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Epiplastic Microalgae Community on Food and Beverage Plastic Waste at Ancol Lagoon Beach, North Jakarta, Indonesia

Riani Widiarti[1*], Elisabeth Hermine[1], Niken Balqis Fisabila Helmi[1], Danang Ambar Prabowo[2]

[1]Department of Biology, Universitas Indonesia, Depok, West Java, Indonesia
[2]National Agency for Research and Innovation, Cibinong, West Java, Indonesia
[*]Corresponding Author: rianiwid@sci.ui.ac.id

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ABSTRACT

Plastic waste is one of the major problems affecting Indonesian oceans and waters. Plastic surface can create new pelagic habitats for microorganisms, hence it plays a great role in the distribution of toxic and non-toxic microalgae with the potential to trigger harmful algal blooms (HABs) into other areas. This study aimed to assess the presence of microalgae attached to *Polypropylene* (PP) and *Polyethylene Terephthalate* (PET) plastic food and beverage waste, as well as its relationship with water quality at Ancol Lagoon Beach, North Jakarta. Sampling was carried out by collecting plastic waste that was submerged in the water, using purposive random sampling at 3 station points. The results showed that there were 21 genera of epiplastic microalgae originating from 3 classes, namely Bacillariophyceae (17 genera), Dinophyceae (1 genus), and Cyanophyceae (3 genera). In addition, 5 had the potential to cause HABs, namely *Coscinosdiscus, Thalassiosira,* and *Trichodesmium* from the Red Tide Maker group, as well as *Prorocentrum* and *Pseudonitzschia* from the Toxin Producer group. The Pearson correlation showed that water acidity, brightness, salinity, and dissolved oxygen had a positive correlation with the abundance of epiplastic microalgae. The microalgae community that caused HABs and were found attached to plastic waste must be closely monitored. This was primarily because the waste could be carried by currents and dispersed to other areas, including Jakarta Bay and the Seribu Islands, both of which frequently experienced HABs.

INTRODUCTION

The accumulation of large amounts of plastic waste is one of the major problems affecting Indonesian oceans and waters. The waste is largely produced from land-based activities, including river estuaries, drainage systems, and marine tourism **(World Bank, 2021)**. In addition, the activities pose a severe threat to marine ecosystems and biota, causing hypoxia or low oxygen conditions due to the obstruction of gas exchange. These conditions negatively affect coral reefs and fish, leading to a significant decrease in populations **(Goldberg, 2002)**. The abundant presence of plastic can also create new pelagic habitats for microorganisms and invertebrates. It also plays a role in the distribution of toxic and non-toxic microalgae with the potential to trigger water pollution or other dangerous phenomena in new areas **(Reisser *et al.*, 2014)**.

According to previous studies, Polypropylene (PP) plastic is a major environmental pollutant in marine ecosystems. This material is commonly used in snack packaging due to its slightly stiff nature, resistance to brittleness, and durability, with decomposition taking up to hundreds of years. In addition, another type of plastic waste with a fairly large percentage is from packaged beverages, which typically consist of Polyethylene Terephthalate (PET). Several studies have shown that PET plastic waste has various properties, such as high resistance to natural degradation when compared to other types. Due to the resistance and lightweight, it can be carried by currents to distant places without damage or changes in shape. These properties make PP and PET plastic suitable substrates for attachment and distribution for epiplastic microalgae. As substrate, plastic provides a habitat that can last longer than most natural substrates, thereby increasing the potential for the distribution of epiplastic microalgae **(Barnes, 2002)**.

The most common microalgae found in tropical waters are the diatom (Bacillariophyceae), blue green algae (Cyanophyceae), green algae (Chlorophyceae), and dinoflagellate (Dinophyceae) **(Nontji, 2006)**. These organisms can live attached to a substrate, either natural or artificial **(Vila *et al*., 2001)**. Although microalgae play an essential role for other organisms, rapid overgrowth can lead to a population explosion, posing serious risks by causing harmful algal blooms (HABs) **(Nontji, 2006)**. Several studies have shown that HABs typically occur when there is an overabundance of microalgae, either toxic or non-toxic, which affects the aquatic ecosystem **(Hallegraeff, 1993)**. One factor that can trigger microalgae productivity is eutrophication or an excessive increase in nutrient levels **(Hallegraeff *et al.*, 2003)**.

