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The variability of algal blooms and the trophic state index for Dighalipukhuri in Guwahati, Assam

Jayati Das
Department of Botany, University of Science and Technology, Meghalaya, Kling Road, Baridua, Ri-Bhoi, Meghalaya, India
Corresponding author email: jayatidas2022@gmail.com

Mautushi Das
Department of Botany, University of Science and Technology, Meghalaya, Kling Road, Baridua, Ri-Bhoi, Meghalaya, India

***Abstract*---**Algae react to changes in their environment, such as temperature, nutrients, etc. The uncertainty in aquatic environments exacerbates several interacting pressures. As a result, lakes are vital to society because they help to mitigate flood risks. It maintains the natural equilibrium, allowing flora and fauna to flourish. The primary objective of this research is to identify the trophic state index, category, and algal assemblages of Dighalipukhuri Lake. The findings show that algal blooms of the *Microcystis* species are the most abundant and have a higher occupancy in the Dighalipukhuri Lake, which has a TSI of 58.6, indicating that it is Supereutrophic. Thus revealing that the quality is poor and unsatisfactory.

***Keywords*---**Dighalipukhuri, algae, trophic status, phytoplankton, quality.

Introduction

Reservoirs and dams are being created in large numbers to influence the natural aquatic system. These were originally designed for electricity-generating but are now utilized for a variety of other purposes such as flood control, irrigation, and water supplies. The future availability of water is jeopardized due to population growth and insufficient sewage treatment (Elser & Goldman, 1991). Lakes are important to society because they aid in the mitigation of flood dangers. It keeps the natural balance in check, allowing flora and fauna to grow. Although it attracts a variety of tourists, it has an impact on people's lives and their surroundings (Donadi et al., 2017). The growth of phytoplankton in lakes is

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influenced by seasonal variations and other disturbances. As a result, it is critical to maintain the ecological balance in the face of environmental vulnerability (Cunha et al., 2013). The dynamics of the phytoplankton population are described by a variety of mathematical models. Phytoplankton physiology does not determine unique lake characteristics. However, research into population density and nutritional concentration are necessary. During the winter and early spring, lakes have high nitrogen levels. Phytoplankton blooms in the spring and continues until it is depleted (O'Brien, 1974). Phytoplankton is the foundation of aquatic food, and it regulates ecosystems. As a result of these differences, management efforts may be complicated.

Algae respond to various habitat fluctuations like temperature, nutrients, etc. Multiple interacting stresses are exacerbated by the uncertainty in aquatic ecosystems (Wendt-Rasch et al., 2004). Chlorophyll content has long been used as a proxy for algal biomass (Rusak et al., 2018). Models of water quality anticipate the influence of pollution in lakes. Eutrophication models were created after the 1960s (Stevenson & Rollins, 2017). Regression models focus on Chl-concentration and their relationship with environmental factors. However, the accuracy of algal bloom forecasting continues to be a source of concern for water authorities (Bae & Seo, 2018).

Trophic State Index helps in water resource management. The Trophic State Index for tropical/subtropical reservoirs classifies ecosystems into five categories: ultraoligotrophic, oligotrophic, mesotrophic, eutrophic and supereutrophic and hypereutrophic (Cunha et.al., 2013). Thus trophic state index and its relationship between total chlorophyll and total phosphorus enable us to understand the lakes' temperature regions (Bilgin, 2020). The algal biomass in lakes is measured by the trophic status index. Chlorophyll and total phosphorus are biomass surrogates and support the construction of the trophic status index. As a direct metric of algal biomass, chlorophyll is used. TSI_{chl} is a solid indicator of trophic status (Bolgrien et al., 2009).

The purpose of this study is to determine the Dighalipukhuri Lake's trophic state index, category, and algae assemblages. The study examines the 12 water quality characteristics of Guwahati City's Dighalipukhuri Lake in Assam State. The research aids in understanding the current state of water quality and identifying the key sources of contamination in the lake under consideration, performing statistical analysis. The samples data were analyzed for chlorophyll-a, total phosphorus, total nitrogen, Temperature (^{0}C), pH, Alkalinity (mg/L), Hardness (mg/L), Turbidity (NTU), Nitrate [NO_3—N] (mg/L), Iron (mg/L), Zinc (mg/L), Manganese (mg/L), and Copper (mg/L). As a result, policymakers will be able to design a strategy for effective management and consideration of the Dighalipukhuri Lake. Previous research hasn't included trophic state indexes and standards for Dighalipukhuri Lake, thus it's time to revise and update it.

Materials and methods

Study area

Guwahati is the largest city in Northeast India, with eighteen hills surrounding it. It has a surface area of 328 km^2 and is 55.5 meters above sea level. The longitude is 91°45'0"E and the latitude is 26°10'45" N. The city is located on the southern bank of the Brahmaputra River, with the Khasi Hills of Meghalaya forming the city's southern and eastern borders (Rajashekar & Vijaykumar, 2008). The river Bharalu cuts through it for around 9 kilometers. Guwahati is built on top of typical Precambrian rock units, which are covered in young and recent alluvium. The city has a humid subtropical climate with peak summer temperatures of 38°C and winter temperatures of 10°C. The average annual rainfall is 1746.5mm, with 90 % of that falling between April and September, with May, June, July, and August being the rainiest months (Russell et al. 2006). The current research is being carried out on the city's ancient lake, Dighalipukhuri, a half-mile-long rectangular man-made lake in Guwahati. The majority of Guwahati's lakes were used for recreation, storage, and temple purposes. Bhagadatta, son of Narakasura, constructed the lake in the seventh century AD. It is connected to the Brahmaputra to the north and is used by the Ahoms as a naval dockyard (Sharma & Bora 2020). The map of the study area is given in Figure 1. Table 1 depicts the description of the Dighalipukhuri lake.

