The Bioscan
AN INTERNATIONAL QUARTERLY JOURNAL OF LIFE SCIENCES
19(2)S1: 29-37, 2024
www.thebioscan.com

SPATIO-TEMPORAL DYNAMICS OF PHYTOPLANKTON DIVERSITY IN TWO PERENNIAL LENTIC FRESH WATER BODIES OF DHANBAD (JHARKHAND)

Sharmila Kumari and Shailendra Kumar Sinha

Department of Zoology, Binod Bihari Mahto Koyalanchal University, Dhanbad- 826004, Jharkhand, India

Corresponding author:

E-mail: **kumarisharmila967@gmail.com**

DOI: https://doi.org/10.63001/tbs.2024.v19.i02.pp29-37

KEYWORDS
Limnological,
Phytoplankton,
Shannon Index,
Evenness Index.

Received on:

Accepted on:

Corresponding author

ABSTRACT

Limnological and phytoplankton studies provide crucial insights into the overall health and dynamics of freshwater ecosystems. The present study aims to evaluate limnological characteristics as well as to analyse the phytoplankton community composition of the two selected aquatic environment i.e., Karbala (P1) and Pandey (P2) pond during the study period from November 2020- October 2021. The annual mean values of the key limnological parameters of Karbala (P1) – Pandey Pond (P2) such as, Temperature 26.8ºC – 25.08ºC, EC 1139.58 µs/cm – 736 µs/cm, TDS 968.66 mg/L – 510.42 mg/L, pH 7.4 – 7.36, BOD 5.07 mg/L – 2.26 mg/L, COD 81.35 mg/L – 23.01 mg/L, DO 4.47 mg/L – 6.33 mg/L, Cl^- 117.92 mg/L – 40.31 mg/L, Ca^{2+} 76.28 mg/L – 26.64 mg/L, Mg^{2+} 28.25 mg/L – 8.71 mg/L, NO_3^- 2.78 mg/L – 1.42 mg/L, PO_4^{3-} 1.18 mg/L – 0.99 mg/L respectively, have been recorded. In the present study, phytoplankton community represented by 4 major classes, i.e., Cyanophyceae, Chlorophyceae, Bacillariophyceae, Euglenophyceae. In P1, the dominated phytoplankton group were observed in the order of Cyanophyceae (40.8 %) > Chlorophyceae (31.3 %) > Bacillariophyceae (26.3 %) > Euglenophyceae (1.7 %). In P2, the phytoplankton group showed the following trend, Bacillariophyceae (43.8 %) > Chlorophyceae (33.1 %) > Cyanophyceae (22.9 %) > Euglenophyceae (0.2 %). The biodiversity indices in both ponds, P1 and P2, the high evenness value of 0.95 and 0.91 respectively, shows an equitable distribution of species, while the Shannon index value indicates a lower to moderate level of species diversity.

INTRODUCTION

The microscopic, unicellular, free-floating algae known as phytoplankton are a very diverse collection of organisms found in aquatic environments. (Wetzel, 2001 and Ariyadej *et al.*, 2004). Phytoplankton, the photosynthetic flora are the major primary producer in any aquatic food chain and contributing significantly to oxygen production through photosynthesis. In addition, phytoplankton plays a crucial role in the food webs as they are the principal food source for zooplankton fishes and other aquatic fauna (Suseela, 2009; Jagadeeshappa and Kumara, 2013 Vajravelu *et al.*, 2018).

For the overall health of aquatic environment, the sustainability of plankton composition in freshwater settings must be addressed. (Reiss *et al.*, 2009). Aquatic's physico-chemical properties determine the prevalence and abundance of phytoplankton species. The algal population reacts promptly to changes in the aquatic environment, particularly when it comes to limnological parameters. (Chellappa *et al.*, 2008). The perusal of the structure and distribution of phytoplankton species is an effective bioindicator for assessing water quality (Peerapornpisal *et al.*, 2004). Many studies revealed that microscopic analysis have long been used as indicator of pollution status of water environment (Michelutti *et al.*, 2001; Simboura and Zenetos, 2002; Tiwari and Chauhan, 2006; Smol and Stoermer, 2010 Jafari and Alavi, 2010 Bere and Tundsi, 2011;).

Understanding the relationship between phytoplankton and these physicochemical parameters is critical for managing freshwater ecosystems efficiently. In order to maintain healthy phytoplankton populations and general biological balance in freshwater bodies, it is essential to monitor and manage nutrient inputs, prevent pollution, and regulate water flow.

The aim of the present study is to understand the various aspects, viz., the physical and chemical factors, their interactions and impact on the composition, prevalence, abundance, dispersion and diversity of algal community, of the two selected fresh water ponds (Karbala Pond, P1 and Pandey Pond, P2) in the district of Dhanbad, Jharkhand.

MATERIALS & METHODS

STUDY AREA

The study was carried out into perennial freshwater ponds located in two different geographical areas of district Dhanbad in the state of Jharkhand. The two selected ponds named as Karbala Pond P1, situated in the Jharia Coldfield (JCF) region with a latitude 23°44'03" N and Longitude 86°24'12" E and Pandey Pond P2, situated in the non- coalfield region of Dhanbad lies between the latitude 23°50'05" N and longitude 86°25'33" E.

SAMPLING AND ANALYSIS

Samples were taken from the aforementioned water bodies for the analysis of Limnological and biotic factors from November 2020 to October 2021. A total of twelve parameters were taken into account for analysis water temperature, pH and Electrical Conductivity (EC) were measured by using Celsius thermometer (0° C to 100° C), Portable Conductivity and pH meter respectively, at the site of sampling. Other parameters like Total Dissolved Solids (TDS), Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Chloride (Cl^-), Nitrate (NO_3^-) and Phosphate (PO_4^{3-}), were analysed in accordance with standard methods provided in APHA, 2005.

PHYTOPLANKTON SAMPLING

For phytoplankton analysis 50 litre of water filtered in a bolting silk plankton net with a mesh size 25µm. The collected samples were preserved with 5% Lugol's solution. A Sedgewick Rafter counter cell was used for quantitative analysis of phytoplankton by using 1 mL of sample. Phytoplankton, then identified up to the genus level with the help of keys and monographs (Needham and Needham, 1966; Prescott, 1962; Tonapi, 1980; Adoni *et al.*, 1985).

