Sriwijaya Journal of Environment
Article
ojs.pps.unsri.ac.id

Trends of The Phytoplankton Community and Physical Chemical Factors as Determinants of Pollution Level in The Electric Steam Power Plant (ESPP) Teluk Sirih Waters

Gusna Merina [1*], Indra Junaidi Zakaria [2], Ahmad Mursyid [3], Wandanil Putra [3], Rahma Wirni [4]

[1]*Departement of Aquatic Resource Management, Faculty of Science, University of Nahdlatul Ulama Sumate Barat, Padang, Indonesia*
[2]*Departement of Biology, Faculty of Mathematics and Science, Andalas University, Padang, Indonesia*
[3]*The Indonesian Society for Bioinformatics and Biodiversity (MABBI), Indonesia*
[4]*PT Barika Ensustain Konsultan, Lubuk Kilangan Regency, Padang city, West Sumatera, Indonesia*
**Corresponding author: merinagusna@gmail.com*

Article history

Received	Received in revised form	Accepted	Available online
25 March 2023	5 May 2023	10 June 2023	12 June 2023

Abstract: The existence of the Electric Steam Power Plant (ESPP) in Teluk Sirih located on the seafront will certainly have an impact on changes in environmental factors such as physical, chemical, and biological factors because the water needed for the ESPP operational process comes from sea water. Changes in the physicochemical factors of sea surface water due to ESPP activity will affect organisms in these waters, one of which is phytoplankton. Therefore, the purpose of this research is to look at changes or trends in the phytoplankton community and its relation to pollution by the physics and chemistry of the waters around the ESPP Teluk Sirih. This research was conducted from June 2019 to June 2021, sampling was carried out annually for three years. This study used a purposive sampling method and plankton sampling using a plankton net horizontally, then the samples were taken to the laboratory for identification. A sampling of water physics and chemistry was carried out in situ and ex-situ, namely by being preserved for further transport to the laboratory. The results of this study indicate the trend of phytoplankton fluctuating from the number of abundance, taxa, and diversity index. This is because the physicochemical factor also fluctuates, there is one parameter above the quality standard, namely phenol whose levels are more than 0.02 mg/L. However, It can be concluded that the level of pollution in the waters of the Teluk Sirih Steam Power Plant area is still low in the good category so it is still safe for marine biota
Keywords: ESPP Teluk Sirih, trends, Phytoplankton, community physical, chemical factors

1. Introduction

The city of Padang is a city located in West Sumatra Province directly adjacent to the sea coast so that various activities exist on the sea coast of West Sumatra, one of which is the Steam Power Plant (ESPP). The ESPP is located in Sirih Bay, so it is known as the ESPP Teluk Sirih. In its operation, ESPP Teluk Sirih requires coal fuel. This ESPP is one part of the accelerated project in Presidential Regulation Number 71 of 2006 concerning Assignments to PT Perusahaan Listrik Negara (Persero) to Accelerate the Development of Power Plants Using Coal. The location of the ESPP Teluk Sirih is on the Padang–Painan Sumatera Cross Road KM 25, Teluk Kabung Tengah, Bungus Teluk Kabung District, Padang City. Teluk Sirih ESPP has a capacity of 2x112 MW which was fully operational in September 2014 [1].

The area where the ESPP is located is ± 51 hectares, located above a protected forest area under the Decree of the Minister of Forestry Number SK.424/Menhut-II/2009. This power plant has joined the Sumatra interconnection to increase the electricity supply to the Sumatra Island network in general and the West Sumatra Province in particular.

Teluk Sirih ESPP uses a CFB (Circulating Fluidized Bed Boiler) working system. In the condenser cooling process, water is needed after that the water is returned to the surrounding waters which are known as hot water, this will change the waters. As a result of the entry of this hot water, it will directly or indirectly affect abiotic components such as enrichment of elements/increase water fertility and affect biotic components, one of which is plankton. Plankton are organisms that live floating in the water column whether they can move or not, and have limited swimming ability so they are unable to fight against the movement of water [2].

The Plankton component consists of Zooplankton from animal groups such as Protozoa, Crutacea, Rotifera, larvae of in- and vertebrate animals, and Phytoplankton from plant groups (Bacteria, Fungi, and Algae). So that in the waters, phytoplankton is a primary producer. These primary producers will produce carbohydrates and energy. To form carbohydrate compounds ($C_6H_{12}O_6$) which are an energy source for phytoplankton, the element carbon is needed. These carbohydrate compounds are synthesized by phytoplankton in an anabolic manner which is called the process of photosynthesis [3].