Figure 1 Map of the Study Area

Table 1 Description of Dighalipukhuri Lake

Lake	Latitude	Longitude	Type	Area(m^2)
Dighalipukhuri	26o11’19.0”N	91o45’02.0”E	Recreational	43785.56

Data Collection and analysis

The data was collected from the study region and tracked for four seasons in 2020. The analysis used total phosphorus and chlorophyll-a concentrations (mg/L) as well as statistical measurements. Equation (1) was used to calculate the mean for each variable (Hu et al. 2020).

$$Mean\ m = \sqrt[n]{y1y2y3 \ldots yn} \quad (1)$$

The total phosphorus and chlorophyll-a average values were organized. Ultraoligotrophic, oligotrophic, mesotrophic, eutrophic, supereutrophic and hypereutrophic are some of the other classifications. Equations (2), (3), and (4) were used to calculate Trophic Status (Cunha et al., 2013) for the reservoirs of tropical and subtropical regions.

$$TSI(TP)_{tsr} = 10[6 - \left(\frac{-0.27637\ In\ TP + 1.329766}{In\ 2}\right)] \quad (2)$$

$$TSI(Chla)_{tsr} = 10[6 - \left(\frac{-0.2512\ In\ Chla + 0.842257}{In\ 2}\right)] \quad (3)$$

$$TSI_{tsr} = \frac{TSI(TP)_{tsr} + TSI(Chla)_{tsr}}{2} \quad (4)$$

Results and Discussion

Physicochemical Parameters

The results of the physical and chemical characteristics of water provide significant insight into the water quality of the city's lakes. The physicochemical parameters obtained were compared to those published by the Bureau of Indian Standards. Table 2 shows descriptive information such as mean and standard deviation.

Table 2 Descriptive statistics of the water quality parameters

Water Parameters	Winter, 2020		Pre-Monsoon, 2020		Monsoon, 2020		Post-Monsoon, 2020	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Temperature ^{0}C	20.03	0.1175	26.25	0.1595	29.87	0.2035	27.47	0.29
pH	8.06	0.229	7.3	0.1525	7.07	0.2245	7.457	0.1015
Alkalinity (mg/L)	130.16	3.315	123.33	3.5935	120.44	0.892	125.567	1.801
Hardness (mg/L)	129.78	3.076	127.18	1.054	120.593	1.06	126.907	0.713
Turbidity (NTU)	7.74	0.8205	8.54	0.541	11.39	0.659	8.954	0.3615
Nitrate [NO_3-N] (mg/L)	1.069	0.0695	0.771	0.091	0.665	0.1185	0.925	0.008
Iron (mg/L)	0.064	0.004	0.05	0.011	0.0015	0.001	0.002	0.001
Zinc (mg/L)	0.066	0.0035	0.045	0.007	0.025	0.0065	0.0245	0.005
Manganese (mg/L)	0.0495	0.004	0.039	0.0085	0.02	0.0075	0.027	0.0085
Copper (mg/L)	0.0205	0.003	0.0145	0.007	0.017	0.007	0.025	0.0115
Total Nitrogen (mg/L)	1.136	0.049	0.853	0.0645	0.684	0.094	0.973	0.0285
Total Phosphorus (mg/L)	0.087	0.015	0.075	0.0095	0.0685	0.037	0.092	0.02

Table 2 shows the descriptive statistics for the four seasons for the various water quality parameters. Winter, Pre-Monsoon, Monsoon, and Post-Monsoon are the four seasons examined. Winter, Pre-Monsoon, Monsoon, and Post-Monsoon temperatures are 20.03, 26.25, 29.87, and 27.47 degrees Celsius, respectively. Surface water temperature rises as a result of global warming, influencing thermal stratification in lakes. The temperature has an impact on the chemistry of water. At increasing temperatures, the rate of chemical reactions tends to rise. The graph of temperature variation is shown in Figure 2. Warm water stores less dissolved oxygen than cool water, resulting in insufficient oxygen for aquatic life to survive. Water temperature has a significant impact on aquatic life's biological activity and growth. The temperature of a pond determines how much-dissolved oxygen it can contain.

