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WATER QUALITY OF LAKE TOBA BY SPACE AND TIME BASED ON ENVIRONMENTAL PHYSICS, CHEMICAL FACTORS AND COMMUNITY PHYTOPLANKTON

Ika Rosenta Purba
Universitas Sumatera Utara, Indonesia
Email: kevinfathan@gmail.com

ABSTRACT

The characteristics of lake waters, like waters in general, have specific characteristics such as common property, various sectors and multiple policies, as well as various administrative areas. This research has been carried out in the waters of Lake Toba based on space and time for 6 months with 2 seasons. The details of the research area are divided into four parts, namely control, wharf, agriculture and marine cages. This research was conducted based on the activities of the local community in the waters of Lake Toba. Community activities include agriculture, fisheries with the KJA system, docks and control in the form of the Binangalom waterfall. Based on data on the diversity and abundance of phytoplankton, the quality of the waters of Lake Toba is still in the good category, in this case the diversity index (H') > 3. The phytoplankton found in the waters of Lake Toba are 36 species belonging to 23 families, 15 orders, 5 classes and 3 phyla

KEYWORDS *lake toba; community phytoplankton; environmental physics*

INTRODUCTION

The characteristics of lake waters, like waters in general, have specific characteristics such as common property, various sectors and multiple policies, as well as various administrative areas. The different characteristics possessed by lake waters are the cause of sensitivity from human activities that provide a burden in the form of nutrient and mineral input, which is related to the type of water body and the highly variable germplasm community (Hidayat Lukman et al., 2017).

The social benefits that can be provided from the existence of lakes can be optimally received if lake management policies are interrelated, comply with regulations that contribute to the potential of lakes for the benefit of the community, and balance the contributions of attention and values that can be provided (Klessig,

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2001). The values in question are the values of beauty, economy, education, culture, individual freedom, and spirituality in the lake environment.

Lake Toba is an inland waters that plays a role in every sector, including the role of local communities and national roles, maybe even international. Based on national policies, the Lake Toba area is used as one of the Master Plans for National Tourism Development 2020-2024 (Strategic Plan of the Ministry of Tourism and Creative Economy, 2020) because it has great potential.

The great potential of the waters of Lake Toba, one of which is the presence of water flowing through the inlet which has been utilized for the Sigura-gura Hydroelectric Power Plant (PLTA), which has a large capacity of up to 286 Megawatts (MW), compared to the Maninjau PLTA which is only 68 MW, and has operating since 1982 (Kompas, 22 September 2005).

Aquaculture is a potential that has also developed in the waters of Lake Toba through the floating net cage system (KJA). This system was first implemented in 1988 (Dharma, 1988). The results of aquaculture from this KJA system in 2010 were recorded at 28,132.01 tons with 13,160 KJA (Ministry of Marine Affairs and Fisheries of the Republic of Indonesia, April 2021).

The existence of conflicting needs between the needs of the community in the form of socio-economic, production achievement, environmental conservation and the carrying capacity of the waters makes this KJA activity reap a lot of controversy. (I. Ridwansyah Lukman, 2010) explains that the development of the KJA system will be beneficial if the balance between ecological factors, carrying capacity, and the interests of the surrounding community is carefully considered.

In line with this, the Ministry of Maritime Affairs and Fisheries of the Republic of Indonesia through a coordination meeting on April 20, 2021, urges the Regional Government (Pemda) to control the KJA around the Lake Toba area by referring to Government Regulation (PP) Number 81 of 2014 concerning Spatial Planning for the Lake Toba Region. and its surroundings for the preservation of this volcanic lake from pollution. The uncontrolled growth of KJA results in a decrease in water quality. (Maulana, Wiranto, Kurniawan, Syamsu, & Mahmudin, 2018).

Deby (2013) explains that the increasing number of KJA causes a high amount of feed that enters the lake waters. This excessive feeding (over feeding) results in organic waste or nutrients originating from the rest of the feed that is not consumed, plus the entry of fish feces into the lake waters is increasing (Nontji, Patenjengi, Rasyid, & Pirman, 2016); (Maulana et al., 2018); (Zulfiah & Aisyah, 2016).

(Siagian, 2010) stated that the presence of organic waste from KJA activities will have an impact on phosphate levels and the availability of dissolved oxygen which is a parameter / measure of the quality of the aquatic environment. The results of (Barus, 2004) proved that in November 2004 the cause of mass death of carp in the Haranggaol waters of Lake Toba was the dissolved oxygen (DO) value which decreased to the lowest level of 2.95 mg/l. This proves that the availability of oxygen is very limited.

The value of 14 mg/l of Biochemical Oxygen Demand (BOD) gives an estimate of the high organic matter in the water, which comes from the rest of the feed that is not consumed by farmed fish, as well as nutrients such as nitrogen and phosphorus which indicate an excess of the threshold that has been set. established (Barus, 2004).

Terangna et al. (2002) described that the location of the waters in the middle of the lake about 500 m from the edge of the lake is oligotropic, this is because it has a very low nutrient content, light penetration only reaches 11-14 m, and oxygen levels at a depth of more than 200 m can still be detected. In addition, the large amount of water hyacinth at the fish farming location detects the presence of high levels of nutrients.

High levels of nutrients, one of which also comes from the waste of agricultural fertilizers, nitrogen from the atmosphere, phosphate from detergents, other nutrients from soil erosion, and waste from domestic and industrial (Álvarez-Vázquez, Bendicho, & Prego, 2014). Concentration of nutrients is a source of energy that can affect water quality, causing eutrophication.

Eutrophication is a buildup or surge due to water pollution from excessive nutrients such as phosphate (PO4) which threatens especially freshwater ecosystems. In recent years, Lake Toba has experienced eutrophication with a surge in phosphate nutrients (Fauziyah & Wijopriono, 2010) and changes in nutrient-rich water conditions (I. Ridwansyah Lukman, 2010).

