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Existence of Phytoplankton in Waters Affected by Hot Water of Electric Steam Power Plant (ESPP) of Teluk Sirih as Ecological Bioindicator Reference for Climate Change Mitigation

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Abstract: The seashore Electric Steam Power Plant (ESPP) in Teluk Sirih will undoubtedly cause changes in physical, chemical, and biological environmental parameters. Phytoplankton is one of the components that will be impacted. The research objective was to study the community structure of phytoplankton in the waters affected by the hot water of the ESPP of Teluk Sirih which was carried out in August 2023 with four sample stations namely Outfall, Inlet, Jetty, and the middle of the sea as controls. The results of the study showed that the community structure of phytoplankton in the waters around the ESPP of Teluk Sirih was not significantly affected by hot water. This is illustrated by the diversity results which are classified as well H' ranging from 1.710-2.156. Evenest Index (E) 0.562-0.761 and Dominance Index (C) 0.188-0.295. The E and C values show that the phytoplankton are evenly distributed and no species dominates the ESPP of Teluk Sirih. The physics and chemistry of water are all above the quality standards of the Ministry of Environment No. 51. 2004 as temperature ranges from 29-32^{0}C, pH 7-8, transparency >3m, Salinity 31.4-32.2 ‰. Dissolved oxygen 5 mg/L, Carbon dioxide 48-62 mg/L, BOD_5 4-5 mg/L, Nitrates 0.02-0.031 mg/L, and orthophosphate as phosphate 0.014-0.018 mg/L.
Keywords: community structure, hot water, phytoplankton, ESPP of Teluk Sirih

1. Introduction

The operational system of Teluk Sirih ESPP is a CFB (the circulating Fluidized Bed Boiler). Water is required for the condenser cooling process. Once the water is finished, it is released to the surrounding waters—also referred to as hot water—which will alter the water. The introduction of this hot water will have an impact on biotic components, including plankton, as well as abiotic ones like element enrichment and increased water productivity. Plankton are organisms that float in the water column whether or not they can swim. Because they can't swim very well, they can't resist the flow of water Nybakken, and Bertness. 2005 in [1].

One of the steam power plants that provides Central Sumatra with electricity is ESPP in Teluk Sirih. This ESPP, which has a combined electrical system capacity of about 2x112 MW in units 1 and 2, is situated on the west coast of West Sumatra [1]. This ESPP's condenser cooler is made of water in its operating system. By using the outlet canal, the condenser cooling water consumed by this ESPP is often returned to the surrounding waters, where it adds heat [2]. This is anticipated that the operation of this disposable cooling system will alter the biota that inhabits the water bodies and the water quality, both directly and indirectly [3].

Phytoplankton, an aquatic organism that functions as a primary producer and plays a crucial part in the food chain in the waters, is among those impacted [4–5]. It is also very susceptible to alterations in the physical and chemical conditions of the waters. Furthermore, heat pollution can have an impact on plankton ecosystems by lowering phytoplankton biomass and production [6]. A hot water by-product of an ESPP is produced at a temperature higher than the water temperature before cooling purposes [7]. The PLTU's maximum unit capacity determines how much cooling water is required. Generally speaking, 45–55 liters of cooling water per second are needed at full load for every kilowatt [7] in [18]. According to research findings from the ESPP of Teluk Sirih waters in 2019–2021, the outfall's seawater temperature ranges from 29–32°C, and phytoplankton data indicates that the abundance varies from 6,187 cell/L in 2019 to 6,233 cell/L in 2020, and then drops significantly to 2,869 cell/L in 2021. The phytoplankton diversity index was 0.746 in 2019; however, it dropped to 0.354 in 2020 and rose to 1.135 in 2021 [1].

Zooplankton from animal groups and phytoplankton from plant groups make up the plankton component. For phytoplankton to be a primary producer in the seas carbs and energy will be produced by these primary producers. Carbon is required to

generate carbohydrate molecules ($C_6H_{12}O_6$), which provide energy to phytoplankton. The mechanism known as photosynthesis is how phytoplankton synthesizes these carbohydrate molecules in an anabolic manner [1]. Although phytoplankton makes up over 70% of the surface of the earth, it is the primary trophic level in aquatic ecosystems and is found exclusively in phytoplankton-filled waters [8]. To use the data for Ecological Bioindicator Climate Change Mitigation, boiling water will affect the physical and chemical conditions of water, such as temperature changes. This will affect on the existence of phytoplankton around the Teluk Sirih Steam Power Plant (ESPP) Hot Waters.