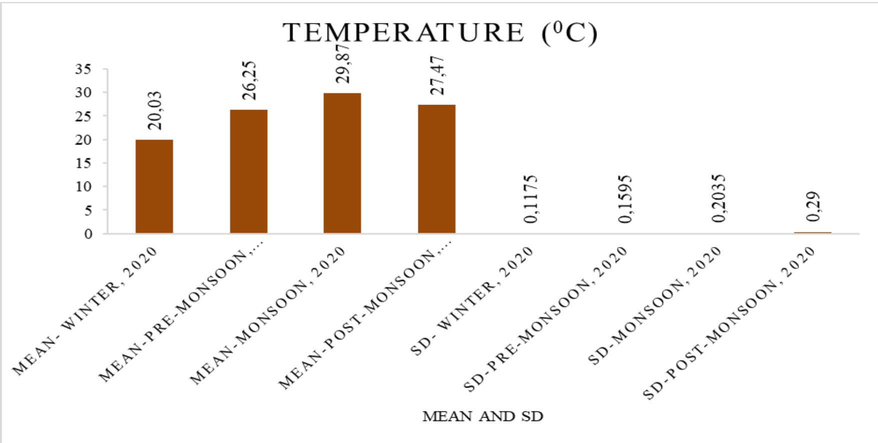

Figure 2 Temperature Variation

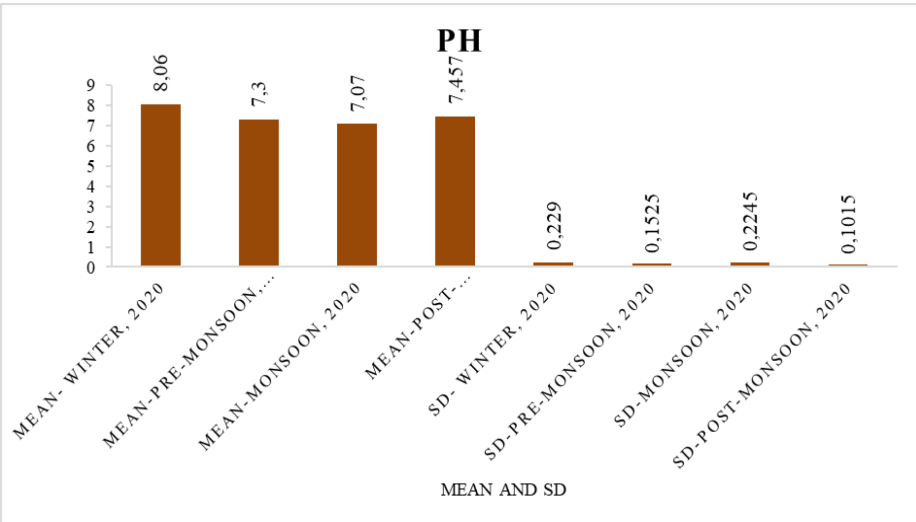

Figure 3 pH Variation

The pH variations are shown in Figure 3. Winter, Pre-Monsoon, Monsoon, and Post-Monsoon have variations of 8.06, 7.3, 7.07, and 7.457, respectively. The maximum pH is 8.06, while the lowest pH is 7.07. The pH variation could be related to the existence of dissolved gases such as carbon dioxide, hydrogen sulphide, and ammonia, among others. A pH range of 6.0 to 8.5 implies that the water body is productive, which is consistent with our findings, as all of the lakes include some type of aquatic life.

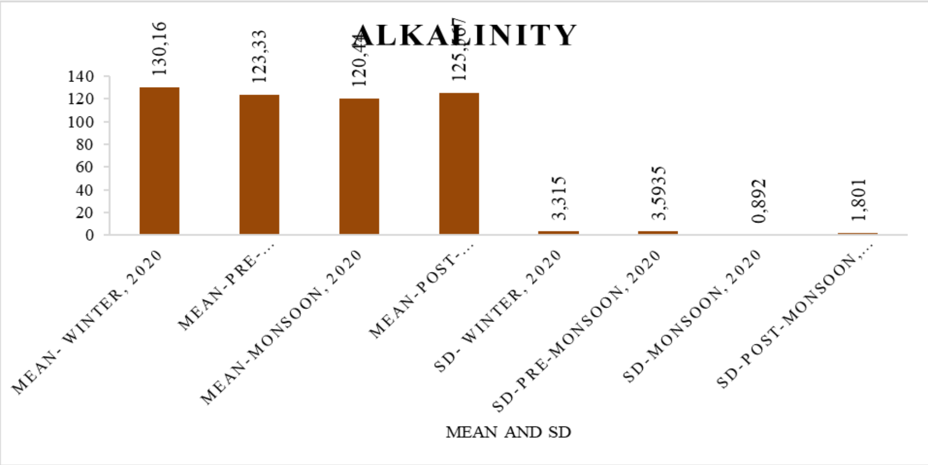

Figure 4 Alkalinity Variations

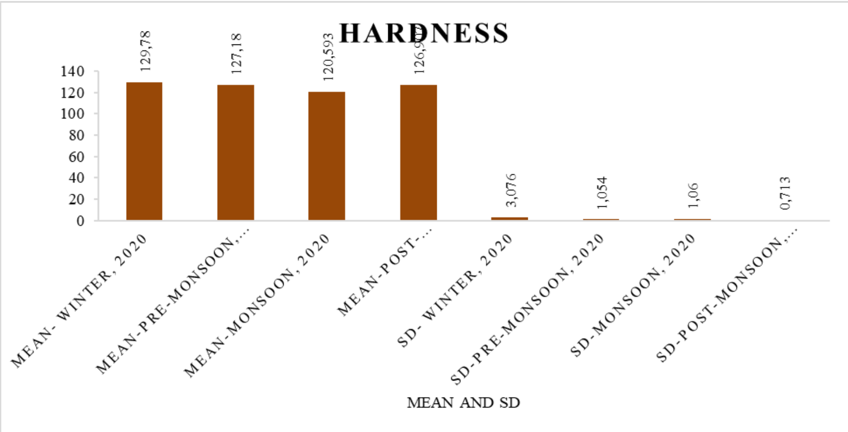

Figure 5 Hardness Variations

The ability of water to neutralize acids is measured chemically as alkalinity. The alkalinity variation is depicted in Figure 4. The variations are 130.16, 123.33, 120.44, and 125.567 for Winter, Pre-Monsoon, Monsoon, and Post-Monsoon, respectively. It's the ability to withstand pH variations when acids or bases are added. For average drinking water, the quantity of alkalinity that should be present is 20-200 mg/L. High alkalinity in our drinking water is beneficial since it keeps the water safe to consume (Rajashekar & Vijaykumar, 2008). This demonstrates that the water is unsafe to drink. Figure 5 displays the hardness variation in the same way. For Winter, Pre-Monsoon, Monsoon, and Post-Monsoon, the variations are 129.78, 127.18, 120.593, and 126.907, respectively. The presence of alkaline earth metals is responsible for the total hardness of the water. It is a characteristic of water that inhibits the creation of lather with soap and raises the boiling point of water. Based on hardness, water can be classed as mild (75 mg/L), moderately hard (75-150 mg/L), hard (150-300 mg/L), or very hard (300 mg/L) (Russell et al., 2006). The total hardness of the water was found to be in the range of 120 mg/L to 129 mg/L, indicating that it is moderately hard.

