.Assessment of Seasonal Impacts of Water Quality Parameters of Lakha Banjara Lake in District Sagar, (M.P.)

Dr. Asha Soni[1*], Dr. Durga Mahobia[2]

1. Department of Chemistry, Associate Professor, Eklavya University, Damoh (M.P.), India-470661
2. Department of Geography, Assistant Professor, Eklavya University, Damoh (M.P.), India-470661

Abstract

The present study focused on estimating the current status of physicochemical parameters of water samples seasonally over a year, from July 2023 to June 2024, for Lakha Banjara Lake in district Sagar (M.P.). Water quality is specified according to physical, chemical, and biological characteristics. The results show that the maximum parameters, such as Total Dissolved Solids (331-592 ppm), Biological Oxygen Demand (5.1- 11.9 ppm), Chemical Oxygen Demand (10.9- 14.0 ppm), and Nitrate content (18.4- 37.3 ppm), were in high concentration, set by BIS and WHO. Lake water availability and quality are highly affected by anthropogenic activities and environmental factors. This study revealed how effluents from small-scale industries, domestic waste dumping and other human activities contaminate the Lakha Banjara Lake. The high variation in results underscores the urgent need for water quality management to meet the water quality standards.

***Keywords*:** Physicochemical, Seasonally, effluent, Anthropogenic, Domestic waste.

1. INTRODUCTION

The pollution of water bodies is increasing steadily due to rapid population growth, urbanisation, improving living standards and diverse human activities. Time is perhaps not too far when pure and clean water may be unavailable to maintain natural human life. There are several ways to assess water quality as deemed fit for drinking, irrigation and industrial use. Some parameters affect the usability of water for a particular purpose. Surface water is one of the principal water sources for people in India and other parts of the world. Water pollution has been reported to cause 30% of infant mortality and 80% of human diseases [1]. Therefore, it is essential to monitor the quality of groundwater pollution in various parts of our country [2]. The earth's surface covers 71% of water and is vital for all known life forms [3]. Only 1.2% of the earth's water is freshwater, and 98.8% is ice. Less than .03% of freshwater is contained within biological bodies and manufactured products [4]. Water pollution is the loss of potency of water for beneficial uses due to the addition of excess material harmful to humans, animals or aquatic life due to human activity. Water pollution occurs when contaminants are disposed off into water bodies directly or indirectly without proper treatment to remove harmful pollutants. The WHO states that one-sixth part of the population of the world, approximately 1.1 billion people, do not have fresh and uncontaminated water, and 2.4 billion people lack essential cleanliness and hygiene [5]. Polluted water consists of sewage water, Industrial discharged effluents, rainwater pollution[6] and pollution by agriculture or households that causes damage to human health or a harmful impact on the Environment. This water pollution affects the quality and health of vegetation and soil [7]. Some water pollution effects are

recognised immediately, whereas others don't appear for months or years [8]. The threat of the sources of food supply and water shortages severely lower biodiversity in aquatic ecosystems[9]. Thus, it is imperative to strengthen lake water pollution assessment, water pollution process excavation and management [10,11]. Plants and organisms living in polluted water bodies are affected by water pollution [12]. Almost all cases, the effect damages individual species, populations, and natural biological communities[13-15]. The Lakha Banjara lake is unique in Sagar district (M.P.). India concerning its geographic and physiographic settings. The geographic and physiographic peculiarities have their manifestations in the form of unusual natural environmental problems. Survival of life and sustenance of agriculture in this vulnerable ecosystem is possible only by mitigating the impacts of these problems through modification of the natural system. These modifications in the form of developmental projects, in turn, induced new sets of adverse environmental impacts. In lower Sagar, agriculture is below the water level, and water is pumped from paddy fields to the Lake. Hence, the present study has determined the water quality parameters in upper and lower Lakha Banjara Lake Sagar, M.P. India.

2. MATERIALS AND METHODS

2.1 Study area

This study was conducted at Lakha Banjara Lake in the Sagar district of M.P. India. The locations for the sampling and analysis are shown in Figure 1. The Lake is situated in the centre of the city and spread over an area of about 1166.4 m^2 [16]. The location of Lake is in the centre of Sagar city (23° 50' N: 78° 45' E) with an area of 82 hectares. It is a shallow, rainy lake with a small catchment (588 ha), and its northwest drainage agrees well with the general northwest drainage flow pattern of the Sagar district [17]. The Lakha Banjara Lake is divided into two parts: the main Lake is 68 hectares, and a small wetland is 14 hectares. It has the deepest point (5.5 m) near the fort side and an average depth of about 2.56 m at the full tank level. The main Lake is surrounded by many ghats, temples, houses, roads and a stone fence wall that eventually ends up in a small wetland of satellites that connect the main Lake with a narrow passageway, except for the southern ghats. The small wetland (Chhota Talab) is surrounded by many trees, roads, hospitals, and the newly made Atal Park.

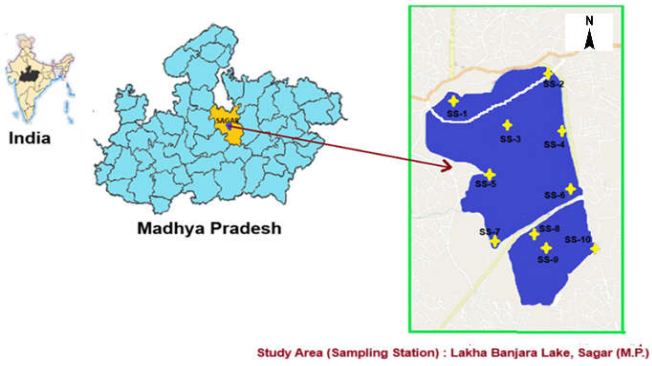


Fig. 1. Map Showing 10 Sampling Stations In Lakha Banjara Lake, Sagar (M.P.)

2.2 Sampling Location

In the current study, a survey of water quality parameters of the lake water was studied for rainy, winter and summer seasons for one year, from July 2023 to June 2024. For this study, the water samples available from *ten* locations of the Lake, i.e. sampling station SS1 –SS10, were used for analysis, mainly *seven* from the Main lake (Station 1 – 7) and three from the Small wetland - Chhota Talab (Station 8 – 10). The details of these sampling stations are given in Table 2.1.

Table 2.1: Ten Sampling Stations for the Current Investigation

S.No.	Sampling Station	Name	S.No.	Sampling Station	Name
1	SS1	Chakra Ghat	**6**	SS6	Dr. Morya Nallah
2	SS2	Sagar Road	**7**	SS7	Siddha Hanuman Ji Temple
3	SS3	Centre of Lake	**8**	SS8	Sanjay Drive
4	SS4	Dhobi Ghat	**9**	SS9	Centre of Wetland
5	SS5	Ganga Temple	**10**	SS10	Atal Park

2.3 Apparatus & Reagents

All the analytical grade chemicals used in the current experiment are from E. Merck India, S.D. Fine Chemicals. TDS meter, Thermometer, burette, pipette, test tube, pH meter, water analysis kit, and Spectrophotometer (SQ 118) were used to analyse all the parameters. The glassware used by Borosil India Ltd.

2.4 Sampling procedure

Water sampling and analysis were performed according to standard protocols [18]. Water samples for the current study were collected season-wise from July 2023 to June 2024 in the morning from Sagar main lake and small wetland. Samples were collected in sterile plastic sampling bottles. After collection, the samples were placed in an ice-cold box before being transported to the laboratory.

2.5 Method of Analysis

Analytical methods employed in assessing the various physicochemical parameters and their compliance with water quality standards [19,20,21] are shown in Table 2.2.

Table 2.2: Analytical methods employed in assessing the various physicochemical parameters.