Plankton have any size, ranging from 0.02-20 µm (femtoplankton) to >20 cm (megaplankton) [2]. Although the size of plankton is relatively small, especially phytoplankton, which has a large ecological role in the biosphere, it can play an important role in maintaining the geothermal balance by controlling the expansion and thickness of clouds that pass through the oceans. Phytoplankton from the Coccolithopore group plays an important role in this. Coccolithophore sp. has two flagella like Dinoflagellates but this type is not poisonous [4].

This type can emit a substance that quickly turns into a gas that is reactive to sulfur known as dimethyl sulfide or DMS. Dinoflagellates, Coccolithophores, and Cyanobacteria are divisions that often cause DMSP. Examples are Alexandrium tamerense from the taxa Dinoflagellates, Emiliania huxleyi [5], and Phaeocystis spp. [6] of the taxa Coccolitophores [7]. In aquatic ecosystems, phytoplankton is the main trophic level in the food pyramid which occupies more than 70 percent of the earth's surface area, so it is absolute in the waters of phytoplankton [8]. The presence of phytoplankton is closely related to the physical and chemical quality of the waters. Therefore, we have conducted research for the last 3 years, so we can see the trend of phytoplankton and physico-chemical factors as determining factors for water pollution at ESPP Teluk Sirih.

2. Material and Methods

2.1. Materials

The tools used in this study were net plankton, GPS (Global Positioning System), buckets, plastic, 250 ml sample bottles (dark and light), film bottles, 300 ml brown bottles, erlenmeyer, dropper pipettes, label paper, pH meter, thermometer, 2 liters jerry can, 90% acetone, ice box/freezer, spectrophotometer, object glass, cover glass, titration kit, microscope, camera and stationery. The materials used were 40% formalin, $MnSO_4$, KOH/KI, concentrated H_2SO_4, 1% starch, 0.02N NaOH, 0.025N $Na_2S_2O_3$, 1% phenolphthalein, 1% lugol, aluminum foil, $MgCO_3$, and distilled water. Identification of phytoplankton using books [9] and [10], [11] and [12], [13], and [14]. The data obtained between physical and chemical parameters, the value of phytoplankton abundance, diversity index, dominance index, and evenness index as well as the correlation of physical and chemical parameters with phytoplankton diversity were explained descriptively.

2.2. Methods

2.2.1. Sample collection and preparation

This research was conducted using from 2019 until 2021. The survey method with a qualitative and quantitative approach. Phytoplankton collection was carried out by vertical screening method using a 30µm mesh plankton net. The location (station) for plankton sampling was determined by Purposive Random Sampling by considering the surrounding environmental baseline which would have an impact on physical, chemical, and biological factors. Based on these considerations, each sampling point was determined to be 2 observation stations with 2 repetitions in three years. Namely the outfall and inlet of ESPP Teluk Sirih. The exact location of the outfall is at coordinates 1º 04' 29" S and 100º 22' 00" E and the inlet is at coordinates 1º 04' 25" S and 100º 22' 20" E. Outfall is water coming out of the ESPP Teluk Sirih process (hot water) while the inlet is seawater entering the ESPP Teluk Sirih process. Complete location and sampling method Figure 1 and Figure 2 Plankton Sampling.