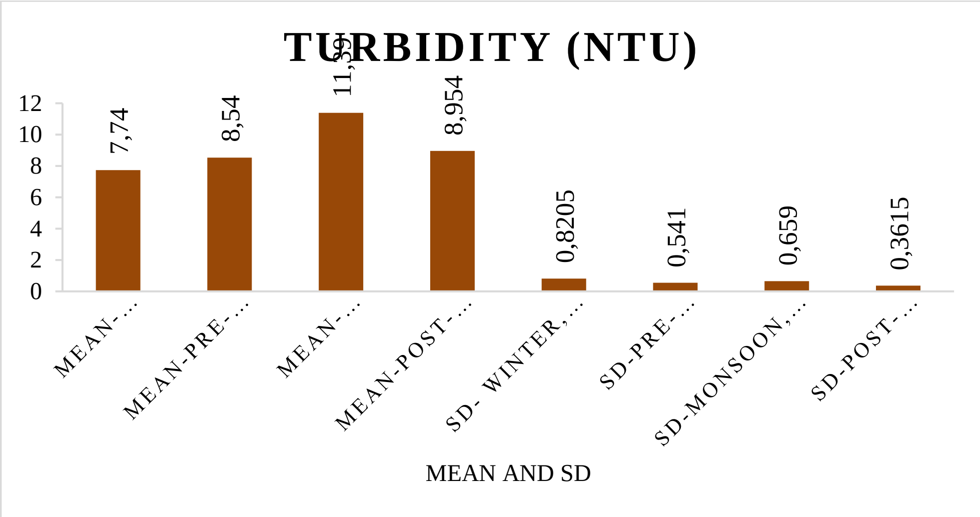

Figure 6 Turbidity Variations

Turbidity is the cloudiness in water that prevents us from seeing through it, ranging from excessive turbidity to spring water that appears to be entirely clear (low turbidity). The turbidity fluctuation is depicted in Figure 6. Winter, Pre-Monsoon, Monsoon, and Post-Monsoon turbidity variations are 7.74, 8.54, 11.39, and 8.954 respectively. The amount of suspended sediment in the water can harm aquatic life in a variety of ways (Wendt-Rasch et al., 2004). Turbidity is caused by suspended sediments that can limit light to aquatic plants, suffocate aquatic species, and transport toxins and pathogens like lead, mercury, and bacteria. Depending on the season, high turbidity might have detrimental consequences for a lake or river. Although turbid water is not intrinsically harmful, it may contain particles that humans should avoid (Stevenson & Rollins, 2017). As a result, the existence of a pollutant in the water body can be established. The most evident effect of increased turbidity on aquatic environments is a reduction in the amount of light available for photosynthesis. This decreases plant development, which in turn affects the number of aquatic species that feed on these plants, affecting fish communities that rely on aquatic organisms for food. More than 9 NTU turbidity might cause difficulties in aquatic environments. Turbidity was determined to be between 9 and 11 in this investigation, indicating unsafe water (Zhang et al., 2018).

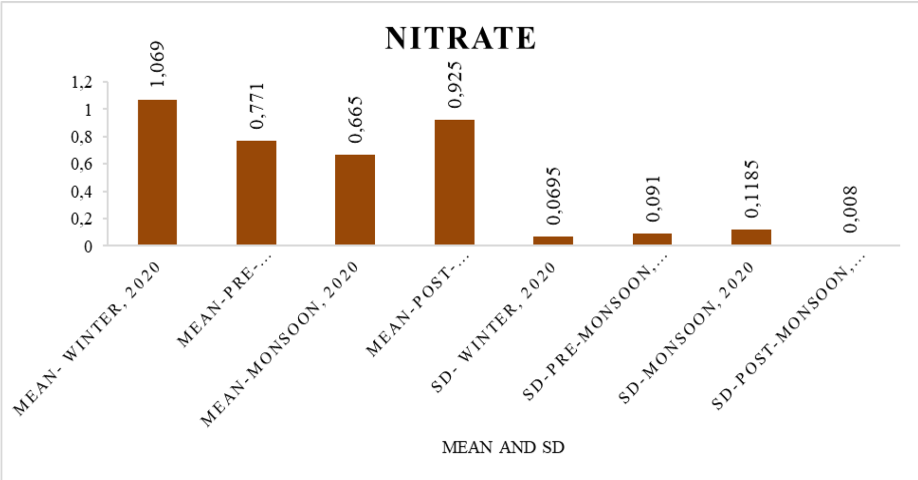

Figure 7 nitrate variations

Nitrates in water can have serious consequences. Septic systems, animal feedlots, agricultural fertilizers, manure, industrial wastewaters, sanitary landfills, and garbage dumps are all common sources of excess nitrate reaching lakes and streams. During seasons of high phytoplankton growth, phosphorus and nitrates are heavily absorbed in the upper portion of lakes. The nitrate variation is depicted in Figure 7. Excess nitrates, when combined with phosphorus, can hasten eutrophication, resulting in substantial increases in aquatic plant growth and changes in the types of plants and animals that dwell in streams. The nitrate changes in the winter, pre-monsoon, monsoon and post-monsoon seasons are 1.069, 0.771, 0.665, and 0.925, respectively. As a result, the water is unfit for human consumption.

