

RESEARCH ARTICLE



Water Quality Degradation in the Deli River Watershed, North Sumatra: Impacts of Land Use and Pollution Sources

Rusdi Leidonald, Ahmad Muhtadi, Muhammad Arif Ashshiddiq, Vania S.P. Siahaan, Bunga Ulita Manurung

Department of Aquatic Resources Management, Faculty of Agriculture, Universitas Sumatera Utara, Medan, 20155, Indonesia

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ABSTRACT

The Deli Watershed is crucial in Medan's hydrological cycle and the surrounding areas. It serves as a clean water source for Medan, but is also affected by urbanisation and industrial discharge. This study aims to assess water quality using pollution indices and spatial analysis across the Deli Watershed. Water samples were collected from the river in the watershed, North Sumatra Province, between June and July 2023. Observations were made at 46 spatial points through purposive sampling. These points represent the downstream (five points), middle (16 points), upstream (10 points), and tributaries (15 points). The pollution status of the basin was determined using the Pollution Index, the National Sanitation Foundation-Water Quality Index (NSF-WQI), the Canadian Council of Ministers of the Environment (CCME), and the SingScore Method. The spatial water pollution in the Deli Watershed varies from poor to good or excellent. The most severe river conditions are observed in the downstream parts of the Sei Sekambing and Deli sub-watersheds, characterised by moderately to poorly polluted water. Good or unpolluted river water quality was only found in 3 of 42 observation points, especially in the upper reaches of the Sembah River and the Simai Mai River. Therefore, serious steps are needed from the government to restore and rehabilitate the Deli River Basin area, namely forest areas, plantations, and tourist areas, especially in the upper reaches of the Deli River Basin, namely in the Karo and Deli Serdang Regencies.

Introduction

Watersheds are interconnected ecosystems of rivers and tributaries that flow into the sea and are bounded by hills or mountains. Rainwater in the watershed flows through rivers and eventually reaches the sea [1,2]. The river basins are divided into upstream (water-giving) and downstream (water-receiving) regions. These factors influence each other in the watershed ecosystems [3,4]. Watersheds are integral to the processes of catchment, storage, and distribution of water resources. They are vital for maintaining ecological biodiversity, serving as habitats for diverse aquatic organisms [5–8]. Moreover, watersheds significantly contribute to the socioeconomic and cultural vitality of communities by supporting transportation, agriculture, and tourism, and offer potential for renewable energy generation through the development of micro and mini hydropower systems [9–11].

The Deli Watershed covers Karo Regency, Deli Serdang, and Medan. It had an area of $\pm 353.2 \text{ km}^2$. Its upstream region is in the Deli Serdang Regency (Sibolangit) and Karo, and it flows to Belawan (Medan) [12]. The Deli Watershed plays a crucial role in the hydrological cycle of the Medan area and its surroundings. The upstream part of the Deli Basin serves as a recharge area and source of clean water for Medan [13]. The Deli River divides Medan into eastern and western regions. Historically, the Deli River served as a waterway during the era of the Deli Kingdom. However, it currently encounters challenges due to uncontrolled urban development, which has caused the riverbanks to be compressed and damaged. Land use in the upper part of the Deli Basin was dominated by farms/plantations (45%), agriculture (24.7%), and settlements (11.45%). Only 11% of Sibolangit comprises forested areas [14]. Various land-use activities in the watershed area impact the condition of riverbanks and river ecosystems. Uncontrolled land use activities can disrupt a basin's water

Corresponding Author: Rusdi Leidonald  rusdi.leidonald@usu.ac.id  Department of Aquatic Resources Management, Universitas Sumatera Utara, Medan, Indonesia.

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system, thereby causing floods and erosion [15,16]. The expansion of plantations and tourism in the upland areas of Karo and Deli Serdang has made the land vulnerable to erosion and landslides. The downstream part is vulnerable to floods due to land damage along the Deli Watershed (including the middle and downstream riverbanks) because of Medan's urban development, a metropolitan city [14,17–19].

Various human uses and activities along rivers and water catchment areas affect the quality and quantity of river water [20–22]. Changes in land use for agriculture, plantations, and settlements generally cause a decline in water quality and quantity [23]. The decline in water quality and quantity has a significant impact on productivity, carrying capacity, and the capacity of water sources. A decline in river water quality has an impact on water pollution. River pollution is caused by industrial, household/domestic, and agricultural activities that can pollute water sources with waste from these activities. The increasing burden of pollutants entering the river is caused by the habits of people around the river who dispose of both liquid and solid domestic waste. The amount of pollution is directly proportional to the increase in local population [24–26]. River pollution reduces the availability of clean water and poses a risk of spreading various diseases. Therefore, continuous research and monitoring of river water quality are necessary to ensure the availability of clean water and to prevent pollution. The Deli Watershed in Medan City is one of the sources of clean water as an intake for the Medan City and Deli Serdang local water company (*Perusahaan Daerah Air Minum*/PDAM) [17].

Various studies have been conducted on the conditions of the Deli Watershed, including land conditions and water balance. These studies include variations in land use around the Deli Watershed [14], evaluation of water availability [13], and studies of erosion and flooding [17–19]. However, research on the water habitat conditions and water quality status in Deli Watershed has not yet been reported. The latest report on water quality, especially microplastic pollution in the Deli River [27]. This study aims to assess water quality using pollution indices and spatial analysis across the Deli Watershed. This research was also conducted to monitor the condition and quality of water in the Deli Watershed as an initial step in river and river basin management, particularly in the Deli Watershed.

Materials and Methods

Study Area

Water sampling was conducted from June to July 2023 in the Watershed, North Sumatra Province, Indonesia. Observations were made at 46 spatial points using purposive sampling (Figure 1). These points represent the downstream (five points), middle (16 points), upstream (10 points), and tributaries (15 points). Water quality testing was conducted both directly at the research site (in situ) and at the Environmental Health and Disease Control Technical Institute (EHDCTI) Class I in Medan (ex situ).