(Lehmusluoto, Priadie, & Vauhkonen, 2006) proved that one of the triggers for eutrophication in Lake Toba is estimated to come from fish cultivation in KJA and domestic waste. The impact of this eutrophication can affect the phytoplankton in the waters of Lake Toba.

Phytoplankton which acts as a primary producer responds to the state of the waters so that it has a direct impact on the phytoplankton. Thus, it can cause changes in abundance, number of species, and community structure (Ferreira et al., 2011).

Because phytoplankton are the lowest trophic level organisms, the presence of phytoplankton is influenced by several factors, including nutrition, sunlight, temperature, pH, and predation from zooplankton and the participation of planktonic fish (Lau & Lane, 2002); (Yu, Liu, Egolf, & Kitanovski, 2010); (Jiang et al., 2014).

Due to the ability of phytoplankton to carry out photosynthesis, it causes these phytoplankton to become the main energy source for ecosystem activities in the waters through the food chain structure.

(Nontji et al., 2016) describes that the phytoplankton groups commonly found in tropical waters are diatoms (Bacillariophyceae) and dinoflagellates (Dynophyceae). The amount and type of excess phytoplankton can be used as an indicator or measurement of fertility and water conditions (Karydis & Tsirtsis, 1996); (Thoha & Amri, 2011); (Radiarta, 2013).

As explained by (I. Ridwansyah Lukman, 2010), that specific characteristics such as common property, multisectoral policies and interests, as well as the existence of various administrative areas of lake waters are influenced by human activities around the waters of Lake Toba. As a result, it will change the ecological system of the waters of Lake Toba, where this will have an impact on the diversity of organism life in the waters.

The diversity of species can be used as a measure in determining water quality. A group of species is said to have high diversity if it has many species with the number of each species evenly distributed. If there are only a few species in the community, where the number of individuals of each species is not evenly distributed, it can be said that the community diversity is low. This can be used as an indicator of the contamination of a water. The theoretical objective of this study is to determine the water quality in the waters of Lake Toba according to space and time based on the physical and chemical factors of the environment and the community of phytoplankton.

Utilization of Lake Toba in various activities of human life around it, such as fishery cultivation in the form of marine cages, plant cultivation, tourism, transportation, and areas where people live. As a result of these various activities will produce organic or inorganic materials into the waters.

Eutrophication is a symptom of increasing nutrients in aquatic ecosystems. This process results in an increase in the primary productivity of the waters which stimulates the growth of phytoplankton and other flora. Signs of eutrophication are through algae blooms, reduced light penetration into the water, and reduced oxygen. Uncontrolled eutrophication process will have an impact on water quality which causes loss of value and function of the lake.

Like other lakes, Lake Toba also has the potential to experience eutrophication, due to increased human activities in the water catchment area (exagenous) and in the lake waters (indogeneus) which are thought to contribute a certain amount of phosphorus and nitrogen. Fish farming activities can be a source of nitrogen and phosphorus waste, which comes from fish feces, feed residues and other organic materials. The accumulation of organic elements at the bottom of the lake becomes a source of decomposed nitrogen and phosphorus.

The types of living things that occupy the lowest trophic level in aquatic ecosystems are phytoplankton. As a result of the ability of phytoplankton to photosynthesize, making it a source of energy directly or indirectly needed for all aquatic ecosystem life with stages in the food chain structure. Generally in tropical waters, diatom (Bacillariophyceae) and dinoflagellate (Dynophyceae) phytoplankton are found (Nontji et al., 2016). Alleged fertility levels and changing water conditions are factors in the presence of abundant phytoplankton types and compositions in waters (Radiarta, 2013); (Thoha & Amri, 2011); (Karydis & Tsirtsis, 1996).

So the research will focus on: The water quality of Lake Toba according to space and time based on environmental physicochemical factors and the phytoplankton community. In accordance with the title, the formulation of the problem in this study is:

1. How is the water quality of Lake Toba according to time and space based on the physical-chemical factors of the water?
2. How is the water quality of Lake Toba according to time and space based on the phytoplankton community?
3. How is the relationship between the physical and chemical factors of the waters of Lake Toba and its phytoplankton community according to time and space?

The research objective is a factual affirmation related to the expected results of the research. In accordance with the research model formed in this study, the purpose of this study is to analyze the quality of the waters of Lake Toba according to space and time based on the physico-chemical properties of the water. Analyzing the water quality of Lake Toba according to space and time based on its phytoplankton community. Analyzing the relationship between the physical and chemical factors of Lake Toba's waters with the diversity and abundance of phytoplankton according to space and time.

RESEARCH METHOD

The determination of the research area was carried out based on considerations of land use in the study area and the problems studied, namely covering the waters of Lake Toba, so that the selected area is expected to be in accordance with what is the main problem in this study.

This research has been carried out in the waters of Lake Toba based on space and time for 6 months with 2 seasons. The details of the research area are divided into four parts, namely control, wharf, agriculture and marine cages.

This research was conducted based on the activities of the local community in the waters of Lake Toba. Community activities include agriculture, fisheries with the KJA system, docks and control in the form of the Binangalom waterfall.

There are research data obtained in situ, namely measurements and data directly obtained at the research station and there are also ex situ measurements, namely measurements and data acquisition are carried out outside the research station, so it is necessary to take samples taken to the laboratory.

The sampling method used at each station is purposive random sampling. Sampling was carried out for 1 year, starting in April 2018, May 2018, and July 2018 (dry season) and continued in October 2018, November 2018 and December 2018 (BMKG, 2017). Sampling was carried out every month with 4 times of taking by means of 2 times of taking for the morning test and 2 times of taking for the afternoon test. Each station has 2 sub stations. Sampling was carried out vertically and horizontally where vertically it was taken at a depth of 0m and 5m while horizontally it was taken at a distance of 20 m and 50 m from the edge of the lake towards the middle of the lake. The sampling time was carried out in the morning at 08.00-11.30 WIB and in the afternoon at 13.00-16.30 WIB with a sampling time of 90 minutes.