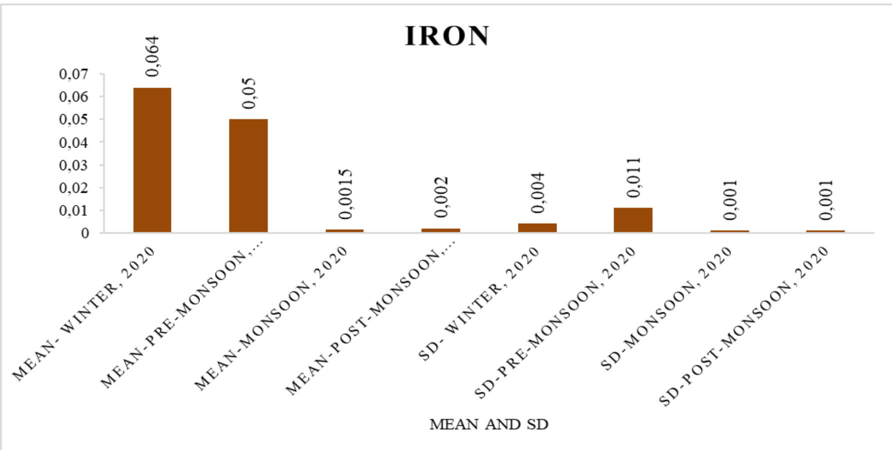

Figure 8 Iron Variations

The iron variations are depicted in Figure 8. The iron changes in the winter, pre-monsoon, monsoon, and post-monsoon seasons are 0.064, 0.05, 0.0015, and 0.002. Iron can be found in rivers, lakes, and underground water in its natural state. Natural deposits, industrial wastes, iron ore refining, and corrosion of ironcontaining metals can all discharge it into the water. Shallow wells and surface water contain a mixture of naturally occurring organic substances and iron. Drinking iron-fortified water can be good for human health. Iron in excess has detrimental consequences.

