



## SEASONAL VARIATIONS IN PHYSICO-CHEMICAL PROPERTIES OF SHAHEED CHANDRA SHEKHAR AZAD BIRD SANCTUARY WETLAND: A RAMSAR SITE, UNNAO, UTTAR PRADESH, INDIA

AANCHAL VERMA<sup>a</sup>, PRIYANSHI SINGH<sup>b</sup>, PRATIBHA<sup>c</sup> AND ALKA KUMARI<sup>d1</sup>

<sup>abcd</sup>Department of Botany, University of Lucknow, Lucknow, U.P., India

### ABSTRACT

The present study deals with the seasonal changes in water quality of a wetland i.e. Nawabganj bird sanctuary notified recently as a Ramsar site in Unnao district of Uttar Pradesh (U.P.). The study examines in a variety of physical and chemical parameters on both temporal and spatial scales, which include water temperature, pH, turbidity, electrical conductivity (EC), total solids (TS), total suspended solids (TSS), total dissolved solids (TDS), biochemical oxygen demand (BOD), dissolved oxygen (DO), phosphate ( $\text{PO}_4^{3-}$ ) and nitrate ( $\text{NO}_3$ ) also. The physico-chemical characteristic of Nawabganj wetland is found to be highly fluctuated with seasonal variations during the present investigation. The winter season has a high value of dissolved oxygen and pH, while the summer season has a high value of BOD, TS, TSS, and TDS. The correlation coefficient showed positive and negative relationships among the parameters. The outcome shows that the necessary mineral nutrients are broadly dispersed and lie within the standard range of water. The results of the present studies revealed that there is no pollution exists, and no organic waste is being brought to the location. It shows the main water source of the wetland is rainwater and is eutrophicated. Wetland habitat includes substantial amounts of nutrients, as wetlands support high levels of biodiversity and have many biomes.

**KEYWORDS:** Water Quality, Ramsar Site, Physico-Chemical Parameters, Seasonal Variations, Correlation

Wetlands are among the earth's most valuable and diverse ecosystems, encompassing a wide range of habitats characterized by the presence of water for prolonged periods. Wetlands, which range from inland floodplains and peat lands to coastal marshes and swamps, are crucial for maintaining biodiversity, controlling hydrological cycles, and offering key ecosystem services. The main abiotic components of any ecosystem are soil and water, which are also essential for plant growth. Wetland vegetation includes emergent plants, submerged aquatic species, riparian buffers, and floodplains. Aquatic plant species get their nutrition mainly from water, as do land species from soil, so the quality of water and soil affects plant growth and health. Now a day's pollution has become a serious concern for humans, it also affects the ecosystem, environment, and plants. Soil and water are contaminated with pollution nearly all urban areas. Wetlands are also used by human for several works, which makes them also contaminated.

They make up only 4% of the land area that is free of ice on Earth (Prigent *et al.*, 2001). For conservation purposes, regular monitoring of these ecosystems is necessary to preserve these priceless resources and stop future degradation (Ramachandran *et al.*, 2006). This study offers a thorough examination of the many physicochemical characteristics of soil and

water that are essential to comprehending the ecology of wetlands. Wetlands are probably the earth's most important fresh water resources which provide food and habitat for many aquatic lives including threatened and endangered species. So, conservation of wetlands is very much essential as wetlands are one of the most threatened habitats of the world. The most important step for conservation of wetlands is to maintain a proper water quality. The water quality is directly related to the health of the water body. So, proper management in water quality of aquatic environment is very much essential. Some of the most comprehensive works on water quality of various aquatic environments have been reported viz. Gopalkrushna M. H. (2011), Vaishnav and Dewangan (2011), Matini *et al.* (2012), and Devi *et al.* (2013). Shaheed Chandra Shekhar Azad Bird Sanctuary is also called as Nawabganj Bird Sanctuary is well known for its floral and faunal diversity. The most important step for conservation of floral diversity of the wetlands is to maintain a proper water quality as water quality is directly related to the health of native aquatic floras. So, proper management in water quality of aquatic environment is too much essential. The purpose of the present study is to observe water quality of Nawabganj wetland in terms of seasonal changes in water quality parameters and to find the relationship between different physico-chemical parameters.

