

Phytoplankton community as bioindicator of fertility in belawan river

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Abstract Belawan River is an important river for the Medan residents and its surroundings. It serves as the main raw material for the local drinking water company, as well as domestic, industrial, hotel and tourism. Many human activities had led to the declining condition of water in the river throughout the year. One way to approach the concept of bioindicator is by knowing Abundance, Relative Abundance, Frequency of Attendance, equitability, dominance, and diversity of the phytoplankton itself. Results indicated that the phytoplankton community was from 3 different classes: Chlorophyceae, Bacillariophyceae, and Cyanophyceae. Phytoplankton individual abundance was around 2612 to 17755 ind / L. The diversity index was around 2.15 to 2.58, which is considered to have low to moderate diversity with high pollution level. Equitability Index was approaching 0, with relatively high domination from *Sphaeroplea* and *Asterionella*. The water quality that influences the diversity of phytoplankton as bioindicator was dissolved oxygen.

Keywords: Aquatic biota, Sumatera Utara, water quality

1. Introduction

Belawan River is the main river that crosses through Medan. Its flow passes through human residences, industries, electric steam power plant, local water company and aquaculture. With those activities around, waste water is often directly discharged into the water body, and thus can cause a negative impact to the aquatic environment. The utilization of the river itself as a waste water disposal site can cause changes in environmental factors that will be bad for the life of its biota. The quality change in water can greatly affect the life of the biota living in it.

Belawan River is an important river for the people of Medan and its surroundings. The local water drinking company even uses it as a main source of the raw material. Water pollution increases the cost for water treatment, as dissolving pollutants will undergo a longer process with higher cost, or else the quality of drinking water will decrease.

Biota who spends their lives in Belawan River, such as phytoplankton, is a producer in the water and their productivity, can be used as environmental bioindicator. By this nature, environmental changes can heavily affect the abundance and diversity of aquatic biota. This abundance and diversity itself are highly dependent on their tolerance and sensitivity to environmental change. They require a certain minimum amount of oxygen in order to support their lives [1].

Changes in the quality of water are closely related to the potential water viewed from the abundance of phytoplankton. The presence of phytoplankton in waters can provide information about



aquatic conditions. Phytoplankton can be used as an indicator to evaluate the quality and fertility level of a water body. Phytoplankton gives the highest contribution in term of oxygen in the water. The ability of phytoplankton as the initial binding of solar energy makes phytoplankton play an important role in the life of a water body.

The existence of phytoplankton can be used as an indicator of the quality of a water body, describing the number of phytoplankton species living in the water as well as the dominating species, the presence of phytoplankton that can live from blooming substances, can give a picture of the actual state of the water.

The use of aquatic organisms such as phytoplankton as a water bioindicator has several advantages, such as (a) providing relevant information of existing water quality conditions and can be done in an easy and relatively short time; (b) provides an overview of self purification in anaerobic or aerobic circumstances and may recognize toxic effects on the structure of the existing organisms; (c) provide important information, not only on pollution caused by waste water in aquatic environment, but also to complete the special factor, that is, the change of organism's life structure as a result of the existence of various organisms in the water; And (d) provide an overview of the state of water quality over a relatively long period, despite periodic changes. Thus, it is necessary to conduct a research entitled Phytoplankton Community as Bioindicator of Fertility In Belawan River.

This study aims to see the phytoplankton community as a bioindicator of the quality of Belawan River waters with various approaches, namely:

- (1) to know the structure of the phytoplankton community including abundance, diversity, equitability and dominance of phytoplankton.
- (2) the relationship between phytoplankton and water quality.
- (3) to know the water pollution by using phytoplankton as bioindicator.

2. Methods

Sampling was conducted in August-September 2015. Five sample locations were picked based on the difference of community activities with 3 repetitions, from upstream to estuary site of Belawan river

Station I	Salam Tani Village, Pancur Batu Sub-district, Deli Serdang District	No activity/ Upstream Control
Station II	Sunggal Kanan Village, Sunggal Sub-district, Deli serdang District	Habitation, domestic
Station III	Kampung Lalang Village, Sunggal Sub-district, Deli Serdang District	Market, Hotel
Station IV	Kelambir Village, Hamparan Perak Sub-district, Deli Serdang District	Soy industries, Paper industries
Station V	Sicanang Village, Medan Belawan Sub-district, Medan Belawan City	Downstream (estuary)

2.1. Water Quality Sampling

From the measured water quality can be seen in the following table:

No	Water quality	Instrument	Place of measurement
1.	Temperature (° C)	Thermometer	In-situ
2.	Light Penetration (m)	Secchi disk	In-situ
3.	Light intensity (cd)	Luxmeter	In-situ
4.	Flow Rate (sec / m)	Manual	In-situ
5.	pH	pH meter	In-situ
6.	DO (Dissolved Oxygen)	Winkler Method	In-situ
7.	BOD	Winkler & incubation Method	Laboratory
8.	COD	Reflux Method	Laboratory

2. 2. *Phytoplankton sampling*

Samples were taken using 5-liter bucket for 5 times using plankton net. Samples trapped in the plankton net was poured into the film bottle, then two drops of Lugol were added. Plankton was observed under a microscope and identified using the reference books [2,3,4,5]. Abundance (K), Relative Abundance (KR), Presence Frequency (PF), Equitability (E), Dominance (D), and Diversity (H) of the phytoplankton were then measured and analyzed in order to see the current pollution level of the Belawan river.