STATISTICAL ANALYSIS AND BIODIVERSITY INDICES

Various formulas were used to compute the following indices as given below

1. **Simpson's Index (D)**

It is used to measure the species dominance, developed by Simpson in 1949. The value of D ranges between 0 and 1, 0 represent an infinite diversity and 1 represent no diversity. Which means, the greater the D value, the lower the diversity. The equation is

$$D = \frac{\sum_i^S ni(n_i - 1)}{N(N-1)}$$

Where,

D = Simpson Index (Dominance)

S = Total number of species in sample

n_i = number of individuals of the i-th species

N = total number of individuals in the sample

2. **Simpson's Index of Diversity (1-D)**

In this index, the value also ranges between 0 and 1, but here, the greater the value, the greater the sample value.

$$D = 1 - \frac{\sum_i^S ni(n_i - 1)}{N(N-1)}$$

3. **Shannon - Weiner Diversity Index**

Shannon index is a measure used to quantify the diversity of species in community. It takes into account both species abundance and species evenness. The Shannon Index is denoted as H'. The Shannon index is calculated by the equation given below:

$$H' = \sum_{n=1}^{s} Pi\ In\ ni/N$$

Where,

H'= Shannon Index

S= number of taxa

Pi= Proportion of total number of individuals

ni = number of individuals of each species

N = total number of individuals

4. **Evenness Index**

It quantifies how evenly individuals are distributed among different species in an ecosystem. The values range between 0 and 1. Higher values represents the higher evenness.

$$E = \frac{H'}{H'\ max}$$

Where,

E = Evenness index

H' = diversity index

H' max = In S

5. **Pearson's Correlation Coefficient**

This statistical method used to quantify the structure and direction of the linear relationship between two continuous variables on the same interval.

$$r = \frac{n\sum xy - \sum x \sum y}{\sqrt{n\sum x^2 - (\sum x)^2}\ \sqrt{n\sum y^2 - (\sum y^2)}}$$

Where,

r = Karl Pearson's Correlation Coefficient

n = number of total observations

x & y = Two different variables

6. **Canonical Correspondence Analysis (CCA)**

CCA is another multivariate ordination technique used to explore and evaluate the interrelationship between the environmental variables and species composition. It allows for a better understanding of the phytoplankton population, pattern, and structure in relation to the aquatic ambient conditions. (Fan, *et al.*, 2012; Khan *et al.*, 2017).

All the above-mentioned indices and statistical analysis were done by using the software PAST version 4.03 and MS Excel 2007.

Result and Discussion

SPATIO-TEMPORAL VARIATIONS IN LIMNOLOGICAL VARIABLES

Monthly fluctuations and calculated mean and standard deviation (SD) values are summarised in table 1.

Water temperature (WT) ranged between 18 ° C to 36 °C with annual mean value 26.8°C in P1. Whereas in P2, WT ranges between 16 °C to 34°C with a mean value of 25.08°C (Kumari and Sinha, 2023) Temperature greatly impacts a number of critical variables including pH, DO and Conductivity (Jena *et al.*, 2013; Chatap *et al*, 2016).

The ability of water to transfer electrical current is referred to as conductivity. In a nutshell, conductivity is a direct indicator of the amount of ions present in the water. (Kumari and Sinha, 2023) EC values varied from 986 µS/cm to 1321 µs/cm (1139 µs/cm) in P1 while 583 µs/cm to 879 µs/cm with mean value 736 µs/cm in P2 during the study period.

In the present investigation, TDS range between 804 mg/L – 1098 mg/L with annual average value 968.66 mg/L in P1. In P2, TDS readings fluctuated between 426mg/L to 597 mg/L with annual mean 510.42 mg/L during November 2020-October 2021. The taste, smell, and overall quality of water for drinking and other uses can all be impacted by high TDS levels.

pH is a crucial water chemical parameter, essential for determining the growth, biological functions and survival of biotic factors. Any aquatic environment has annual pH fluctuations due to seasonal changes and a number of physico-chemical variables. (Lawson, 2011; Ishaq and Khan, 2013). In the present study the value of pH fluctuates between 7.1 to 7.9 with annual mean value 7.4 in P1 whereas 7.1 to 7.7 with an annual mean 7.36 at P2.

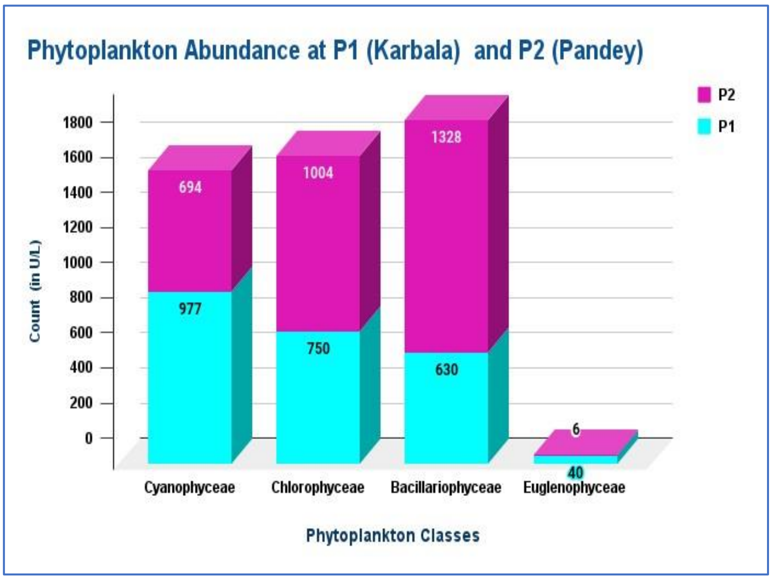
Biological Oxygen Demand (BOD) ranges between 3.1 mg/L to 7.5 mg/L with annual mean value of 5.07 mg/L in P1 and 1.4 mg/L to 2.9 mg/L with annual mean 2.26 mg/L in P2. The range of COD, 62.7 mg/L to 94 mg/L were recorded during the study period in P1 (81.35 mg/L) while 18.6 mg/L to 28.2 mg/L were recorded in P2 with mean value 23.01 mg/L. BOD and COD are crucial factors to elucidate the pollution level of any water bodies (Jain and Dhanija, 2000; Panda *et al*, 2018).

In P1, the range of DO lies between 3.7 mg/L to 5.5 mg/L with mean value 4.46 mg/L. In P2, DO spanned between 5.8 mg/L to 7.2 mg/L with 6.33 mg/L mean value. Dissolved oxygen; is a vital component of any aquatic ecosystems or living organism. A number of variables like temperature, pressure and existence of photosynthetic organisms can affect the amount of dissolved oxygen in water bodies. Many investigations on seasonal variations in the DO concentrations have been done by Ramulu and Benarjee, 2013; Sing *et al.*, 2013; Panda *et al*, 2017; Lawson, 2011; Naseer and Sinha, 2023; Kumari and Sinha, 2023.