<sup>1</sup>Corresponding author

## MATERIALS AND METHODS

### Geographical Information & Site Description of Study Area

The selected area of the present study is Shaheed Chandra Shekhar Azad Bird Sanctuary also known as Nawabganj Bird Sanctuary situated in the Hasanganj tehsil of Unnao district of Uttar Pradesh (U.P.) state in India. The present study was conducted on the physico-chemical parameters of the Nawabganj wetlands which is shallow marshland situated on the Lucknow-Kanpur highway near about 50 Km from Lucknow. It is 18 Km from district head quarter Unnao. It possesses variable climates which is majorly divided into three seasons: summer (March –June), rainy (July – October) and winter (November – February).

It is a freshwater wetland with an average depth of 1.8 m to 8.6 m. It was designated as Ramsar site (No. 2412) on 19.09.2019. It covers approximate area of 224.6 ha and stretched between 26<sup>0</sup>36'N 80<sup>0</sup>39'E coordinates. Government of U.P. has been identified it as one of the wetlands of 'National Importance' for conservation and sustainable use based on its bio-diversity and socio economic importance. Nawabganj wetland has unique habitat form any fresh water fishes along with some rare and endangered species of flora and fauna. The lake support diverse aquatic vegetation. Monsoon rains feed this diverse wetland while the Sarada Canal supplies additional water. The Sanctuary supports recreation and tourism activities as well as local biodiversity. It is a haven for birds, with 25,000 water birds regularly recorded and 220 resident and migratory species documented. Among these are globally threatened species including the endangered Egyptian vulture and Pallas's fish eagle as well as the vulnerable lesser adjutant woolly-necked stork. Protection and afforestation measures have helped increase the overall diversity of wildlife, with golden jackal and jungle cat now present. The highly invasive common water hyacinth poses a threat, as does the removal of timber from the forests. The sanctuary is jointly governed by State forest officers along with the Office of the Conservator of Forest (Wildlife).

### Sampling Methods

The water samples were collected in triplicates from the main water pond at three different sites of Nawabganj wetland. Water sampling were done thrice in a year ie. after 4 months intervals/year from March 2022 to February 2024 (during 9.00 – 11.00 am) by submerging a fresh and sterilized sample bottle about 1 foot depth. Water color, odor and temperature were observed on the site spot. Water temperature was taken

with the help of a mercury thermometer; thereafter, water samples were carried to the laboratory for further analysis.

### Analysis of Water Quality Parameters

Several other physico chemical parameters such as pH, turbidity, dissolved oxygen (DO<sub>2</sub>), free carbon dioxide (FCO<sub>2</sub>), total alkalinity (TA), electrical conductivity, total suspended solids (TSS), total dissolved solids (TDS), chloride (Cl), biochemical oxygen demand (BOD), chemical oxygen demand (COD), phosphate (PO<sub>4</sub><sup>3-</sup>) and nitrate (NO<sub>3</sub>) were estimated in the laboratory using standard methods (APHA 1998). Estimation of pH has been done by digital pH –meter (Systronics Type-335). Turbidity was measured by Water Analyzer, Model no. WQC- 22A, Electrical conductivity was measured by conductivity meter. (Esico Microprocessor based conductivity meter, Model 1601), TDS was measured with the help of Digital TDS meter. AR grade reagents, distilled water and Borosil glasswares were used for preparation of solutions and analysis.

### Statistical Analysis

The correlation between various physico-chemical parameters of water samples were analyzed statistically conducting Pearson correlation analysis with the help of SPSS software (16.0).

## RESULTS AND DISCUSSION

Physico-chemical parameters (Mean±S.D) of Nawabganj wetlands carried during the present investigation (during March 2022 - July 2024), is presented in table-1.