S.No.	Parameter		Unit	Determination Method	Water Quality Standard
1	Physical	Temperature	°C	Thermometer	25
2		TDS	ppm	Digital TDS meter	500-2000
3	Chemical	pH	-	Digital pH Meter	6.5-8.5
4		DO	ppm	modified Wrinkler's method	5
5		BOD	ppm	modified Wrinkler's method	5
6		COD	ppm	Closed reflux method	10
7		Total Hardness	ppm	EDTA complexometric titration	200-600
8		Total Alkalinity	ppm	Acid-Base Titration	200-600
9		Chloride	ppm	Mohr Agregetrometric titration	250-1000
10		Nitrate	ppm	Ion selective electrode	45
11		Phosphate	ppm	UV Visible Spectrophotometer	0.8

3. Result and Discussion

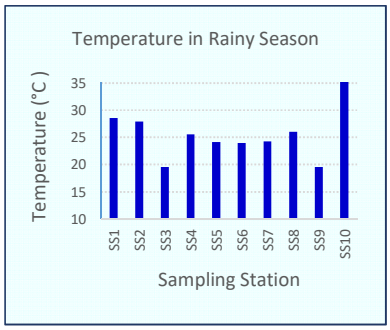
Seasonal variation plays an essential role in identifying the overall quality of lake water. The meticulous collection of data for all 12 physiochemical parameters occurred at 10 distinct locations. Subsequently, the gathered data underwent in-depth analysis, focusing on seasonal variations (Rainy, Winter and Summer), following the criteria set by the Indian Meteorological Department.

3.1 Temperature

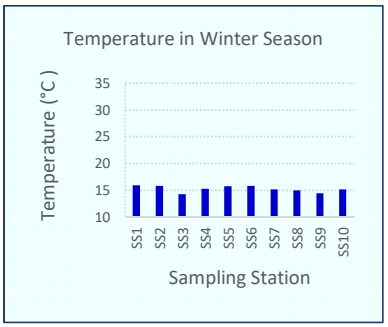
Temperature is a pivotal factor that regulates the pH, Alkalinity, and DO in the aquatic environment [22]. The water temperature during the current study ranged from 19.5°C to 28.3°C in the rainy season, 14.2°C to 15.9°C in the winter, and 25.1°C to 32.3°C during the summer season as shown in Table 3.1 and figure 3.1 (a), (b) and (c). A similar observation was established by [23]. The cause of the higher temperature in summer is the greater sun light penetration at higher intensities over more extended periods during the day. The mean water temperature of Sagar Lake ranged from 15.2 °C in winter to 29.6 °C in summer, as shown in Figure 3.1(d).

Table 3.1: Temperature determination at Sampling Stations and Seasonal Mean from July 2023- June 2024.

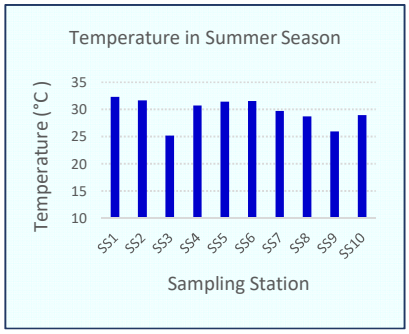
Season	Sampling Station										Min.	Max.	Mean
	SS1	SS2	SS3	SS4	SS5	SS6	SS7	SS8	SS9	SS10			
Rainy	28.3	27.9	19.5	25.5	24.1	23.9	24.2	26.0	19.5	26.8	19.5	28.3	24.6
Winter	15.9	15.8	14.2	15.2	15.7	15.8	15.1	14.9	14.4	15.1	14.2	15.9	15.2
Summer	32.3	31.6	25.1	30.7	31.4	31.5	29.7	28.7	25.9	28.9	25.1	32.3	29.6



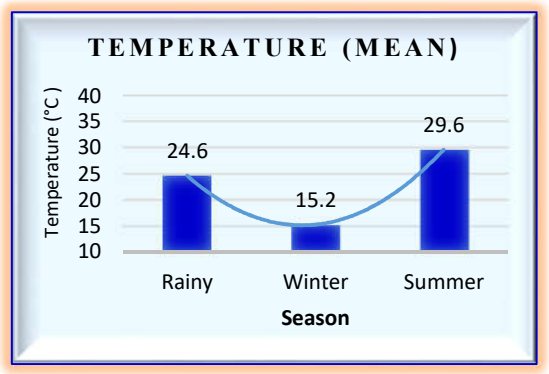
(a)



(b)



(c)



(d)

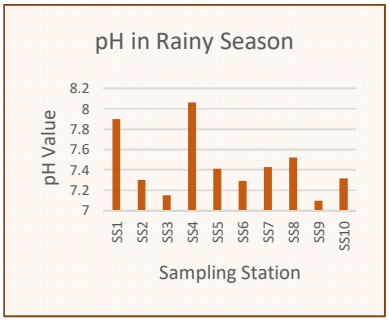
Fig. 3.1. (a)Temperature at SS1-SS10 Sampling station in the Rainy Season
(b) Temperature at SS1-SS10 Sampling Station in the Winter Season
(c) Temperature at SS1-SS10 Sampling Station in the Summer Season
(d) Seasonal Mean study of temperature

3.2 pH

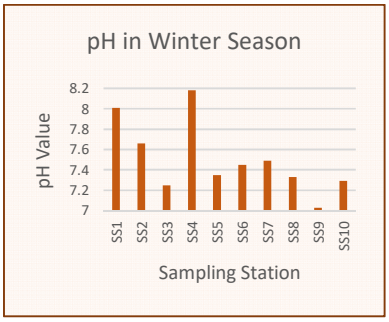
The pH plays a crucial role in assessing water suitability for diverse applications [24]. It significantly impacts various chemical and biological processes. The pH value during the current study ranged from 7.10°C to 8.06°C in the rainy season, 7.03°C to 8.18°C in the winter, and 7.01°C to 7.71°C during the summer season, as shown in Table 3.2 and figure 3.2 (a), (b) and (c). In the present study This increase pH value may be attributed to the depletion of CO2 due to photosynthetic activity, causing surface water to become unsaturated with CO2 in summer, resulting in increased alkalinity and pH values [25]. The mean pH of Sagar Lake ranged from 7.21 in summer to 7.50 in winter as shown in figure 3.2 (d).

Table 3.2: pH Value at Sampling Stations and Seasonal Mean from July 2023- June 2024.

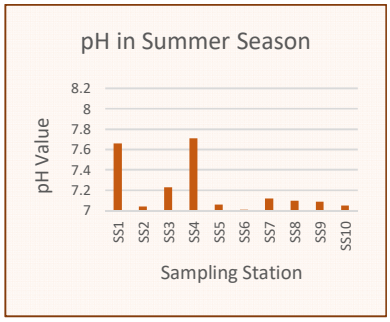
Season	Sampling Station										Min.	Max.	Mean
	SS1	SS2	SS3	SS4	SS5	SS6	SS7	SS8	SS9	SS10			
Rainy	7.90	7.30	7.15	8.06	7.41	7.29	7.43	7.52	7.10	7.32	7.10	8.06	7.45
Winter	8.01	7.66	7.25	8.18	7.35	7.45	7.49	7.33	7.03	7.29	7.03	8.18	7.50
Summer	7.66	7.04	7.23	7.71	7.06	7.01	7.12	7.10	7.09	7.05	7.01	7.71	7.21