Table 1: Seasonal Variations in limnological factors in P1 and P2 during November 2020 – October 2021

Parameters	Karbala Talab (P1)				Pandey Pond (P2)			
	Min.	Max.	Mean	SD	Min.	Max.	Mean	SD
Temp (° C)	18	36	26.8	5.67	16	34	25.08	5.74
EC (µs/cm)	986	1321	1139.58	107.33	583	879	736	89.24
TDS (mg/L)	804	1098	968.66	88.48	426	597	510.42	41.34
pH	7.1	7.9	7.4	0.25	7.1	7.7	7.36	0.18
BOD (mg/L)	3.1	7.5	5.07	1.41	1.4	2.9	2.26	0.44
COD (mg/L)	62.7	94	81.35	10.53	18.6	28.2	23.01	3.22
DO (mg/L)	3.7	5.5	4.467	0.57	5.8	7.2	6.33	0.458
Cl^- (mg/L)	98	134	117.92	11.3	32	50	40.31	5.63
Ca^{2+} (mg/L)	66.3	88	76.28	6.95	18.7	33.8	26.64	4.8
Mg^{2+} (mg/L)	20.83	40.15	28.25	6.485	0.36	17.7	8.71	5.66
NO_3^- (mg/L)	1.79	4.03	2.78	0.71	0.93	1.84	1.42	0.25
PO_4^{3-} (mg/L)	0.72	1.41	1.18	0.203	0.46	1.4	0.99	0.29

Graph 1: Class-wise phytoplankton abundance in P1 and P2.



Chloride value ranged from 98 mg/L to 134 mg/L and 32 mg/L to 50 mg/L in P1 and P2 respectively. In both ponds, chloride concentrations lied within the permissible limits as per WHO & BIS. However, high chloride concentrations can be toxic to aquatic organisms. Chloride ions can disrupt the osmoregulatory balance which may lead to physiological stress, reduced growth rates, reproductive issues and even mortality (Hunt, *et al.*, 2012).

The concentration of calcium at P1, ranged between 66.3 mg/L to 88 mg/L with mean value of 76.28 mg/L while 18.7 mg/L to 33.8 mg/L at P2 with mean value 26.64 mg/L were measured during the study year. Magnesium level vary from 20.83 mg/L to 40.15 mg/L with annual mean 28.25 mg/L at P1 whereas 0.36 mg/L to 17.7 mg/L with mean 8.71 mg/L at P2. Although Calcium and magnesium are frequently associated but magnesium's concentration is typically lower than calcium (Venkatasubramani and Meenambal, 2007).

Nitrate level oscillated between 1.79 mg/L to 4.03 mg/L with 2.78 mg/L mean value at P1 while 0.93 mg/L to 1.84 mg/L with mean value 1.42 mg/L at P2. Elevated concentrations of nitrate, a nutrient that is vital to aquatic plants, can lead to eutrophication, which can worsen the quality of water bodies and result in dangerous algal blooms (Naseer and Sinha, 2023). In the present investigation, Phosphate readings fluctuated between 0.72 mg/L to 1.41 mg/L with annual mean 1.18 mg/L at P1 (Karbala Pond) and 0.46 mg/L to 1.4 mg/L at P2. Similar to nitrate, elevated level of phosphate may also alter the water quality.

TEMPORAL Variations and Abundance of Phytoplankton

An investigation was carried out to determine the occurrence and abundance of phytoplankton community in both P1 and P2. In both ponds, all total 23 phytoplankton genera were recorded during the study period. Assessment of phytoplankton variation is an excellent method for evaluating the pollution status and biotic potential of any aquatic ecosystem (Pawar *et al*, 2006). Class-wise monthly variations and average values of phytoplankton in P1 and P2 depicted in table 2 & 3.

PHYTOPLANKTON ABUNDANCE IN KARBALA POND (P1)

In the present study, a total of 17 phytoplankton genera were recorded during November 2020 to October 2021 belonged to four major classes as Cyanophyceae (6 species), Chlorophyceae (5 species), Bacillariophyceae (5 Species) and Euglenophyceae (1 species). Class Cyanophyceae includes *Anabaena* sp., *Merismopedia* sp., *Microcystis* sp., *Nostoc* sp., *Oscillatoria* sp., *Spirulina* sp.

Class Chlorophyceae includes genera viz., *Closterium* sp., *Eudorina* sp., *Pediastrum* sp., *Scenedesmus* sp., *Spirogyra* sp. Bacillariophyceae characterised by *Bacillaria* sp., *Diatoma* sp., *Fragilaria* sp., *Navicula* sp., *Nitzschia* sp. Single genera *Euglena* sp. represents the Euglenophyceae. Among the total phytoplankton count i.e., 2397, Cyanophyceae was the most abundant group constituting 40.8 %. Chlorophyceae contributed 31.3 % of the total count. Bacillariophyceae accounted for 26.3 % and Euglenophyceae represent the least contributed group with only 1.7 % of the total Population (Depicted in Graph 1).

The present study showed that, maximum phytoplankton count was recorded during summer season with total count 894 U/L followed by winter season (827 U/L) and lastly lowest number of phytoplankton were recorded in rainy season with 676 U/L count in Karbala Pond P1. Kumar *et al.*, 1990; Richardson *et al.*, 2000; Verma *et al.*, 2001; Izaguirre *et al.*, 2001; also observed similar trend in order of Summer > winter > rainy.

Table 2: Phytoplankton species count in both ponds during November 2020-October 2021.