RESULTS AND DISCUSSION

1. Physical and Chemical Factors of Lake Toba Waters

The average results of measurements of physical and chemical factors of water in Lake Toba according to the space and time of sampling during the study are presented in Table 1 and Table 2.

Table 1
The Mean Result of Measurement of Water Physics and Chemical Factors based on Sampling Room

No.	Parameter	Unit	Control	Agriculture	Dock	KJA	**Quality standards**
1	PO_4	mg/L	0.009	0.011	0.013	0.01 2	**0.2**
2	BOD_5	mg/L	0.8 0	0.9 0	0.69	0.7 6	**3**

3	Temperature	°C	26, 60	26.41	26.69	26,70	**Deviation 3**
4	Degree of Acidity (pH)	-	8.02	7.89	8.27	8.12	**6-9**
5	Dissolved Oxygen (DO)	mg/L	6.79	6.76	6.42	4	**>4**
6	Conductivity	S/cm	163.61	164, 60	163.31	166.23	**-**
7	TDS	mg/L	91.4 8	94.39	98.11	97.39	**1000**
8	Total Nitrates	mg/L	2.14	3.29	2.14	3.95	**10**
9	Light Penetration	m	5,10	4.9 6	3.93	3.44	**-**

Table 2
Average Results of Measurement of Water Physics and Chemical Factors Based on Sampling Time

No	Parameter	Unit	Dry season			Rainy season			**Quality standards**
			April	May	July	Oct	Nov	Des	
1	Phosphate (PO_4)	mg/L	0.011	0.011	0.01	0.011	0.014	0.01	**0.2**
2.	BOD $_5$	mg/L	0.42	0.26	1.14	0.39	0.88	1.63	**3**
3	Temperature	°C	26.76	26.56	26.72	26.90	26.21	26.45	**Deviation 3**
4	Degree of Acidity (pH)	-	8.04	8.12	7.74	8.50	8.20	7.85	**6-9**
5	Dissolved Oxygen (DO)	mg/L	5.91	6.17	5.94	5.77	5.82	6.36	**>4**
6	Conductivity	S/cm	168.41	166.75	164.99	160.52	161.48	164.47	**-**
7	TDS	mg/L	109.19	104.70	104.68	46.62	102.50	104.36	**1000**
8	Total Nitrates	mg/L	2.31	2.38	1.89	3.73	3.55	3.43	**10**
9	Light Penetration	m	4.36	4.30	5.23	4.81	4.14	3.28	**-**

Based on Table 1 and Table 2 of the physical and chemical parameter conditions based on space, the dissolved oxygen (DO) parameter in the KJA is worth 4 which means it is at the threshold of the quality standard. According to (Garno, Nugroho, & Hanif, 2020), the water quality of Lake Toba is included in the class II category based on water quality standards. Class II water uses are intended for infrastructure/facilities such as water recreation, freshwater fish farming, livestock farming, water for irrigating crops, and/or other uses that require the same water quality as those uses.

2. Phosphate (PO 4)

The average phosphate (PO_4) measurement by space was in the range of 0.009 mg/L - 0.013 mg/L. The lowest value of phosphate (PO4) was found in the control area/Binangalom Situmurun with a value of 0.009 mg/L and the highest value of phosphate (PO4) was in the dock area/Ajibata with a value of 0.013 mg/L. According to (Tungka, Haeruddin, & Ain, 2016), phosphate can be in organic form (organically bound phosphorus) or inorganic form (including orthophosphates and polyphosphates). The cause of high phosphate levels in the waters is due to the presence of domestic waste containing detergent. Detergents can increase phosphate levels because phosphate ions are one of the constituents of detergents.

The average PO4 measurement based on time is in the range of 0.01 mg/L - 0.014 mg/L. The lowest phosphate value is in the dry season to be precise in July and in the rainy season to be precise in December with a value of 0.01 mg/L, while the highest phosphate value is in the rainy season to be exact in November with a value of 0.014 mg/L. According to (Patty, Arfah, & Abdul, 2015) the main source of phosphate and nitrate nutrients comes from the decomposition process of weathering or decomposition of plants and the remains of dead organisms both from the waters themselves and from the plains that enter the waters. Based on the PO4 data obtained, Lake Toba's water is still in a good range, which is still below 0.2 mg/L. The average Phosphate (PO_4) diagram based on the space and time of sampling can be seen in Figure 1.

