurnal Pengelolaan Sumberdaya Alam Dan Lingkungan (Journal of Natural Resources and Environmental Management) **12**, 706 (2022)
14. A. I. S. Purwiyanto, T. Prartono, E. Riani, A. F. Koropitan, Y. Naulita, N. D. Takarina, and M. R. Cordova, Mar Pollut Bull **184**, 114117 (2022)
15. M. R. Cordova, M. R. Iskandar, D. Surinati, M. T. Kaisupy, S. P. A. Wibowo, R. Subandi, Y. I. Ulumuddin, T. Purbonegoro, D. Yogaswara, S. Y. Sani, R. Puspitasari, R. Rositasari, E. Riani, S. Zheng, X. Sun, and Z. Wang, Front Mar Sci **11**, (2024)