### Water Temperature

Water temperature is one of the essential parameter, since it influences the growth and distribution of flora and fauna. Oxygen status of any water body is greatly influenced by temperature (Mishra *et al.* 2008). Water temperature recorded as minimum value of 16.17 °C and maximum of 54.5°C during the two year study period (March 2022 to July 2024) with a mean value of 27.05°C ±4.26 table-1. The average water temperature observed during the first year study period was 26.88 °C±4.01 whereas during the second year of observation the mean water temperature was 28.05°C±4.6. In the present investigation, minimum water temperature was obtained during winter season and maximum during summer (figure-1). This investigation is also in close conformity with the finding of Chaturbhuj *et al.* (2004), Mishra *et al.* (2008), Arya *et al.* (2011) and Abir Shib (2014). Water temperature showed highly significant with positive relationship (p<0.01 level) with turbidity

( $r=0.830$ ),  $CO_2(r=0.905)$ ,  $EC(r=0.751)$ ,  $TSS(r=0.787)$ ,  $TDS (r=0.784)$ ,  $BOD(r=0.690)$ ,  $COD (r=0.832)$  and Significant negative correlation with  $pH (r=- 0.590)$ ,  $DO (r= -0.890)$  and Total alkalinity ( $r= - 0.879$ ) as depicted in table-2.

**pH**

pH is the concentrations of hydrogen ions ( $H^+$ ) present in water and is a measure of acidity or alkalinity. During the present study period (March 2022 to July

2024), the pH of the Nawabganj wetlands was observed near neutral to alkaline ranging from 6.8 to 9.0 which was considered to be conducive for aquatic life. The maximum pH recorded during winter season especially in the month of December 2022 (9.0) and minimum pH (6.8) was obtained during summer (April 2022) in the two years study period figure-2, with mean value of  $7.8\pm0.5$  (Table-1). These findings are also in accordance with Mishra *et al.* (2008) and Tara *et al.* (2011).

**Table 1: Physico-chemical parameters (Mean±S.D) of Nawabganj Bird Sanctuary wetland during March 2022–February 2024**

Parameters	First year study period (March 2022–Feb. 2023)		Second year study period (March 2023–Feb. 2024)	
	Range	Mean ±SD	Range	Mean ±SD
Water Temperature (°C)	16.8-34.6	26.8±2.07	17.9-28.0	26.57±3.55
pH	7.3-8.44	7.8± 0.41	6.8-9.0	7.89± 0.606
Turbidity (NTU)	15.75-51.0	25.65±9.27	14.86-47.0	25.78± 10.16
Dissolved oxygen (mg/L)	4.26-8.6	6.17±1.37	3.8-8.27	6.26±1.43
Free Carbon dioxide (mg/L)	1.5-6.8	3.47±1.55	1.45-7.09	3.67±1.94
Total alkalinity (mg/L)	127.3- 252.0	193.5± 38.97	121.0- 232.5	188.66 ±36.45
Electrical conductivity (µmho/cm)	40.0- 126.0	83.17± 25.66	60.76- 108.2	75.35±16.6
Total Suspended Solids (mg/L)	40.0- 100.25	73.64± 21.66	41.45- 118.62	81.24±27.6
Total Dissolved Solids (mg/L)	80.0- 210.0	133.8± 38.36	100.0- 216.0	165.9± 32.15
Chloride(mg/L)	24.0- 34.12	28.71±3.49	32.8-44.1	38.03±3.49
BOD(mg/L)	1.22-4.2	2.48± 0.708	2.28-3.11	2.56±0.22
Chemical Oxygen Demand (mg/L)	21.32- 66.75	46.47±15.7	26.63- 101.6	50.078 ±22.49
Phosphate(mg/L)	0.894-4.78	3.048±1.32	0.52-5.36	2.31±1.53
Nitrate(mg/L)	2.4-7.36	5.55±1.54	2.8-8.1	5.54±1.65

**Table 2: Correlation matrix among the physico-chemical parameters of Nawabganj Bird Sanctuary wetland during March 2022–February 2024**

	WT	pH	TUR	DO <sub>2</sub>	FCO <sub>2</sub>	TA	EC	TSS	TDS	Cl	BOD	COD	PO <sub>4</sub> <sup>3-</sup>	NO <sub>3</sub>
WT	1	-.590**	.830**	-.890**	.905**	-.879**	.751**	.787**	.784**	.284	.690**	.832**	.457*	-.475*
pH		1	-.397	.554**	-.588**	.520**	-.550**	-.440*	-.380	-.161	-.286	-.477*	-.271	.472*
TUR			1	-.826**	.907**	-.876**	.564**	.671**	.765**	.345	.723**	.745**	.270	-.495*
DO <sub>2</sub>				1	-.906**	.895**	-.748**	-.785**	-.761**	-.240	-.563**	-.880**	-.436*	.521**
FCO <sub>2</sub>					1	-.917**	.699**	.793**	.795**	.391	.638**	.787**	.365	-.574**
TA						1	-.689**	-.675**	-.784**	-.400	-.712**	-.835**	-.221	.604**
EC							1	.447*	.572**	.070	.732**	.685**	.318	-.643**
TSS								1	.664**	.188	.326	.726**	.601**	-.128
TDS									1	.497**	.689**	.758**	.287	-.372
Cl										1	.333	.332	-.346	-.413*
BOD											1	.711**	.127	-.497*
COD												1	.220	.398*
PO <sub>4</sub> <sup>3-</sup>													1	.287
NO <sub>3</sub>														1