2.3. *Data Analysis*

Abundance (A)

$$A = \frac{T}{L} \times \frac{P}{p} \times \frac{V}{v} \times \frac{1}{W} \quad (1)$$

With: A = Abundance of plankton per liter
 T = Surface Area of Haemocytometer
 L = Area of view
 P = Number of enumerated Plankers
 p = Number of field observed
 V = The volume of plankton concentration in the bucket
 v = Volume of concentration under the cover glass
 W = The volume of the medium water filtered with plankton net

Relative Abundance (RA)

$$RA = \frac{n_i}{\sum N} \times 100\% \quad (2)$$

With: n_i = the number of individuals of a kind
 $\sum N$ = total of all individuals

Presence Frequency (PF)

$$PF = \frac{\text{The number of plots occupied by a genera}}{\text{Total number of plots}} \times 100 \quad (3)$$

With: PF = 0-25 (Very rarely)
 25-50 (Rarely)
 50-75 (Many)
 > 75 (Very much)

The Shannon-Wiener Diversity Index (H')

$$H' = - \sum_{i=1}^S p_i \ln p_i \quad (4)$$

With: H' = Shannon-Wiener diversity index
 p_i = n_i / N (comparison of the number of individuals (a type with all types))
 Ln = natural logarithm

Equitability Index (E)

$$E = \frac{H'}{H_{MAX}} \quad (5)$$

With: H' = Shannon-Wiener's diversity index (H')
 H_{max} = maximum diversity index
 E = Equitability Index

Dominance Index (D)

$$D = -\sum_{i=1}^S \frac{ni^2}{N} \quad (6)$$

With: D = Simpson's dominance index
 N_i = the number of individuals of a kind
 N = total number of individuals
 S = genera

2.4. Water Quality Relationship with Phytoplankton

Environmental data such as temperature, penetration of light, light intensity, flow rate, pH, DO, BOD, COD were statistically tested and analyzed to observe its relationship with phytoplankton using SPSS correlation analysis Ver. 13 to see the current pollution level of the river.

3. Results and discussions

3.1. Belawan River Water Quality

The results obtained by the phytoplankton community as a bioindicator of Belawan river water quality are obtained as Table 1.

Table 1. The average value of water quality in Belawan river

No	Parameter	Station I	Station II	Station III	Station IV	Station V
1.	Temperature (°C)	28	29	28	28	29
2.	Light concentration (cm)	51	74	62	60	30
3.	Light Intensity (Cd)	244	267	228	573	143
4.	Flow Rate (sec / m)	24	71	24	42	17
5.	pH	7.86	7.93	7.50	7.60	7.63
6.	DO (mg/L)	8.4	6.8	6.8	4.8	4.7
7.	BOD ₅ (mg/L)	1.40	0.70	1.70	1.05	1.05
8.	COD(mg/L)	15,488	9,152	10,342	18,304	24,800

It can be seen from Table 1 that the water temperature in the five stations ranges from 28-29 °C, with the highest temperature at station II and V which was situated near the habitation and estuary with overall the temperature is relatively the same. Penetration of light ranges from 30-74 cm with the highest amount of penetration of light at station II as because the area was more open with slightly overgrown plants, which could absorb light to easily penetrate into the water. The intensity of light ranges from 143-573 Candela with the highest light intensity in station IV, which was due to the ability of light to absorb was relatively high. The pH ranges from 7.60 - 7.93 with the highest pH at the second station II, which was near the industries, though the overall pH was almost the same

Dissolved Oxygen (DO) ranged from 4.7 - 8.4 mg/L with the highest dissolved oxygen at station I. This is caused by the environmental conditions that support photosynthesis well to contribute much oxygen in the waters. Biological Oxygen Demand (BOD) 5 ranged from 0.70 - 1.70 mg/L with

the highest BOD₅ at station III which was a highly populated residential area that produced domestic waste in the form of organic materials in which the oxygen in the water was used by microorganisms to decompose the organic material. Chemical Oxygen Demand (COD) ranged from 9,152 – 24,800 mg/L with the highest COD at Station IV which was the estuary area where the substrate from upstream of the river that caused the area to have higher organic materials so that the oxygen needed to decompose those organic matters was also chemically high.