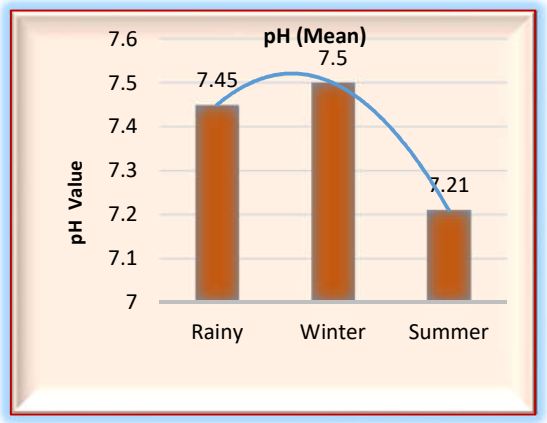
(a)



(b)



(c)



(d)

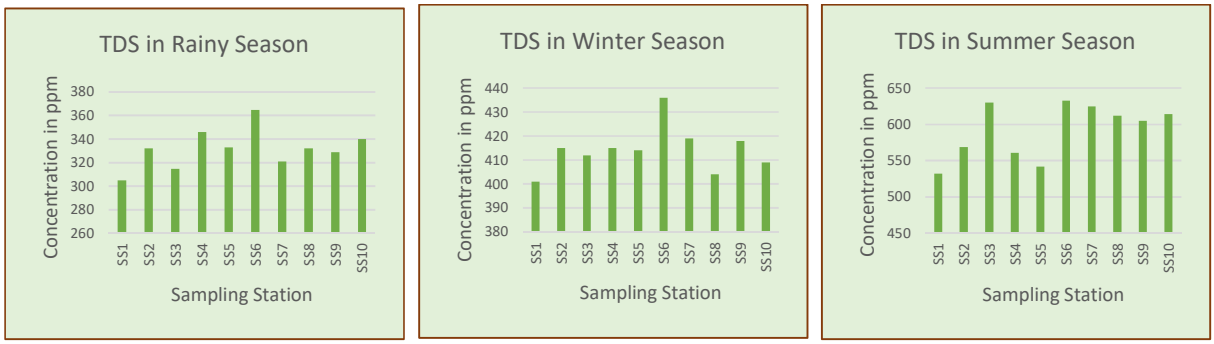
Fig. 3.2. (a) pH Value at SS1-SS10 Sampling station in the Rainy Season
(b) Value at SS1-SS10 Sampling Station in the Winter Season
(c) Value at SS1-SS10 Sampling Station in the Summer Season
(d) Seasonal Mean study of pH

3.3 Total Dissolve Solid (TDS)

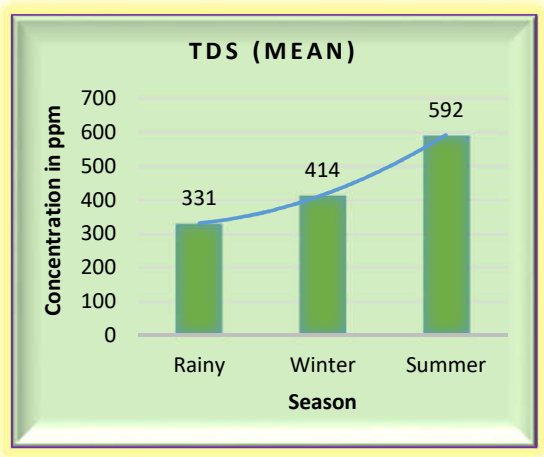
Total dissolved solids mainly represent the various minerals in the water. This composition indicated the presence of inorganic pollution in a water system [26]. The amount of TDS in Sagar Lake ranges between 305 ppm to 633 ppm., as shown in Table 3.3 and Figure 3.3 (a), (b) and (c). The amount of Total dissolved solid was recorded maximum during the summer season (532-633 ppm), and the lowest range of TDS was obtained in the rainy season (305-365 ppm). Due to contamination of sewage water, garbage, chemicals, fertiliser, pesticides, etc, in the lake water body, the value of TDS was reported to be high for drinking purposes. A high concentration of TDS enriches the nutrient status of the water bodies, resulting in the aquatic ecosystems' eutrophication—similar results obtained in some Laurentian Great Lakes [27]. High levels of TDS in water can be harmful to health and appliances. The mean TDS values ranged from 331 ppm in the rainy season to 592 ppm in the summer seasons, well below the 500–2000 mg/L range specified by BIS standards, but this range is unsafe for drinking purposes, as shown in Figure 3.3 (d).

Table: 3.3 Concentration of TDS at Sampling Stations and Seasonal Mean from July 2023- June 2024.

Season	Sampling Station										Min.	Max.	Mean
	SS1	SS2	SS3	SS4	SS5	SS6	SS7	SS8	SS9	SS10			
Rainy	305	332	315	346	333	365	321	332	329	340	305	365	331
Winter	401	415	412	415	414	436	419	404	418	409	401	436	414
Summer	532	569	630	561	542	633	625	612	605	614	532	633	592



(a) **(b)** **(c)**



(d)

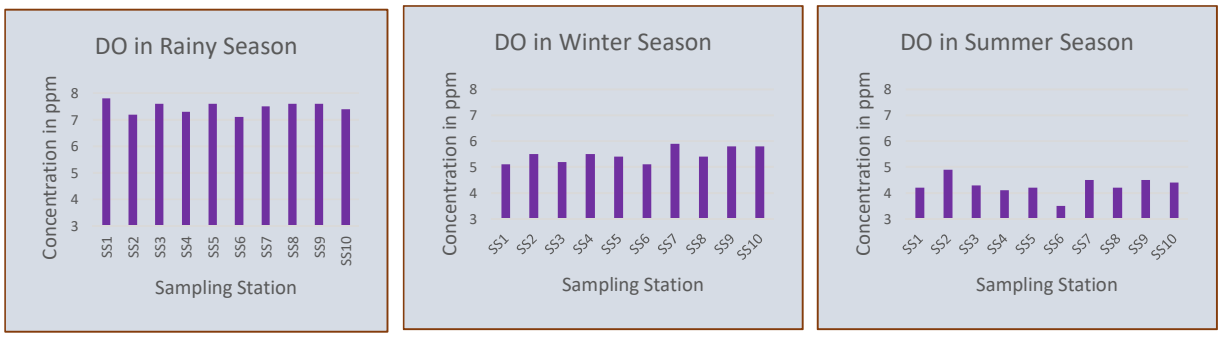
Fig. 3.3. (a) Concentration of TDS at SS1-SS10 Sampling station in the Rainy Season
(b) Concentration of TDS at SS1-SS10 Sampling Station in the Winter Season
(c) Concentration of TDS at SS1-SS10 Sampling Station in the Summer Season
(d) Seasonal Mean study of TDS

3.4 DO (Dissolved Oxygen)

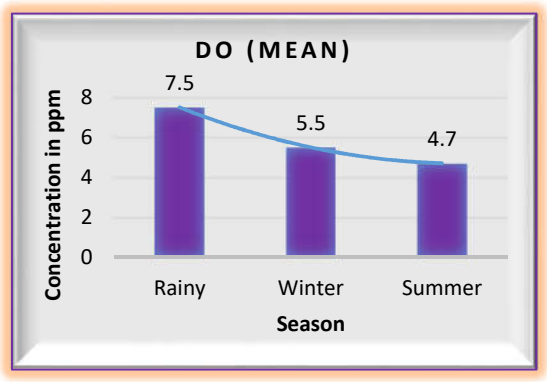
DO is a crucial factor in aquatic ecosystems. In this study, the amount of Dissolved Oxygen recorded in Sagar Lake ranges between 3.5 ppm during the summer season to 7.8 ppm during the rainy season, as shown in Table 3.4 and Figure 3.4 (a), (b) and (c). The mean DO values ranged from 4.7 ppm in summer to 7.5 in the rainy season, as shown in Figure 3.4 (d). This discrepancy may be attributed to factors such as the slow rate of photosynthesis by biological organisms [28] and due to high temperature and increased microbial activity [29].