\*.Correlation is significant at the 0.05 level (2-tailed)\*\*. Correlation is significant at the 0.01 level (2-tailed). WT= Water Temperature, TUR= turbidity, DO<sub>2</sub>=dissolved oxygen, FCO<sub>2</sub> = Free carbon dioxide, TA= total Alkalinity, EC=electrical conductivity, TSS=total suspended solids, TDS= total dissolved solids, Cl= chloride, BOD= Biochemical Oxygen Demand, COD= Chemical Oxygen Demand, PO<sub>4</sub><sup>3-</sup> = Phosphate, NO<sub>3</sub>= Nitrate.

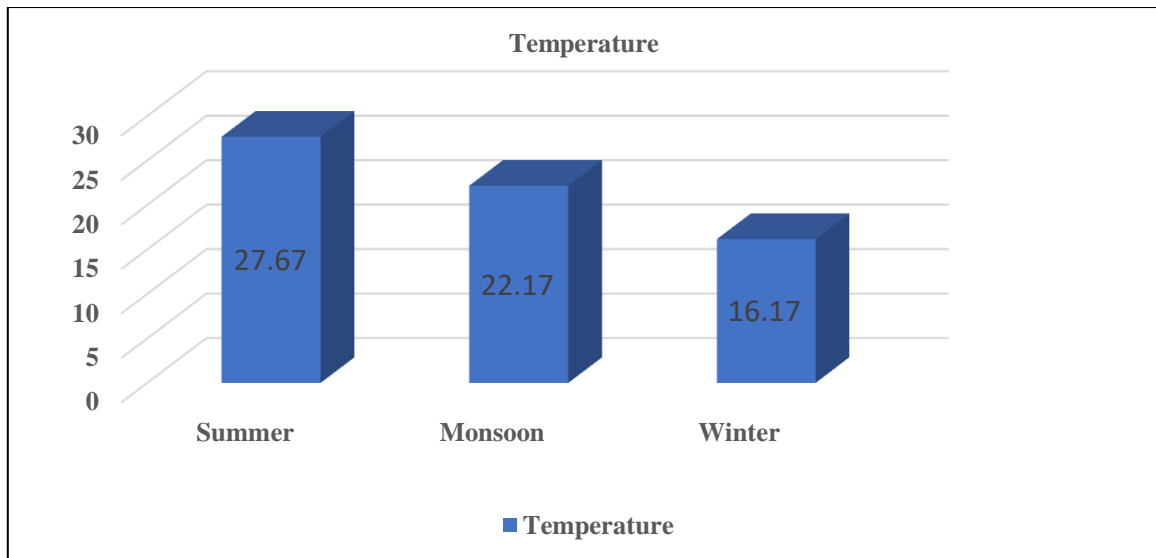


Figure 1: Showing temperature range of wetland water in different seasons

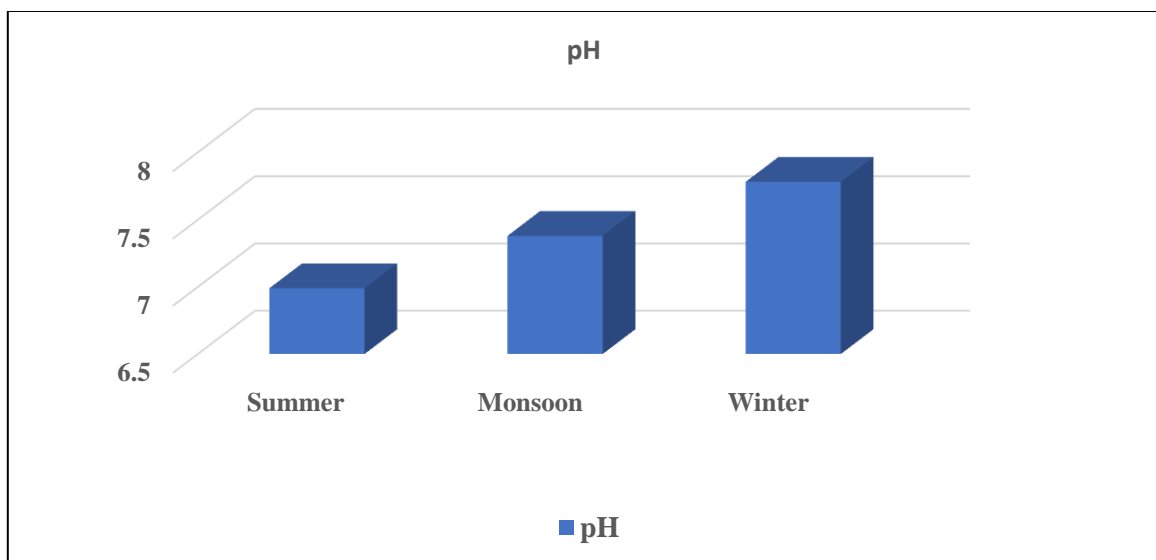