In line with these findings, Ancol Lagoon Beach is Indonesian waters with high nutrient content; it serves as a tourist and family recreation spot in North Jakarta. The high nutrient content is primarily due to water pollution, and the various sources of contamination can change the abundance of microalgae as well as increase the potential for HABs **(Aminah *et al.*, 2020)**. In addition, Ancol Lagoon Beach is a recreation area with a high percentage of PET beverage waste **(Sasmitha, 2017; Republika, 2022)**. This has raised concerns that PP and PET plastic waste can increase the possibility of HABs, with the potential for the waste to be carried out by currents to distant waters, further spreading microalgae. Therefore, this study aimed to assess the presence of microalgae attached to PP and PET plastic food and beverage waste, as well as its relationship with water quality at Ancol Lagoon Beach. This was important because the waste could be carried by currents and dispersed to other areas, including Jakarta Bay and the Seribu Islands, both of which are frequently experienced by HABs.

MATERIALS AND METHODS

The sampling location was determined based on the presence of plastic waste substrates for food and beverage packaging in Jakarta Bay, namely Ancol Lagoon

Beach. Determination of sampling points was carried out using the purposive random sampling method. The study was conducted by creating 3 station points spread across the coast, and the coordinates of the 3 stations were then recorded using GPS (Fig. 1). Station 1 (STA 1) was located in the open sea near the boundary of Taman Impian Jaya Ancol, Station 2 (STA 2) was situated along the shoreline of Lagoon Beach, while Station 3 (STA 3) was located at the tourist boat dock.

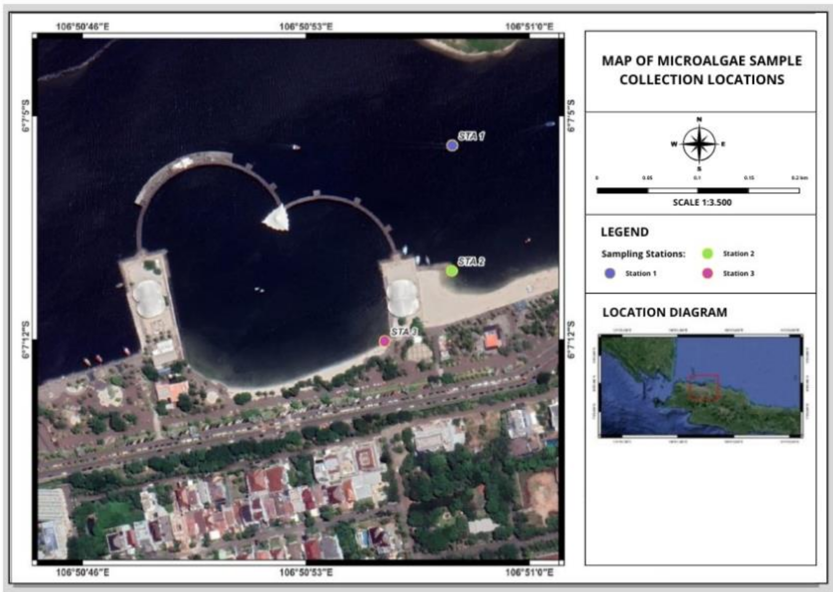

Fig. 1. Sampling location in Ancol Lagoon Beach, North of Jakarta

The main tools and materials used in the study were sample bottles, 25 and 125µm graduated sieves, spray bottles, measuring glass, cover glasses, object glasses, pippette, Olympus CX Series light microscopes, Vernier Stainless Steel Temperature Probe thermometers, Atago Master S/Mill-E Handheld Refractometers, and Krisbow KW06-28 Light Meters. Other tools included the DO meter Vernier Optical DO Probe, Lamotte Secchi disc, floating droadge, stopwatch, universal indicator, PET and PP plastic waste of food and beverage packaging, filtered seawater, and 40% formalin.