Table 3.4: Concentration of DO for Sampling Stations and Seasonal Mean from July 2023- June 2024.

Season	Sampling Station										Min.	Max.	Mean
	SS1	SS2	SS3	SS4	SS5	SS6	SS7	SS8	SS9	SS10			
Rainy	7.8	7.2	7.6	7.3	7.6	7.1	7.5	7.6	7.6	7.4	7.1	7.8	7.5
Winter	5.1	5.5	5.2	5.5	5.4	5.1	5.9	5.4	5.8	5.8	5.1	5.9	5.5
Summer	4.2	4.9	4.3	4.1	4.2	3.5	4.5	4.2	4.5	4.4	3.5	4.9	4.7



(a) **(b)** **(c)**



(d)

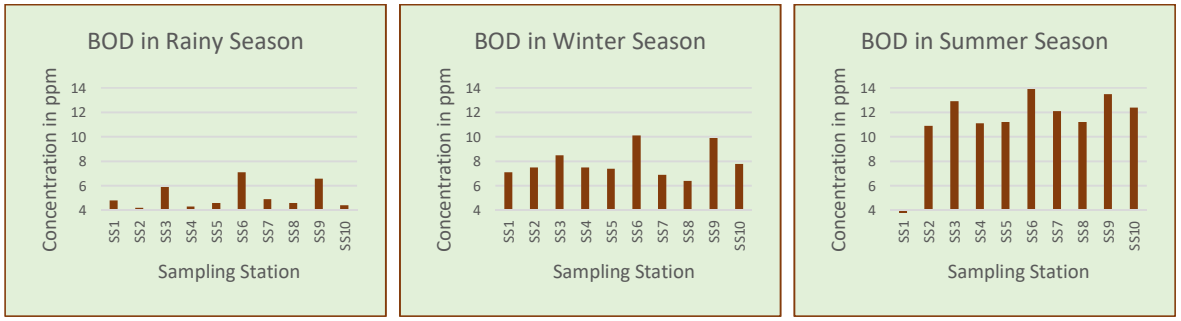
Fig. 3.4 (a) Concentration of DO at SS1-SS10 Sampling station in the Rainy Season
(b) Concentration of DO at SS1-SS10 Sampling Station in the Winter Season
(c) Concentration of DO at SS1-SS10 Sampling Station in the Summer Season
(d) Seasonal Mean study of DO

3.5 Biochemical Oxygen Demand (BOD)

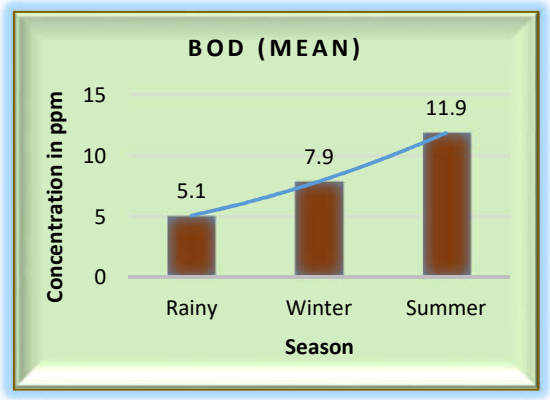
BOD refers to the oxygen used by the microorganism during the aerobic oxidation of organic matter and emerges as a crucial parameter in assessing the pollution stemming from organic waste [30]. The BOD increases with an increase in the amount of organic matter in the water. The BOD value in Sagar Lake ranges between 4.2 ppm to 13.9 ppm., as shown in Table 3.5 and Figure 3.5 (a), (b) and (c). The minimum demand for oxygen in the water was recorded during the rainy season, whereas the maximum demand was recorded during the summer. Throughout the study period, the mean BOD values exhibited a range from 5.1 ppm in rainy seasons to 11.9 ppm in the summer season, as shown in Figure 3.5 (d). The higher value of BOD during the summer was due to organic waste input. A similar result was observed by [31] in the Ramsagar reservoir of Datia and by[32] in Maddur Lake. This result signifies poor water quality conditions for drinking purposes and suggests a need for closer monitoring.

Table 3.5: Value of BOD for Sampling Stations and Seasonal Mean from July 2023- June 2024.

Season	Sampling Station										Min.	Max.	Mean
	SS1	SS2	SS3	SS4	SS5	SS6	SS7	SS8	SS9	SS10			
Rainy	4.8	4.2	5.9	4.3	4.6	7.1	4.9	4.6	6.6	4.4	4.2	7.1	5.1
Winter	7.1	7.5	8.5	7.5	7.4	10.1	6.9	6.4	9.9	7.8	6.4	10.1	7.9
Summer	10.2	10.9	12.9	11.1	11.2	13.9	12.1	11.2	13.5	12.4	10.2	13.9	11.9



(a) **(b)** **(c)**



(d)

Fig. 3.5 (a) Concentration of BOD at SS1-SS10 Sampling station in the Rainy Season
(b) Concentration of BOD at SS1-SS10 Sampling Station in the Winter Season
(c) Concentration of BOD at SS1-SS10 Sampling Station in the Summer Season
(d) Seasonal Mean study of BOD

3.6 Chemical Oxygen Demand (COD)

COD is a amount of various chemically oxidisable organic substances of different natures entering the water body. Throughout the study period COD ranges from 9.9 ppm to 15.9 ppm, as shown in Table 3.6 and Figure 3.6 (a), (b) and (c). During the study period, the mean COD values range from 10.9 ppm in rainy seasons to 14.0 ppm in the summer, as shown in Figure 3.6 (d). COD was high due to high temperature, continuous flow of sewage from different sources into the Lake and increasing concentration of organic matter [33]. Suppressed COD levels in water bodies

render them unsuitable for fisheries and agricultural activities [34]. However, the observed COD values surpassed the established standards of the BIS, indicating contamination from organic pollutants, likely due to high oxygen consumption in chemical processes.

Table 3.6: Value of COD for Sampling Stations and Seasonal Mean from July 2023- June 2024.

Season	Sampling Station										Min.	Max.	Mean
	SS1	SS2	SS3	SS4	SS5	SS6	SS7	SS8	SS9	SS10			
Rainy	10.8	10.2	11.9	10.3	10.6	12.5	10.9	9.9	11.6	10.4	9.9	12.5	10.9
Winter	12.5	12.5	13.5	12.5	12.1	14.1	12.9	12.4	13.9	12.7	12.1	14.1	12.9
Summer	13.3	13.9	14.9	13.3	14.4	15.9	13.2	13.0	14.5	13.4	13.0	15.9	14.0

