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Seasonal Variation in Physicochemical Characteristics and Protozoan Diversity in Kaylana Lake, Jodhpur (Rajasthan)

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Abstract
A Study on the physico-chemical status and diversity of Protozoa in Kaylana Lake was carried out at Site1 over a period of two years (2022-23 and 2023-24) across four distinct seasons: spring, summer, monsoon and winter. The findings revealed that the water temperature, pH, BOD, COD, Total Alkalinity, Total Hardness, and chloride levels peaked during the summer months and reached their lowest levels in winter. Eight groups of Protozoa, namely *Amoeba proteus, Balantidium coli, Euglena sp., Paramecium sp., Vorticella sp., Euglena viridis, Difflugia oblonga and Arcella vulgaris* were examined and it was observed that their abundance followed a seasonal decline in order of summer, spring, monsoon, and winter. A correlation was established between various physico-chemical parameters and the Protozoa present in Kaylana Lake; as temperature, pH, Total Hardness, Total Alkalinity, COD, and BOD increased during the summer, the number of Protozoa also rose. Conversely, a decrease in temperature during winter corresponded with a reduction in physicochemical parameters and a significant decline in Protozoan populations.

Keywords: Kaylana Lake, physico-chemical status, Protozoa, correlation.

1. INTRODUCTION

The condition of any water body depends on its physicochemical status. And the topography of the water body, type of rocks, surrounding environment, temperature and amount of rainfall have direct and indirect effects on physicochemical. The physiochemical conditions directly affect the abundance and diversity of Protozoa in the water body, which represent zooplanktons. Dutt and Monda (2020) in their study concluded that Protozoa diversity of a water body was influenced by its physicochemical factors. With the increase in temperature, the amount of algae and other phytoplankton increases in the water body. Their increased quantity creates favorable conditions of food for Protozoa. And their number increases with the increase in temperature. Jilani, *et al.* (2018) also found in their study that with the increase in temperature, the number of Protozoa in the water body increases and with the decrease in temperature, their number decreases comparatively. Protozoa consume autotrophic phytoplankton as food and on the other hand act as food for heterotrophs. For the proper management of any water body, its physicochemical factors and status of zooplankton are important factors.

2. Study Area

Kaylana Lake is the main water source of Jodhpur city and nearby towns and villages. This lake is situated between 26°17'0' north and 72°58'0' east. This is an artificial lake which was built by Maharaja Pratap Singh in 1872 A.D . The lake is spread over about 0.84 square kilometres. It receives water from Indira Gandhi Canal through *Hathi Nahar*. The lake is situated on a surface with a geological structure of igneous rocks.

2.1. Study Period

The study of Kaylana Lake was conducted by collecting water samples in standard plastic bottles every month over a period of two years (March 2002 to April 2024). The collected samples were mainly analysed based on four seasons –

1. Spring season (February to April every year)
2. Summer season (May to July every year)
3. Monsoon season (August to October every year)
4. Winter season (November to January every year)

3. Methods

The analysis of various physicochemical parameters was done by the following methods -
Temperature: Digital thermometer was used for measuring water temperature.
pH: Digital pH meter was used for measuring pH.
Total Hardness: EDTA solution method was used for measuring total hardness of water. Erochrome Black T was used as indicator (USEPA, 1971).
Total Alkalinity: Total alkalinity was determined by the method described by APHA (1980). Total Alkalinity is the ratio of carbonate and bicarbonate alkalinity.
BOD: Dissolved oxygen was determined by Winkler azide method (APHA 1980) for measuring BOD.
COD: Potassium dichromate method was used for measuring COD in the water of Kaylana Lake. In which mercury sulphate and silver sulphate sulphuric acid were used.
Chloride: Silver nitrate solution method was used for chloride. In which potassium chromate was used as indicator.

3.1. Protozoa Analysis Method –

Protozoa were collected from Kaylana Lake by filtering 100 litres of water samples with a 20 µm zooplankton net at monthly intervals. These Protozoa samples were collected in 50 ml bottles and preserved with the help of 4 % formalin (Steadman, 1976).