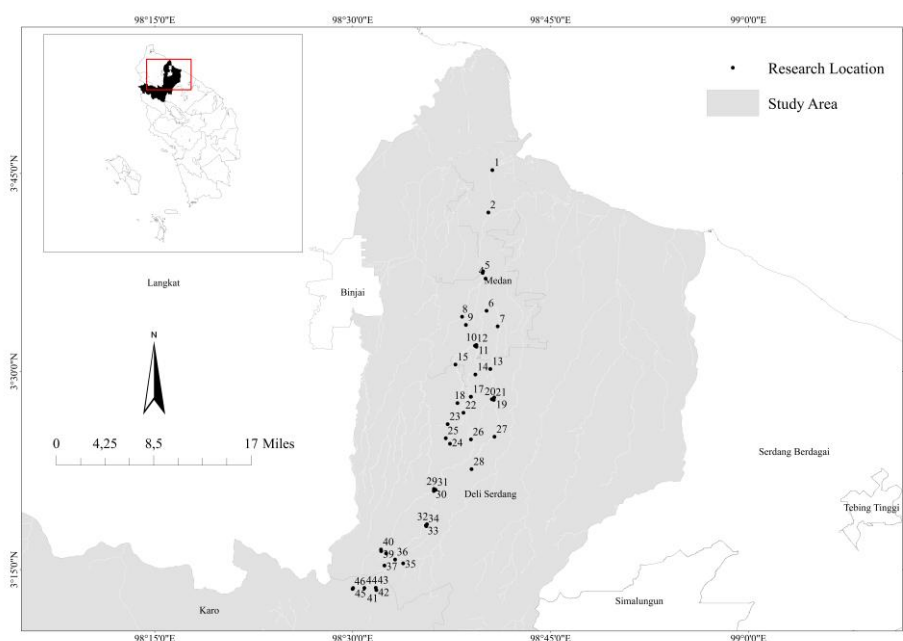


Figure 1. Map location research in the watershed.

Measurement and Water Sampling

The measured habitat and water quality parameters included 11 physical, six chemical, and two biological parameters (Table 1). Certain parameters were measured directly in the field, whereas other parameters were analyzed in the laboratory. The Medan Public Health Laboratory Center performed the laboratory analysis. Laboratory measurement and analysis methods refer to the American Public Health Association (APHA) [28–32].

Table 1. Instruments for Water Quality Parameter Measurement.

Parameters	Instrument/method	Unit	Description
Temperature	DO meter/ Lutron DO-5510	°C	In-site
Brightness	Secchi disc	m	In-site
Turbidity	Turbidity meter	NTU	In-site
Depth	Scale board	m	In-site
Current velocity	Flow meter	m/s	In-site
TDS	TDS meter	mg/L	In-site
TSS	Spectrophotometer	mg/L	Ex site
River width (wetted area)	Roll meter	m	In-site
River width	Roll meter	m	In-site
Riverbed substrate	Visual	-	In-site
pH	pH meter (Atago DPH-2)	-	In-site
DO	DO meter/Lutron DO-5510	mg/L	In-site
BOD	Incubation and Winkler titration	mg/L	Ex site
COD	Reflux method	mg/L	Ex site
Nitrate	Spectrophotometer (UV-Vis Shimadzu 1240)	mg/L	Ex site
Phosphate	Spectrophotometer (UV-Vis Shimadzu 1240)	mg/L	Ex site
Total coliform	<i>Most Probable Number</i> (MPN)	MPN/ 100 mL	Ex site
Macroinvertebrate	Family presence	-	Ex site

Data Analysis

Pollution Index (PI) Method

The PI method has been developed for specific purposes. It was then expanded for several purposes for an entire water body or a part of it. This method was determined by selecting parameters that indicate good water quality if their values are low [33,34]. The pollution index calculations are expressed in Equation 1.

$$PI = \sqrt{\frac{\left(\frac{Ci}{Li}\right)^2_{\text{maximum}} + \left(\frac{Ci}{Li}\right)^2_{\text{average}}}{2}} \quad (1)$$

Explanation:

PI : Pollution index, which is a function of Ci/Li

Li : Standard value

Ci : Measured concentration of water quality parameter (i)

The water quality is classified based on the PI Method as follows: 0–1 (good), 2–5 (lightly polluted), 6–10 (moderately polluted), and > 10 (heavily polluted) [33,34].

National Sanitation Foundation-Water Quality Index (NSF-WQI) Method

NSF-WQI is an index of water quality developed in the United States by Ott [35]. It can be used in public water bodies, including lakes, rivers, and estuaries. This index has been widely used in various countries. To determine water quality, the NSF-WQI method uses nine parameters: temperature, turbidity, pH, BOD, nitrate, total phosphate, total solids, dissolved oxygen (DO), and fecal coliforms. To calculate water quality, the sub-index (Si) value for each parameter was determined based on the measured parameter results in water samples extracted in the field (Xi) using functional sub-index curves. The NSF-WQI can be calculated using an online Water Quality Index Calculator website. The sub-index values obtained for each parameter (Si) were multiplied by the weights for each parameter (Wi). The formula used in the NSF-WQI method is as expressed in Equation (2). The water quality is classified based on the NSF-WQI as follows: 0–25 (Very poor); 26–50 (Poor); 51–70 (Fair/moderate); 71–90 (Good); 91–100 (Very good) [35].

$$NSF - WQI = \sum_{i=1}^n w_i \times S_i \quad (2)$$

Explanation:

NSF-WQI : National Sanitation Foundation Water Quality Index

W_i : Final weight of each parameter after adjustment

S_i : Sub-index of water quality for each parameter obtained from the analysis results and measurements compared with the sub-index curve

n : Number of parameters

Canadian Council of Ministers of the Environment (CCME) Method

CCME was used to obtain water quality data through benchmark comparisons. CCME has been used in Canada and other countries to determine sediment quality, drinking water quality, and agriculture. It can be calculated using the formula [36] expressed in Equation (3). Water quality is classified as follows based on the CCME method: 95–100 (excellent), 80–94 (good), 65–79 (moderate), 45–64 (marginal), and 0–44 (poor) [36].

$$CCME = 100 - \frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732} \quad (3)$$

Description:

F₁ : Number of parameters that do not satisfy the water quality standard

F₂ : Number of test results that do not satisfy the water quality standard

F₃ : Magnitude of the difference between the test results for a parameter and its standard value

1.732 : Normality value ranges from 0 to 100

SingScore Method

The SingScore method is an improved version of the Biological Monitoring Working Party (BMWP) score [37] and BMWPTHai [38] by Blakely et al. [39]. This index was initiated by the Public Utilities Board (PUB) of Singapore (the National Water Agency) based on the need for a macroinvertebrate biotic index specific to Singapore's flowing waters to monitor health and assess river ecosystems. SingScore Likely Water Quality categories are as follows: 0–79 Poor; 80–99 Fair; 100–119 Good; and > 120 Excellent [39]. The SingScore formula is as expressed in Equation (4).

$$SingScore = \frac{\sum_{i=1}^S a_i}{S} \times 20 \quad (4)$$

where S is the total number of taxa in the sample, and a_i is the tolerance value for the i^{th} taxon.

Results and Discussion

Results

Water Quality Characteristics

Generally, the Deli Watershed is characterized by sandy-gravel substrates from downstream to upstream (sub-watersheds of Patene, Babura, and Bekala) (Table 2–3). Only a few rocky substrates exist in the upper part of the Sembahe River in the Sibolangit. This causes the Deli Watershed to appear turbid because the substrate is constantly stirred, which results in higher turbidity levels. The turbidity in the Deli River ranges from 6.6 to 78.3 NTU. Clear waters were observed only on rocky substrates in the middle of the Patene sub-watershed and the upper reaches of the Sembahe River. In addition to substrate factors, land cover conditions influence turbidity: clear water locations are observed in the upper reaches of the Sembahe and Simai Mai Rivers, which are still forested. This is consistent with previous studies in the Batangtoru [5], Alasingkil watersheds [6,40], and Wampu watershed [41]. This indicates that sandy substrates exhibit higher turbidity than rock-gravel substrates. Similarly, areas with more open land cover, such as plantations or other agricultural activities, have higher turbidity than areas that are still covered by forests. Turbidity in the Deli Watershed was also caused by extensive sand mining.

Dissolved oxygen concentrations in the Deli Watershed show different concentration differences between river segments. In the upstream and middle parts, respectively, and the oxygen concentration was high. The presence of river currents and the low organic material content caused this. Currents in rivers are the main

source of oxygen in water. The concentration of organic matter in the Deli Watershed was higher downstream than in the upstream and middle regions. This can be observed from the high concentrations of BOD and COD downstream. However, in the middle part, the BOD content is also quite high because it is a residential area in Medan city. In several other cases in Indonesian rivers, the same trend is observed, with BOD and COD concentrations being higher downstream than upstream. This is an accumulation of organic material that builds up from the upland part and is carried downstream [42–44].

Phosphate measurements revealed relatively high values ranging from 0.4 to 6.0 mg/L downstream. Even in the upstream areas, the phosphate values range from 0.2 to 0.6 mg/L. The phosphate values range from 0.4 to 2.0 mg/L in the upper reaches of Kwala Bekala. This is reasonable given that the upstream areas of Patene in Brastagi are agricultural fields, whereas the upper reaches of Bekala and Babura have palm oil plantations. Lower phosphate concentrations are observed in the upper reaches of the Sembah River (forest areas: 0.1–0.15 mg/L). In this study, the total coliform levels in samples from the Deli Watershed ranged between 1,600 and 16,000 MPN/100 ml. The highest coliform value was observed at points 1 and 2 (16,000 MPN/100 ml), whereas the lowest was observed at point 15 (1,500 MPN/100 ml).

Table 2. Water conditions and quality in the Deli sub-watershed area.

Parameter	Unit	Sub-watershed						
		Deli Watershed		Petane		Simai Mai		
		Down stream	Middle stream	Middle stream	Upstream Petane	Upstream Sembah	Middle stream	Upstream
Temperature	°C	29.7–31.0	28.0–30.5	24.5–27.0	22.3–32	20.6–22.1	26	21.1
TDS	mg/L	56–86	15–102	77–165	54–779	16–178	77	70
EC	µS/cm	84–160	33–175	145–335	92–1,020	32–326	145	138
TSS	mg/L	7–26	7–10	7–9	8–20	2–8	9	4
Turbidity	NTU	37.4–78.3	6.6–32	1.73–3.96	2.56–516	0.5–1.07	2.85	0.84
Current velocity	m/s	0.5–1.5	0.5–1.3	0.5–1.2	0.3–1.5	0.3–1.1	0.2–0.5	0.3–0.6
Substrate	-	Muddy-sand	Sand-gravel	Rock	Gravel-rock	Rock	Sand	Gravel-rock
River width (wetted area)	m	20–50	8–25	10–13	0.5–2.5	2–5	10	1.5
River width	m	28–60	12–35	15–20	1.5–4	3–10	15	2.5
Brightness	m	0.2–0.4	0.2–0.5	0.2–1.1	0.3–1.5	0.2–0.5	28	0.2
Depth	m	0.2–1.5	0.2–1.3	0.2–1.1	0.2–1.5	0.2–0.5	28	0.2
Surrounding land	-	Settlement	Settlement-agriculture	Farm/plantation	Farm/tourism	Forest	Farm	Forest
pH	-	6.0–8.0	7.6–8.7	8.2–8.3	5.5–7.3	7.6–8	8.7	8
DO	mg/L	2.7–4.1	7.1–8.3	9.0–9.7	6.1–8.3	9.2–8.8	10	9.4
BOD	mg/L	12.3–18.1	5.4–8.2	4.3–5.8	2.4–15	1.5–4.3	4.5	2.2
COD	mg/L	41.2–65	17.3–30.3	15.6–46.7	10–35	5–14.3	15.6	10
Nitrate	mg/L	3.2–5.4	0.4–5.8	2.1–3.4	1.7–3.8	1.5–2.5	2.3	1.5
Phosphate	mg/L	0.4–1.0	0.1–0.4	0.1–0.4	0.2–0.6	0.1–0.15	0.16	0.1
Total coliform	MPN/100 ml	16,000	1,700–16,000	1,500–1,700	500–1,600	0–1,700	1,500	500