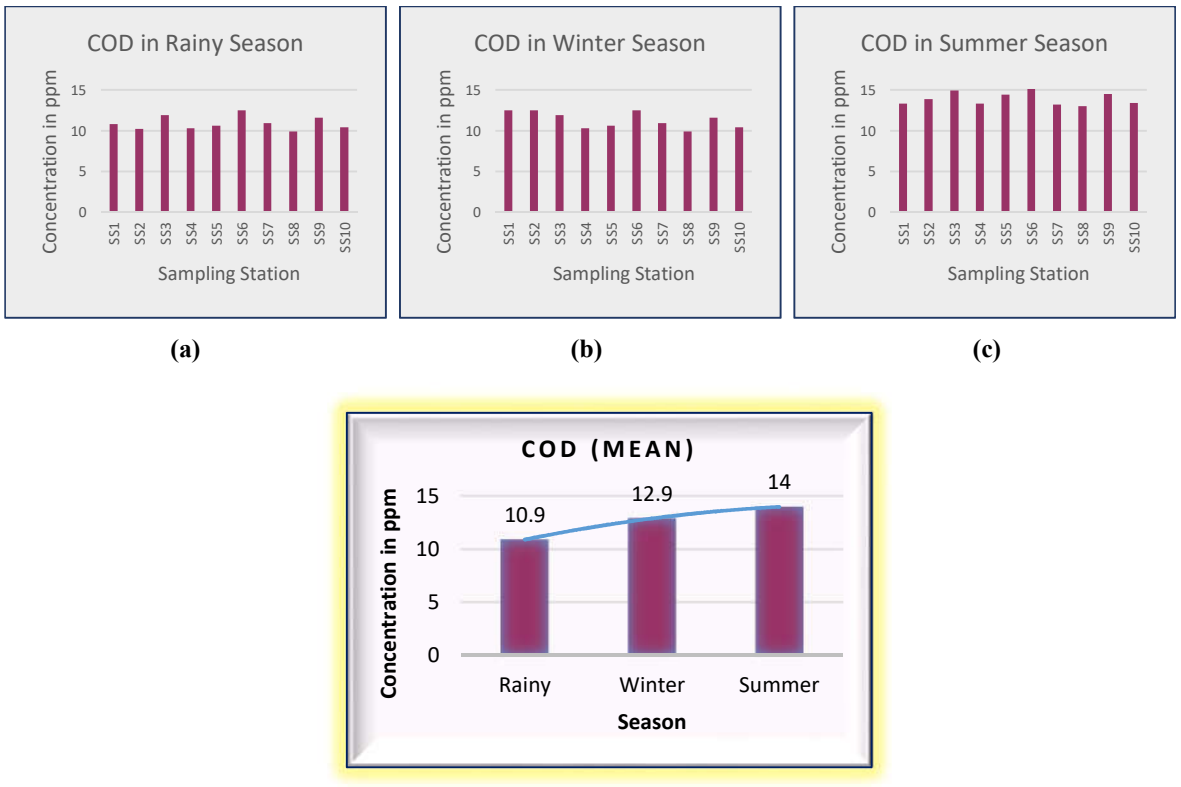


Fig. 3.6 (a) Concentration of COD at SS1-SS10 Sampling station in the Rainy Season
(b) Concentration of COD at SS1-SS10 Sampling Station in the Winter Season
(c) Concentration of COD at SS1-SS10 Sampling Station in the Summer Season
(d) Seasonal Mean study of COD

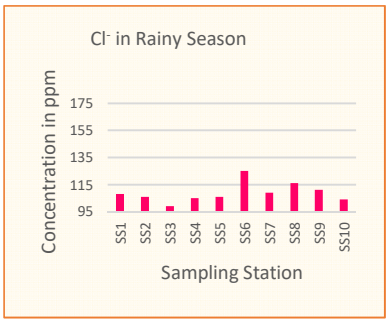
3.7 Chloride

Chloride is the most common inorganic anion present in surface water in the form of sodium, calcium, and magnesium salts. Chloride concentration increases due to human-caused factors such as road salt, sewage contamination and water

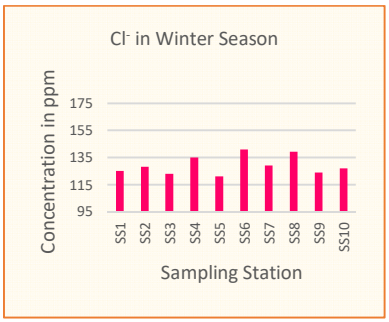
softeners. Throughout the study period, Chloride ranges from 99 ppm to 189 ppm, as shown in Table 3.7 and Figure 3.7 (a), (b) and (c). During the study period, the mean chloride values exhibited a range from 108 ppm in rainy seasons to 145 ppm in the summer, as shown in Figure 3.7 (d). A lower chloride range was observed explicitly during the rainy season, suggesting the dilution effect. All the lake water samples show chloride values within the acceptable limit of ISI standards. The higher range recorded in summer denotes the impact of higher temperature and rapid reduction in water mass [36,36].

Table 3.7: Chloride Concentration for Sampling Stations and Seasonal Mean from July 2023- June 2024.

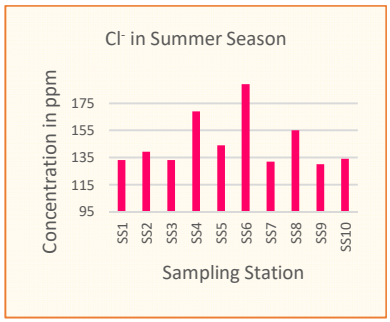
Season	Sampling Station										Min.	Max.	Mean
	SS1	SS2	SS3	SS4	SS5	SS6	SS7	SS8	SS9	SS10			
Rainy	108	106	99	105	106	125	109	116	111	104	99	116	108
Winter	125	128	123	135	121	141	129	139	124	127	121	141	129
Summer	133	139	133	169	144	189	132	155	130	134	132	189	145



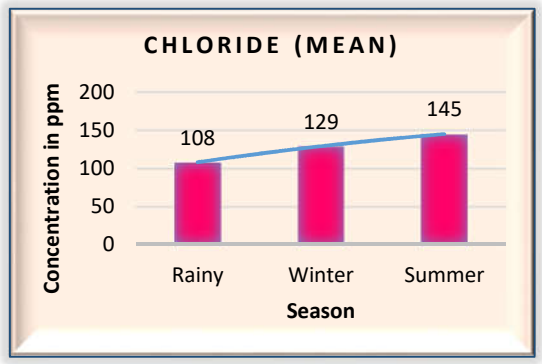
(a)



(b)



(c)



(d)

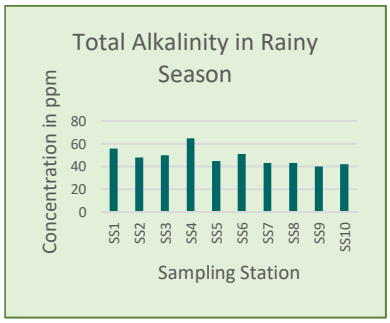
Fig. 3.7 (a) Concentration of Chloride at SS1-SS10 Sampling Station in the Rainy Season
(b) Concentration of Chloride at SS1-SS10 Sampling Station in the Winter Season
(c) Concentration of Chloride at SS1-SS10 Sampling Station in the Summer Season
(d) Seasonal Mean study of Chloride

3.8 Total Alkalinity

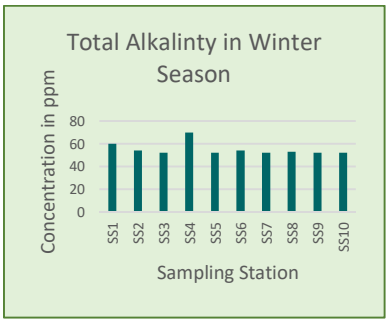
The alkalinity of water is a measure of the concentration of base ions (OH^-, CO_3^{--}, HCO_3^-). It can also be referred as the buffering capacity of water. Throughout the study period, total alkalinity ranged from 40 ppm to 81 ppm, as shown in Table 3.8 and Figure 3.8 (a), (b) and (c). During the study period, the mean of the total alkalinity exhibited a range from 48 ppm in rainy seasons to 73 ppm in the summer, as shown in Figure 3.8 (d). The decomposition of living organisms, plants and biodegradable waste is one of the reasons for increased carbonate and bicarbonate, resulting in increased alkalinity value [37]. Above the expected value, the water taste becomes unpleasant, and high alkalinity should be corrected for both economic and health concerns.