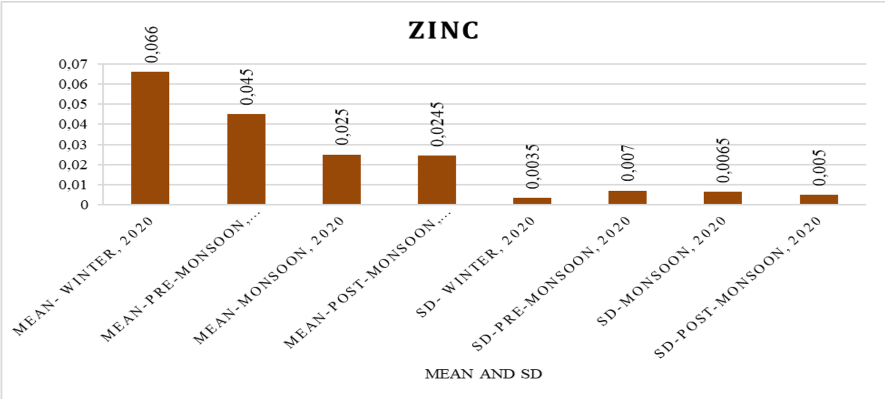

Figure 9 Zinc Variations

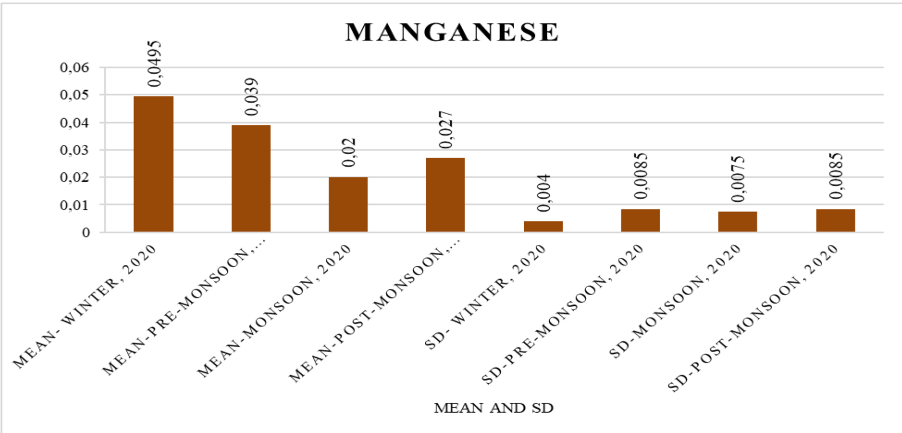

Figure 10 Manganese Variations

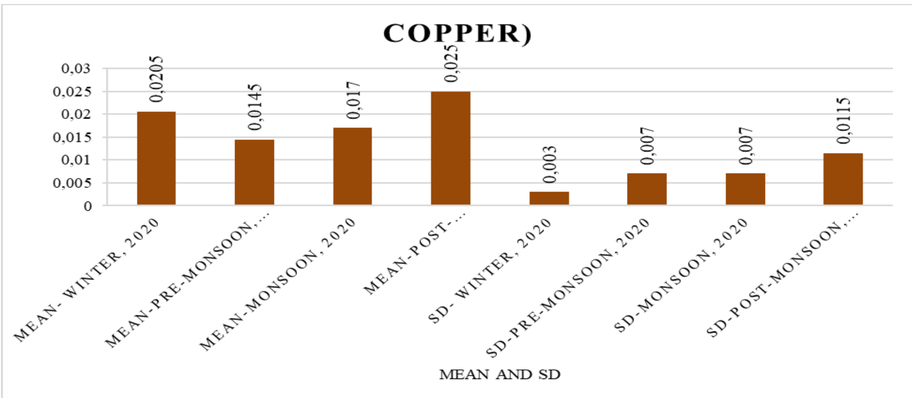

Figure 11 Copper Variation

Zinc, manganese, and copper variations are depicted in Figures 9, 10, and 11. Water contains zinc naturally. Because of taste, the EPA recommends that drinking water have no more than 5 mg of zinc per liter of water (5 mg/L or 5 ppm). Manganese and copper, on the other hand, have negative consequences. Zinc fluctuations are 0.066, 0.045, 0.025, and 0.0245 in the winter, pre-monsoon, monsoon, and post-monsoon seasons, respectively. Manganese changes are 0.0495, 0.039, 0.02, and 0.027 in the winter, pre-monsoon, monsoon, and post-monsoon seasons, respectively. Copper variations are 0.0205, 0.0145, 0.017, and 0.025, respectively.

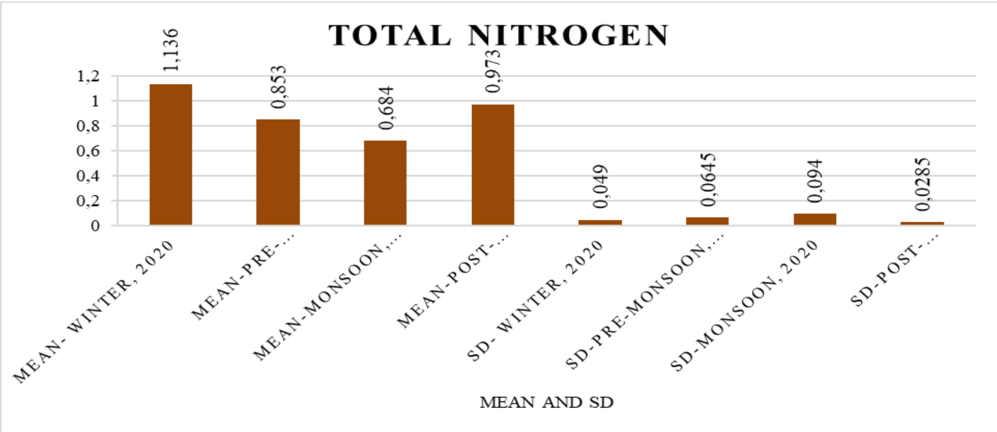

Figure 12 Total Nitrogen

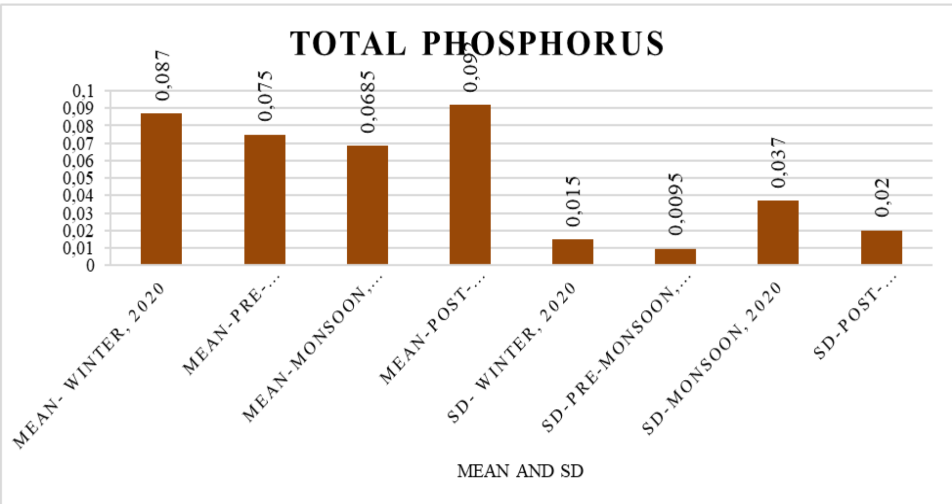

Figure 13 Total Phosphorus

Figures 12 and 13 depict total nitrogen and total phosphorus, respectively. Total Nitrogen variations for the winter, pre-monsoon, monsoon and post-monsoon seasons are 1.136, 0.853, 0.684, and 0.973, respectively. The variances in Total Phosphorus are 0.087, 0.075, 0.0685, and 0.092. Organic and inorganic pollution from anthropogenic sources, such as home wastewater, untreated municipal sewage discharge, release from industrial effluents, and water treatment plants, is indicated by the presence of such contaminants. It is believed that 70-90 % of water usage in Guwahati is discharged as wastewater. The majority of the city's wastewater is sanitary and household sewerage, as well as liquid waste from commercial businesses such as hotels, restaurants, and hospitals/health care units (Yang et al., 2012).