2. Material and Methods

2.1. Materials

Plankton nets, buckets, plastic, erlenmeyer, dropper pipettes, label paper, thermometers, pH meters, thermometers, 2-liter jerry cans, box ice, object glasses, cover glasses, titration kits, microscopes, cameras, and stationery were among the equipment used in this investigation. 40% formalin, 90% acetone, 1% lugol, and distilled water were the ingredients. Phytoplankton identification concerning literature [9], [10], [11], [12], [13], and [14]. The association between physical and chemical parameters and phytoplankton diversity, as well as the values of phytoplankton abundance, diversity index, dominance index, and evenness index, were all described descriptively.

2.2. Methods

2.2.1. Sample collection and preparation

Taking the sample in August 2023, a survey method using both a qualitative and quantitative methodology was used to perform this research. A 30µm mesh plankton net was used for the vertical screening method of phytoplankton collecting. Purposive random sampling was used to choose the plankton sampling location (station), taking into account the baseline environmental conditions that might affect the physical and chemical parameters listed in Table 1. Each sampling point was found to consist of four observation stations with two replications based on these factors. Specifically, the Jetty and station as control, the outfall, and the inlet. Figures 1 and 2 depict the location and sampling methodology in full for plankton sampling.

Table 1. Physical, and chemical factors

No.	Parameter	Unit	Tools	Remarks
1	Temperature	^oC	Alcohol Thermometer	In situ
2	Transparency	m	Secchi Disk	In situ
3	pH		pH universal	In situ
4	Salinity	‰	Spectrophotometry	Laboratory
5	DO	mg/L	DO meter	Laboratory
6	CO_2	mg/L	DO meter	Laboratory
7	BOD_5	mg/L	DO meter	Laboratory
8	Nitrate	mg/L	Spectrophotometry	Laboratory
9	Orthophosphate	mg/L	Spectrophotometry	Laboratory

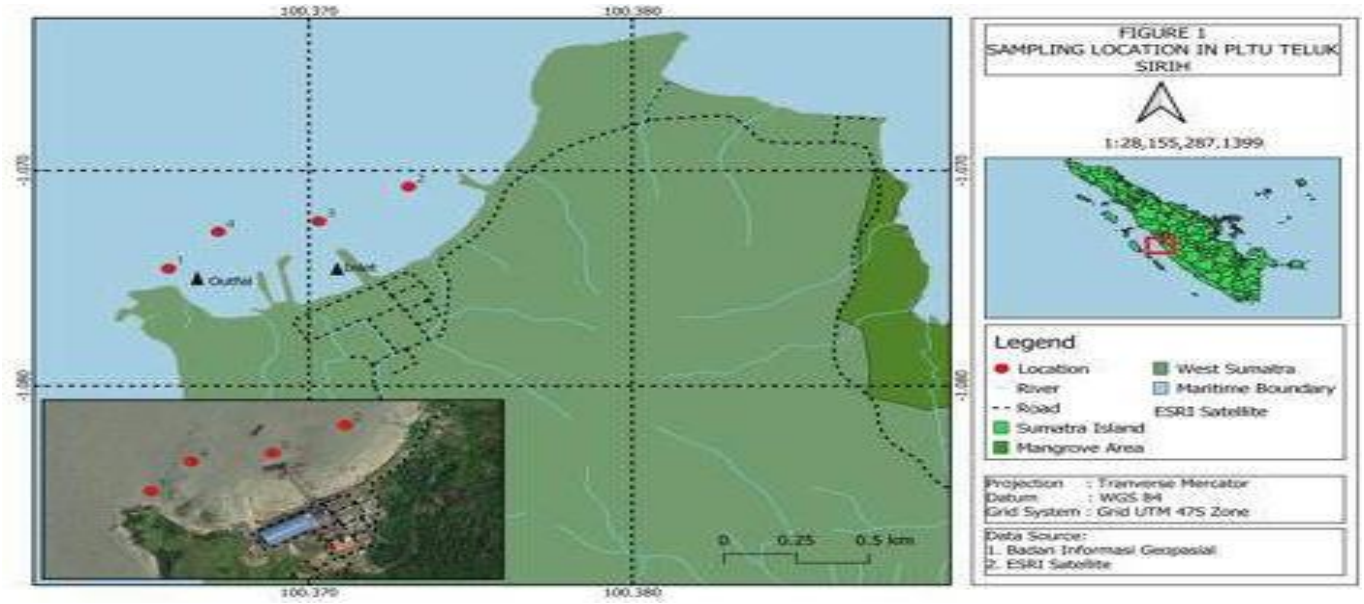

Figure 1. A map showing the locations and venues for sampling (station I at the outfall, station II at the outlet, station III at the jetty temporary and station IV as control).
Source: GIS And Google Earth Pro 3,22,16