Table 3. Water conditions and quality in the Deli sub-watershed area.

Parameter	Unit	Sei Sekambing	Babura	Bekala	Sei Sekambing	Babura
		Middle stream	Middle stream	Upstream	Middle stream	Middle stream
Temperature	°C	30.2–30.3	28.9–31.1	26.0–29.3	30.3–31.0	26.0–26.5
TDS	mg/L	149–175	88–96	101–104	99–102	60–104
EC	µS/cm	225–266	168–184	198–206	168–200	110–204
TSS	mg/L	18–25	16–21	12–18.3	18–27	13–18
Turbidity	NTU	59.3–78.3	21.5–44.1	19.3–93.3	49.1–56.3	19.3–23.7
Current velocity	m/s	0.1–0.4	0.2–0.8	0.2–0.7	0.1–0.7	0.2–0.5
Substrate	-	Concrete	Sand-gravel	Gravel-rock	Sand-gravel	Gravel-rock
River width (wetted area)	m	6.5–13	3.5–11	5–13	11–15	6–7
River width	m	11.8–18	5–13	10–20	15–18	10–12
Brightness	m	0.5–0.6	0.2–0.3	0.1–0.2	0.2–0.4	0.2–0.3
Depth	m	0.1–0.9	0.2–0.7	0.1–0.3	0.2–0.8	0.2–0.5

Parameter	Unit	Sei Sekambing	Babura	Bekala	Sei Sekambing	Babura
		Middle stream	Middle stream	Upstream	Middle stream	Middle stream
Surrounding land	-	Settlement	Settlement	Farm	Settlement-agriculture	Farm/plantation
pH	-	6.0–6.1	6.9–7.8	6.2–7.8	6.1–6.3	6.2–6.7
DO	mg/L	2.4–3.1	5.2–8.3	5.8–8.2	3.5–4.1	6.8–8.6
BOD	mg/L	15.3–18.9	7.5–19.8	5.5–21.0	15.6–18.4	21.0–22.0
COD	mg/L	45–75	15–80	18–80	40–65	77–80
Nitrate	mg/L	0.4–0.7	4.0–5.6	2.5–4.5	0.3–3.8	2.9–4.0
Phosphate	mg/L	0.3–6.0	0.21–0.5	0.4–1.1	0.2–0.4	0.4–2.0
Total coliform	MPN/100 ml	15,000–16,100	1,700	1,700	1,700	1,700

Water Quality Status

It is evident from the calculation results of the various water quality indices and bioindicator methods that the spatial conditions of the water bodies in the Deli River Watershed vary from poor to good or very good (Table 4). The worst river conditions were observed in the Sei Sekambing sub-watershed, with water status ranging from moderately polluted to poor. Field observations also indicate that the condition of the Sei Sekambing sub-watershed can be considered poor. It is characterized by an unpleasant smell and black water. The polluted condition of the Sei Sekambing sub-watershed is reasonable because its headwaters do not reach the Karo Highlands/Sibolangit area, but only in the northern part of Medan City. This causes the water flow to deviate from normal, similar to other sub-watersheds. The Sei Sekambing sub-watershed appears to be a more precise drainage channel for urban waste in Medan. In the downstream part of the Deli River Watershed, the water conditions displayed marginal pollution (CCME method/water quality standard class II) to poor conditions (NSF-WQI and Sing score). The PI method indicates marginal pollution (water quality standard class II). The statuses differed owing to variations in several parameters calculated for the various indices. In the downstream and middle parts of the Deli River, where turbidity levels were high, NSF WQI measurements were significantly affected. However, in the PI and CCME methods, turbidity is not included in the calculations because the turbidity parameters do not have standardized values according to regulations in Indonesia [45]. Based on the SingScore method, focusing on macroinvertebrates as bioindicators, only a group of molluscs that were highly tolerant to pollutants was observed. This condition belongs to the poor category according to the SingScore method [39].

Table 4. Pollution status of the Deli River Watershed, North Sumatra Province.