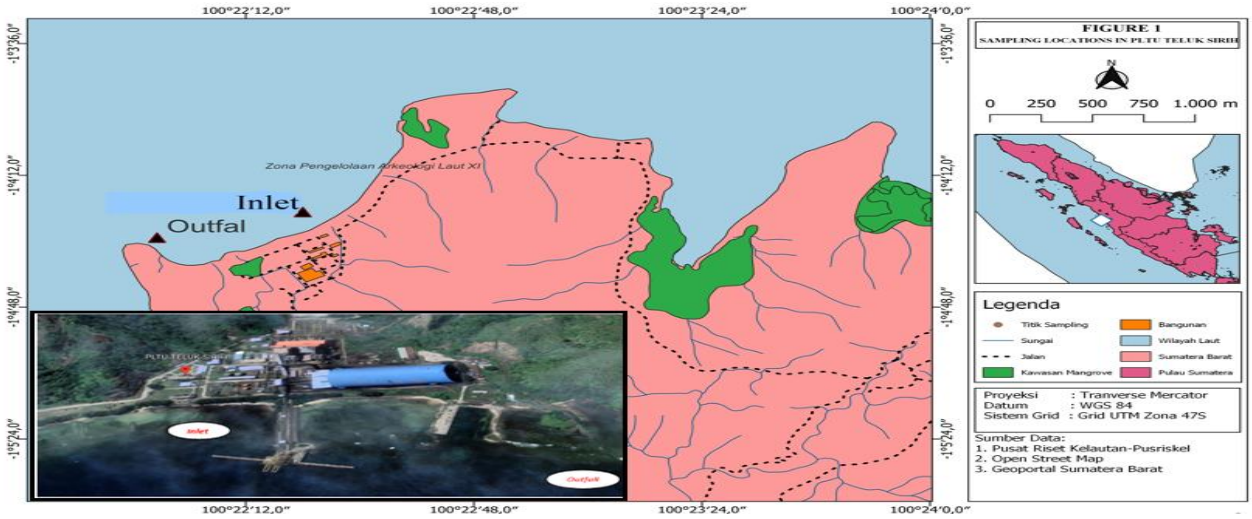

Figure 1. Map of sampling locations and sampling sites
Source: Google Earth Pro And GIS 3,22,16

Figure 2. Plankton Sampling at ESPP Teluk Sirih
Source: Documentation on 2021

2.3. Data Analysis

The composition of phytoplankton can be explained with Data Density (D) and Relative Density (RD %) of phytoplankton can be calculated using the following formula base on [15]:

$$\text{Density (D)} = \frac{axc}{L}$$

Where
a = The average type of plankton in 1 ml
c = Sample volume concentrate
L = Filtered water volume (liters)

Relative Density (RD%)

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

The structure of phytoplankton consists of the diversity index, evenness index, and dominance index. Diversity index (H') is calculated by H' Shannon-wiener using the following formula and its value is compared with the water quality scale according to the diversity index of aquatic biota [16] (**Table 1**).

$$H' = -\sum_{i=1}^{s} \frac{Ni}{N} \ln \frac{Ni}{N}$$

where,
H' = Diversity index
Ni = Total Individual in a species
N = Total individual all species

Table 1. Water Quality According to Phytoplankton and Zooplankton Diversity Index

No.	Diversity Index (H') Plankton	Categories	Scale
1	<0.3	Very Ugly	1
2	0.3 – 0.7	Bad	2
3	0.7 – 1	Pretty good	3
4	1 – 5	Well	4
5	>5	Very good	5

Source [17]

2.3.1. Evenness Index (E)

The evenness index is to see whether the distribution of phytoplankton is evenly distributed or not which is marked with a value close to 1 [16]. The evenness index and domination index are as follows

E = H' / H max

where
E = Evenness Index
H' = Diversity Index
Hmax = ln(S)
S = All Types

2.3.2. Dominance Index (C)

The dominance index shows the presence or absence of dominant phytoplankton organisms in an aquatic habitat [16]. Calculated by the following formula:

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

where
C = Dominance Index

Ni = Number of individuals to i species
N = Total number of individuals of all species

Dominance index values (C) range from 0 to 1. If the C value is close to 0 then some individuals dominate, but if the C value is close to 1 then no individual dominates [17].

3. Results and Discussion

Based on the results of observations and laboratory analysis, it was found that plankton outfall for three consecutive years was in 2019, namely 17 species, in 2020 there were 13 species and in 2021 it increased to 22 species. Whereas in the inlet, phytoplankton was found in 2019, namely 19 species, in 2020 there were 19 species and in 2021 it decreased to 17 species. The phytoplankton is grouped into 3 classes, namely Bacillariophyceae, Cyanophyceae, and Dinophyceae.

The Bacillariophyceae class is the most commonly found in the sea, followed by Dinophyceae and Cyanophyceae which are only one type, namely Trichodesmium sp. However, it dominates in the waters during the study with its relative abundance reaching 94.29%. Several types that are often found in ESPP Teluk Sirih waters can be seen in Figure 3. The trend of phytoplankton data can be seen in Figures 4 and 5 below.