Sl. No.	Class	Phytoplankton Genera/Species	Karbala Pond (P1) Total Count	Karbala Pond (P1) Average Count	Pandey Pond (P2) Total Count	Pandey Pond (P2) Average Count
1	Cyanophyceae	*Anabaena* sp.	275	22.91	211	17.58
2		*Merismopedia* sp.	143	11.92	-	-
3		*Microcystis* sp.	158	13.17	-	-
4		*Nostoc* sp.	131	10.92	213	17.75
5		*Oscillatoria* sp.	188	15.66	144	12
6		*Spirulina* sp.	82	6.83	126	10.5
7	Chlorophyceae	*Closterium* sp.	106	8.83	151	12.58
8		*Cosmarium* sp.	-	-	137	11.41
9		*Eudorina* sp.	197	16.42	191	15.91
10		*Microspora* sp.	-	-	154	12.83
11		*Pediastrum* sp.	217	18.08	-	-
12		*Scenedesmus* sp.	112	9.33	-	-
13		*Spirogyra* sp.	118	9.83	207	17.25
14		*Staurastrum* sp.	-	-	164	13.66
15	Bacillariophyceae	*Bacillaria* sp.	102	8.5	267	22.25
16		*Cymbella* sp.	-	-	253	21.08
17		*Diatoma* sp.	124	10.33	182	15.17
18		*Fragilaria* sp.	20	1.66	160	13.33
19		*Navicula* sp.	234	19.5	126	10.5
20		*Nitzschia* sp.	150	12.5	-	-
21		*Pinnularia* sp.	-	-	190	15.83
22		*Synedra* sp.	-	-	150	12.5
23	Eugleno phyceae	*Euglena* sp.	40	3.33	6	0.5

PHYTOPLANKTON ABUNDANCE IN PANDEY POND (P2)

The total phytoplankton count of 3032 have been recorded in Pandey Pond (P2) during November 2020 to October 2021.

A total of 18 phytoplankton genera belonged to four major classes i.e., Cyanophyceae, Chlorophyceae, Bacillariophyceae and Euglenophyceae, were observed during the study period. Among 18 phytoplankton genera, the order of dominant class as follows Bacillariophyceae (7) > Chlorophyceae (6) > Cyanophyceae (4) > Euglenophyceae (1). Following species were observed include *Anabaena* sp. *Nostoc* sp., *Oscillatoria* sp., *Spirulina* sp., *Closterium* sp., *Cosmarium* sp., *Eudorina* sp., *Microspora* sp., *Spirogyra* sp., *Staurastrum* sp., *Bacillaria* sp., *Cymbella* sp., *Diatoma* sp., *Fragilaria* sp., *Navicula* sp., *Pinnularia* sp., *Synedra* sp., *and Euglena* sp.

In Pandey Pond P2, among the total phytoplankton count (3032), Bacillariophyceae was the most dominant with 43.8 %. The second dominant group was Chlorophyceae with 33.1 % of total count. Cyanophyceae contributed 22.9 % and Euglenophyceae contributed only 0.2 % of total phytoplankton count (Depicted in Graph 1).

In the present study, in P1, the most dominated taxa were *Anabaena* sp. followed by *Navicula* sp., *Pediastrum* sp. *Eudorina* sp., *Oscillatoria* sp., *Microcystis* sp., *Nitzschia* sp., *Merismopedia* sp., *Nostoc* sp. These taxa's existence indicates an excessive pollution load and nutrient rich environment. (Pundhir and Rana, 2002; Chellappa, 2008).

In overall, Cyanophyceae was the most dominant group in P1, which also suggests its eutrophic and nutrient rich nature (Muhammad *et al.*, 2005; Tas and Gonulol, 2007; Sharma et al., 2016)

In P2, the most dominant species was *Bacillaria* sp., *Cymbella* sp., *Nostoc* sp., *Anabaena* sp., *Spirogyra* sp., *Staurastrum* sp., *Pinnularia* sp., *Synedra* sp. Phytoplankton genera like, Cosmarium sp., Microspora sp., Staurastrum sp., Pinnularia sp., and Synedra sp., were only observed in P2. Whereas these abovementioned genera were not observed in P1, elevated levels of sewage and organic pollution might be the contributing factors and vulnerable to the pollution. Similar observations were also reported by Rajagopal *et al.*, 2010. Phytoplankton community has long been reported as bioindicators of aquatic environment (Shashi et al., 2008; Fekadu and Chanie, 2017)

Table3: Monthly variation in phytoplankton count in (P1) Karbala Pond and (P2) Pandey Pond during November 2020- October 2021.

Month	Karbala Pond (P1)		Pandey Pond (P2)	
	Total Count (U/L)	Average Count (U/L)	Total Count (U/L)	Average Count (U/L)
Nov. 2020	189	8.22	219	9.52
Dec. 2020	204	8.87	254	11.04
Jan 2021	223	9.69	245	10.65
Feb 2021	211	9.17	257	11.17
March 2021	202	8.78	308	12.61
April 2021	254	11.04	276	11.043
May 2021	201	8.74	254	12
June 2021	237	10.304	302	13.13
July 2021	145	6.304	222	9.65
Aug 2021	211	9.17	290	13.39
Sept 2021	167	7.26	183	7.96
Oct. 2021	153	6.65	222	9.65
Total	2397		3032	

Based on the seasonal comparison, in P2, the lowest phytoplankton count (917 U/L) were recorded during rainy season and highest during summer (1140 U/L) and moderate in winter (975 U/L). The primary reason of the lowest phytoplankton count during monsoon season might be due to intense flooding (Verma et al., 2001; Bhaskar *et al.*, 2015). According to (Ravishanker et al., 2009), the temperature of the water also affects the quantity and occurrence of phytoplankton. The summer months are ideal for the growth and reproduction of phytoplankton as a result of high temperature and prolonged photoperiod (Farahani *et al.*, 2006; Chowdhury *et al.*, 2007; Tyor and Deepti, 2012).

COMPARATIVE ANALYSIS OF PHYTOPLANKTON DIVERSITY INDICES BETWEEN P1 AND P2.

The average value of phytoplankton diversity indices of P1 & P2 is provided in the Table 4.

The phytoplankton diversity index is well documented and reliable tool to elucidate the evenness, richness and stability of communities (Mousing *et al.*, 2016). The aim of the present study is to shed light upon the distribution and diversity of phytoplankton in both aforementioned ponds. The average value of Simpson's diversity index at P1 & P2 is 0.92 and 0.94 respectively, indicating higher species diversity. However, there were no substantial differences in diversity in both the water bodies. Shannon's index, with a value of 2.7 in P1 indicates low to moderate level of species richness and abundance. Likewise, P2 also represents lower average value of 2.8 for the Shannon's index.

Table 4: Fluctuations in average count in diversity indices in both ponds (P1 & P2) from November 2020- October 2021.

Diversity Indices	Karbala Pond (P1)		Pandey Pond (P2)	
	Average Count (U/L)	Standard Deviation	Average Count (U/L)	Standard Deviation
Simpson's Index (D)	0.075	0.0071	0.063	0.0014
Simpson's Index of Diversity (1-D)	0.92	0.0072	0.936	0.0014
Shannon Index (H´)	2.65	0.079	2.797	0.0108
Evenness_e^H/S	0.909	0.031	0.951	0.0212

With high evenness index value of 0.95 and 0.91 at P2 and P1 respectively, signifies the distribution of individual among different species is quiet even. According to Pielou (1975), it shows that both ponds have a diversified and harmonious environment.