Table 3.8: Total Alkalinity for Sampling Stations and Seasonal Mean from July 2023- June 2024.

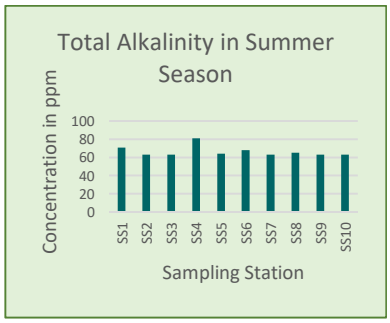
Season	Sampling Station										Min.	Max.	Mean
	SS1	SS2	SS3	SS4	SS5	SS6	SS7	SS8	SS9	SS10			
Rainy	56	48	50	65	45	51	43	43	40	42	40	65	48
Winter	60	54	52	70	52	54	52	53	52	52	52	70	55
Summer	71	63	63	81	64	68	63	65	63	63	63	81	73



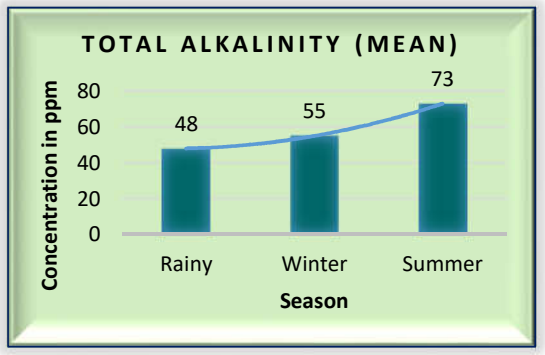
(a)



(b)



(c)



(d)

Fig.3.8 (a) Concentration of Total Alkalinity at SS1-SS10 Sampling Station in the Rainy Season

(b) Concentration of Total Alkalinity at SS1-SS10 Sampling Station in the Winter Season

(c) Concentration of Total Alkalinity at SS1-SS10 Sampling Station in the Summer Season

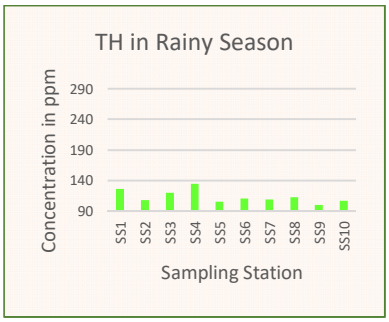
(d) Seasonal Mean study of Total Alkalinity

3.9 Total Hardness (TH)

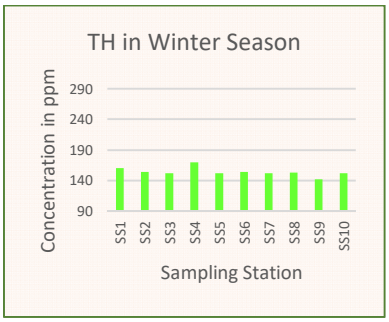
The hardness of water is primarily attributed to the presence of magnesium and calcium cations. Throughout the study period, total alkalinity ranged from 100 ppm to 281 ppm, as shown in Table 3.9 and Figure 3.9 (a), (b) and (c). The alkalinity ranged from 100 ppm to 135 ppm in the rainy season, 142 to 170 ppm in winter and 226 to 281 ppm during the summer season. During the study period, the mean values of total hardness ranged from 113 ppm in rainy seasons to 263 ppm in the summer, as shown in Figure 3.9 (d). The high value of hardness may be due to the increased and regular addition of large quantities of sewage and detergent into lakes from the nearby residential localities [38,39]. Notably, all observed TH values fell slightly above the permissible range recommended by BIS standards.

Table 3.9: TH for Sampling Stations and Seasonal Mean from July 2023- June 2024.

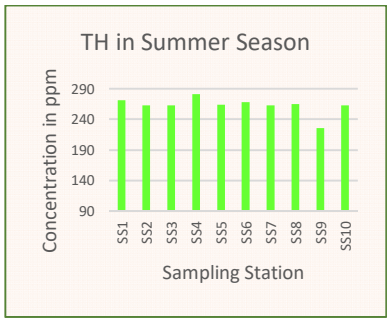
Season	Sampling Station										Min.	Max.	Mean
	SS1	SS2	SS3	SS4	SS5	SS6	SS7	SS8	SS9	SS10			
Rainy	126	108	120	135	105	111	109	113	100	107	100	135	113
Winter	160	154	152	170	152	154	152	153	142	152	142	170	154
Summer	271	263	263	281	264	268	263	265	226	263	256	281	263



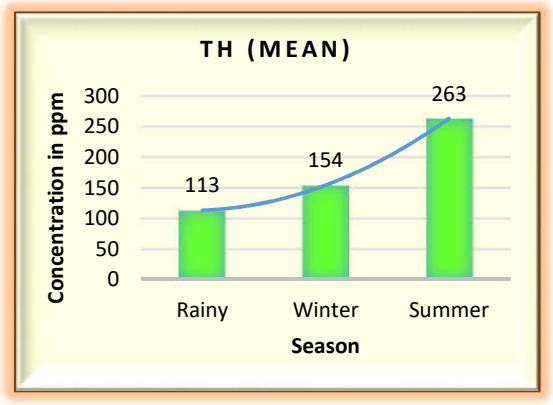
(a)



(b)



(c)



(d)

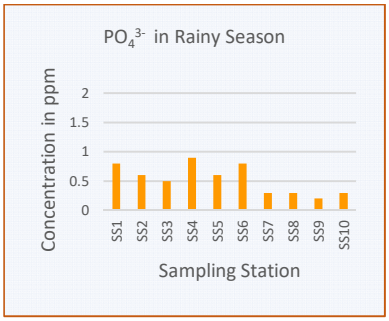
Fig. 3.9 (a) Concentration of TH at SS1-SS10 Sampling station in the Rainy Season
(b) Concentration of TH at SS1-SS10 Sampling Station in the Winter Season
(c) Concentration of TH at SS1-SS10 Sampling Station in the Summer Season
(d) Seasonal Mean study of TH

3.10 Phosphate

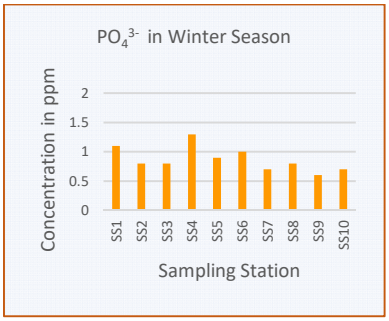
Phosphates are an oxide of phosphorus. One of the primary nutrients responsible for biological productivity is phosphate. For the growth of algae, aquatic plants and bacteria in water systems, tt plays a crucial role in fostering [40]. Throughout the study period, total phosphate levels ranged from 0.2 ppm to 1.4 ppm, as shown in Table 3.10 and Figure 3.10 (a), (b) and (c). The amount of phosphate ranged from 0.2 to 0.9 ppm in the rainy season, 0.6 to 1.3 ppm in winter and 1.1 to 1.4 ppm in the summer. Summer recorded the highest values (1.1–2.1 ppm), exceeding the WHO limit at all sampling stations. During the study period, the mean values of the amount of phosphate exhibited a range from 0.5 ppm in rainy seasons to 1.4 ppm in the summer, as shown in Figure 3.10 (d). The washing of large amounts of clothes by people and laundry workers and the continuous entry of domestic sewage in some areas are responsible for the increase in the amount of phosphate. The increased phosphorus value is accountable for using chemical fertilisers in the surrounding area for agricultural purposes.

Table 3.10: Concentration of PO_4^{3-} at Sampling Stations and Seasonal Mean from July 2023- June 2024.