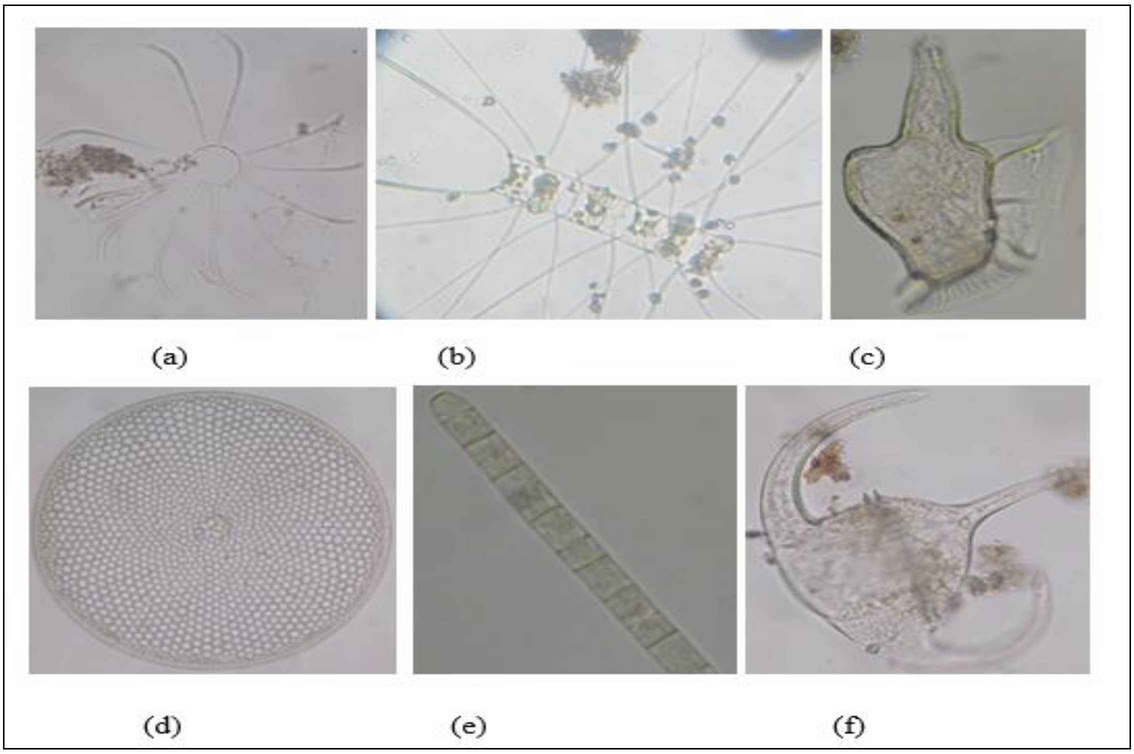

Figure 3: Frequently phytoplankton species recorded: *a) Bacteriastrum sp., b) Chaetoceros sp. c) Dinophysis sp. d) Coscinudiscus sp. e) Trichodesmium sp. f) Ceratium sp. Olympus Magnification Microscope 400x.*
Source: *Laboratory Documentation, 2021*

In Figure 4. Have been seen the trend of the tendency of phytoplankton to outfall, namely the abundance fluctuates from 2019 to 6,187 cell/L, in 2020 it increased to 6,233 cell/L, while in 2021 it decreased significantly to 2,869 cell/L. The tendency for the abundance of phytoplankton to decrease in 2021 is thought to be influenced by sampling conditions with extreme weather, namely rainstorms, this also has an impact on water-physico-chemical factors such as the temperature dropping to 24^0C and also phenol increasing far above the Threshold Limit Value (NAV). namely 0.053 mg/L.

According to [18], the high content of phenolic compounds can cause blooms of phytoplankton which release poisons such as saxitoxin ($C_{10}H_{17}N_7O_4$) and the like. Saxitoxin-type poison is one of the causes of Paralytic Shellfish Poisoning (PSP). The poison will show symptoms such as dizziness, headache, mouth stiffness, muscle weakness causing difficulty moving and speaking, diarrhea, vomiting, difficulty breathing, and others. Examples of phytoplankton that produce PSP are Pyrodinium sp., Gymnodinium sp., Protoperidium sp., Prorocentrum sp., and Dynopsis caudate. Dynophysis sp. which was found at the time of this study was still low, namely a Relative Abundance of 0.087%. Likewise, the phytoplankton diversity index fluctuated following the number of taxa in the three years of study. While the phytoplankton diversity index in 2019 was 0.746, in 2020 it decreased to 0.354, and in 2021 it increased to 1.135. If the diversity index value refers to the literature [17], the plankton condition is quite stable but reflects to well water quality.