Sub-watershed	Segment	Calculation method			
		PI*	NSF-WQI	CCME*	SingScore
Deli Watershed	Down stream	Lightly polluted (3.07–3.74)	Poor (36.61–44.21)	Marginal (65)	Poor (20–40)
	Middle stream	Lightly polluted (2.63–3.62)	Poor (45.18–48.06)	Marginal (78)	Fair (86.67–100)
Sei Sekambing	Middle stream	Moderately polluted (5.15–6.16)	Poor (36.61–37.01)	Poor (40)	Poor (20–40)
Babura	Middle stream	Lightly polluted (2.57–3.82)	Fair/moderate (55.12–63.93)	Fair (60)	Fair (90–100)
	Upstream	Lightly polluted (2.46–3.39)	Fair/moderate (62.46–64.58)	Fair (65)	Good (112–120)
Bekala	Middle stream	Lightly polluted (3.61–3.70)	Fair/moderate (60.28–65.20)	Fair (62)	Fair (86.67–100)
	Upstream	Lightly polluted (3.61–3.70)	Fair/moderate (57.97–70.27)	Fair (70)	Good (108–120)
Petane	Upstream Sembahe	Lightly polluted (1.40–3.29)	Fair/moderate (58.75–66.42)	Fair (75)	Good (112–120)
	Upstream Petane	Good (0.58–0.67)	Good (81.61–82.09)	Good (90)	Excellent (126–190)
Simai Mai	Middle stream	Lightly polluted (1.32–2.36)	Fair/moderate (57.47–67.77)	Fair (77)	Fair (86–90)
	Upstream	Good (0.70–0.76)	Good (81.60–82.08)	Good (85)	Excellent (130–170)

*Quality standards refer to class II [45].

In the middle part of the Deli River Watershed, water conditions range from lightly polluted to poor. This poor condition is based on the NSF-WQI method. Turbidity plays a role in determining whether the middle section belongs to the poor category. However, when observed in the field, the middle section of the Deli River should likely be categorized as moderate. This is because water flow and river discharge, which can help "cleanse" pollutants, still exist. This provides habitat for aquatic organisms. This is also evident from field observations, where native river fish are found in the middle part of the Deli River. *Mystacoleucus marginatus* was abundant in this area. Catfish (*Mystus*) are still commonly observed and are popular among fishermen for fishing activities in the Deli River. This was supported by observations performed using the SingScore method. This places the middle part of the Deli River in the fair category. The water quality status also displays light pollution in other segments of the Deli River Watershed, namely the Babura, Bekala, and Upstream Petane Sub-watersheds. Pollutants in these river segments include organic matter, phosphate, and total coliforms. This is reasonable because these river segments are located in agricultural, residential, and tourist areas. River segments classified as good/very good in the Deli River Watershed were observed in the headwaters of the Sembahe and Simai Mai Rivers. This is because of the natural conditions of the rivers in forested areas.

Discussion

According to a report from the Watershed Management Agency II (RBMA) [46], the Deli Watershed is divided into five sub-watersheds: the Deli Sub-watershed, Sei Sekambing, Babura, Bekala, Patene, and Simai Mai (Table 2). The Deli Sub-watershed includes an urban area and part of the northern region. Residential and plantation areas characterize it. It constitutes the downstream and middle streams of the watershed, with river conditions constrained by settlements. The substrate characteristics were silt and sandy mud from an estuary downstream of Medan Labuhan. In certain areas, riverbanks are constructed using retaining walls. The habitat characteristics and water quality in the middle part of the Deli Sub-watershed are characterized by sandy and gravelly sandy substrates. According to a recent report, land cover in the watershed is dominated by plantations (45%), agriculture (24.7%), and settlements (11.45%). Only 11% is designated as forested area in the Sibolangit region [14]. This is the primary reason that the Deli watershed becomes turbid directly, particularly during the rainy season. Agricultural activities contribute to nutrient pollution (particularly phosphate) in the Deli Watershed [44].

In general, it can be stated that the Deli River Watershed is polluted, except for the headwaters of the Sembahe and Simai Mai Rivers. The pollution sources in the Deli River Watershed originate from community activities in the upstream and middle parts of the watershed, mainly agricultural, plantation, and tourism. In downstream areas, pollution results from the accumulation of upstream pollutants combined with urban community activities. Domestic waste from urban areas, containing detergents, household waste, and industrial waste, increases the BOD and COD values and pathogenic bacteria (which are discharged directly into water bodies). The abundance of coliform bacteria indicates a biological deterioration in the environmental conditions of the river because coliform bacteria serve as indicators of water pollution [47,48]. The presence of coliform bacteria in water indicates the presence of pathogenic microbes, which are hazardous to human health. The high coliform bacterial content in the water samples can result in the presence of other pathogenic bacteria. This is because coliforms are positively correlated with other pathogenic bacteria. The higher the level of coliform bacterial contamination, the higher is the risk of the presence of other pathogens commonly observed in human and animal feces. *Escherichia coli* is a pathogenic bacterium that may be present in contaminated water. It is a microbe that causes symptoms such as diarrhea, fever, abdominal cramps, and vomiting [49–51].

Several rivers and watersheds in Indonesia have varying levels of pollution. The Belawan River in North Sumatra displays mild to moderate pollution [42,43]. The Ciliwung River in Jakarta and West Java exhibits moderate to severe pollution [44,52]. The Cisadane River in Banten is moderately polluted [53]. The Citarum River Watershed in West Java belongs to the category of moderate-severe pollution [20,21,54]. In general, river pollution in Indonesia comprises organic pollution, with certain cases involving heavy metals [20,48–50]. Meanwhile, using several methods to strengthen the results obtained, especially in the middle and upper reaches of the river, the difference was only noticeable downstream, where a slight difference was observed. This also occurs because of the quality standards, where if Class I is used in the IP and CCME methods, the results are close to those of the NSF-WQI and SingScore. This indicates that the Deli River is no longer classified as a Class I (clean water source), except for the upper reaches of the Sembahe River.

The quality status of the Deli Watershed and its polluted tributaries is a warning to the community and the government. This is based on the Deli Watershed water being used by the community in the upstream and middle areas as a source of clean water; even the local water company (PDAM) utilizes it as one of the sources of clean water in Medan. It is known that organics, including total coliforms, pollute the Deli River water and pose a health risk. Water contaminated with coliforms can serve as a vector for human diseases. Therefore, real action is needed from the government to restore and improve the Deli watershed ecosystem. Conversion and land clearing in the upper part of this river basin are significant issues that contribute to habitat destruction and river pollution. It is necessary to reorganize the upper lands that have been converted into plantations and tourist areas. This land clearing causes erosion and increases the river turbidity, resulting in frequent flooding. Controlling the use of river boundaries is also a step that needs to be taken by the government, considering that the banks of the Deli watershed, especially the Medan City area, are becoming uncontrolled.