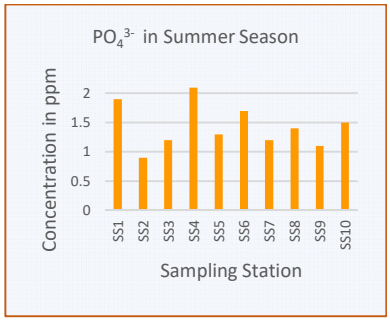
Season	Sampling Station										Min.	Max.	Mean
	SS1	SS2	SS3	SS4	SS5	SS6	SS7	SS8	SS9	SS10			
Rainy	0.8	0.6	0.5	0.9	0.6	0.8	0.3	0.3	0.2	0.3	0.2	0.9	0.5
Winter	1.1	0.8	0.8	1.3	0.9	1.0	0.7	0.8	0.6	0.7	0.6	1.3	0.9
Summer	1.9	0.9	1.2	2.1	1.3	1.7	1.2	1.4	1.1	1.5	1.1	2.1	1.4



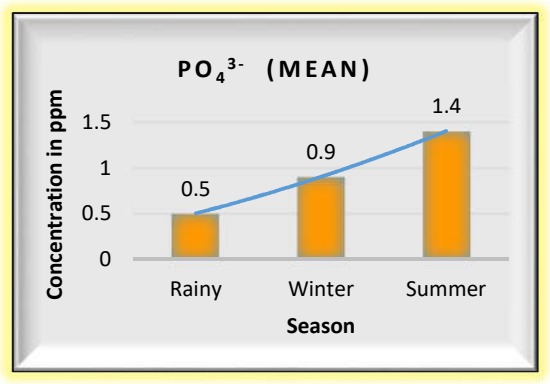
(a)



(b)



(c)



(d)

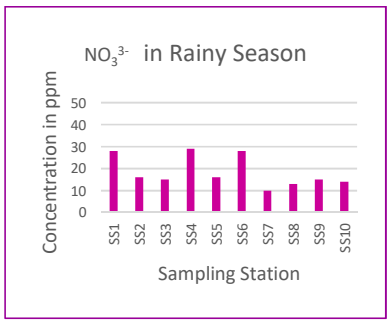
Fig. 3.10 (a) Concentration of PO_4^{3-} at SS1-SS10 Sampling station in the Rainy Season
(b) Concentration of PO_4^{3-} at SS1-SS10 Sampling Station in the Winter Season
(c) Concentration of PO_4^{3-} at SS1-SS10 Sampling Station in the Summer Season
(d) Seasonal Mean study of PO_4^{3-}

3.11 Nitrate

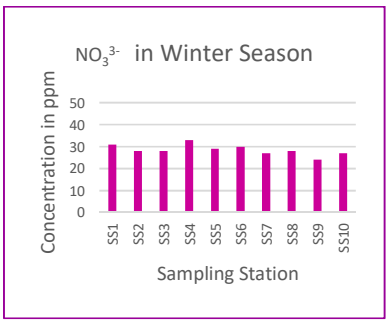
Nitrates (NO_3^{3-}) are one of the most crucial nutrients in aquatic ecosystems. During this study period, nitrate ranges from 10 ppm to 49 ppm, as shown in Table 3.11, figure 3.11 (a), (b) and (c).. The amount of phosphate ranged from 10 to 29 ppm in the rainy season, 24 to 33 ppm in winter and 31 to 49 ppm in the summer. Notably, summer recorded the highest values (31-49 ppm). During the study period, the mean values of the amount of nitrate exhibited a range from 18.4 ppm in rainy seasons to 37.3 ppm in the summer, as shown in Figure 3.11(d). Water bodies with elevated NO_3^{-3} concentrations, often resulting from anthropogenic effluents, can trigger the overgrowth of algae and aquatic plants, a phenomenon recognised as eutrophication [41].

Table 3.11: Concentration of Nitrate at Sampling Stations and Seasonal Mean from July 2023- June 2024.

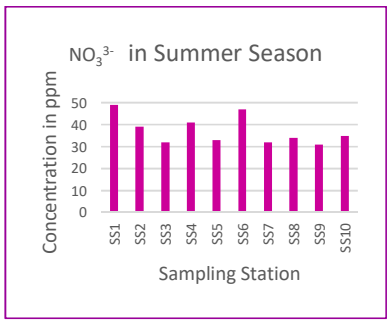
Season	Sampling Station										Min.	Max.	Mean
	SS1	SS2	SS3	SS4	SS5	SS6	SS7	SS8	SS9	SS10			
Rainy	28	16	15	29	16	28	10	13	15	14	10	29	18.4
Winter	31	28	28	33	29	30	27	28	24	27	24	33	28.5
Summer	49	39	32	41	33	47	32	34	31	35	31	49	37.3



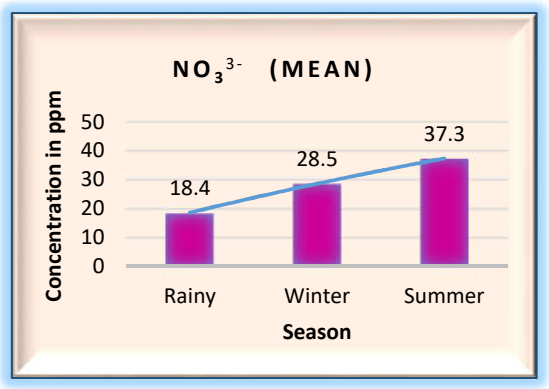
(a)



(b)



(c)



(d)

Fig 3.11. (a) Concentration of NO_3^{3-} at SS1-SS10 Sampling station in the Rainy Season
(b) Concentration of NO_3^{3-} at SS1-SS10 Sampling Station in the Winter Season
(c) Concentration of NO_3^{3-} at SS1-SS10 Sampling Station in the Summer Season
(d) Seasonal Mean study of NO_3^{3-}

4. Conclusion

A comprehensive analysis of the Seasonal Impacts of Water Quality Parameters of Lakha Banjara Lake in District Sagar (M.P.) was conducted, and it was found that the maximum number of parameters was above the desirable limit when compared with WHO and BIS standards. The study reveals significant fluctuations in water quality parameters across various seasons and sites, suggesting pollution of the Lake by different anthropogenic stressors. High TDS, BOD, COD and nitrate ion concentrations are the major threats in Lakha Banjara Lake. A high level of variation is a result of human activity and the discharge of wastewater into the Lake. Lake water can be used for irrigation and washing purposes only, as it contains a large amount of organic matter, which could be suitable for crops. Overall, Lakha Banjara Lake's water quality experiences seasonal variations, with the winter season exhibiting 'Poor' water conditions and the summer season yielding the most concerning results, indicating 'Unsuitable' water conditions at many sampling stations. Very soon, Lakha Banjara Lake will become biologically inactive if a similar condition continues for a longer time.

5. References

1. Raza, Irfan, et al. (2024). Geospatial Interpolation and Hydro-geochemical Characterization of Alluvial Aquifers in the Thal Desert, Punjab, Pakistan. *PLoS One*, 19(8), p. e0307025.
2. Singh, K.,P. and Parwana, H., K. (1992) . Groundwater pollution due to industrial wastewater in Punjab state and strategies*, I. J. Environmental Protection*, 19 (4), 241-244.
3. Ahuja, S. (2009). Handbook of Water Quality and Purity. *Elsevier Inc*. eBookISBN: 9780080921129, 1-456.
4. Gleick, P. (1993) Water in Crisis: A Guide to the World's Fresh Water Resources. *Oxford University Press*, New York. ISBN:019507627, 1-24.