CORRELATION ANALYSIS BETWEEN LIMNOLOGICAL FACTORS AND PHYTOPLANKTON ABUNDANCE

The result of correlation coefficient (P> 0.05) between limnological factors and phytoplankton abundance in both ponds P1 and P2 shown in Table 5 & 6 respectively. Water Temperature shows significant positive relationship with EC with value of 0.69 at P1 and 0.96 at P2. As the EC increases with high temperature. There is positive correlation between EC and TDS with a value of 0.52 and 0.43 at P1 and P2 pond respectively, signifies the presence of high content of salts and ions (Perlman, 2014). There is a negative correlation between pH and WT with a value of -0.73 and -0.83 at P1 and P2 respectively. Similar results were also observed by Kumari and Sinha, 2023. There is significant positive relationship between BOD and COD at both the ponds i.e., P1 (0.3) and P2 (0.81).

Phytoplankton abundance shows positive relationship with nitrate and phosphate with a value of 0.01 and 0.5 respectively at P2. Nitrate and phosphate are the key element that enhance the phytoplankton growth. On the contrary, at P1 Phytoplankton abundance shows negative relationship with nitrate (-0.54) and phosphate (-0.25). Similar results were also observed by Suresh *et al.*, 2013; Sharma *et al.*, 2016. These findings revealed that matrix elucidation of Pearson's Correlation Coefficient is used to assess the interrelationship between the biotic and abiotic factors. (Matta *et al.*, 2009; Elayaraj and Selvaraju, 2014).

[Table 5: Pearson's Correlation Matrix among limnological parameters and Phytoplankton Average count of Karbala Pond (P1) during November 2020-2021]

Karbala Pond (P1) Correlation Matrix

	TEMP	*EC*	*TDS*	*pH*	*DO*	*BOD*	*COD*	*Ca+*	*Mg2+*	*Cl-*	*Nitrate*	*Phosphate*	*Phyto*
TEMP	1												
EC	0.69233	1											
TDS	0.841737	0.529601	1										
pH	-0.73089	-0.72922	-0.74494	1									
DO	0.130824	-0.43802	0.428236	0.088852	1								
BOD	0.287111	0.800442	0.035275	-0.38696	-0.84937	1							
COD	-0.70102	-0.16085	-0.83496	0.323628	-0.72101	0.302412	1						
Ca+	0.12389	-0.4105	0.328492	0.225369	0.820315	-0.73424	-0.58547	1					
Mg2+	0.079464	0.441991	-0.28108	-0.23421	-0.80804	0.737322	0.451581	-0.85053	1				
Cl-	0.218237	0.765417	0.021516	-0.29656	-0.67905	0.831217	0.320913	-0.5453	0.482842	1			
Nitrate	0.079277	-0.40163	0.46434	-0.10272	0.833386	-0.76819	-0.53507	0.821053	-0.83412	-0.65163	1		
Phosphate	-0.32173	-0.49758	0.116207	0.333501	0.671981	-0.64252	-0.35811	0.611978	-0.69891	-0.57013	0.664567	1	
Phyto	-0.17662	0.241339	-0.29688	-0.05011	-0.73911	0.627927	0.540526	-0.56922	0.562382	0.388945	-0.54029	-0.25257	1

CANONICAL CORRESPONDENCE ANALYSIS (CCA)

CCA is another multivariate statistical technique, used to explore and evaluate the interrelationship between two sets of data. CCA is notably an extremely efficient tool for understanding the effects of ecological factors on a set of species abundance in an ecological system. (Fan, *et al.*, 2012; Khan *et al.,* 2017). CCA analysis plot demonstrated the four major classes of phytoplankton, at P1 (Figure 1) and P2 (Figure 2), was governed by a set of ecological parameters viz., WT, EC, TDS, pH, DO, BOD, COD, Ca^{2+}, Mg^{2+}, Cl^{-}, NO_3^{-} and PO_4^{3-}. For P1 (Karbala Pond), eigen value for the first two axes were 0.007 and 0.006 respectively. CCA plot for P2 showed the eigen values for the first two axes were 0.008 and 0.004 respectively. CCA plot for P1 showed the negative relationship between temperature and pH. Bacillariophyceae and Euglenophyceae showed positive relationship with summer season. Whereas, Cyanophyceae had positive relationship with winter season.

CCA plot for P2, pH had negative relation with temperature, TDS, EC. Cyanophyceae showed positive relation with post-monsoon season. Whereas, Euglenophyceae and Bacillariophyceae showed positive relationship with summer season and Chlorophyceae had positive relation with rainy season.

The results of CCA analysis revealed that Temperature, pH and nutrients are the primary environmental variables controlling changes in the structure and pattern of the phytoplankton community in both the ponds (P1 and P2), the results agreed with other research on the variables affecting the algal abundance and diversity. (Fadel *et al.*, 2015; Devi *et al.,* 2016; Gogoi *et al.*, 2020; Badila *et al.,* 2022).

CONCLUSION

In the present study, in P1, Cyanophyceae dominated the phytoplankton community with (40.8 %) followed by Chlorophyceae and Bacillariophyceae with 31.3 % and 26.3 % respectively. Whereas, in P2, the dominated phytoplankton group were observed in the order of Bacillariophyceae (43.8 %) > Chlorophyceae (33.1 %) > Cyanophyceae (22.9 %) > Euglenophyceae (0.2 %). The dominance of *Anabaena sp.*, *Navicula sp., Pediastrum sp. Eudorina sp., Oscillatoria sp., Microcystis sp., Nitzschia sp., Merismopedia sp., Nostoc sp.* and highest density of Cyanophyceae group in P1, indicates its eutrophic and nutrient rich nature.

In the both ponds P1 and P2, the Shannon index values indicate lower to moderate level of species diversity and high evenness index value with 0.91 and 0.95 respectively, indicates even distribution of species. The Pearson's Correlation and Canonical Correspondence analysis, signifies the interconnection between spatio-temporal variations in the concentrations of physico- chemical factors and the phytoplankton's composition, abundance and pattern.

The present study comprehends the role of phytoplankton as bio-indicators, indicating the quality status of water environment and vice-versa, providing baseline for understanding the ecological and phytoplankton dynamics for the future researchers.