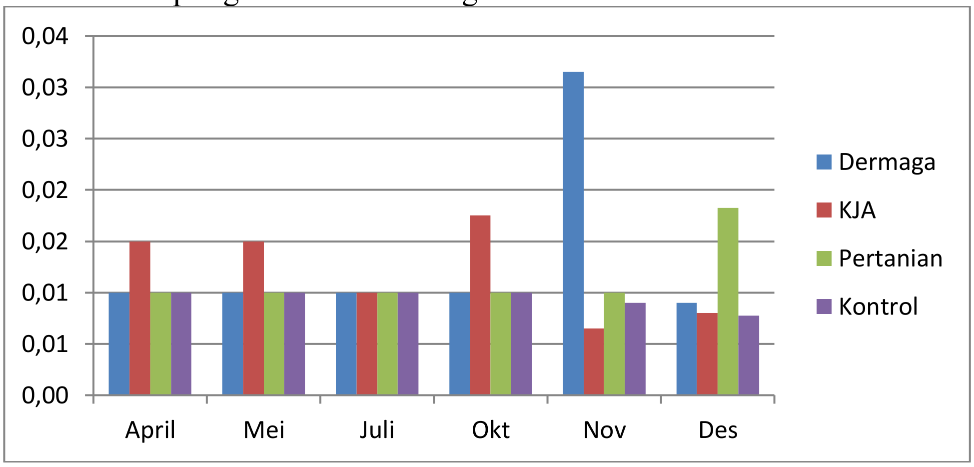

Figure 1

Diagram of Mean PO 4 Measurement Results by Space and Time

A. Biochemical Oxygen Demand (BOD 5)

The average BOD 5 measurement based on space is in the range of 0.69 mg/L - 0.90 mg/L. The lowest BOD 5 value was found in the dock area/Ajibata with a value of 0.69 mg/L and the highest BOD 5 was in the agricultural area/Laguboti with a value of 0.90 mg/L. The BOD 5 obtained is relatively low, so it can be concluded that the levels of organic compounds such as household waste which are easily biodegradable in Lake Toba are relatively small. According to Barus (2004), the value of BOD 5 is derived from the amount of dissolved oxygen used by microorganisms to biodegrade organic compounds such as household waste. According to (Lee, 1978), the classification of the level of pollution of organic compounds in waters can be determined based on the value of BOD_5. The following is a list of water quality statuses based on BOD 5 values, namely 2.9 classified as unpolluted, 3.0-5.0 classified as lightly polluted, 5.10-14.9 moderately polluted, and 15 heavily polluted.

The average BOD 5 measurement based on the time of sampling was in the range of 0.26 mg/L - 1.63 mg/L. The lowest BOD 5 average was found in the dry season, precisely in May with a value of 0.26 mg/L and the highest BOD 5 average was found in the rainy season, precisely in December with a value of 1.63 mg/L. In the rainy season BOD 5 has increased due to the entry of organic matter, especially household waste from the mainland to a lower place, namely water. Organic matter that is easily decomposed by aerobic microorganisms biologically can increase the value of BOD $_5$ in a waters. According to (Andika, Wahyuningsih, & Fajri, 2020), stated that BOD_5 can be measured from the amount of dissolved oxygen used by microorganisms during the decomposition process of organic matter under aerobic conditions. The BOD $_{5\ value}$ is not absolutely used to indicate the amount of organic matter actually contained in a water, but only to measure the amount of oxygen needed by aerobic bacteria to decompose organic matter that is easily decomposed (Andika et al., 2020).

data from the BOD $_{5\ measurement}$ in the waters of Lake Toba above shows that the quality of the waters of Lake Toba is good, which is in the range below 2 mg/ L. The BOD $_5$ value obtained shows an indication of low levels of organic matter in the waters, because the BOD $_{5\ value}$ indicates the oxygen demand used by aerobic bacteria in the waters to carry out the oxidation process of organic matter in the water which indirectly indicates the presence of easily decomposed organic matter in the waters (Ginting, 2002). The BOD $_{5\ average\ diagram}$ based on space and time of sampling can be seen in Figure 2.

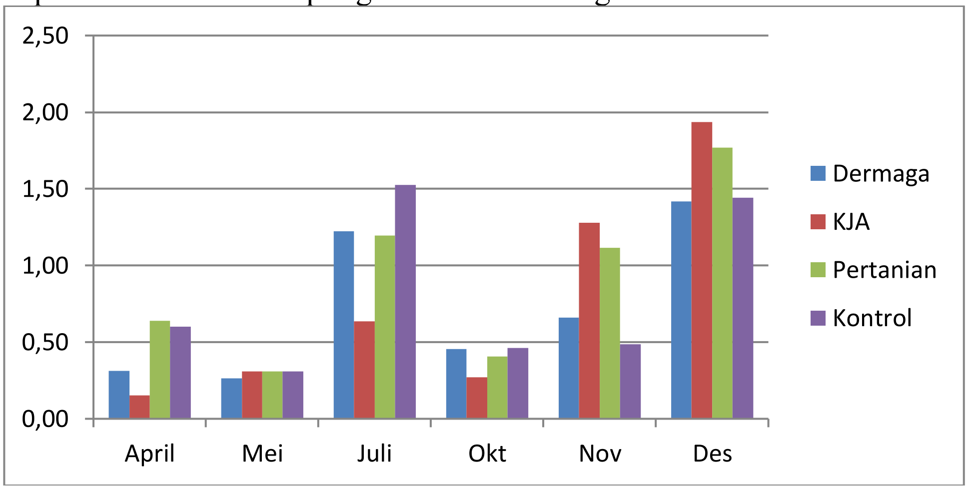

Figure 2
Diagram of Mean BOD 5 Measurement Results by Space and Time

Temperature

The average temperature measurement results in Lake Toba by space are in the range of 26.41°C - 26.70°C. The temperature at each research location did not show a significant difference between one location and another. The lowest temperature was at the farm/Laguboti location with a value of 26.41 and the highest temperature was at the KJA/Haranggaol location with a value of 26.70. Temperatures in agricultural areas/Laguboti are low due to agricultural activities, where plants in agricultural areas utilize sunlight for photosynthesis, thereby reducing the intensity of sunlight entering the lake which further affects the decrease in ambient temperature. The temperature in the KJA/Haranggaol area is high because of the many activities of the surrounding community such as fish farming, docks and local community settlements. High activity can increase the temperature in water bodies. According (Ginting, 2002), the pattern of increasing temperature in a waters can be influenced by *anthropogenic* factors (factors caused by human activities around the lake). (Maniagasi, Tumembouw, & Mudeng, 2013), states that the temperature of a waters can increase and decrease due to several factors including the altitude of an area, high rainfall, and the intensity of sunlight that penetrates a waters.

The average temperature measurement results in Lake Toba based on time are in the range of 26.21 - 26.90 °C. The lowest temperature is in the rainy season, precisely in November with a value of 26.21 °C and the highest temperature is in the rainy season, precisely in October with a value of 26.90 °C. The temperature in each season and month did not change significantly, because at the time of sampling the weather was not too hot and the rainfall in Lake Toba was not too high. October is the first month of the rainy season, this month the light intensity is still as in the dry season and at the time of sampling there has been no rain in the Lake Toba area, while in November enters the second month of the rainy season where the rain begins to fall so that the temperature in the Lake area experiences decline. According to (Brower, Zar, & Von Ende, 1990), water temperature conditions can be influenced by atmospheric conditions that regulate climate, seasons, changes in weather and changes in sunlight intensity. According to (Barus, 2004), temperature fluctuations in tropical waters throughout the year are not too high so that the annual water temperature measurement value is not too high. The optimum temperature that is good for phytoplankton life in waters is around 20 °C - 30 C, in that range plankton can grow and reproduce optimally and quickly. High temperatures can affect the level of water density and the ability of phytoplankton to float on the surface of the waters (Maresi & Yunita, 2015) The average temperature diagram based on space and time of sampling can be seen in Figure 3.