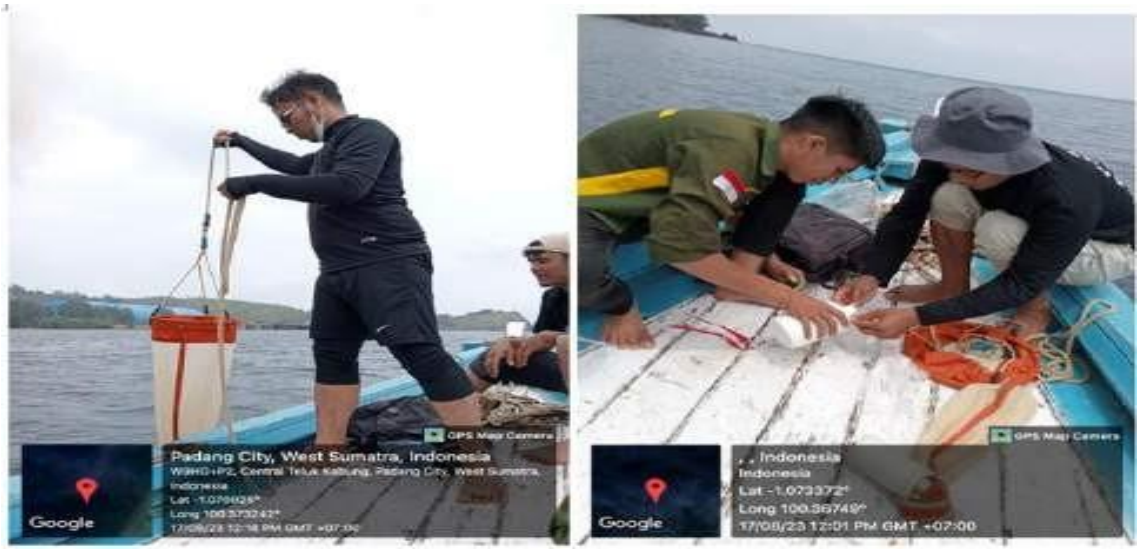

Figure 2. Sampling Plankton at ESPP Teluk Sirih
Source: Documentation on 2023

2.3. Data Analysis

Can we explain the phytoplankton's composition using Based on [15], the following formula can be used to determine the phytoplankton's Data Density (D) and Relative Density (RD%):

Density (D) = $\frac{axc}{L}$ [15]:

Where:
a = The average plankton generous in one milliliter
c = The concentrate sample
volume
L = Volume of filtered water (liters)

The Relative Density (RD%)

$$RD\% = \frac{\text{Density of the species}}{\text{Density of all species}} 100\%$$

The dominance, evenness, and diversity indices make up the phytoplankton structure. The index used to determine the degree of species variety within a phytoplankton population Utilizing Shanon-Wiener's [1] diversity index (Table 2), the diversity index (H) was computed as follows.:

$$H' = -\sum pi \ln pi$$

Where :
H' = The Diversity of index
Pi = ni/N,
ni = Every individual within a species
N = Total individual among all species

Table 2: Phytoplankton and Zooplankton Diversity Index-Based Assessment of Water Quality

No.	Plankton Diversity Index (H')	Classifications	The assessment
1	<0.3	Very bad	1
2	0.3 – 0.7	Bad	2
3	0.7 – 1	Quite good	3
4	1 – 5	Good	4
5	>5	Very good	5

Source: [1], [15], [17]

The Evenness of Index (E)

This evenness index is used to determine the degree of community-level similarity between the distribution of several members of each clan. Index Evenness may be calculated with the following formula:

E = H' / H max

where,

E = Index of Evenness
H' = Diversity Index
Hmax = ln (S)
S = All Genus

The Evenness Index (E) value ranges from 0 to 1, if theE value is <0.5, it indicates that the evenness between genera is low, meaning that the richness of the individuals in each genus is very different. E = >0.5, indicating that the distribution between genera is relatively uniform or relatively the same [1], [15], [17], [23].