[Table 6: Pearson's Correlation Matrix among limnological parameters and Phytoplankton Average count of Pandey Pond (P2) during November 2020-2021]

Pandey Pond (P2) Correlation Matrix													
	TEMP	*EC*	*TDS*	*pH*	*DO*	*BOD*	*COD*	*Ca+*	*Mg2+*	*Cl-*	*Nitrate*	*Phosphate*	*Phyto*
TEMP	1												
EC	0.961477	1											
TDS	0.565372	0.431622	1										
pH	-0.83291	-0.89221	-0.31359	1									
DO	0.244241	0.139266	0.44153	0.194125	1								
BOD	-0.11897	0.007961	-0.42393	-0.27426	-0.94706	1							
COD	0.204815	0.316055	-0.02144	-0.57416	-0.77389	0.819522	1						
Ca+	-0.25527	-0.38847	0.324617	0.547014	0.685255	-0.76952	-0.63882	1					
Mg2+	0.132062	0.270079	-0.26941	-0.5344	-0.8389	0.875874	0.840255	-0.91134	1				
Cl-	0.34431	0.507904	-0.03437	-0.70562	-0.66771	0.760539	0.842766	-0.83194	0.859898	1			
Nitrate	-0.23019	-0.21238	0.110813	0.419735	0.647522	-0.71193	-0.70927	0.650982	-0.73815	-0.50341	1		
Phosphate	-0.38417	-0.2751	-0.51383	0.010013	-0.89166	0.859943	0.695239	-0.48699	0.653666	0.520348	-0.46724	1	
Phyto	0.083518	0.206634	0.054852	-0.26365	-0.40329	0.452489	0.478227	-0.48198	0.473273	0.687678	0.011598	0.509293	1

Figure 1: Canonical Correspondence Analysis (CCA) plot of seasonal variations in limnological factors and Phytoplankton Groups in Karbala Pond (P1) during the study period.

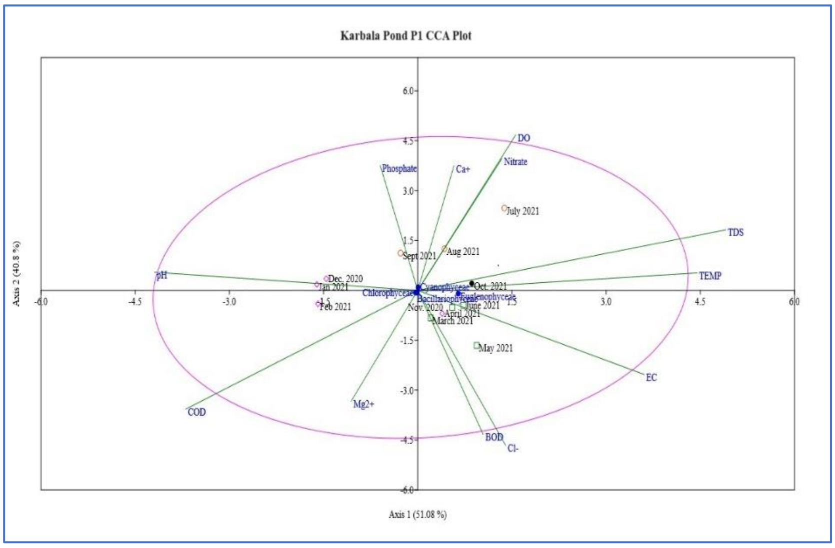
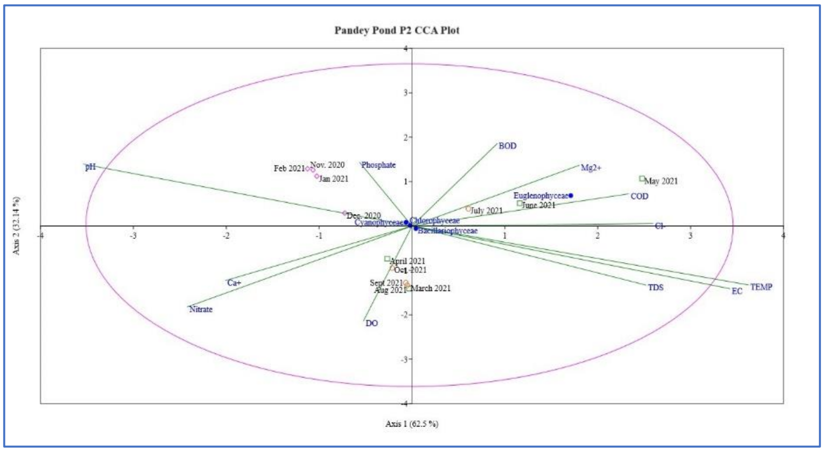


Figure 2: Canonical Correspondence Analysis (CCA) plot of seasonal variations in limnological factors and Phytoplankton Groups in Pandey Pond (P2) during the study period.



REFERENCE

Adoni, A., Joshi, D. G., Gosh, K., Chaurasia, S. K., Vaishya, A. K., Yadav, M. and Verma, H. G., 1985. Workbook on Limnology. Pratibha Publisher, Sagar. 1-166.

APHA, 2005. American Public Health Association, Standard Methods for the Examination of Water and Waste Water. American Public Health Association, Washington, DC.

Ariyadej, C., Tansakul, R., Tansakul, P., and Angsupanich, S. 2004. Phytoplankton Diversity and its relationship to the Physico-chemical Environment in the Banglang Reservoir, Yala Province Songklanakarin. J. Sci. Technol. **26**: 595-607.

Badila, A., Matulessy, M. and Kolibongso, D. 2022. Distribution of Phytoplankton Diversity and abundance in Manokwari Waters, West Papua - Indonesia. IOP Conf. Series: Earth and Environmental Science. 1137.

Bere, T. and Tundsi, J. G. 2011. Diatom-based Quality Assessment in streams influence by Urban Pollution: Effects of Natural and Two Selected Artificial Substrates, Sao Corlos-sp.., Brazil. Braz. J. Aquat. Sci. Technol. **15:** 54-63.

Bhaskar, K., Nautiyal, S., Khan, Y. D. I. and Rajanna, L. 2015. A Preliminary Study on Phytoplankton in Fresh Water – Lake of Gogi, Yadgir District, Karnataka. International Journal of Innovative Research in Science, Engineering and Technology. **4(4).**

Chatap, P. B., Telkhade, P. M. and Khinchi, P. J. 2016. Physico- chemical investigation of river Penganga at Kodsi village, Taluk, Korpana District, Chandrapur, Int. J. of Researches in Biosciences, Agriculture and Technology. 5-7.