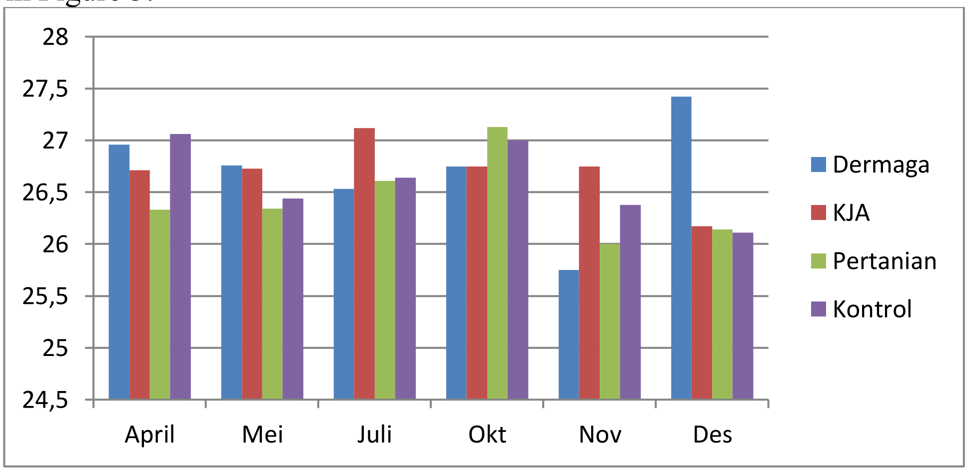

Figure 3
Diagram of the Average of Temperature Measurement Results by Space and Time

Degree of Acidity (pH)

The average result of pH measurement based on space is in the range of 7.89-8.27. The lowest value is found in the agricultural area/Laguboti with a value of 7.89 and the highest value is found in the dock area/Ajibata with a value of 8.27. The pH value can decrease and increase due to the process of photosynthesis and changes in the concentration of oxygen (O2) from photosynthesis and CO2 $_{\text{to help}}$ the photosynthesis process. According to Anisah (2017), the pH value can also be lower due to high concentrations of organic matter, in addition to other factors that can also affect the high and low pH values, including biological activity, photosynthetic activity, temperature, and fluctuations in O2 and CO2 concentrations.

The average pH measurement results based on the time of the sample are in the range of 7.44-8.50. The lowest average pH is in the dry season, precisely in July with a value of 7.74 and the highest penetration is in the rainy season, precisely in October with a value of 8.50. According to (Berutu, 2018), the ideal pH for freshwater biota life is around 6.8-8.5. A pH value that is too low will increase the solubility of metals in water and an increase in metals in water causes toxic properties for aquatic organisms, whereas a high pH can increase the concentration of ammonia in water which is also toxic for aquatic organisms. The decreasing pH value in waters is indicated by the increasing organic compounds in the waters. The average pH diagram based on space and time of sampling can be seen in Figure 4.

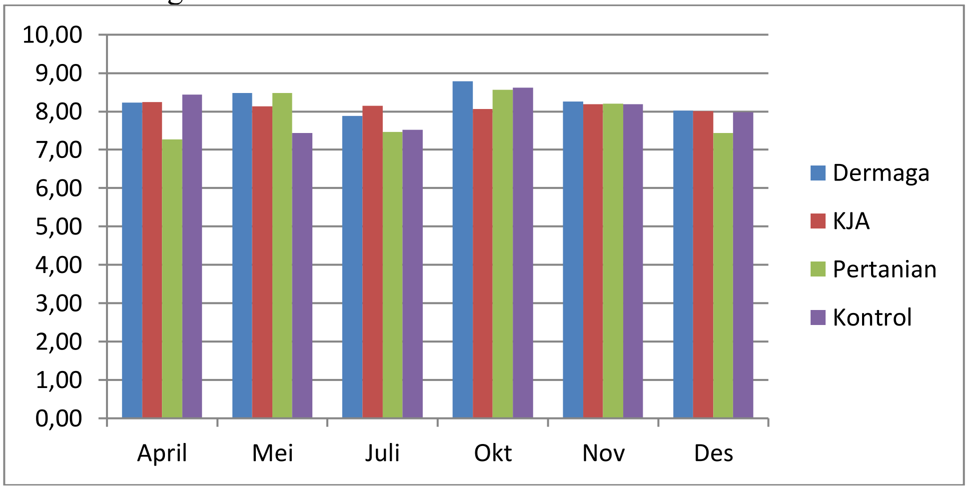

Figure 4
Diagram of Average Results of Ph Measurements Based on Space and Time

DISSOLVED OXYGEN (DO)

The average DO measurement based on space is in the range of 4 mg/L-6.79 mg/L. The lowest DO value was in the KJA/Haranggaol area with a value of 4 mg/L and the highest DO was in the control area/Binangalom Situmurun. The KJA/Haranggaol area has the lowest DO value due to the use of dissolved oxygen (DO) for fish respiration and aerobic decomposition of feed and fish waste. The control area has a high DO because in that area there is no activity or little activity. According to (Suryanti & Sumartini, 2013) dissolved oxygen (DO) levels can be reduced due to the presence of pollutants that can use oxygen when decomposed by aerobic microorganisms. Pollutants consist of organic and inorganic materials originating from various sources.