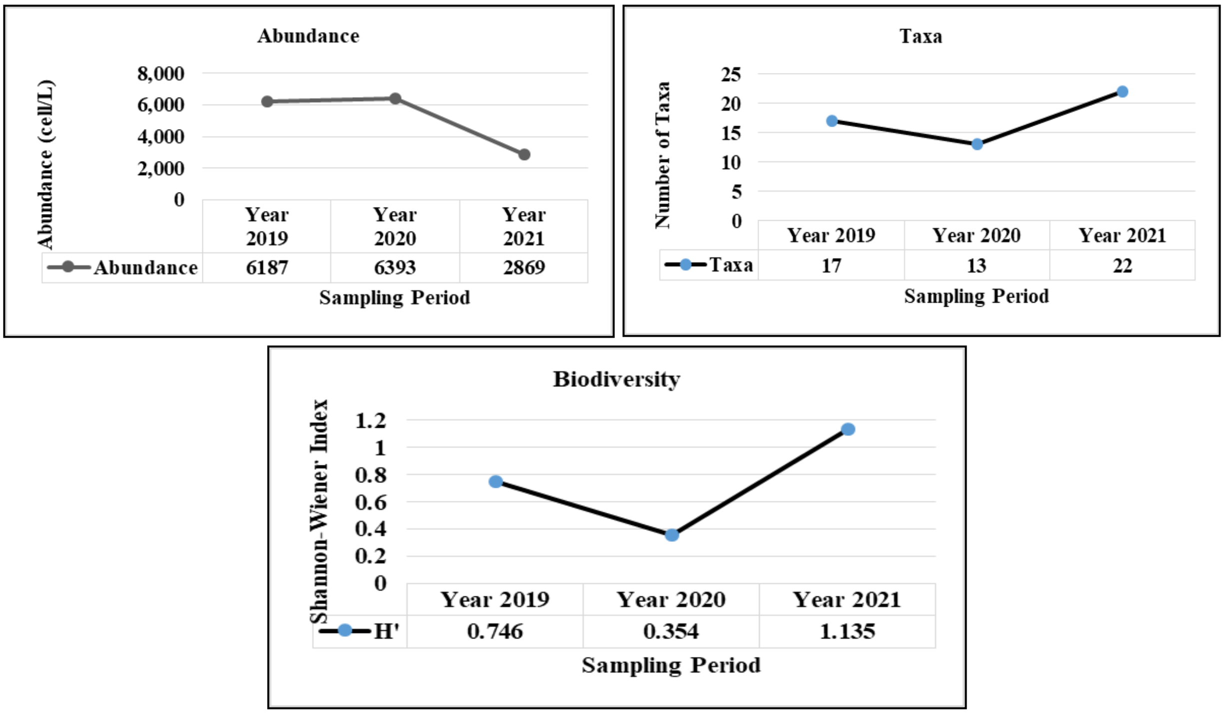

Figure 4. Graph of Trends in Abundance Trends, Number of Taxanes, and Phytoplankton Diversity Index (H') at Outfall Locations