5. EPHA, (2009). Air, Water Pollution and Health Effects. *EPHA*, https://epha.org/category/website-transfer/attic/old-environment/air-water-pollution-and-health-effects/
6. Ashraf, M. A., Maah, M. J., Yusoff, I., & Mehmood, K. (2010). Effects of Polluted Water Irrigation on Environment and Health of People in Jamber, District Kasur, Pakistan. *International Journal of Basic & Applied Sciences*, 10, 37-57.
7. Kotsis, K. T. (2024). Using the water pollution of Lake Pamvotis for science education in high school and college. Aquademia, 8(1), ep24003, 1-10.
8. Kumar, M., G., V., Mishra (2024). Causes and Impacts of Water Pollution on Various Water Bodies in the State of Rajasthan, India: *A Review. Environment and Ecology*, 42 (2A): 645—654.
9. Kılıc, Z. (2020) The importance of water and conscious use of water. *Int J Hydro*, 4(5): 239–241.
10. Dalin, L., Faming, H., Wenjing, K., Yaoxian, D., Zhongshan, C. (2019). Water Pollution Index Evaluation Of Lake Based On Principal Component Analysis. *IOP Conf. Series: Earth and Environmental Science,* 300(3), 1-8.
11. Zhuo, H., Wu, Y., Liu, M., Zheng, H., Lan, J. (2017). Trend Study Of Water Quality In The Three Gorges Reservoir . *Resources And Environment In The Yangtze Basin*, 26(06): 925-936.
12. Long-wei, W., G., Zheng, LI, C. (2009). Applying PAC-SOM Combined Model to Assess Lake Water Quality [J]. *Environmental Science & Technology*, 3, 173-177.
13. Abhijna, U., G., Ratheesh, R., Kumar, A.(2013). *Journal of Environmental Biology* , 34(3), 605-611.
14. Nahid Parveen and Y. Rohan, Heavy metal contaminations in Sagar lake and drinking water sources of Sagar city, *Int. J. Appl. Biol. Pharmaceut. Technol.,* 3(1), 152, (2016).
15. Nahid, P., Rohan, Y. (2017). Spectrophotometric determination of some environmental sample, *J. Environ. Res. Develop.,* 6(1), 57-62.
16. Payamara, J. (2010). Assessment of toxic heavy metal pollutant in an urban atmosphere in Tehran, *Asian J. Chem.,* 21(8), 6584.
17. Jain, A., Koshta, M., K.(2016). Physicochemical Studies Of Water Quality On Lakha Banjara Lake Sagar: Review. *International Journal of Innovation in Engineering Research & Management* , 3(3), 1-8.
18. Mishra, S., K. (1969). On Sagar Lake, *Vasundhara,* 5, 119-121.
19. Roy, R. (2019). An Introduction to Water Quality Analysis. *International Journal for Environmental Rehabilitation and Conservation*, 6. 201-205.
20. Baird, R.,B., Eaton, A.,D., Rice, E.,W. (2017). Standard Methods for the Examination of Water and Wastewater, 23th ed. American Public Health Association (APHA), American Water Works Association, Water Environment Federation, Washington, DC, USA.
21. BIS, 2012. Indian Standard for Drinking Water - Specification IS 10500:2012.
22. WHO (World Health Organization), 2017. Guidelines for drinking- water quality (4th edition).
23. Jindal, M., Wats, M. (2022). Evaluation of surface water quality using water quality indices (WQIs) in Lake Sukhna, Chandigarh, India. *Appl Water Sci* 12 (2), 1–14.
24. Verma, P., Chandawat, D., Gupta, U., Solanki, H. (2012). Water quality analysis of an organically polluted lake by investigating different physical and chemical parameters. *International Journal of Research in Chemistry and Environment*, 2(1),105-111.

25. Ahipathy, M.,V., Puttaiah, E.,T. (2006). Ecological characteristics of Vrishabhavathy river in Bangalore (India). *Environ. Geol*. 49 (8), 1217–1222.
26. Castrillon-Munoz, F., J., Gibson, J.,J., Birks, S.,J. (2022). Carbon dissolution effects on pH changes of RAMP lakes in northeastern Alberta, Canada. *Journal of Hydrology. Regional Studies,* 40, 1-15. https://doi.org/10.1016/j.ejrh.2022.101045.
27. Bhutiani, R., Ahamad, F., Tyagi, V., Ram, K., (2018). Evaluation of water quality of river Malin using water quality index (WQI) at Najibabad, Bijnor (UP) India. *Environ. Conserv. J.* 19 (1&2), 191–201. https://doi.org/10.36953/ECJ.2018.191228.
28. Beeton, A., M., (1965), Eutrophication of the St. Lawrence Great Lakes. *Limnol, Oceanogr*, 10: 240-254.
29. Kangabam, R., D., Bhoominathan, S., D., Kanagaraj, S., Govindaraju, M., (2017). Development of a water quality index (WQI) for the Loktak Lake in India. *Appl Water Sci*, 7, 2907–2918. https://doi.org/10.1007/s13201-017-0579-4.
30. Kataria, H., C., Singh, A. (2006), Studies on water Quality of Dahod Dam, India. *Poll. Res*. 25(3): 553-556.
31. Siraj, S., Yousuf, A.,R., Bhat, F.,A., Parveen, M., (2010). The ecology of macrozoobenthos in Shallabugh wetland of Kashmir Himalaya, India. *J. Eco. Nat. Environ*. 2 (5), 84–91.
32. Garg, R. K., Saksena, D. N., and Rao, R. J., (2009), Water quality and conservation management of Ramsagar reservoir, Datia (M.P.), J. of Environ, Biol. 30(5): 909-916.
33. Devaraju, T., M., Venkatesha, M., G., and Singh, S. (2005). Studies on physicochemical parameters of Muddur Lake with reference to suitability for aquaculture. *Nat, Environ. Pollution. Tech,* 4: 287-290.
34. Boyd, C., E. (1981). Water Quality in Warm Water Fish Ponds. 2nd Edition, *Craftmaster, Printers Inc*., Auburn.
35. Effendi, H., Romantob, Wardiatno, Y. (2015). Water quality status of Ciambulawung River, Banten Province, based on pollution index and NSF-WQI. *Procedia Environ. Sci*. 24, 228–237. https://doi.org/10.1016/j.proenv.2015.03.030.
36. Pejaver, M., Raut, N.(2002) Nutrient management from lakes in Thane city (Maharashtra) Indian *J.Environ. and Ecoplan*, 6(2): 349-354.
37. Mani, B., Gaikwad, S.,A. (1998) Physico-Chemical Characteristics of Lake Pokharan. *Journal of Environment and Toxicology*, (2), 56-58.
38. Tecklie, A., Nigussie, Y., Bilale, A. (2024). Assessment of Water Quality Parameters in Lake Hayq, Northeastern Ethiopia. *ScientificWorldJournal.* Doi: 10.1155/2024/7439024. PMID: 39263585; PMCID: PMC11390204.
39. Kaur, H., Dhillon, S., S., Bath, Mander, G. (1996), Analysis of the Elements pollution river Gaggar in the region of Punjab. *Journal of Environment and Pollution.* 3(2), 65–68.
40. Mohanta, B., K., Patra, A., K. (2000). Studies on the Water Quality index of river Sanamachhakandana at Keonjhar Garh, Orrisa, *Poll. Res.*,19(3), 377-385.
41. Li, J., Jin, Q., Liang, Y., Geng, J., Xia, J., Chen, H., Yun, M. (2022). Highly efficient removal of nitrate and phosphate to control eutrophication by the dielectrophoresis-assisted adsorption method. *Int. J. Environ. Res. Public Health* 19 (3), 1890. https://doi.org/10. 3390/ijerph19031890.