The average DO measurement based on time is in the range of 5.77 mg/L-6.36 mg/L. The lowest DO average is in the rainy season, precisely in October with a value of 5.77 mg/L and the highest DO is in the rainy season, precisely in December with a value of 6.36 mg/L. According to Barus (2004), DO has daily and seasonal fluctuations that are influenced by temperature and photosynthetic activity that produces oxygen. rainy season increases DO because the water temperature decreases. A good DO value in the waters ranges from 6.3 mg/L, the lower DO value if the level of pollution in the waters is high. The data from the research showed a good DO value because it was above 6.3 mg/L, except in the KJA location which had a DO value below 6.3 mg/L. The average DO diagram based on space and time of sampling can be seen in Figure 5.

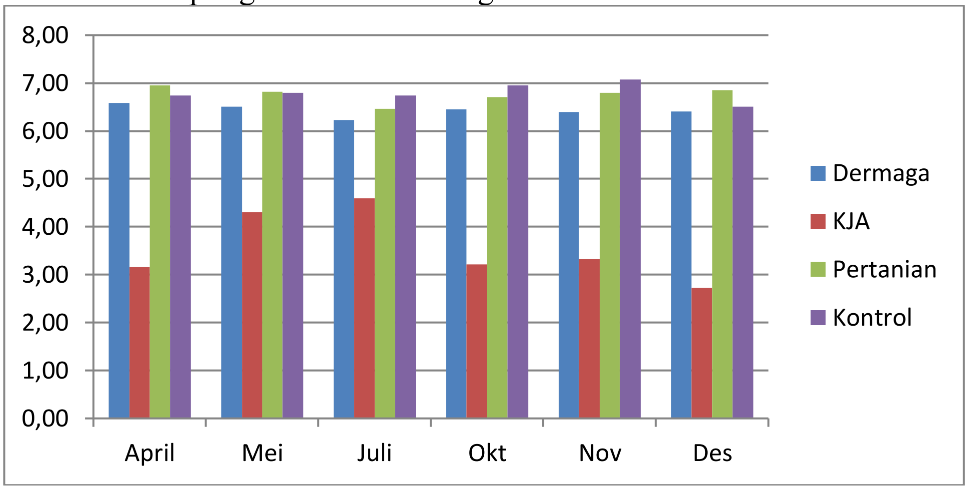

Figure 5
Diagram of the Average of DO Measurement Results by Space and Time

Conductivity

The average conductivity measurement based on space is in the range of 163.61 S/cm - 166.23 S/cm. The lowest conductivity value was in the control area/Binangalom Situmurun and wharf/Ajibata with a value of 163.61 S/cm and the highest conductivity was in the KJA/Haranggaol area with a value of 166.23 S/cm. According to (Irwan & Afdal, 2016), conductivity is a measure of the ability of an organic and inorganic compound dissolved in water bodies to conduct electric current. The electric current in the solution is carried by the cations and anions contained in the solution. Ions have their own characteristics in conducting electric current. The number of ions in a solution is affected by the dissolved solids. The greater the amount of dissolved solids in the solution, the greater the number of ions in the solution, so the value of conductivity or electrical conductivity is greater.

The average conductivity measurement based on time is in the range of 160.52 S/cm - 168.41 S/cm. The lowest average conductivity is in the rainy season, precisely in October with a value of 160.52 S/cm and the highest conductivity in the dry season, precisely in April, with a value of 168.41 S/cm. The dry season results in the accumulation of dissolved solids in the waters. The more dissolved solids increase the ions that can conduct electric current in a waters. According to (Alina, Soeprobowati, & Muhammad, 2015), conductivity or electrical conductivity is used as an indicator of fertility and water pollution levels. High electrical conductivity indicates the amount of waste in the form of organic and mineral types that enter the water body. Normal conditions in waters have electrical conductivity values ranging from 20-1500 Siemens/cm (Zaharuddin, Wahyuningsih, & Mutadi, 2016). Therefore, based on the value of electrical conductivity in the waters of Lake Toba, it is still included in the good category. The average conductivity diagram based on space and time of sampling can be seen in Figure 6.

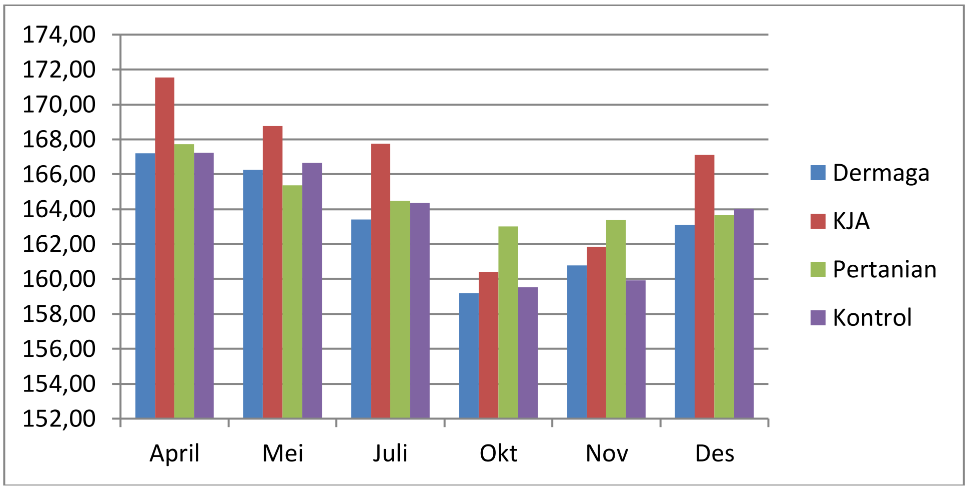

Figure 6
Diagram of the Means of Conductivity Measurement Results by Space and time

Total Dissolved Solids (TDS)

The average TDS measurement (total dissolved solids) based on space is in the range of 91.47 mg/L - 98.11 mg/L. The lowest TDS value was in the control area/Binangalom Situmurun with a value of 91.47 mg/L and the highest TDS was at the wharf/Ajibata research site with a value of 98.11 mg/L. This is because in general the surrounding community often uses Lake Toba for daily activities such as washing and disposing of household waste around the pier. According to (Hidayat, Suprianto, & Dewi, 2016), waste disposal from the results of population activities, fisheries, industry and port or shipping activities is quite influential on aquatic ecosystems and the accumulation of waste disposal will be very dangerous for the health of the people around the waters. Changes in the concentration of TDS can be dangerous because it will cause changes in salinity, changes in the composition of the ions, and the toxicity of each ion. Changes in salinity can disrupt the balance of aquatic biota, biodiversity, cause species that are less tolerant, and cause high toxicity in the life stages of organisms (Hidayat et al., 2016).