Conclusions

Spatially, the condition of the waters in the Deli River Basin can be said to be in a worrying condition. The downstream part of the Deli River is in an unhealthy state. The downstream part of the Deli River is included in the category of lightly polluted (PI method with a score of 3.07–3.74 and CCME with a score of 65, according to class II water quality standards) to bad (NSF-WQI with a score of 36.61–44.21 and Singscore with a score of 20–40). The middle and upstream segments of the Deli River Basin also exhibit polluted water conditions, as indicated by the same four methods, which all show the same status. Good water status was still found in the upstream areas of the Sembahe River (Petane Sub-DAS) (IP Score 0.58–0.67; NSF-WQI Score 81.61–82.09; CCME Score 75–90; Singscore Score 126–190) and Simai Mai (IP Score 0.7–0.76; NSF-WQI Score 81.60–82.08; CCME Score 77–85; Singscore Score 130–170).

Author Contributions

RL: Conceptualization, Data Curation, Funding Acquisition, Methodology, and Writing - Original Draft; **AM:** Investigation, Methodology, Supervision, and Writing - Review & Editing; **MAS:** Investigation and Methodology; **PSPS:** Investigation and Methodology; **BUM:** Investigation and Methodology.

Conflicts of Interest

There are no conflicts to declare.

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References

1. Stanford, J.A.; Alexander, L.C.; Whited, D.C. Riverscapes. In *Methods in Stream Ecology*; Hauer, F.R., Lamberti, G.A., Eds.; Elsevier: Cambridge, MA, 2017; Vol. 1, pp. 3–19, ISBN 978-0-12-416558-8.
2. Dodds, W.K.; Whiles, M.R. *Freshwater Ecology: Concepts and Environmental Applications of Limnology*, 3rd ed.; Academic Press: Cambridge, MA, 2019; ISBN 978-0-12-813255-5.
3. Nepal, S.; Flügel, W.-A.; Shrestha, A.B. Upstream-Downstream Linkages of Hydrological Processes in the Himalayan Region. *Ecol Process.* **2014**, *3*, 1–16, doi:10.1186/s13717-014-0019-4.
4. Ha, D.T.T.; Kim, S.-H.; Bae, D.-H. Impacts of Upstream Structures on Downstream Discharge in the Transboundary Imjin River Basin, Korean Peninsula. *Applied Sciences* **2020**, *10*, 1–15, doi:10.3390/app10093333.
5. Muhtadi, A.; Leidonald, R.; Desrita. Habitat Characteristics and Water Quality Status in the Batangtoru Watershed, North Sumatra Province, Indonesia. *IOP Conf. Ser. Earth Environ. Sci.* **2020**, *454*, 012092, doi: 10.1088/1755-1315/454/1/012092.

6. Muhtadi, A.; Leidonald, R.; Fauzia, A.D. Habitat Characteristics and Biodiversity of Nekton in the Alas-Singkil River Basin, Northern Sumatra, Indonesia. *Biodiversitas* **2023**, *24*, 3673–3689, doi:10.13057/biodiv/d240704.
7. Desrita; Muhtadi, A.; Leidonald, R.; Sibagariang, R.D.; Nurfadillah. Biodiversity of Nekton in Batangtoru River and Its Tributaries in North Sumatra, Indonesia. *Biodiversitas* **2020**, *21*, 2344–2352, doi:10.13057/biodiv/d210602.
8. Desrita; Muhtadi, A.; Tamba, I.S.; Ariyanti, J.; Sibagariang, R.D. Community Structure of Nekton in the Upstream of Wampu Watershed, North Sumatra, Indonesia. *Biodiversitas* **2018**, *19*, 1366–1374, doi:10.13057/biodiv/d190424.
9. Shrestha, J.P.; Pahlow, M.; Cochrane, T.A. Development of a SWAT Hydropower Operation Routine and Its Application to Assessing Hydrological Alterations in the Mekong. *Water* **2020**, *12*, 1–25, doi:10.3390/W12082193.
10. Lange, K.; Meier, P.; Trautwein, C.; Schmid, M.; Robinson, C.T.; Weber, C.; Brodersen, J. Basin-Scale Effects of Small Hydropower on Biodiversity Dynamics. *Front Ecol Environ.* **2018**, *16*, 397–404.
11. Melesse, A.M.; Abtew, W.; Setegn, S.G. *Nile River Basin: Ecohydrological Challenges, Climate Change and Hydropolitics*; Springer: Cham, Switzerland, 2014; Vol. 53; ISBN 978-3-319-02720-3.
12. Government of the North Sumatra Province. Peraturan Daerah Provinsi Sumatera Utara Nomor 2 Tahun 2017 tentang Rencana Tata Ruang Wilayah Provinsi Sumatera Utara Tahun 2017–2037; Government of the North Sumatra Province: Medan, ID, 2017;
13. Marselina, M.; Hanie, M.Z.; Nurhayati, S.A. Understanding and Mitigating Water Resource Decline in the Deli Watershed: A Comprehensive Analysis. *H2Open Journal* **2024**, *7*, 1–22, doi:10.2166/h2oj.2023.074.
14. Verawaty, I.; Widiatmaka; Firmansyah, I. Modeling of Land Use and Cover Changes (LUCC) in Deli Serdang Regency, North Sumatra Province. *Jurnal Pengelolaan Sumberdaya Alam dan Lingkungan (Journal of Natural Resources and Environmental Management)* **2023**, *13*, 237–251, doi:10.29244/jpsl.13.2.237-251.
15. Razali, A.; Ismail, S.N.S.; Awang, S.; Praveena, S.M.; Abidin, E.Z. Land Use Change in Highland Area and Its Impact on River Water Quality: A Review of Case Studies in Malaysia. *Ecol Process.* **2018**, *7*, 1–17, doi:10.1186/s13717-018-0126-8.
16. Cheng, Z.; Yu, B. Effect of Land Clearing and Climate Variability on Streamflow for Two Large Basins in Central Queensland, Australia. *J Hydrol (Amst)*. **2019**, *578*, 1–18, doi:10.1016/j.jhydrol.2019.124041.
17. Agustin, U.; Siregar, M.A.P. Frequency Analysis of Deli River Flood Distribution Plan Using the Gumbel Probability Distribution Method. *Sinkron: Jurnal Dan Penelitian Teknik Informatika* **2023**, *7*, 1474–1485, doi:10.33395/sinkron.v8i3.12543.
18. Hutapea, S. The Damage of Deli River Watershed Causing Flood, Medan, Indonesia. *Global Journal of Agricultural Research* **2018**, *6*, 32–42.
19. Wardhana, A.; Samsuri; Aththorick, T.A. Analysis of Flood Inundation Vulnerability to the Deli Watershed of North Sumatra Using Remote Sensing and GIS Techniques. *Journal of Environmental and Development Studies* **2024**, *5*, 11–24, doi:10.32734/jeds.v5i01.12340.
20. Djuwita, M.R.; Hartono, D.M.; Mursidik, S.S.; Soesilo, T.E.B. Pollution Load Allocation on Water Pollution Control in the Citarum River. *Journal of Engineering and Technological Sciences* **2021**, *53*, 182–196.
21. Ramadhiani, A.F.; Suharyanto. Analysis of River Water Quality and Pollution Control Strategies in the Upper Citarum River. *IOP Conf. Ser. Earth Environ. Sci.* **2021**, *623*, 1–8, doi:10.1088/1755-1315/623/1/012052.
22. Gumelar, A.R.; Alamsyah, A.T.; Gupta, I.B.H.; Syahdanul, D.; Tampi, D.M. Sustainable Watersheds: Assessing the Source and Load of Cisadane River Pollution. *International Journal of Environmental Science and Development* **2017**, *8*, 484–488, doi:10.18178/ijesd.2017.8.7.1001.
23. Souter, N.J.; Shaad, K.; Vollmer, D.; Regan, H.M.; Farrell, T.A.; Arnaiz, M.; Meynell, P.-J.; Cochrane, T.A.; Arias, M.E.; Piman, T.; et al. Using the Freshwater Health Index to Assess Hydropower Development Scenarios in the Sesan, Srepok and Sekong River Basin. *Water* **2020**, *12*, 1–32, doi:10.3390/w12030788.