Plastic waste of food and beverage packaging on the shores of Ancol Lagoon Beach was taken, then put into a container, and soaked in filtered seawater. This was shaken for 2 minutes and then sprayed with a spray bottle over the entire surface, using filtered seawater. Furthermore, the water from the spraying was combined with the water from the shaking. The water samples obtained from the shaking and spraying process were stored in a container, filtered with a 125µm sieve and then with a 25µm sieve. Microalgae caught on the 25-micron sieve were rinsed using a spray bottle containing 85ml of clean filtered seawater, stored in a sample bottle and then added with 15ml of 40% formalin solution.

Microalgae observation was carried out by taking 0.04ml of sample water using a pippette, dropping it onto an object glass, and then covering it with an $18x18mm^2$ cover glass. The samples were observed under an Olympus CX Series light microscope with a magnification of 4x10 to observe the presence and to calculate the abundance of microalgae. The observed microalgae were counted and photographed, then identified using the identification book guide **(Taylor *et al.*, 2007; Al-Yamani & Saburova, 2010; Bellinger & Sigee, 2015)** to the genus level.

The formula used to calculate the abundance of microalgae was based on **Kibler *et al.* (2012)** which was also used by **Firdaus *et al.* (2021)** in their study:

$$S = \frac{J}{H} \, x \, \frac{I}{G} \, x \, \frac{F}{N}$$

The symbol S represented the abundance of microalgae (cells/gram), and J was the number of cells observed in the object glass. The symbol H was the volume of the sample observed using the object glass (ml), and the final volume after filtering and rinsing was represented by I (ml). The volume of the filtered sample was represented by G (ml), and the symbol F was the total volume of samples taken from the field (ml). Lastly, N was the wet weight of the PP and PET plastic food and beverage waste samples used (grams).

Environmental parameter measurements at Ancol Lagoon Beach were also carried out at 3 station points. The environmental parameters measured were temperature using a thermometer, light intensity using a lux meter, salinity using a refractometer, acidity or pH using a universal indicator, water clarity using a Secchi disc, ocean currents using floating droudge, and dissolved oxygen content using a DO meter.

Statistical analysis was used to highlight the relationship or correlation between microalgae abundance and the physical-chemical parameters of the environment at 3 different points. This analysis was used to spot the possibility of environmental factors influencing microalgae growth. If a relationship between environmental factors and microalgae is found, then this analysis shows the most optimum environmental factors for microalgae growth. The statistical analysis was carried out using the Pearson correlation analysis method.

RESULTS

There were 17 genera of epiplastic microalgae that were successfully identified from the substrate of PP plastic food packaging waste in the waters of Ancol Lagoon Beach. This microalgae came from 3 classes, namely Bacillariophyceae (14 genera), Dinophyceae (1 genus), and Cyanophyceae (2 genera) which included *Achnanthes, Cocconeis, Coscinosdiscus, Cymbela, Gyrosigma, Trichodesmium, Mastogloia, Merismopedia, Navicula, Nitzschia, Paralia, Pleurosigma, Prorocentrum, Skeletonema, Stephanopyxis*, *Thalassionema*, and *Thalassiosira* (Fig. 2).