Limnological Variations

Table 3 Limnological Variations

Season	Chl a (µg/L)	TP (µg/L)
Winter, 2020	14.5	0.09
Pre-Monsoon, 2020	12.126	0.078
Monsoon, 2020	19.8	0.074
Post-Monsoon, 2020	21.7	0.102

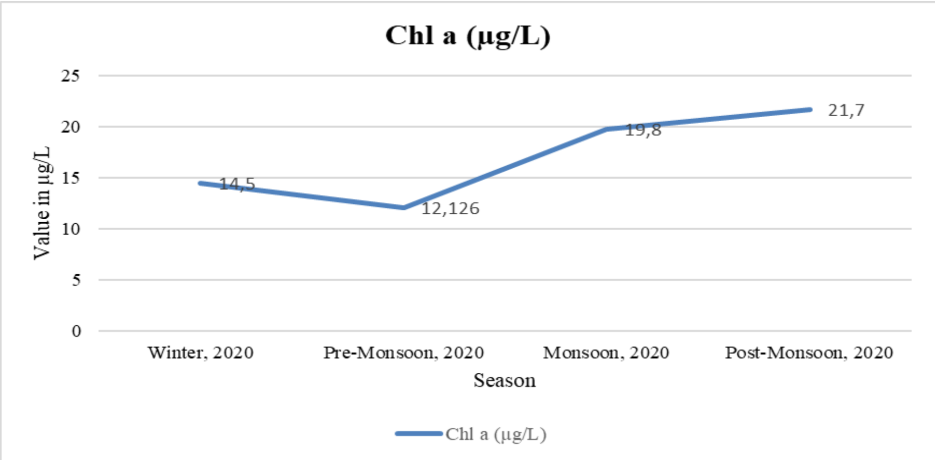

Figure 14 Chl a (µg/L) Graph

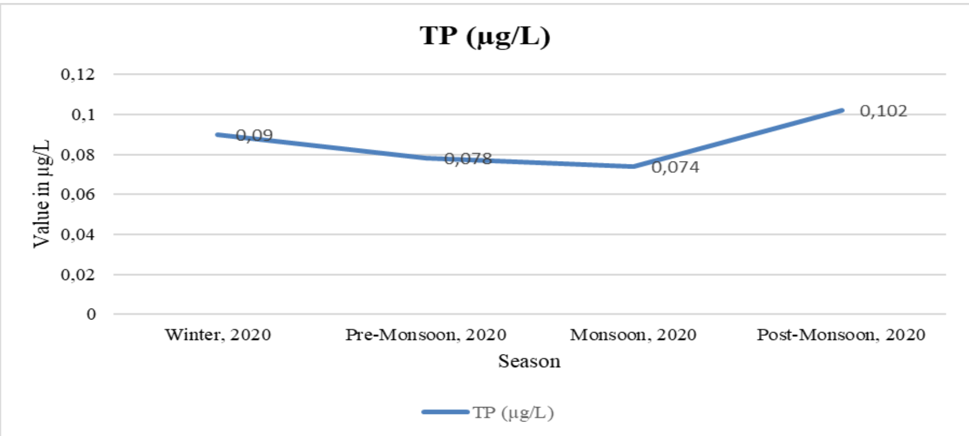

Figure 15 TP (µg/L) Graph

The limnological changes in terms of chlorophyll-a and total phosphorus are shown in Table 3. Chlorophyll is the most common green pigment found in algae, and it allows them to utilize sunshine to produce food. Because most algae rely on chlorophyll pigments for survival, the concentration of all chlorophyll pigments present in a sample can be used to estimate the proportion of free-floating algae in a water body. Table 3 and Figure 14 illustrate the chlorophyll concentration of the lake during the current study, which ranged from 12.126 µg/l to 21.7 µg/l. As a result, Chlorophyll concentrations increase phytoplankton in low-quality water. Phosphorus is an essential component for algae growth. The differences in Total Phosphorus are depicted in Figure 15. The phosphate content increased throughout the research period, with the highest levels occurring after the monsoon. Summer values are lowest because of strong phosphorus utilization by phytoplankton photosynthetic activity.

Algae community

The identified algae community is presented in Tables 4(a) and 4(b).

Table 4(a) Identified Algae community

Dighalipukhuri					
Winter, 2020			**Pre Monsoon, 2020**		
Total algal cell density (cells/ml)	**The algal cell density of individual species (Cells/ml)**	**Algal cell density according to genus (Cells/ml) and % in the Total Count**	**Total algal cell density (cells/ml)**	**The algal cell density of individual species (Cells/ml)**	**Algal cell density according to genus (Cells/ml) and % in the Total Count**
1.9×10^4 cells/ml	i. *Microcystis aeruginosa:* 1.615×10^4 cells/ml **(85%)**	*Microcystis* sp: 1.748×10^4 cells/ml **(92%)**	1.6×10^4 cells/ml	i. *Microcystis aeruginosa:* 1.312×10^4 cells/ml **(82%)**	*Microcystis* sp: 1.44×10^4 cells/ml **(86%)**
	ii. *Microcystis flos-aquae*: 0.076×10^4 cells/ml **(4%)**			ii. *Microcystis flos-aquae*: 0.064×10^4 cells/ml **(4%)**	
	iii. *Microcystis ramose :* 0.057×10^4 cells/ml **(3%)**			*Nostoc sp* 0.064×10^4 cells/ml **(4%)**	*Nostoc* sp 0.064×10^4 cells/ml **(4%)**
	i. Anabaena spiroides : 0.038×10^4 cells/ml **(2%)**	*Anabaena* sp: 0.057×10^4 cells/ml **(3%)**		*Ankistrodesmus sp*: 0.048×10^4 cells/ml **(3%)**	*Ankistrodesmus* sp: 0.048×10^4 cells/ml **(3%)**
	ii. Anabaena laxa : 0.019×10^4 cells/ml **(1%)**			*Anabaena variabilis* : 0.032×10^4 cells/ml **(2%)**	*Anabaena* sp: 0.08×10^4 cells/ml **2%)**
	Phormidium sp: 0.057×10^4 cells/ml **(3%)**	*Phormidium* sp: 0.057×10^4 cells/ml **(3%)**		i. *Oscillatoria agardhii* : 0.048×10^4 cells/ml **(3%)**	*Oscillatoria* sp: 0.08×10^4 cells/ml **(5%)**
	Lyngbya rubida : 0.038×10^4 cells/ml **(2%)**	*Lyngbya rubida* : 0.038×10^4 cells/ml **(2%)**		ii. *Oscillatoria pseudofilamentosa*: 0.032×10^4 cells/ml **(2%)**	