24. Howard, M. Water Scarcity: 8 Facts You Need to Know. 2025. Available online: <https://www.worldwildlife.org/stories/water-scarcity-8-facts-you-need-to-know> (accessed on 26 January 2025).
25. Liyanage, C.P.; Yamada, K. Impact of Population Growth on the Water Quality of Natural Water Bodies. *Sustainability* **2017**, *9*, 1–14, doi:10.3390/su9081405.
26. Boretti, A.; Rosa, L. Reassessing the Projections of the World Water Development Report. *npj Clean Water* **2019**, *2*, 1–6, doi:10.1038/s41545-019-0039-9.
27. Harpah, N.; Ageng, P.; Addauwiyah, R.; Rizki, A.; Perdana, Z.; Suryati, I.; Leonardo, R.; Husin, A.; Faisal, M. Microplastic Pollution in Deli River Medan. *IOP Conf. Ser. Earth Environ. Sci.* **2021**, *802*, 012019, doi:10.1088/1755-1315/802/1/012019.
28. Baker, L.M. Introduction. In *Standard Methods for The Examination of Water and Wastewater*, 23rd ed.; Baird, R.B., Eaton, A.D., Rice, E.W., Eds.; American Public Health Association, American Water Works Association, Water Environment Federation: Washington, DC, USA, 2017; ISBN 9780875532875.
29. Baxter, T.E. Physical and Aggregate Properties. In *Standard Methods for The Examination of Water and Wastewater*, 23rd ed.; Baird, R.B., Eaton, A.D., Rice, E.W., Eds.; American Public Health Association, American Water Works Association, Water Environment Federation: Washington, DC, USA, 2017; ISBN 9780875532875.
30. Lipps, W.C. Inorganic Nonmetallic Constituents. In *Standard Methods for The Examination of Water and Wastewater*, 23rd ed.; Baird, R.B., Eaton, A.D., Rice, E.W., Eds.; American Public Health Association, American Water Works Association, Water Environment Federation: Washington, DC, USA, 2017; ISBN 9780875532875.
31. Parnell, R.S. Aggregate Organic Constituents. In *Standard Methods for The Examination of Water and Wastewater*, 23rd ed.; Baird, R.B., Eaton, A.D., Rice, E.W., Eds.; American Public Health Association, American Water Works Association, Water Environment Federation: Washington, DC, USA, 2017; ISBN 9780875532875.
32. Braun-Howland, E.B.; Hunt, M.E. Microbiological examination. In *Standard Methods for The Examination of Water and Wastewater*, 23rd ed.; Baird, R.B., Eaton, A.D., Rice, E.W., Eds.; American Public Health Association, American Water Works Association, Water Environment Federation: Washington, DC, USA, 2017; ISBN 9780875532875.
33. Ministry of Environment. Keputusan Menteri Lingkungan Hidup Nomor 115 Tahun 2003 Tentang Pedoman Penentuan Status Mutu Air; Ministry of Environment Republic of Indonesia: Jakarta, ID, 2003;
34. Ministry of Environment and Forestry. Peraturan Menteri Lingkungan Hidup Dan Kehutanan Nomor 27 Tahun 2021 tentang Indeks Kualitas Lingkungan Hidup; Ministry of Environment and Forestry Republic of Indonesia: Jakarta, ID, 2021;
35. Ott, W.R. *Environmental Indices: Theory and Practice*; Ann Arbor Science Publishers: Ann Arbor, Michigan, USA, 1978; ISBN 9780250401918.
36. CCME. *Canadian Water Quality Guidelines for the Protection of Aquatic Life: CCME Water Quality Index User's Manual 2017 Update*; Canadian Council of Ministers of the Environment (CCME): Winnipeg, Canada, 2017;
37. National Water Council. *River Quality: The 1980 Survey and Future Outlook*; National Water Council: London, UK, 1981; ISBN 9780901090362.
38. Mustow, S.E. Biological Monitoring of Rivers in Thailand: Use and Adaptation of the BMWP Score. *Hydrobiologia* **2002**, *479*, 191–229, doi:10.1023/A:1021055926316.
39. Blakely, T.J.; Eikaas, H.S.; Harding, J.S. The Singscore: A Macroinvertebrate Biotic Index for Assessing the Health of Singapore's Streams and Canals. *Raffles Bulletin of Zoology* **2014**, *62*, 540–548.
40. Muhtadi, A.; Aldiano, R.; Khairunnisa; Leidonald, R. Morphometric Characteristics of the Alas-Singkil Drainage Basins. *IOP Conf. Ser. Earth Environ. Sci.* **2022**, *977*, 012090.
41. Muhtadi, A.; Dhuha, O.R.; Desrita; Siregar, T.; Muammar, M. Habitat Conditions and Diversity of Necton in Catchman Area of Wampu River, Langkat Regency, North Sumatra Province. *Depik* **2017**, *6*, 90–99, doi:10.13170/depik.6.2.5982.