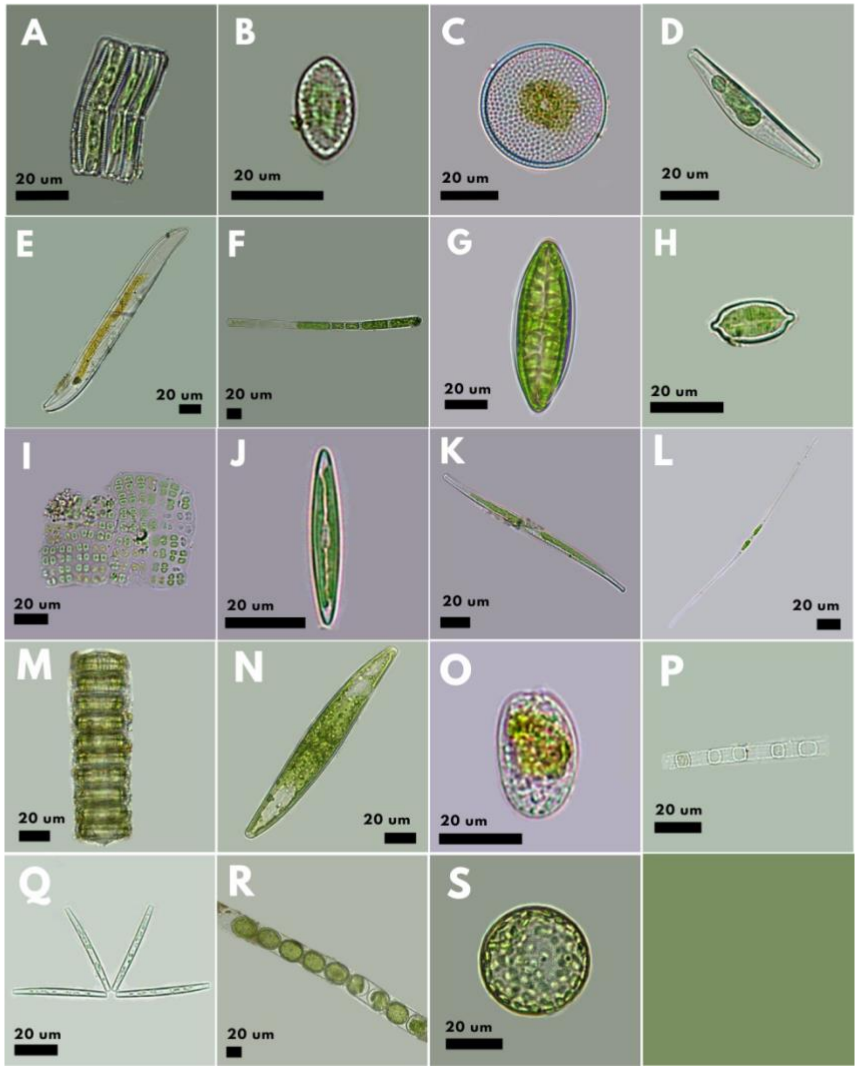

Fig. 2. Microalgae genera found (**A**) *Achnanthes* (**B**) *Cocconeis* (**C**) *Coscinodiscus*, (**D**) *Cymbella* (**E**) *Gyrosigma* (**F**) *Trichodesmium* (**G - H**) *Mastogloia* (**I**) *Merismopedia* (**J**) *Navicula* (**K – L**) *Nitzschia* (**M**) *Paralia* (**N**) *Pleurosigma* (**O**) *Prorocentrum* (**P**) *Skeletonema* (**Q**) *Thalassionema* (**R**) *Stephanopyxis* (**S**) *Thalassiosira*. The line showed a scale of 20 μm [Source, Personal Documentation]

The epiplastic microalgae found on PET plastic beverage packaging on Ancol Lagoon Beach, numbered 15 genera. The number of genera consisted of 13 Diatom genera, 1 dinoflagellate genus, and 1 cyanobacteria genus (Fig. 3). The Bacillariophyceae found consisted of genera *Achnanthes*, *Coscinodiscus*, *Cymbella*, *Gyrosigma*, *Licmophora*, *Navicula*, *Nitzschia*, *Odontella*, *Pleurosigma*, *Pseudo-Nitzschia*, *Skeletonema*, *Stephanopyxis*, and *Thalassiosira*. There was one genus of Dinophyceae found, namely *Prorocentrum* and the genus of Cyanophyceae found was *Trichodesmium*.