Table 4(b) Identified Algae community

Dighalipukhuri					
Monsoon, 2020			**Post Monsoon, 2020**		
Total algal cell density (cells/ml)	**The algal cell density of individual species (Cells/ml)**	**Algal cell density according to genus (Cells/ml) and % in the Total Count**	**Total algal cell density (cells/ml)**	**The algal cell density of individual species (Cells/ml)**	**Algal cell density according to genus (Cells/ml) and % in the Total Count**
$1.4x10^4$ cells/ml	i. *Microcystis aeruginosa:* 0.966 $x10^4$ cells/ml **(69%)**	*Microcystis* sp: 1.148 $x10^4$ cells/ml **(82%)**	$1.8x10^4$ cells/ml	i. *Microcystis aeruginosa:* 1.35 $x10^4$ cells/ml **(75%)**	*Microcystis* sp: 1.584 $x10^4$ cells/ml **(88%)**
	ii. *Microcystis pulverea* : 0.112 $x10^4$ cells/ml **(8%)**			ii. *Microcystis robusta*: 0.162 $x10^4$ cells/ml **(9%)**	
	iii. *Microcystis flos-aquae* : 0.07 x 10^4 cells/ml **(5%)**			iii. *Microcystis pseudofilamentosa*: 0.072 $x10^4$ cells/ml **(4%)**	
	Lyngbya mucicola: 0.098 x 10^4 cells/ml **(7%)**	*Lyngbya mucicola*: 0.098 x 10^4 cells/ml **(7%)**		*Lyngbya rubida*: 0.072 $x10^4$ cells/ml **(4%)**	*Lyngbya rubida*: 0.072 $x10^4$ cells/ml **(4%)**
	Nostoc muscorum: 0.07 x 10^4 cells/ml **(5%)**	*Nostoc* sp: 0.07 x 10^4 cells/ml **(5%)**		i. *Anabaena circinalis* : 0.018 $x10^4$ cells/ml **(1%)**	*Anabaena* sp: 0.054 $x10^4$ cells/ml **(3%)**
	Euglena viridis : 0.042 $x10^4$ cells/ml **(3%)**	*Euglena viridis* : 0.042 $x10^4$ cells/ml **(3%)**		ii. *Anabaena oryzae*: 0.018 $x10^4$ cells/ml **(1%)**	
	Anabaena affinis: 0.042 $x10^4$ cells/ml **(3%)**	*Anabaena affinis*: 0.042 $x10^4$ cells/ml **(3%)**		iii. *Anabaena spiroides* : 0.018 $x10^4$ cells/ml **(1%)**	
				Scenedesmus communis : 0.054 $x10^4$ cells/ml **(3%)**	*Scenedesmus communis* : 0.054 $x10^4$ cells/ml **(3%)**
				Pinnularia viridis: 0.036 $x10^4$ cells/ml **(2%)**	*Pinnularia viridis*: 0.036 $x10^4$ cells/ml **(2%)**

Trophic State Index

Table 5 TSI_{tsr} value of Dighalipukhuri determining Trophic status

Chl a(µg/L)	TP(µg/L)	TSI Value	TS Category
21.29	80	58.6	Supereutrophic

As a result of the investigation, it was discovered that Dighalipukhuri Lake has a TSI_{tsr} of 58.6, indicating that it is Supereutrophic. These water basins may host an abundance of aquatic plants and are dominated by algae because of the presence of excessive nutrients, particularly nitrogen and phosphorus (Zhang et al. 2018). The Chl a and TP levels were also determined to be 21.29 and 80 g/L, respectively, indicating that the Dighalipukhuri lake water is poor and only acceptable for irrigation and industry. It is unfit for consumption.

Conclusion

The occurrence of algal blooms *Microcystis* sp: $1.748x10^4$ cells/ml was discovered as the dominating and higher occupancy in the Dighalipukhuri Lake, according to the study. It was seen in 92 % in the winter, 86 % in the pre-monsoon, 82 % in the monsoon, and 88 % in the post-monsoon. Dighalipukhuri Lake has a TSI of 58.6, indicating that it is Supereutrophic, according to the findings of the investigation. Because of the presence of excessive nutrients, notably nitrogen and phosphorus, these water basins may support an abundance of aquatic plants and be dominated by algae. Further, the water quality index approach, which is used to analyze the quality of surface water in lakes, reveals that the quality is poor and unsatisfactory. The majority of the water quality characteristics of the selected lakes suggest that the lake is not in a hygienic condition and that it requires maintenance and management, according to the results. While the city of Guwahati has a serious solid waste management problem, the authorities appear unconcerned about the rubbish dumps surrounding these lakes. The garbage remains open for several days before being washed into adjacent lakes by rainfall runoff. Domestic sewage, the release of enormous volumes of wastewater, urbanization, industrialization, construction works near to the lakes, uncontrolled drainage systems, and so on the damage the lakes. This study would be a useful tool in the hands of planners and policymakers for selecting the future course of action for making Guwahati clean, green, and environmentally friendly by bringing to light the true status of these water bodies.

Conflict of Interest

The authors declare no conflict of interest

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