Index of Dominance (C)

An aquatic habitat's dominant phytoplankton organisms are indicated by the existence or absence of a dominance index [16]. determined using the

subsequent formula:

$$C = \sum (Ni/N)^2$$

Where:
C = Index of Dominance
Ni = The number of members in a species.
N =The total number of members in every species.

The value of the dominance index is 0–1 (zero to one). A dominance index value near one indicates that a single kind or species dominates the community; if the dominance index is near zero, no type or species dominates. The dominance index is influenced by the number of species found in a water sample, albeit it is mostly based on the quantity of each species' individuals [16].

3. Results and Discussion

The result of this research is that 33 species were discovered after observations and laboratory investigation. Three classes comprise the phytoplankton: Dinophyceae (7 species), Bacillariophyceae (25 species), and Cyanophyceae (1 species). The total abundance can be explained in Figure 3 as follows.

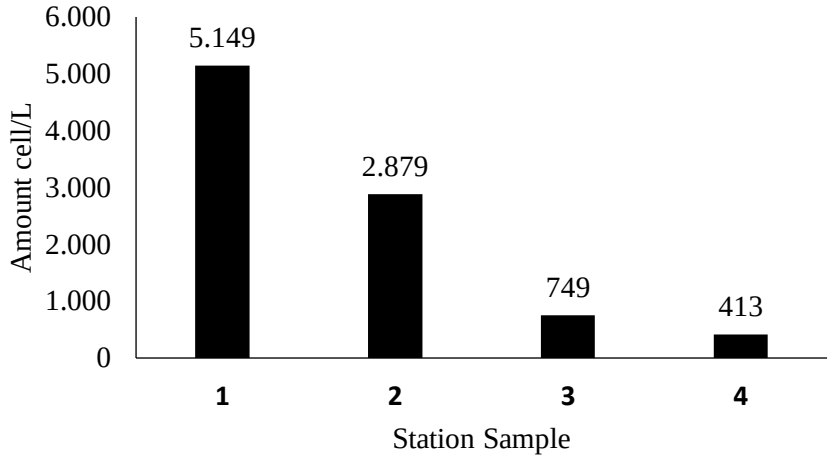

Figure 3. Graph of Abundance Phytoplankton

Based on Figure 3, the abundance of phytoplankton at station 1 was 5,149 cells/L, with the number of taxa being 24 species, the diversity index being 1,840 while at station 2 the abundance of phytoplankton was 5,879 cells/L and the number of taxa was 21 species. The diversity index is 1.710. AbundanceAt station 3 was 749 cells/L, with a total of 20 taxa species, and a diversity index of 1.904, while at station 4the number of phytoplankton species was found, namely 17 species with an abundance of 413 cells/L and a diversity index of 2.165. The highest H' is found at station 4, namely control which is in the middle of the sea. The high diversity is inversely proportional to the low number of taxa abundance. It is suspected that the middle part of the sea has little nutrients, thereby reducing the population of plankton biota. This can also be seen by the levels of nitrate at station 4, which is 0.02 mg/L, and orthophosphate which is 0.015 mg/L Table 2,which is minimal in light of others. Stations IV and III have low nitrate values compared to each other, while Station IV's orthophosphate value is the same as Station II's. The maximum recommended level of phosphate for rivers and waterways that have been published is 0.1 mg/L, according to Anhwange (2012) in [19]. Eutrophic waters are defined as having a phosphate content greater than 0.1 mg/L, and phytoplankton blooms are frequently observed in these waters. The most prevalent class in the sea is the Bacillariophyceae, which is followed by the Dinophyceae, which includes *Peridinium* sp., and the Cyanophyceae, which includes only one kind, *Trichodesmium* sp. Nonetheless, it predominates in the waters throughout the investigation, with a 51.8% relative abundance. Numerous varieties that are frequently found in the ESPP of the waters around Teluk Sirih are observed in Figure 4.The structure of Phytoplankton can be seen in Figures 5,6 and 7 below.