The average TDS measurement based on time and season is in the range of 46.62 mg/L - 109.19 mg/L. The lowest TDS average is in the rainy season, precisely in October with a value of 46.62 mg/L and the highest TDS is in the dry season, precisely in April with a value of 109.19 mg/L. According to (Chandra, Singh, & Tomar, 2012), total dissolved solids are composed of elements and chemical compounds in the form of carbonate, bicarbonate, chloride, sulfate, phosphate, nitrate, calcium, magnesium, sodium, potassium, iron and manganese. The dissolution or weathering of rock and soil slowly dissolves in water and forms dissolved solids. The higher the TDS value and the main ion in the waters, the higher the electrical conductivity/conductivity in these waters (Tessema, Mohammed, Birhanu, & Negu, 2014). The average TDS diagram based on space and time of sampling can be seen in Figure 7.

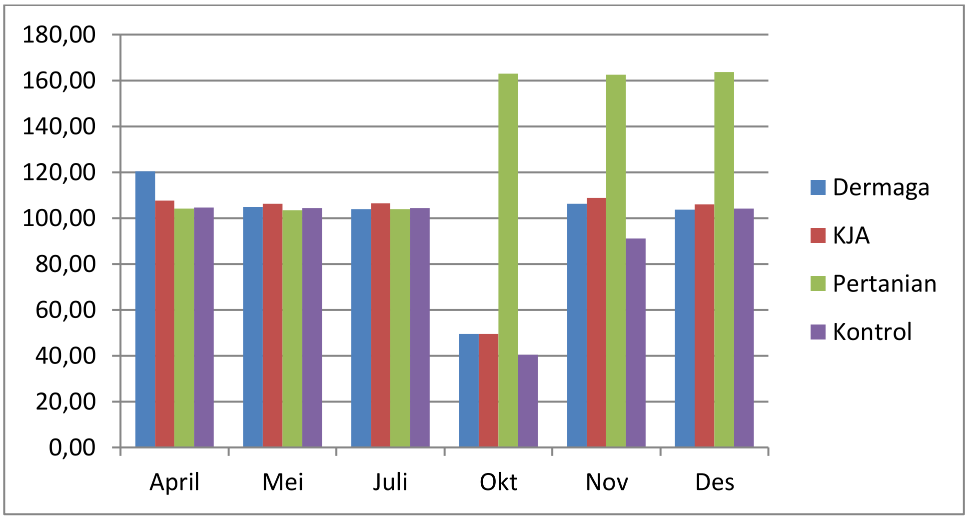

Figure 7
Diagram of the Average of TDS Measurement Results by Space and Time

Total Nitrates

The average measurement of total nitrate by space is in the range of 2.14 mg/L - 3.95 mg/L. The lowest total nitrate value was in the control area/ Binangalom Situmurun and wharf/Ajibata with a value of 2.14 mg/L, while the highest total nitrate value was in the KJA/Haranggaol area with a value of 3.95 mg/L. This is because in the KJA area there are continuous activities such as feeding fish which tends to cause a buildup or increase in the content of nitrate produced in these waters. According to Putri *et al* . (2014), KJA contributes nitrogen in the waters, namely in the form of leftover feed that is not eaten by fish, fish feces, and fish metabolic waste in the form of ammonia and urea. The feed given to fish contains about 68% - 86% nitrogen released into the aquatic environment and the rest is eaten by fish.

The average measurement of total nitrate based on time is in the range of 1.89 mg/L - 3.73 mg/L. The lowest total nitrate value was found in the dry season, precisely in July with a value of 1.89 mg/L and the highest total nitrate value was in the rainy season, precisely in October with a value of 3.73 mg/L. According to (Effendi, 2003), the value of the nitrate content contained in the waters can be used as a parameter of the fertility level of a waters. Oligotrophic waters have nitrate values ranging from 0 – 1 mg/l, mesotrophic waters have nitrate values ranging from 1 – 5 mg/l and eutrophic waters have nitrate levels ranging from 5 – 50 mg/l. Diagram of the average total nitrate based on space and time of sampling can be seen in Figure 4.8.

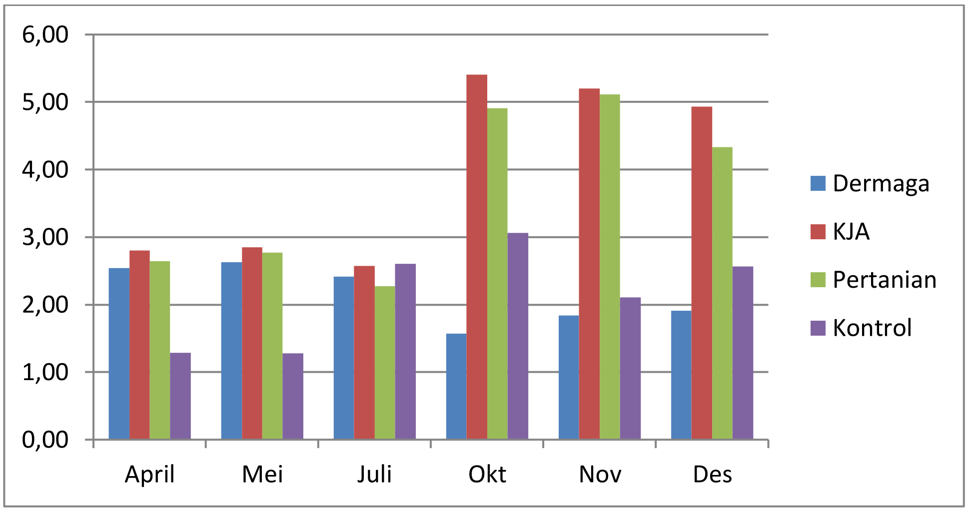

Figure 8
Diagram of Average Measurement Results of Total Nitrate by Space and Time