42. Pane, Y.; Ridwan, F.M.; Hassan, Z.; Sembiring, D.S.P.S. Analysis of Water Pollution Problem Belawan Waters. *IOP Conf. Ser. Earth Environ. Sci.* **2023**, *1135*, 012027, doi:10.1088/1755-1315/1135/1/012027.
43. Mirandha, A.; Irvan; Wahyuningsih, H. Spatial Distribution of Water Quality in Belawan River, North Sumatra. *IOP Conf. Ser. Earth Environ. Sci.* **2021**, *713*, 012011, doi:10.1088/1755-1315/713/1/012011.
44. Rajagukguk, J.R.; Pranoto, D.A. Research on The Impact of Ciliwung River Water on The Surrounding Environment in The DKI Jakarta Area. *IOP Conf. Ser. Earth Environ. Sci.* **2023**, *1175*, 012013, doi:10.1088/1755-1315/1175/1/012013.
45. Government of the Republic of Indonesia. Peraturan Pemerintah Nomor 22 Tahun 2021 tentang Penyelenggaraan Perlindungan dan Pengelolaan Lingkungan Hidup; Government of the Republic of Indonesia: Jakarta, ID, 2021;
46. Ministry of Public Works and Housing. *Rencana Pengelolaan Sumberdaya Air Wilayah Sungai Belawan-Ular-Padang*; Ministry of Public Works and Housing Republic of Indonesia: Jakarta, ID, 2021;
47. Seo, M.; Lee, H.; Kim, Y. Relationship between Coliform Bacteria and Water Quality Factors at Weir Stations in the Nakdong River, South Korea. *Water* **2019**, *11*, 1–16, doi:10.3390/w11061171.
48. Some, S.; Mondal, R.; Mitra, D.; Jain, D.; Verma, D.; Das, S. Microbial Pollution of Water with Special Reference to Coliform Bacteria and Their Nexus with Environment. *Energy Nexus* **2021**, *1*, 1–9, doi:10.1016/j.nexus.2021.100008.
49. Susanti, E. Risk Factors for Diarrhea Cases in Communities Living Along Deli River, North Sumatera. *Journal of Epidemiology and Public Health* **2019**, *4*, 47–54.
50. Shrestha, S.; Aihara, Y.; Yoden, K.; Yamagata, Z.; Nishida, K.; Kondo, N. Access to Improved Water and Its Relationship with Diarrhoea in Kathmandu Valley, Nepal: A Cross-Sectional Study. *BMJ Open* **2013**, *3*, e002264, doi:10.1136/bmjopen-2012-002264.
51. Elder, L.; Funfrock, J.; Castro, E.; Lamichhane-Khadka, R. Assessing Biosocial Vectors in Water Contamination, the Incidence of Water-Borne Illnesses, and Insecurity in Kathmandu, Nepal. *J Water Health* **2024**, *22*, 1794–1807, doi:10.2166/wh.2024.095.
52. Ratnaningsih, D.; Nasution, E.L.; Wardhani, N.T.; Pitalokasari, O.D.; Fauzi, R. Water Pollution Trends in Ciliwung River Based on Water Quality Parameters. *IOP Conf. Ser. Earth Environ. Sci.* **2019**, *407*, 012006, doi:10.1088/1755-1315/407/1/012006.
53. Purwati, S.U.; Lestari, N.S.; Nasution, E.L. Water Quality Assessment of Cisadane River Using Pollution Indicator Parameters. *IOP Conf. Ser. Earth Environ. Sci.* **2019**, *407*, 012009.
54. Permatasari, P.A.; Amalo, L.F.; Pangestu, R.; Putra, M.D. Pollution Load Capacity in the Downstream Citarum Watershed: 4 Years after Citarum Harum Program. *Jurnal Pengelolaan Sumberdaya Alam dan Lingkungan (Journal of Natural Resources and Environmental Management)* **2022**, *12*, 706–719, doi:10.29244/jpsl.12.4.706-719.