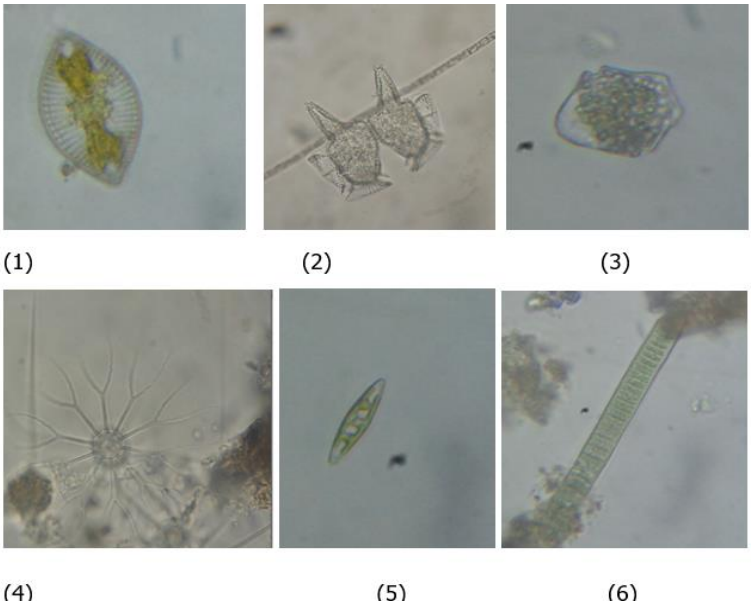

Figure 4*:* Frequently phytoplankton species recorded: *Amphipora* sp.*, 2) Dinophysis* sp. 3) *Peridinium* sp. 4) *Bacteriastrum* sp. 5) *Navicula* sp. 6). *Trichodesmium* sp. Microscope Olympus Magnification 400x. *Source: Laboratory Documentation, 2023.*

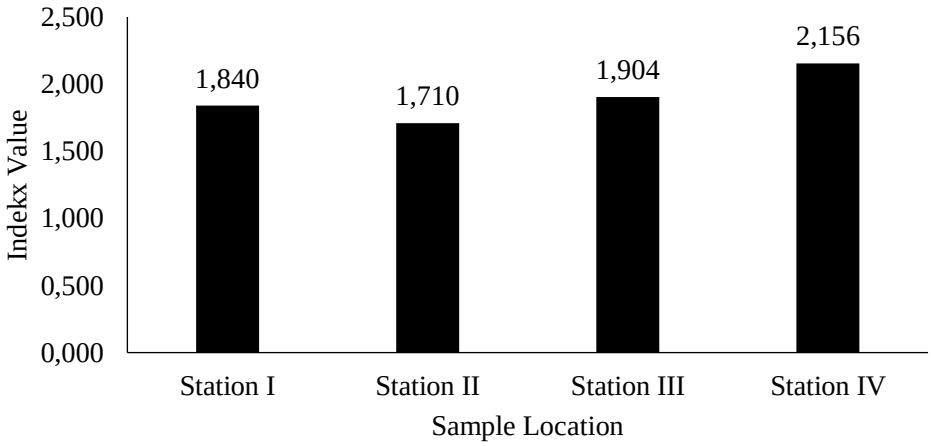

Figure 5. Graph of Phytoplankton Diversity Index (H') atESPP of ESPP Teluk Sirih

Based on the graph in Figure 5, the highest diversity is seen at the control point far from ESPP with the measurement results showing a value of 2.156. Followedby successive inlet and outfall points which have diversity values of 1.710 and 1.840. Meanwhile, for the jetty, the diversity value shown is 1.904. Furthermore, atthe Outlet point, the results of the diversity calculation show values ranging from 1.710-2.156. The lowest diversity value is at the inlet point. When viewed as a whole, the value of diversity in ESPP Teluk Sirih waters, Outfall, Inlet, Jetty, and Control points are classified as quite high diversity and good community stability. The variety index is already able to demonstrate the good quality of the water. Thus, the phytoplankton community structure in the waters surrounding Teluk Sirih's ESPP is not greatly impacted by hot water. The case study was conducted in East Java's ESPP Paiton [18].

From Figure 6, the highest evenness index (E) calculationresult is at the middle of the sea control point, which is 0.761. Then at point 3 jetty, namely 0.636. Furthermore,at the Outfall 1 point of 0.579. The inlet point is 0.562 and the lowest evenness value is at the inlet point, whichis 0.562. From the calculation results, the evenness valuein the ESPP of Teluk Sirih waters is $0.562 < E \leq 0.761$, then the community in these waters is said to be unstable(Krebs (1973) in [1]).