Chellappa, N.T., Borba J.M. and Rocha, O. 2008. Phytoplankton Community and Physical-chemical Characteristics of Water in the Public Reservoir of Cruzeta, RN, Brazil. Braz. J. Biol. **68:** 477-494.

Chowdhury, M. M. R., Mondol, M. R. K. and Sarker, C. 2007. Seasonal variation in Plankton Population of Borobila Beel in Rangpur District," University Journal of Zoology, Rajshahi University. **26:** 49–454.

Devi, M. B., Gupta, S. and Das, T. 2016. Phytoplankton Community of Lake Baskandi Anua, Cachar District, Assam, North East India – An Ecological Study. Knowl. Manag. Aquat. Ecosyst. **417, 2**

Elayaraj, B. and Selvaraju, M. 2014. Studies on some Physico-chemical Parameters of Cyanophycean Members and Correlation Coefficient of Eutrophic Ponds in Chidambaram, Tamil Nadu, India. International Letters of natural Sciences. **11(2):** 145-156.

Fadel, A., Atoui, A., Lemaire, B. J., Vincon-Leite, B. & Slim, K. 2015. Environmental factors associated with phytoplankton succession in a Mediterranean reservoir with a highly fluctuating water level. Environmental Monitoring and Assessment. **187 (10):** 633.

Fan, Y., Li, J., Men, X. and Liu, Y. 2012. Preliminary description of diatom community and its relationship with water physicochemical variables in Qixinghe Wetland. Chin. J. Oceanol. Limnol. **30:** 379–387.

Farahani, F., Korehi, H., Mollakarami, S., Skandari, S., Zaferani, S. G. G. and Shashm, Z. M. C. 2006. Phytoplankton Diversity and Nutrients at the Jajerood River in Iran," Pakistan Journal of Biological Sciences. **9(9):** 1787–1790.

Fekadu, A. and Chanie, S., 2017. A Seasonal Study on Phytoplankton Diversity and Dynamics of Lake Chamo, Ethiopia**.** Aquatic Living Resources. **30**, 40.

Gogoi, P., Das, S. K., Das Sarkar, S., Chanu, T. N., Manna, R. K., Sengupta, A., Raman, R. K., Samanta, S. and Das, B. K. 2020. Environmental factors driving phytoplankton assemblage pattern and diversity: insights from Sundarban eco-region, India. Ecohydrology & Hydrobiology.

Hunt, M., Herron, E. and Green, L. 2012. Chlorides in Fresh Water. URI watershed watch. **4(3).**

IS: 10500. 2012. Bureau of Indian Standards, Standards for Drinking Water.

Ishaq, F. and Khan, A. 2013. Heavy metal analysis of river Jamuna & their relation with some physicochemical parameters, Global J. of Environmental Research. **7(2):** 34-39.

Izaguirre, I., Farrell, I. O. and Tell, G. 2001. Variation in Phytoplankton Composition and Limnological Features in a Water-Water Ecotone of the Lower Paran´a Basin (Argentina). Freshwater Biology. **46(1):** 63–74.

Jafari, N. and Alavi, S. S. 2010. Plankton Community in Relation to Physico-chemical Characteristics of the Talar River, Iran. J. Appl. Sci. Environ. Manage. **14:** 51-56.

Jagadeeshappa, K. C. and Kumara, V. 2013. Influence of Physico-chemical Parameters on the Diversity of Plankton Species in Wetlands of Tiptur Taluk, Tumkur, District, Karnataka State, India Carib. J. Sci. Tech. **1:** 185-193.

Jain, Y. and Dhanija, S. K., 2000. Studies in a Polluted Centric Water Body of Jabalpur with Special Reference to Which Physico-chemical and Biological Parameters. J. Envi. Biol. **7:** 83-88.

Jena, V., Gupta, S. and Matic, N. 2013. Assessment of Kharoon river water quality at Raipur by physico-chemical parameters analysis: Asian J of Experimental Biological Science. **4(1):** 79-83.

Khan, M., Khan, S.M., Ilyas, M., Alqarawi, A.A., Ahmad, Z. and Abd-Allah, E.F. 2017. Plant Species and Communities Assessment in Interaction with Edaphic and Topographic Factors: An Ecological Study of the Mount Eelum District Swat, Pakistan. Saudi J. Biol. Sci. **24:** 778–786.

Kumar, K. 1990. Management and Development of Govind Sagar Reservoir – A case Study. Proc. Nat. Workshop Reservoir Fish. 13-20.

Kumari, S. and Sinha S. K. 2023. Studies on Physico-chemical Parameters of the Two Lentic Water Bodies of District Dhanbad, Jharkhand. The Bioscan. **18(1):** 137-147.

Kumari, S. and Sinha, S. K. 2023. Qualitative Evaluation of Limnological factors of the Perennial Lentic Water Bodies of District Dhanbad, Jharkhand by Using Water Quality Index. European Journal of Pharmaceutical and Medical Research. **10(6):** 343-350.

Lawson, E.O. 2011. Physico-chemical parameters and heavy metal contents of water from the mangrove swamps of Lagos Lagoon, Logose, Nigeria, Advances in Biological Research. **5(1):** 08-21.

Matta, G., Bhutiani, R., Kumar, D., Singh, V., Ashraf, J., and Khanna, D. R. 2009. A study of zooplankton diversity with special reference to their concentration in River Ganga at Haridwar. Environment Conservation J. **10:** 15-20.

Michelutti, N. Laing, T. and Smol, J. P. 2001. Diatom Assessment of Past Environmental Changes in Lakes Located Near Noril'sk (Siberia) Smelters. Water Air Soil Pollut. **125:** 231-241.

Mousing, E. A., Richardson, K., Bendtsen, J., Cetinic, I. and Perry, M. J. 2016. Evidence of small-scale spatial structuring of phytoplankton alpha- and beta-diversity in the open ocean. J. Ecol. **104**: 1682–1695.

Muhammad, A., Salam, A., Sumayya, I., Tasveer, Z.B., Qureshi, K. A., 2005. Studies on Monthly Variations in Biological and Physico-chemical Parameters of Brackish Water Fish Pond, Muzaffargarh, Pakistan. J. Res. (Sci.) **16**: 27–38.

Naseer, B. and Sinha, S. K. 2023. Temporal Dynamics of Plankton Communities in an Abandoned Environment: A Comprehensive Pond Study. The Bioscan. **18 (2):** 131-136.

Needham, J. G., and Needham, P. R. 1966. A guide to the freshwater biology. 5th ed., Holden day Inc. San. Fransisco, Calif. p. 108.