Fig. 3. Results of Identification of Epiplastic Microalgae **(A)** *Achnanthes*, **(B)** *Coscinodiscus*, **(C)** *Thalassiosira*, **(D)** *Gyrosigma*, **(E)** *Pleurosigma* **(F)** *Odontella*, **(G – H)** *Nitzschia*, **(I)** *Pseudo-Nitzschia*, **(J)** *Cymbella*, **(K)** *Navicula*, **(L)** *Licmophora*, **(M)** *Skeletonema*, **(N)** *Stephanopyxis*, **(O)** *Prorocentrum*, **(P)** *Trichodesmium.* The scale showed 20μm [Source, Personal Documentation]

The highest number of genera found on the substrate of PP plastic food packaging waste was at station 3 with 15 genera, and the fewest genera were found at station 2 with 12 genera (Fig. 4). The identification results obtained 2 genera of microalgae that could produce toxins, namely *Trichodesmium* and *Prorocentrum*. The abundance of epiplastic microalgae on the substrate of PP plastic food packaging waste at Ancol Lagoon Beach ranged from 174 - 24,051 cells/gram (Fig. 5). The highest abundance of epiplastic microalgae was at station 3 with an abundance value of 204,508 cells/gram and the lowest at station 1 with an abundance value of 77,723 cells/gram. Based on the genus, it could be seen that the highest abundance of epiplastic microalgae obtained in the study was the genus *Navicula* at 121,342 cells/gram. The second-highest abundance of microalgae found in the study was the genus *Cymbella* with an abundance value of 109,540 cells/gram. Furthermore, the genus *Merismopedia* in the report had the smallest abundance value, which was 249 cells/gram, and was only found at 1 station point at Station 2.

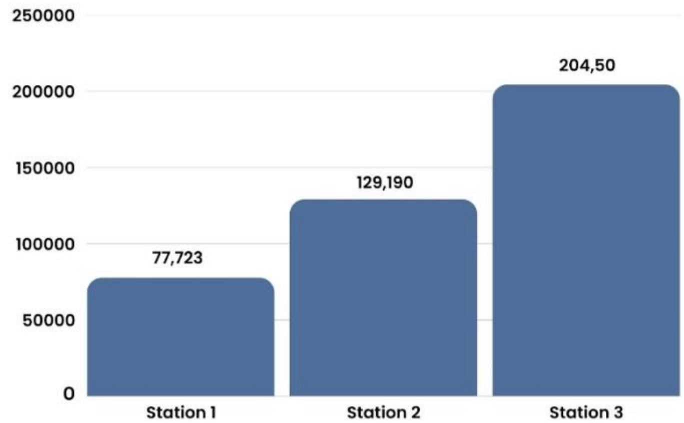

Fig. 4. Abundance of epiplastic microalgae in plastic waste of food packaging type PP at the 3 stations (cells/gram)

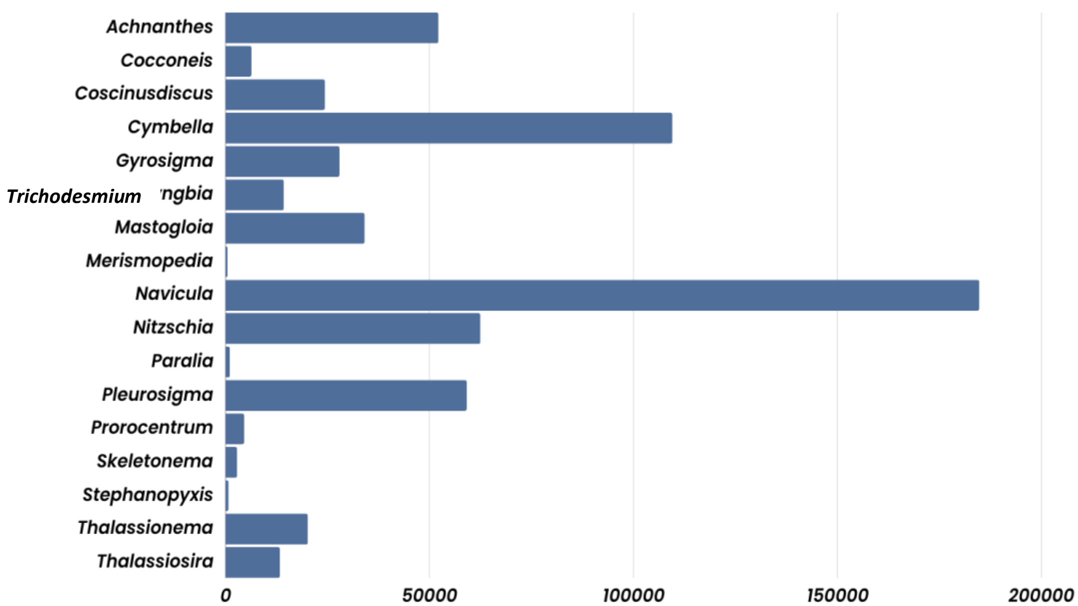

Fig. 5. Abundance of epiplastic microalgae in plastic waste of food packaging type PP at Ancol Lagoon Beach (cells/gram)