3.2. Abundance Value (A) (ind / m²), Relative Abundance (RA) (%) and Presence Frequency (PF) (%) Phytoplankton in Belawan River

Results of the Abundance Value (A) (ind / m²), Relative Abundance (RA) (%) and Presence Frequency (PF) (%) of Phytoplankton in Belawan River are shown in Table 2.

Table 2. Abundance Value (A) (ind / m²), Relative Abundance (RA) (%) and Presence Frequency (PF) (%) Phytoplankton at Belawan River at Station I and II

No.	Taksa	Station I			Station II		
		A	RA	PF	A	RA	PF
I	Chlorophyta						
A	Chlorophyceae						
	1. Chaetosphaeridium						
	2. Closteriopsis						
	3. Gonatozygon	204.08	769.23	100.00	285.71	10.94	66.67
	4. Oocardium	326.53	12.31	66.67	326.53	12.50	33.33
	5. Pediastrum						
	6. Schroederia						
	7. Sphaeroplea						
	8. Stigeoclonium				163.27	6.25	66.67
	9. Trochiscia						
	10. Volvox	81.63	3.08	66.67			
	11. Zygnema	448.98	16.92	66.67	326.53	12.50	100.00
II	Chrysophyta						
B	Bacillariophyceae						
	12. Asterionella						
	13. Gomphonema				204.08	7.81	66.67
	14. Coscinodiscus						
	15. Cylindrotheca						
	16. Gyrosigma						
	17. Mastogloia				285.71	10.94	100.00
	18. Melosira						
	19. Navicula	244.90	9.23	100.00	367.35	14.06	66.67
	20. Nitzschia	367.35	13.85	66.67			
	21. Stauroneis	81.63	3.08	33.33	285.71	10.94	66.67
	22. Surirella						
	23. Synedra	204.08	7.69	33.33			
	24. Tabellaria						

III	Cyanophyta						
C	Cyanophyceae						
	25. Aphanizomenon	163.27	6.15	33.33			
	26. Coelosphaerium						
	27. Oscillatoria	530.61	20.00	100.00	367.35	14.06	66.67
	Total	2653.06	100.00		2612.24	100.00	

Table 3. Abundance Value (A) (ind / m²), Relative Abundance (RA) (%) and Presence Frequency (PF) (%) of Phytoplankton at Belawan River at Station III, IV, and V

No.	Taksa	Station III			Station IV			Station V		
		A	RA	PF	A	RA	PF	A	RA	PF
I	Chlorophyta									
A	Chlorophyceae									
	1. Chaetosphaeridium							1836.73	10.34	100.00
	2. Closteriopsis							1020.41	5.75	66.67
	3. Gonatozygon	693.88	22.97	66.67						
	4. Oocardium									
	5. Pediatrum				367.35	8.91	66.67	1755.10	9.89	100.00
	6. Schroederia				163.27	3.96	33.33	285.71	1.61	33.33
	7. Sphaeroplea				204.08	4.95	33.33	2122.45	11.95	100.00
	8. Stigeoclonium									
	9. Trochiscia							367.35	2.07	33.33
	10. Volvox	285.71	9.46	66.67						
	11. Zygnema									
II	Chrysophyta									
B	Bacillariophyceae									
	12. Asterionella				612.24	14.85	100.00	2000.00	11.26	100.00
	13. Gomphonema	204.08	6.76	33.33	367.35	8.91	66.67	163.27	0.92	66.67
	14. Coscinodiscus				326.53	7.92	100.00	1510.20	8.51	100.00
	15. Cylindrotheca	163.27	5.41	100.00						
	16. Gyrosigma				81.63	1.98	33.33	489.80	2.76	66.67
	17. Mastogloia	367.35	12.16	100.00						
	18. Melosira				612.24	14.85	66.67	1755.10	9.89	66.67
	19. Navicula	81.63	2.70	33.33						
	20. Nitzschia	244.90	8.11	33.33						
	21. Stauroneis				326.53	7.92	66.67	163.27	0.92	33.33
	22. Surirella							163.27	0.92	66.67
	23. Synedra	448.98	14.86	66.67	163.27	3.96	33.33	244.90	1.38	100.00
	24. Tabellaria				204.08	4.95	33.33	1346.94	7.59	100.00
III	Cyanophyta									
C	Cyanophyceae									
	25. Aphanizomenon	367.35	12.16	100.00						
	26. Coelosphaerium							1673.47	9.43	100.00
	27. Oscillatoria	163.27	5.41	33.33	693.88	16.83	100.00	857.14	4.83	100.00
	Total	3020.41	100.00		4122.45	100.00		17755.10	100.00	