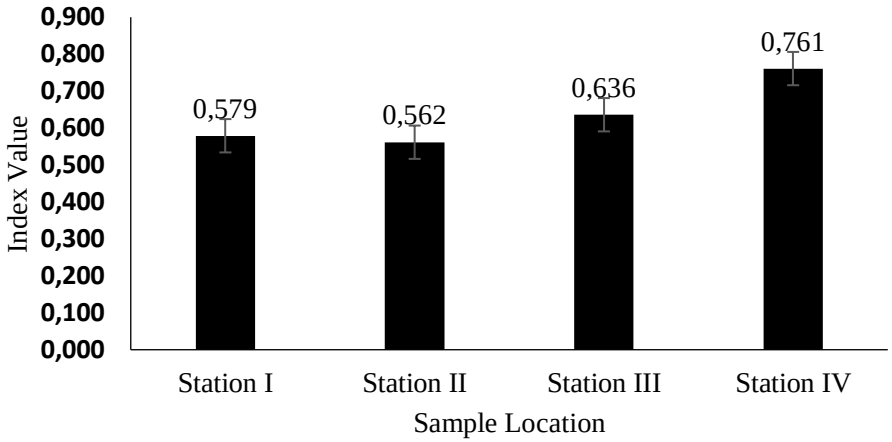

Figure 6. Graph of Phytoplankton Evenest Index (E) at ESPPof ESPP Teluk Sirih

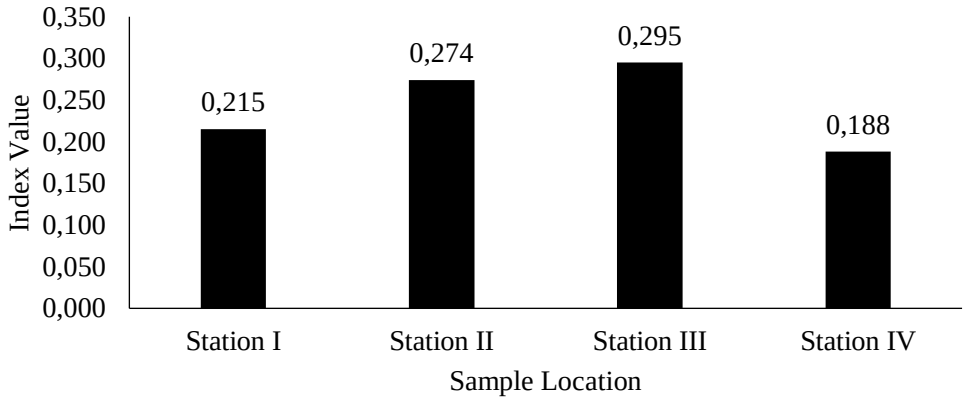

Figure 7. Graph of Phytoplankton Domination Index (C) at ESPP of PLTU Teluk Sirih

The dominance index found ranges from 0.188-0.295. This value indicates that there is no dominant species. This is the same as research [2]. Table 3 shows other water-chemical and physical parameters that were observed in this study.

Table 3. Physic and Chemical Factors of Water

No.	Parameter	Locations				*QS
		1	2	3	4	
1	Temperature	32	32	32	32	nature
2	Transparency	>3 m	>3 m	>3 m	>3 m	>3
3	pH	7	7	7	8	7-8.5
4	Salinity	31.4	31.8	31.5	32.2	nature
5	DO	5	5	5	5	>5
6	CO_2	62	48	53	57	-
7	BOD_5	5	5	4	4	20
8	Nitrate	0.026	0.031	0.02	0.02	0.008
9	Orthophosphate	0.018	0.015	0.014	0.015	0.015

Source: Laboratory Analysis Results of Environment Engineering of Andalas University, West Sumatra Province, 2023
*QS=Quality Standards [20]

Physical characteristics such as transparency greater than three meters, when compared to the quality level of [20], are still above the standard and in good condition, according to data in Table 3 from the analysis of seawater quality above. Because phytoplankton can use more light for photosynthesis when sunlight penetrates the water at a deeper angle, transparency has a direct impact on phytoplankton development [21]. The measurement results of the pH value ranged from 7-8. All stations are the same except station 4 whichhas a high pH range of 8. The pH level is relatively stablein marine and coastal waters and is in a small range of 7.6 – 8.3 which is in research by [19]. Whereas station 1 which is at an outfall of 7 is almost close to neutral pH, this is becauseit gets input from the mainland, which is a

small river.