The genera of microalgae in PET-type beverage packaging plastic found at all stations were *Coscinodiscus*, *Cymbella*, *Navicula*, and *Nitzschia*, and were found in every sample taken. The genus of microalgae that was least frequently found was *Lycmophora* which was only found in a sample at 1 station and *Odontella* which was found in 2 samples at 1 station.

The abundance of each genus of epiplastic microalgae in PET beverage plastic waste in each sample ranged from 118 - 13,578 cells/gram, and the total abundance of microalgae in each sample ranged from 15,305 – 39,263 cells/gram (Fig. 6). Furthermore, the highest total abundance of microalgae was at station 3 with a value of 105,753 cells/gram (Fig. 7), and station 2 had an abundance of 82,785 cells/gram. The lowest abundance was at station 1 with a value of 64,537 cells/gram.

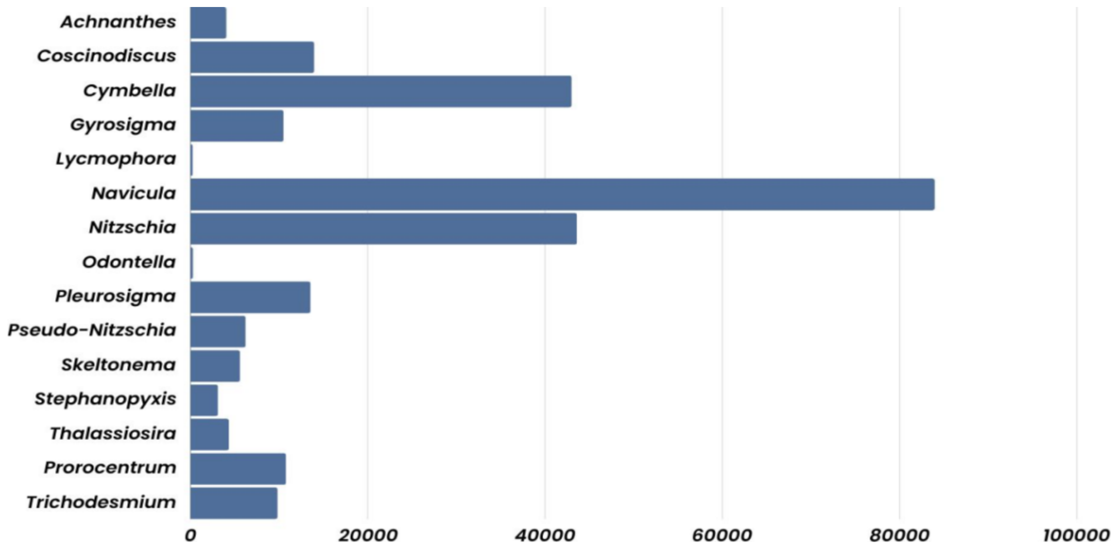

Fig. 6. The abundance of epiplastic microalgae in PET beverage plastic waste at Ancol Lagoon Beach (cells/gram)

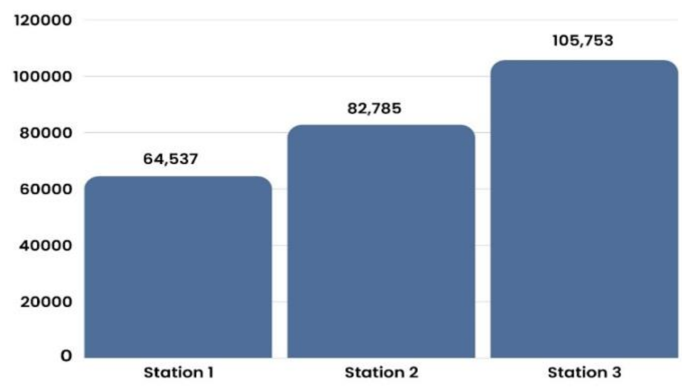

Fig. 7. The abundance of epiplastic microalgae in PET beverage plastic waste at the 3 stations (cells/gram)