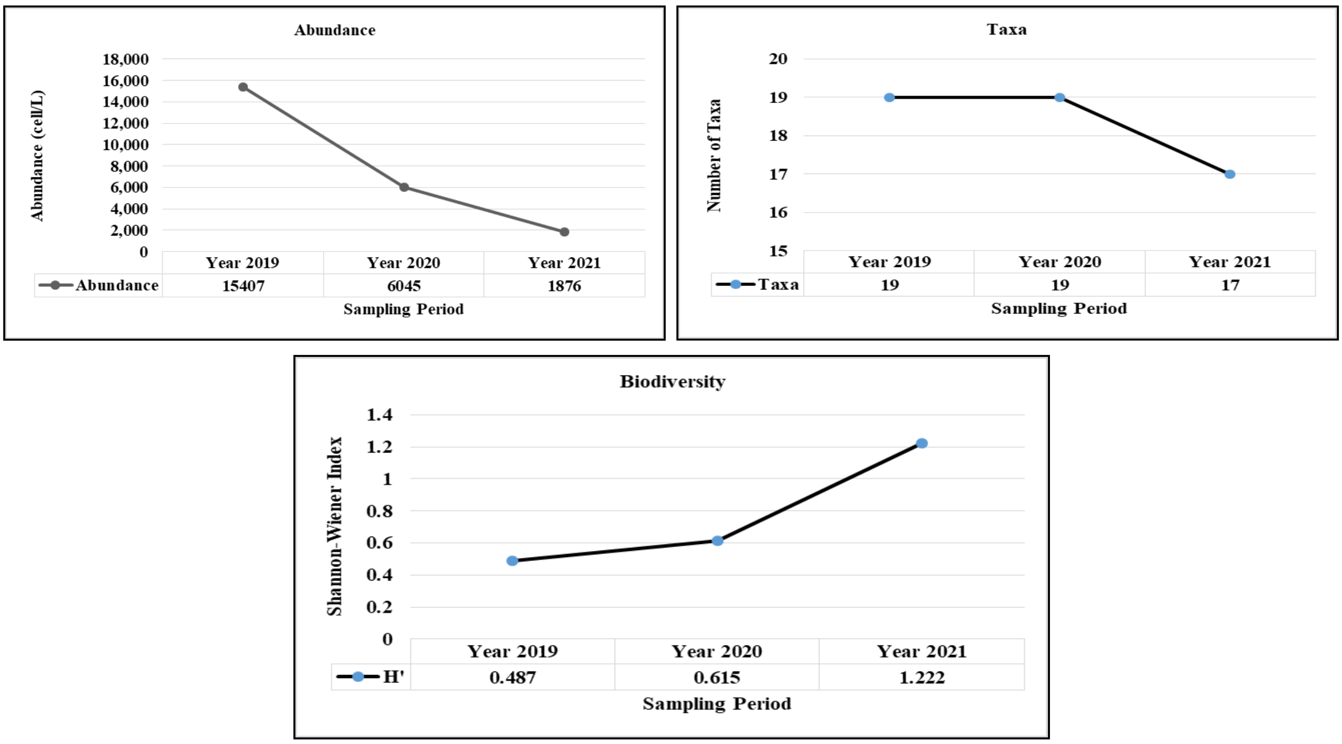

Figure 5. Graph of Phytoplankton Abundance, Number of Taxa, and Diversity Index (H') at Inlet Locations

In Figure 5. Have been seen the trend of abundance and number of phytoplankton taxa at the inlet location tends to decrease while the diversity index increases in 2021. Abundance tends to decrease, namely from 2019 as many as 15,407 cells/L, in 2020 as many as 6,045 cells/L while in 2021 it continues fell to 1,876 cells/L. Likewise in the outfall area, a drastic decrease will occur in 2021. Where the physical and chemical conditions of the water are also almost the same, namely the temperature of 24.60C and 0.011 mg/L of Phenol which has exceeded the quality standard where the Threshold Value (NAV) is 0.002 mg/L. However, the diversity index increased from 2019, which was 0.87. In 2020, it was 0.615, and in 2021, which was 1.222, which was >1. The diversity index can already show that the water quality is well. This research also observed other water-chemical physical factors which can be seen in Table 2 and Table 3 below.

Table 2. Water Chemistry and Physics in Outfall

No.	Parameter	Sampling Location Outfall / Year			Quality Standards
		2019	2020	2021	
	Physic				
1	Brightness (cm)	>5	>5	> 5	>3
2	TSS (Suspended Solids) (mg/L)	12	17	1.6	80
3	Temperature °C	32	29	24.7	Natural
	Chemistry				
4	pH	8.29	8.09	7.76	6,5-8,5
5	Salinity (%o)	33.63	33.74	19.2	Narural
6	Total ammonia (NH3-N) (mg/L)	<0.014	<0.012	0.017	0.3
7	TOC (Hydrocarbon Total) (mg/L)	21	47.4	62.6	110
8	Sulfide (mg/L)	<0.002	0.002	<0.002	0.03
9	Phenol (mg/L)	0.002	0.001	0.053	0.002
10	Detergent (mg/L)	<0.02	0.026	0.033	1
11	Oil and fat (mg/L)	<0.10	<0.345	<0.345	5
12	Mercury (Hg) (mg/L)	<0.0006		<0.0004	0.003
13	Cadmium (Cd) (mg/L)	<0.003	<0.003	<0.003	0.01
14	Copper (Cu) (mg/L)	<0.019	<0.013	<0.016	0.05
15	Lead (Pb) (mg/L)	<0.002	<0.002	<0.020	0.05
16	Zinc (Zn) (mg/L)	<0.010	0.084	<0.016	0.1

Source: Laboratory Analysis Results of UPTD Labkes, West Sumatra Province, 2019, 2020 and 2021
Quality Standards *) [20]

Table 3. Water Chemistry and Physics in Inlet

No.	Parameter	Sampling Location Outfall/ Year			Quality Standards
		2019	2020	2021	
	Physic				
1	Brightness (cm)	>5	>5	>5	>3
2	TSS (Suspended Solids) (mg/L)	11	3	1.1	80
3	Temperature °C	29	29	24.6	Natural
	Chemistry				
4	pH	8.33	8.19	8.18	6.5-8.5
5	Salinity (%o)	36.4	35.52	19.2	Natural
6	Total ammonia (NH3-N) (mg/L)	<0.014	<0.012	0.024	0.3
7	TOC (Hydrocarbon Total) (mg/L)	26	47	62.6	110
8	Sulfide (mg/L)	<0.002	0.006	<0.002	0,03
9	Phenol (mg/L)	<0.002	0.002	0.011	0.002
10	Detergent (mg/L)	0.02	0.079	<0.01	1
11	Oil and fat (mg/L)	<0.1	<0.345	<0.345	5
12	Mercury (Hg) (mg/L)	<0.0006		<0.0004	0.003
13	Cadmium (Cd) (mg/L)	<0.003	<0.003	<0.003	0.01
14	Copper (Cu) (mg/L)	<0.019	<0.013	<0.016	0.05
15	Lead (Pb) (mg/L)	<0.002	<0.002	<0.02	0.05
16	Zinc (Zn) (mg/L)	<0.010	0.038	<0.016	0.1