Light Penetration

The average results of light penetration measurements in Lake Toba by space are in the range of 3.44 m - 5.10 m. The lowest value was found in the KJA/Haranggaol area with a value of 3.44 m and the highest value was found in the control area/Binangalom Situmurun with a value of 5.10 m. The low light penetration value in the KJA/Haranggaol area is due to the large number of community activities around the lake such as fish farming which affects the change in water color and the increasing amount of dissolved solids that block light from entering the water body, while the highest penetration value in control/Binangalom Situmurun is caused by the lack of activity in the water bodies. environment that can produce dissolved solids so that light penetration penetrates deeper water bodies. According to (Suin, 2002), the amount of dissolved solids contained in a body of water affects the penetration of light (the penetration of sunlight into the body of water). The high amount of dissolved solids in the water causes the water to have a cloudy color. This situation can inhibit the entry of light into water bodies which will further affect the distribution and intensity of photosynthesis of aquatic plants including phytoplankton (Sembiring, 2018).

The average result of light penetration measurement based on time is in the range of 3.28 m - 5.23 m. The lowest light penetration value is in the rainy season, precisely in December with a value of 3.28 m and the highest penetration value is in the dry season, precisely in July with a value of 5.23 m. High penetration in the dry season is caused by the low intensity of rain falling to the earth and hot weather always lasts that month, while the low light penetration in the rainy season is caused by the higher intensity of rain falling to the earth so that the research area is often covered with clouds and reduced sunlight entering the earth. The average light penetration diagram based on space and time of sampling can be seen in Figure 9.

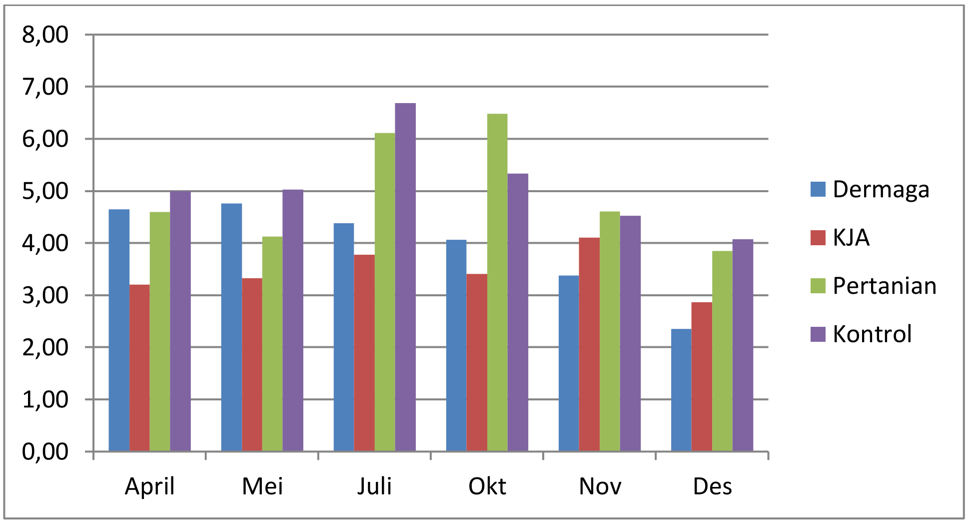

Figure 9
Diagram of the Average of Light Penetration Measurement Results by Space and time

CONCLUSION

From the research that has been carried out, several conclusions can be written, namely the results of measurements of physico-chemical factors in the waters of Lake Toba showing temperature, light penetration, acidity (pH), oxygen solubility (DO), biological oxygen demand (BOD5), conductivity, total dissolved density. (TDS), Nitrate (NO3) content and Phosphate (PO4) content according to space and time are generally still in a good range, except in the KJA area, where the solubility of oxygen (DO) is low or in the range below normal.

Based on data on the diversity and abundance of phytoplankton, the quality of the waters of Lake Toba is still in the good category, in this case the diversity index (H') > 3. The phytoplankton found in the waters of Lake Toba are 36 species belonging to 23 families, 15 orders, 5 classes and 3 phyla. The dominant type of phytoplankton according to space and time is Staurastrum sp. and Sphaerocystis sp. Types of Chlorobotrys sp., Ephitemia sp., and Spirulina sp. found only in the control area. Types of Microcystis sp. found only on the dock. Types Ulothrix sp., Volvox sp., Spirogyra sp. found in control areas, farms and docks and not found in KJA areas. Plectonema sp. found in control areas, cages, and docks and not found in agricultural areas. Types of Cymbella sp. found in the KJA and wharf areas while in control and agricultural areas it was not found. Aphanizomenon sp. found in the control and agricultural areas, while in the KJA and wharf areas were not found.

There are five highest genera obtained based on the time of sampling, one of which is Chroococcus which belongs to the Cyanophyceae class. The high abundance of genera from the Cyanophyceae class can be an indication of organic pollution. The presence of the genera Microcystis, Oscillatoria, and Scenedesmus in large numbers indicates the condition of polluted waters. These genera are associated with polluted waters. There are 7 taxa that are tolerant of organic pollution in Lake Toba, namely Oscillatoria sp., Navicula sp., Nitzschia sp., Synedra sp., Stigeoclonium sp., Closterium sp., and Melosira sp.

Physical and chemical factors of the waters that are significantly related to the diversity of phytoplankton species in Lake Toba based on space and time are total nitrate levels and light penetration with a contribution of 32.7%.

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