4. Result and Discussion

Table 1: Seasonal variation in Physico-chemical Parameters and Protozoa Diversity

Season	Temp. (°C)	pH	T.H. (mg/L)	T.A. (mg/L)	Cl (mg/L)	BOD (mg/L)	COD (mg/L)
Spring 22	27.08	7.74	97.50	65.50	44	4.05	10.23
Summer 22	30.23	8.17	96.53	82.00	54.67	4.08	12.41
Monsoon 22	23.65	7.58	77.53	51.67	30.33	2.93	6.61
Winter 22-23	19.17	7.43	65.00	37.00	26.00	3.40	7.16

Spring 23	21.98	7.58	80.93	54.33	36.00	3.83	11.04
Summer 23	30.48	8.28	102.40	84.33	58.33	4.53	12.99
Monsoon 23	23.72	7.63	74.13	54.33	36.67	3.10	6.71
Winter 23-24	18.10	7.43	57.20	39.00	28.67	3.37	7.56
Spring 24	21.22	7.71	75.20	43.67	35.67	3.70	10.51

At Site 1 of Kaylana Lake, seasonal variations in physicochemical parameters and Protozoan abundance were evident across the study period from spring 2022 to spring 2024. Temperature peaked during the summer seasons (30.23ºC in summer 2022 and 30.48ºC in summer 2023), while the lowest temperatures were recorded in the winter seasons (19.17ºC in winter 2022-23 and 18.10ºC in winter 2023-24). The pH remained relatively stable across seasons, ranging from 7.43 to 8.28, with slightly higher values observed during the summer months. Total Hardness (T.H.) and Total Alkalinity (T.A.) followed a seasonal trend, reaching maximum levels in summer (T.H. 102.40 mg/L and T.A. 84.33 mg/L in summer in summer 2023) and minimum levels during winter (T.H. 57.20 mg/L and T.A. 37.00 mg/L in winter 2022-23). Chloride concentrations were also highest in summer (58.33 mg/L in summer 2023 and lowest in winter (26.00 mg/L in winter 2022-23). Similarly, Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) showed elevated levels in the summer seasons,, while COD peaking at 12.99 mg/L in summer 2023 and BOD at 4.53 mg/L. The abundance of Protozoa was strongly seasonal, with significantly higher counts recorded during summer (235 organisms in summer 2022 and 228 organisms in summer 2023) and the lowest abundance during winter (23 organisms in winter 2022-23 and 30 organisms in winter 2023-24). Spring seasons showed moderate Protozoan abundance, while monsoon seasons exhibited a noticeable decline. This seasonal fluctuation in Protozoan populations appears to correlate positively with temperature, pH, total alkalinity, chloride, and organic pollution indicators such as BOD and COD, highlighting the influence of environmental conditions on biological diversity in the Kaylana Lake. Srinivas and Rajender (2021) also concluded that with the increase in temperature in summer, BOD, COD, Total Alkalinity, Total Hardness and pH of a water body increases.

4.2. Protozoa Diversity -

The status of Protozoa in Kaylana Lake during the study period (February 2022 to April 2024) was as follows –

Table 2: Protozoa Diversity at Site 1 in Kaylana Lake (February 2022 to April 2024)

Protozoa	*Amoeba proteus*	*Balantidium coli*	*Difflugia oblonga*	*Euglena sp.*	*Parameciu m sp.*	*Vorticella campanula*	*Arcella vulgaris*	*Euglena virigis*	Total
Spring 22	09	16	10	07	17	09	05	21	94
Summer 22	31	42	25	29	31	15	19	43	235
Monsoon 22	12	19	10	08	06	06	05	13	79
Winter 22-23	05	04	01	03	03	04	01	02	23

Spring 23	20	24	10	06	12	09	15	11	107
Summer 23	36	35	30	31	31	21	14	30	228
Monsoon 23	11	19	09	09	06	07	02	11	74
Winter 23-24	03	08	03	02	03	03	04	04	30
Spring 24	19	31	15	21	19	15	17	34	171

The maximum number and diversity of Protozoa was reported in summer season. In summer 2022, a total of 235 organisms were found which was found to be 228 organisms in summer 2023. Whereas their number was the lowest in winter season, the total number was only 23 organisms in winter 2022 while the total number was only 30 organisms in winter 2023. This trend indicates that the increase in temperature in summer creates favourable conditions for the growth of Protozoa. During the study period, it was found that the maximum number of *Euglena sp.* was present in spring 2024 (34 organisms), which indicates that moderate temperature is suitable for their growth. The maximum number of *Paramecium sp*. was found in summer, their total number was 31 organisms in summer 2022 and 31 organisms in summer 2023, which shows their adaptability. The number of *Amoeba proteus* was also found to be maximum in summer, 42 organisms were in summer 2022 and 35 organisms in summer 2023.