Source: Laboratory Analysis Results of UPTD Labkes, West Sumatra Province, 2019, 2020 and 2021. Quality Standards *) [20]

Based on the data in Table 2. from the analysis of sea water quality above, physical factors such as brightness of more than 5m, when compared with the quality standard of [20] still above the quality standard and in good condition. Brightness directly affects the growth of phytoplankton because the deeper the sunlight enters the water, the more light the phytoplankton can use for photosynthesis [21]. Furthermore, TSS (Suspended Solids), is also still below the NAV stipulated by [20], namely the value ranges from 1.1 – 11 mg/L with a quality standard of 80 mg/L. TSS is used as an indicator of water quality in an environment, the higher the level of concentration of TSS causes light penetration to water and interferes with photosynthesis [22]. From the research, it was found that the concentration of TSS was low but the value of the abundance of phytoplankton was high. High concentrations of TSS will reduce the primary productivity of aquatic macrophytes and microphytes [23]. However, research found by [8] showed that TSS was already high, ranging from 50-130 mg/L.

The research was conducted in Sungai Pisang Bay. The high TSS in this bay is thought to be due to water runoff from the mainland, which brings material from the land. The temperature found ranged from 24.6-32^{o}C. the highest temperature was found at the outfall station in 2019 and the lowest at the inlet in 2019. In general, the optimal temperature for plankton development is 20^{o}C - 30^{0}C. The minimum temperature of phytoplankton to carry out photosynthesis is 5^{o}C and the maximum temperature of phytoplankton to carry out photosynthesis is 30^{o}C [24]. Water temperature is an abiotic factor that plays an important role in the life of aquatic organisms including plankton [25]. The temperature found in Sungai Pisang Bay ranges from 30-31^{o}C. This temperature is still within the normal range for the growth of aquatic biota [8].

The measured pH levels ranged from 7.76 – 8.33. The highest PH was in 2019 at the inlet station and the lowest was in 2021 at the outfall station. The pH value in ESPP Teluk Sirih waters is high for optimal phytoplankton growth. The ideal pH for the growth of phytoplankton in the waters is 6.5 – 8.0. [8] also found a pH in the range of 8.68-8.8. This is higher than in the current study. The average pH value of Pisang River Bay waters is 8.68-8.83, which is above the quality standard [33].

Salinity ranges from 19.2-36.4‰. The highest salinity occurred in 2019 at the inlet and the lowest in 2021. The salinity value is low because it is still influenced by river flow. Salinity values in coastal areas range from 32 – 34‰, fluctuations in salinity can directly cause changes in osmotic pressure in cells.

The research by [33] salinity in sea water namely 31-32‰. Too high a salinity will cause the osmotic pressure inside the cell to be higher as well so cell activity becomes disrupted. Almost all types of phytoplankton originating from seawater can grow optimally at slightly low salinity. In general, phytoplankton can develop well at a salinity of 15 – 32‰ [27]. The research by [8] found salinity ranged from 31-32‰. The range of salinity in Sungai Pisang Bay is higher than that in Sirih Bay.

Ammonia (NH3-N) can be derived from nitrogen which becomes NH4 at low pH and is called ammonium. The results showed that the concentration of ammonia ranged from <0.012 – 0.024 mg/l. Low fertility with a Total N value of 0 - 0.1 mg/m^3, moderate fertility with a Total N value > 0.1 - 1 mg/m^3, and high fertility with a Total N level > 1 mg/m^3. While the nitrate found in [8] ranges from 0.012-0.025, where the nitrate is still below the quality standard and is still good for plankton growth.

TOC concentration in waters is influenced by several factors, among others; water bathymetry, water substrate, patterns of water currents, the influence of human activities, and aquatic vegetation. The measured TOC concentration at the Teluk Sirih ESPP is 21-62.6 mg/L, this is still below the environmental quality standard of 110 mg/L.

The limit of the measuring instrument used to measure the sulfide content in water is 0.001 mg/l [28]. The measurement results show that the value is still below the limit of the measuring instrument that can be tested, which ranges from <0.001-0.003 mg/L. This sulfide concentration is still below the NAV quality standard, which is 0.03 mg/L, so it is still good for the growth of aquatic biota.

Phenol increased in 2021 monitoring in the Outfall area. Phenol can come from coal, fiber, resin industry, steel, glue, iron, rubber, oil refineries, and waste water from plastic and other synthetic fuel industry effluents. While natural sources are from animal waste and the decomposition of organic matter. This ESPP Teluk Sirih uses coal as fuel the high phenol may be caused by spilled coal from ships and also runoff water [8].