The results of salinity measurements show that the salinity values range from 31.4 to 32.1‰. The lowest salinity value is at Station 1 which is located at the mouth of the outfall estuary with a value of 31.4‰. This is due to the input of fresh water which has low salinity. The salinity values of all stations are almost the same exceptstation 4 has a value of 32.2‰ because it is in waters farfrom the river mouth. The observation station's Dissolved Oxygen (DO) measurement yielded identical values, namely 5 mg/L. The DO concentration in Teluk Sirih ESPP waters is still classified as suitable for marine biota, meaning that it is still better for supporting marine biota life where at each observation station it still meets quality standards. At each data collection station, the DO value obtained indicates that the waters are in good enough condition and still meet the seawater quality standards in the Decree of the Minister of State for the Environment No. 51 of 2004 for marine biota with a DO value of >5 mg/L. Additionally, this supports the findings of [8]'s research.

The results of Biological Oxygen Demand (BOD_5)measurements at observation stations ranged from 4-5mg/L. The BOD_5 value obtained is still below themaximum BOD_5 standard recommended for marinebiota in the Decree of the State Minister for theEnvironment No. 51 of 2004 for marine life with a maximum value of 20 mg/L. BOD_5 ESPP Teluk Sirihwaters is still in normal condition. This is by the research of [8]. The BOD_5parameter is a general parameter that can be used todetermine the level of water pollution from a pollution source. Based on the pollution level criteria from the BOD_5 value, the sea waters of the Teluk Sirih ESPP are classified as low pollution levels. The higher concentration of BOD_5 indicates that the water is polluted, while the concentration of BOD is still low andcan be categorized as good water. The pollution level islow if the BOD_5 value is 0 – 10 mg/l, while the pollutionlevel is moderate if the BOD_5 value is 10 – 20 mg/l [22].

The results of the analysis show that the concentration of nitrate at the measuring station ranges from 0.02 – 0.031 mg/l. The concentration of nitrate obtained in this study was relatively similar to other waters of West Sumatra, as reported by [8] that the concentration of nitrate in coastal waters of West Sumatra ranged from 0.012 – 0.025 mg/l. Based on the nitrate content, Teluk Sirih ESPP waters are included in oligotrophic waters with nitrate levels between 0 – 1 mg/l. The concentration of nitrate-nitrogen in natural waters is rarely more than 0.1 mg/l [21]. Based onthe quality standards for nitrate content in waters in the Decree of the State Minister for the Environment No. 51of 2004, the nitrate content in ESPP Teluk Sirih waters has largely exceeded the quality standard, where the standard quality standard for nitrate concentration for marine biota is 0.008 mg/L because the water is close to land and also the increase in oxygen levels due to the nitrification process where ammonia is converted into nitrite and then into nitrate so that the nitrate content in the water is high.

Phosphate is a nutrient needed for the process of growth and metabolism of phytoplankton and other marine organisms in determining the fertility of waters, the condition is unstable because it is easily subjected to erosion, weathering, and dilution. The distribution of phosphate from offshore areas to coastal areas shows higher concentrations towards the coast [19].

The analysis's findings indicated that the measuring station's phosphate content concentration ranged from 0.014 to 0.018 mg/L. According to the Decree of the Minister of State for the Environment No. 51 of 2004, the phosphate level in the waters of ESPP Teluk Sirih has partially exceeded seawater quality limits for marine biota. These standards are 0.015 mg/l. The ESPP Teluk Sirih waters' marine biota may be at danger due to these circumstances, which can also result in eutrophication. The maximum recommended level of phosphate for rivers and waterways that have been published is 0.1 mg/L, according to Anhwange (2012) in [19]. Eutrophic waters are those that have a phosphate content of more than 0.1 mg/L; phytoplankton blooms frequently occur in these types of waterways.

4. Conclusion

The study concludes is that the phytoplankton community structure in the waters surrounding Teluk Sirih's ESPP is in good shape. The diversity index (H'), which is still in the good range and runs from 1.710 to 2.156, the evenness value (E) of 0.562 to 0.761, and the dominance index (0.188 to 0.295), which indicates that no species predominates, all demonstrate this. Temperature, salinity, pH, DO, BOD5, CO2, and transparency are environmental characteristics that still meet norms for marine biota quality; phosphate and nitrate, on the other hand, have exceeded standards. It is believed that natural water sources are the source of the parameter increase that has surpassed the maximum quality level.

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