The maximum number of *Balantidium coli* was reported in summer 2022 and 42 organisms in summer 2024. Whereas only 1 to 3 organisms were reported in winter season, the highest number of *Euglena sp*. and *Euglena viridis* were found in summer and spring seasons, whereas a significant decrease in their numbers was reported in winter.

Deepa, *et al*. (2019) also concluded that *Euglena* and other zooplankton increases during summer season. The highest number of *Arcella vulgaris* was reported in spring 2024 (17 organisms) and summer 2024 (21 organisms). In summer the number of Protozoa was increased which may be due to increased temperature and favourable situation of physicochemical parameters. The lowest presence of Protozoa was reported in winter which may be due to low productivity of the Kaylana Lake in winter and also flooding effect of monsoon. The relative increase in Protozoa numbers in spring shows a relationship of increase in temperature.

4.3. Post Hoc Tukey HSD Test Results

The table summarise the pairwise comparisons between seasons: Multiple Comparison of Means – Tukey HSD, FWER = 0.05

Table 3: Post Hoc Tukey HSD Test

Group1	Group2	Mean diff	p-adj	Lower	Upper	Reject
Monsoon	Spring	24.33	0.6587	-33.008	81.675	false
Monsoon	Summer	144.33	0.0016	86.992	201.675	True
Monsoon	Winter	-4.0	0.9982	-76.422	68.422	False
Spring	Summer	120.0	0.0007	62.658	177.342	True
Spring	Winter	-28.3333	0.5196	-100.76	44.092	False
Summer	Winter	-148.3333	0.0015	220.76	-75.908	True

These results confirm that summer has a statistically higher Protozoan abundance compared to monsoon, spring, and winter season.

4.4. Correlation between Physicochemical parameters and Protozoa

The correlation matrix indicated robust positive associations among various physicochemical parameters and the abundance of Protozoa in Kaylana Lake at Site 1. Temperature demonstrated a very strong correlation with total alkalinity (r = 0.980), total hardness (r = 0.951), chloride (r = 0.940), and pH (r = 0.921), suggesting that higher temperatures are linked to increased mineral content and alkalinity in the water. In a similar vein, chloride concentrations were highly correlated with pH (r = 0.976), total alkalinity (r = 0.9690, and chemical oxygen demand (r = 0.845), indicating a trend of ionic enrichment and organic pollution.

Table 4: Correlation between Physicochemical parameters and Protozoa

Parameters	Temperature	pH	T.H.	T.A.	Cl	BOD	COD	Protozoa
Temperature	1							
pH	0.92150788	1						
T.H.	0.95124511	0.86163885	1					
T.A.	0.98046612	0.93803705	0.930924 7	1				
Cl	0.94011994	0.97603762	0.903499 8	0.968823	1			
BOD	0.67438723	0.78259976	0.774491	0.739497	0.832596	1		
COD	0.68851458	0.81897383	0.777712 8	0.756693	0.845247	0.943819	1	
Protozoa	0.79921771	0.93379049	0.779376 7	0.816877	0.888785	0.741958	0.872802	1

The abundance of Protozoa exhibited a strong positive correlation with pH (r = 0.934), chloride (r = 0.889), temperature (r = 0.799), total alkalinity (r = 0.817), and COD (r = 0.873), implying that Protozoa flourish in conditions characterized by higher temperatures, elevated pH, and increased organic and ionic loads. Furthermore, strong correlations were noted between biological oxygen demand and several parameters including pH (r = 0.783), total hardness (r = 0.774), and chloride (r = 0.833). These results suggest that physicochemical parameters, especially those associated with water temperature, ionic concentration, and organic matter, significantly influence the composition of Protozoan communities within the aquatic ecosystem.). Langer, *et al*. (2007) in their research also found correlation between physicochemical parameters and Protozoan abundance.

5. Conclusion

There is seasonal change in physicochemical character and Protozoa abundance in Kaylana Lake. In summer season, under high temperature conditions, alkalinity, total hardness, chloride and pH

increase which leads to increase in the number of Protozoa. And as the temperature decreases and water dilution increases, pH, total hardness, total alkalinity, BOD, COD also decrease and the number of Protozoa decreases comparatively.

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