The physicochemical factors of the Ancol Lagoon Beach waters were still within the quality standards based on Government Regulation No. 22 of 2021 **(PP RI, 2021)** (Table 1). This indicated that the water quality of Ancol Lagoon Beach was still in good condition and optimal for the existence and growth of organisms, including epiplastic microalgae.

Table 1. Environmental physicochemical parameter values at each station

Parameter	Station			Unit	Quality Standard
	1	2	3		
Temperature	31.7	31.1	30.4	oC	28-32
Salinity	30	31	31	ppt	30-34
Dissolved Oxygen (DO)	5.3	5.2	5.7	mg/L	>5
Acidity (pH)	7.1	7.3	7.6	-	7-8,5
Current	0.043	0.012	0.007	m/s	-
Brightness	50	70	150	Cm	-
Light Intensity	20900	26700	23600	Lux	-

Note: Quality standards based on Government Regulation No. 22 of 2021 (**PP RI, 2021**)

Based on the results of the calculation of the correlation between the physical-chemical factors of waters with the abundance of epiplastic microalgae using the Pearson correlation formula, it could be concluded that salinity, dissolved oxygen levels, acidity levels, light intensity, and brightness were positively related to the abundance of epiplastic microalgae because the correlation coefficient ranged from 0.00 to +1.00. Meanwhile, temperature and current were included in the negative correlation relationship with the abundance of epiplastic microalgae because the correlation coefficient ranged from 0.00 to -1.00 (Table 2).

Table 2. Correlation of the abundance of epiplastic microalgae in PP-type food packaging and PET-type beverages with the physical-chemical parameters of waters

Physical-chemical parameter	**PP-type food packaging**	**PET-type beverage packaging**
Temperature	-0.9	-0.99
Salinity	0.8	0.83
Dissolved Oxygen (DO)	0.8	0.79
Acidity (pH)	0.9	0.99
Current	-0.8	-0.89
Brightness	0.9	0.96
Light intensity	0.3	0.40

DISCUSSION

The differences in the abundance and condition of plastic waste across the stations were influenced by variations in water current strength and the intensity of human activities nearby. Station 3 (STA 3) has the most abundant epiplastic microalgae compared to other two stations, because Station 3 is located at the tourist boat dock, where very calm currents caused the accumulation of the largest amount of plastic waste. The waste in this area was generally dirtier, as the location was farther from the main tourist center, allowing for more prolonged accumulation and the growth of microalgae. Station 1 (STA 1) has the lowest abundant of epiplastic microalgae, because the station is located in the open sea near the boundary of Taman Impian Jaya Ancol. The strong water currents in this area resulted in minimal plastic waste being found, and the waste observed was generally clean.

The epiplastic microalgae genera found with the highest abundance in order were *Navicula, Cymbella,* and *Nitzschia*. This was suspected to be due to the cosmopolitan nature of *Navicula*, *Cymbella*, and *Nitzschia*, meaning that these 3 genera could be found in almost all marine waters worldwide **(Taylor *et al.*, 2007)**.

Species from the genus *Navicula* were generally tolerant to high levels of pollution. The genus *Navicula* was often used as an indicator of the level of eutrophication in waters. This was suspected to be the reason *Navicula* had the highest abundance **(Taylor *et al.*, 2007)**. *Cymbella* was known to have various types of species that had different levels of tolerance and location preferences and this reason made *Cymbella* easy to find in almost all waters **(Taylor *et al.*, 2007)**. According to the reference, *Nitzschia* was the second-largest Diatom genus after *Navicula* and was both benthic and planktonic. In addition, *Nitzschia* was also classified as a genus that was tolerant to organic pollution. This was suspected to be the reason *Nitzschia* was found to have high abundance **(Mann, 1986; Lundholm & Moestreup, 2000)**.