Detergent is a pollutant to the environment. Some of the effects of detergent waste on the environment such as decreased DO levels, changes in the physical and chemical properties of water, and the occurrence of eutrophication (enrichment of elements). The detergent found was still below the quality standard, namely <0.01-0.079 mg/l, while the quality standard was 1 mg/L. it can be concluded that the detergent content in ESPP Teluk Sirih waters is still good for the growth of seawater biota [8]. The CO_2 levels ranged from the-4.4 ppm And BOD_5 was 0.12-2.7 ppm [33].

Oil and grease in sea waters can come from ship spills and domestic activities from the mainland. The concentration of oil in ESPP Teluk Sirih waters ranges from 0.1–0.345 mg/L. The concentration of oil content in the outfall and inlet is still below the threshold for oil concentration in marine waters for the survival of marine biota as stipulated in [20], which is 1 mg/L [32]. This high oil and fat will have an impact on marine organisms, including interfering with the process of reproduction, growth, and behavior of marine biota [29].

Mercury (Hg) is rarely found in free form in nature, Hg is generally found in rocks or other minerals, Hg is used to bind gold in the mining process. The mercury value in ESPP Teluk Sirih waters does not cross the seawater quality standard threshold, which ranges from <0.0004-0.0006 where the Hg quality standard is 0.003 mg/L, so this Hg value is still in the safe category for marine biota. Cadmium (Cd) concentration measured at the time of the study was <0.0003 mg/L while the NAV was 0.01 mg/L.

Copper metal (Cu) in the waters is also very little found. The measurement results show that the concentration of Copper (Cu) metal is still below the NAV of marine water quality for biota based on the Minister of Environment Decree [20], namely <0.002 where the quality standard concentration is 0.05 mg/L. so that Cu levels are still good for the growth of marine biota.

The level of lead (lead) in ESPP Teluk Sirih waters is still below the threshold, the permissible quality standard is 0.05 mg/L. Lead levels are <0.002 - 0.02 mg/L. However, the metal content is still relatively small and does not significantly affect biota. sea. The source of lead entry into the waters is thought to come from the activity of ships docking at the Jett, if the volume of these ships docking increases, it is possible that the Pb content will also increase [30].

Zinc (Zn) in seawater comes from the use of chemical fertilizers containing Cu and Zn metals. However, in the process at the Teluk Sirih ESPP, no fertilizer is used. While other sources come from domestic activities containing Zn metal such as the corrosion of water pipes [31]. The results of this three-year Zn study were in the range of <0.01-0.08 mg/L, this value was still below the quality standard of 0.1 mg/L.

4. Conclusion

Based on the research, it can be concluded that the trend of phytoplankton trends during the three years of research at the outfall and inlet is relatively increasing. Likewise, the physical factors of water chemistry are generally under quality standards except for phenol levels which have exceeded quality standards. It can be concluded that the level of pollution in the waters of the Teluk Sirih Steam Power Plant area is still low in the good category so it is still safe for marine biota.

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Appendix

Table 1. Species of Phytoplankton

No.	Classes and Species of Phytoplankton
	BACILLARIOPHYCEAE
1	*Amphiprora* sp.
2	*Amphora* sp.
3	*Bacteriastrum sp.*
4	*Biddulphia* sp.
5	*Chaetoceros* sp.
6	*Climacodium* sp.
7	*Cocconeis* sp.
8	*Coscinodiscus* sp.
9	*Dactyliosolen* sp.
10	*Diploneis sp.*
11	*Ditylum* sp.
12	*Fragilaria* sp.
13	*Guinardia sp.*
14	*Gyrosigma sp.*
15	*Hemiaulus* sp.
16	*Lauderia* sp.
17	*Leptocylindrus* sp.
18	*Melosira* sp.
19	*Navicula* sp.
20	*Nitzschia sp.*
21	*Planktoniella* sp.
22	*Pleurosigma* sp.
23	*Rhizosolenia* sp.
24	*Skeletonema* sp.
25	*Streptotheca* sp.
26	*Striatella* sp.
27	*Tabellaria* sp.
28	*Thalassionema* sp.
29	*Thalassiothrix* sp.
	CYANOPHYCEAE
30	*Trichodesmium* sp.
	DICTYOCHOPHYCEAE
31	*Dictyocha* sp.
	DINOPHYCEAE
32	*Ceratium* sp.
33	*Dinophysis* sp.
34	*Gymnodinium* sp.
35	*Ornithocercus* sp.
36	*Peridinium* sp.
37	*Pyrocystis* sp.