It can be seen from Table 2 and 3 that *Oscillatoria* at station I were found to have the highest Abundance value, Relative abundance and attendance frequency with 530.61 ind / m² (A), 20.00% (RA) and 100% (PF), while the lowest was found in *Volvox* and *Stauroneis*, with 81.63 (A), 3.08% (RA) and 33.33% (PF). *Navicula* and *Oscillatoria* were found in station II to have the highest Abundance value, Relative abundance and presence frequency were 367.35 ind / m² (A), 14.06% (RA) and 66.67% (PF), while the lowest were found from the genera of *Stigeoclonium* 163.27 (A), 6.25% (RA) and 66.67% (PF). *Gonatozygon* were found in station III to have the highest Abundance value, Relative abundance and attendance frequency, with 693.88 ind / m² (A), 22.97% (RA) and 66.67% (PF) and lowest in *Navicula* as equal to 163.27 (A), 6.25% (RA) and 66.67% (PF).

On the station IV, *Oscillatoria* were found to have the highest Abundance value, Relative abundance and attendance frequency, with 693.88 ind / m² (A), 16.83% (RA) and 100% (PF), and the lowest in *Gyrosigma* with 81.63 (A), 1.98% (RA) and 33.33% (PF). *Sphaeroplea* were found in station V to have the highest Abundance value, Relative abundance and presence frequency with 2122.45 ind / m² (A), 11.95% (RA) and 100% (PF), and lowest in *Gomphonema*, *Stauroneis* and *Surirella* of 163.27 (A), 0.92% (RA) and 66.67% (PF). Overall, *Sphaeroplea* has the highest abundance value, relative abundance, and presence frequency in the Belawan River as equal to 2122.45 ind / m² (A), 11.95% (RA) and 100% (PF) at station V, and while the lowest was found in *Volvox*, *Stauroneis* (Station I), *Navicula* (Station II), and *Gyrosigma* (Station IV) with 163.27 (A), 0.92% (RA) and 66.67% (PF).

3.3. Value of Diversity (H') and Equitability (E) in Belawan River

Based on the research conducted, the value of diversity (H') and equitability (E) in Belawan river were as follows:

Table 4. Diversity Values (H') and Equitability Index (E) of phytoplankton in Belawan River

	Station I	Station II	Station III	Station IV	Station V
H'	2.15	2.28	2.16	2.58	2.56
E	0.18	0.19	0.23	0.21	0.21

It can be seen from Table 4 that the highest value of diversity (H') was found from station IV, with 2.58 while the lowest was from station I with 2.15. The diversity of phytoplankton in the 5 stations was low to moderate. Low diversity is when $0 < (H') < 2.302$, medium diversity is when $2.302 < (H') < 6.907$, and high diversity is when $(H') > 6.907$ [6]. The water in the river is said to be heavily polluted if $(H') < 1$, moderately polluted if (H') is between 1.0 to 1, 5, while lightly contaminated when $(H') > 2.0$. The equitability (E) value ranges from 0.18 to 0.23 with the highest equitability found at station III, with the lowest at station I. Equitability value (E) ranges from 0 to 1, where value close to 0 means that equitability is low due to the dominant species [6] like *Sphaeroplea* and *Asterionella*. This means the number of individuals on the type is not equally and evenly distributed.

3.4. Correlation Analysis Value

Correlation value was obtained based on the measurement of the water quality parameters correlated with the value of diversity (Shannon-Wiener Diversity) as in Table 5 below:

Table 5. The Correlated Analysis Value obtained between water quality parameters and phytoplankton diversity

No	Parameters	Diversity (H')
1.	Temperature (° C)	0.32
2.	Light concentration (cm)	-0.43
3.	Light Intensity (Cd)	0.41
4.	Flow Rate (sec / m)	0.02
5.	pH	-0.31
6.	DO (mg/L)	0.94
7.	BOD ₅ (mg/L)	0.52
8.	COD(mg/L)	0.75

From Table 5 it can be seen that DO affects the diversity of phytoplankton as bioindicator. The obtained DO during the study ranged from 0.2 to 4.4 mg / L, this value of was far from the needs of aquatic organisms and partly enough to support the needs of phytoplankton [1], in which means that dissolved oxygen has a very strong relationship to the diversity of phytoplankton.

4. Conclusion

From research conducted on the phytoplankton community as a bioindicator of fertility in Belawan River, it can be concluded that:

1. Phytoplankton obtained consisted of 27 genera from 3 classes and 3 orders, with the highest abundance in the genera of *Sphaeroplea*, while lowest in genus *Volvox*, *Stauroneis*, *Navicula*, and *Gyrosigma*.
2. The diversity of phytoplankton in 5 stations was relatively low to moderate, while the level of pollution based on the diversity value of station I-V was classified as lightly polluted.

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