The least common and lowest abundance microalgae genus was *Merismopedia*, which was only found in a sample at 1 station. *Merismopedia* was a microalgae that was generally found in freshwater, although some species could survive in salt water. The abundance of *Merismopedia* was much higher in rivers than in seawater **(Schulte, 2020)**. The low abundance value of the *Merismopedia* genus could also be because some *Merismopedia* species were planktonic, not attached to the substrate **(Gomes *et al.*, 2021)**.

The microalgae genera with the potential to cause HABs included *Trichodesmium, Prorocentrum, Pseudonitzschia,* and *Coscinodiscus*. *Prorocentum* had the potential to cause HABs because it contained toxins that could cause Ciguatera Food Poisoning (CFP) and Diarrhetic Shellfish Poisoning (DSP) **(Anderson *et al.*, 2001, Vila *et al.*, 2001)**. *Pseudonitzschia* had the potential to cause HABs because it could produce domoic acid which caused Amnesic Shellfish Poisoning (ASP) **(Casteleyn *et al.*, 2008)**. *Coscinodiscus* had the potential to cause HABs at Ancol Lagoon Beach because it had caused mass deaths due to blooming in 2015. Species that did not produce toxins could also potentially cause mass marine life deaths during blooming due to a decrease in oxygen levels in the water. In 2004, 2007, and 2015, the HABs phenomenon occurred due to the explosion of the population of the genera *Coscinodiscus, Skeletonema, Thalassiosira*, and *Prorocentrum* on Ancol Lagoon Beach which caused mass fish deaths.

Based on the results, it was evident that food and beverage packaging waste made of PP and PET plastic could serve as good substrates for microalgae due to the high abundance of microalgae attached to the plastic. A total of 3 of the 21 genera found attached to the substrate of plastic waste of food and beverage packaging of the PP and PET types were toxic. Therefore, the presence of this type of waste had a high potential to distribute harmful algae that could trigger their growth and cause HABs in new areas, such as the Kepulauan Seribu in Jakarta. This result aligns with the study of **Mohapatra *et al.* (2016)**, who stated that microalgae could attach to PP and PET plastic substrates, even though the number of microalgae attached to PP was higher than that of acrylic sheets of plastic waste. In the same study, microalgae of the Chlorophyceae, Cyanophyta, Bacillariophyceae, and Desmidiaceae classes were also found. Furthermore, the genus *Navicula* from the class Bacillariophyceae was the dominant microalgae found, which was attached to plastic waste substrates of the PP and PET types **(Mohapatra *et al.*, 2016)**.

Based on the interpretation of Pearson correlation coefficients by **Guilford (1956)**, most environmental parameters—such as temperature, salinity, dissolved oxygen (DO), pH, light intensity, and current velocity—show a strong correlation (±0.80 to ±1.00) with the abundance of epiplastic microalgae, indicating that these factors significantly influence their presence. In contrast, the correlation with light intensity was weaker (0.3), suggesting a low relationship. This weaker correlation may be due to the wide light tolerance range of the microalgae (1,000–10,000 lux), which allows them to thrive under varying light conditions. Additionally, the minimal variation in light intensity between stations likely reduced its overall impact on microalgae abundance. While light intensity does have some influence, other parameters, such as temperature, salinity, and DO, appear to play a more dominant role in determining the distribution and abundance of epiplastic microalgae in this study area.

CONCLUSION

In conclusion, this study covered several aspects as follows:

1. A total of 21 genera of epiplastic microalgae were found, which were attached to the substrate of plastic waste from food and beverage packaging of the PP and PET types at Ancol Lagoon Beach. The microalgae came from 3 classes, namely *Bacillariophyceae* (17 genera), *Dinophyceae* (1 genera), and *Cyanophycea* (3 genera).
2. A total of 3 potentially toxic epiplastic microalgae genera were found in this study, namely *Trichodesmium*, *Pseudonitzchia,* and *Prorocentrum*.
3. Salinity, dissolved oxygen, acidity, light intensity, and brightness had a positive correlation with the abundance of epiplastic microalgae.

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