Panda P. K. Panda. R. B. and Dash. P. K. 2017. The study of Physico Chemical and Bacteriological Parameters of River Salandi and Assessment of Water Quality from Hadagada dam to Akhandalmani, Bhadrak, Odisha, India, IOSR J. of Environ Sci, Toxicology & Food Tech. **11(4):** Ver II, 31-52.

Panda, P. K., Panda, R. B. and Dash, P. K. 2018. The River Water Pollution in India & Abroad – A Critical Review to Study the Relationship among Different Physico-chemical Parameters. American Journal of Water Resources. **6(1):** 25-38.

Pawar, S. K., Pulle, J. S. and Shendge K. M. 2006. The Study on Phytoplankton of Pethwadaj Dam. Tq. Kandhar, District, Nanded, Maharashtra. J. Aqua. Boil., 21 **(1):** 1-6.

Peerapornpisal, Y., Chaiubol, C., Pekko, J., Kraibut, H., Chorum, M., Chuanunta, J. and Inthasotti, T. 2004. Monitoring of Water Quality in Ang Kaew Reservoire of Chiang Mai University Using Phyroplankton as Bioindicator from 1995 – 2002. Chiang Mai J. Sci. **31:** 85-94.

Perlman, H. 2014. Electrical Conductivity and Water. Report available with the USGS Water Science School.

Piélou, E. C. 1975. Ecological Diversity. New York: John Wiley and Sons.

Prescott, G. W. 1962 Algae of the western great lakes area, vol **2.** W.M.C. Brown Company Publishers, Dubuque Lowa, p. 660.

Pundhir, P. and Rana, K. S., 2002. Population Dynamics of Phytoplankton in the Wetland Area of Keoladeo National Park, Bharatpur (Rajasthan). Ecol. Environ. Conser. **8:** 253-255.

Rajagopal T., Thangamani A. and Archunan, G. 2010. Comparison of Physico-chemical Parameters and Phytoplankton Species Diversity of Two Perennial Ponds in Sattur Area, Tamil Nadu. Journal of Environmental Biology. **31 (5):** 787-794.

Ramulu, K. N. and Benarjee G. 2013. Physico-Chemical factors Influenced Plankton Biodiversity and Fish Abundance – A Case Study of Nagaram Tank of Warangal, Andhra Pradesh, India. International Journal Life Sciences, Biotech & Pharm. Research. 2 (2): 248-260.

Ravishankar, H. G., Murthy, G. P., Lokesh, S., and Poshmani, S. P. 2009. Diversity of Fresh water Algae in Two Lakes of Tumkur, Karnataka State, India. 13th Wuhan Conference. 1-17.

Reiss, J., Bridle, J.R., Montoya, J.M., Woodward, G., 2009. Emerging horizons in biodiversity and ecosystem functioning research. Trends Ecol. Evol. **24(9)**, 505–514.

Richardson, T. L., Gibson, C. E. and Heaney, S. I. 2000. Temperature, Growth and Seasonal Succession of Phytoplankton in Lake Baikal, Siberia. Freshwater Biology. **44(3):** 431–440.

Sharma, R. C., Singh, N. and Chauhan, A. 2016. The Influence of Physico-chemical Parameters on Phytoplankton Distribution in a Head Water Stream of Garhwal Himalayas: A Case Study. Egyptian Journal of Aquatic Research, **42:** 11-21.

Shashi, S., Kiran, B., Puttaiah, E., Shivaraj, Y. and Mahadevan, M., 2008. Phytoplankton as index of Water Quality with reference to Industrial Pollution. J. Environ Biol **29:** 233-236.

Simboura, N. and Zenetos, A. 2002. Benthic Indicators to Use in Ecological Quality Classification of Mediterranean Soft Bottom Marine Ecosystems, Including A New Biotic Index. Mediterr. Mar. Sci. **3:** 77 111.

Sing. T. A., Meetel, N. S. and Metel, L. B. 2013. Seasonal variation of some physico-chemical characteristics of three rivers in Imphal, Manipur: A comparative Evaluation. Current World Environment. **8(1)**: 93-102.

Smol, J. P., Stoermer, E. F. 2010. The Diatoms: Applications for the Environmental and Earth Sciences. Second edition. Cambridge University Press, Cambridge. 667.

Suresh, B., Manjappa, S., and Puttaiah, E. T. 2013. Dynamics of Phytoplankton Succession in Tungabhadra River Near Harihar, Karnataka, India. J. Microbiol. Antimicro. **5(7):** 65-71.

Suseela, M. R. 2009. Conservation and Diversity of Fresh water algae. In: N. Anand. (Eds.), Biology and Biodiversity of Microalgae. Centre for Advanced Studies in Botany, University of Madras, Chennai, India. 41.

Tas, B., Gonulol, A., 2007. An ecological and taxonomic study on phytoplankton of a shallow lake, Turkey. J. Environ. Biol. **28:** 439 445.

Tiwari, A. and Chauhan, S.V. 2006. Seasonal phytoplanktonic diversity of Kitham lake, Agra. J. Environ. Biol. **27**: 35-38.

Tonapi, G. T. 1980. "Freshwater Animals of India" An Ecological Approach. Oxford and IBH Publishing Co., New Delhi, India.

Tyor A. K. and Deepti, S. 2012. Survey and Study of Phytoplankton Ecology in Sukhna Lake, Chandigarh, (India), International Journal of Applied Biology and Pharmaceutical Technology. **3(2):** 229–238.

Vajravelu, M., Martin, Y., Ayyappan, S. and Mayakrishnan, M. 2018. Seasonal Influence of Physio-chemical Parameters on Phytoplankton Diversity, Community Structure and Abundance at Parangipettai Coastal Waters, Bay of Bengal, South East Coast of India. Oceanologia. **60:** 114-127.

Venkatasubramani, R. and Meenambal, T. 2007. Study on subsurface water quality in Mettupalayam Taluk of Coimbatore District, Tamil Nadu, Nature Environment and Pollution Technology. **6(2):** 307–310.

Verma, M. C., Singh, S. and Thakur, P. 2001. Ecology of a Perennial Wetland. An Overview of Limnobiotic Status. J. Environ. Poll. **8(1):** 53-59.

Wetzel, R. G. 2001. Limnology, Michigan State University C. B. S. College, Philadelphia, New York. 7653.

WHO (World Health Organization) 2006. Guidelines for drinking Water Quality, Recommendations. **(1):** 3rd ed. 491-493