Figure 2: Showing pH range of wetland water in different seasons

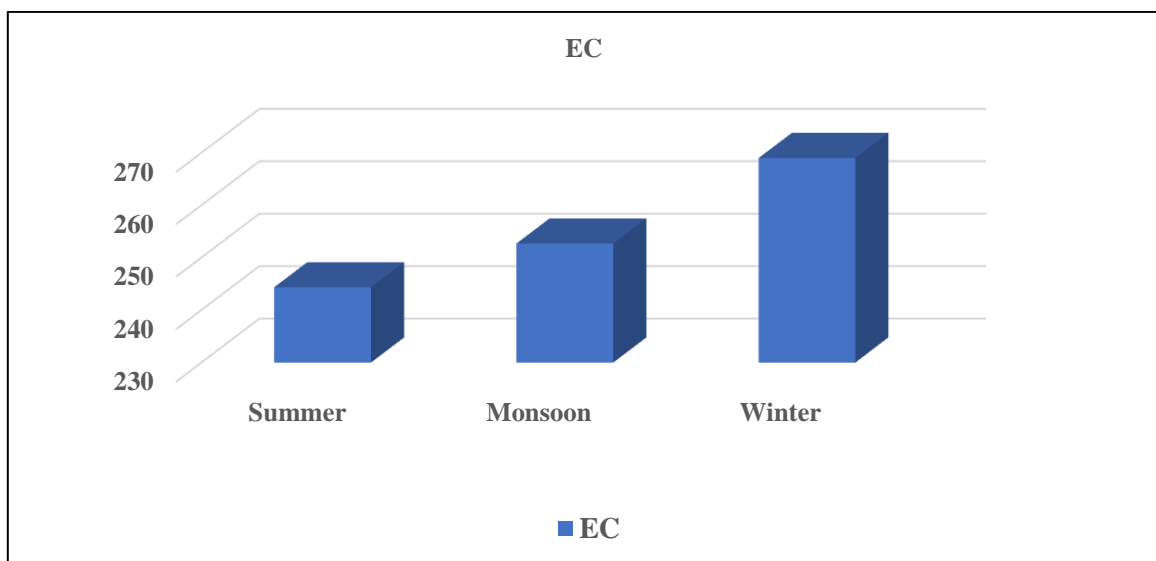


Figure 3: Showing EC range of wetland water in different seasons

### Electrical Conductivity (EC)

Electrical conductivity is a numerical expression of the ability of a water sample to carry an electric current. EC values of Nawabganj wetland were in the range of 40 ( $\mu\text{mho/cm}$ ) to 126 ( $\mu\text{mho/cm}$ ) during the present study (March 2022–February 2024) showing average value of 79.26  $\mu\text{mho/cm}$  (table-2). Seasonal variations of the present investigations revealed that EC was high during summer seasons and low during winter seasons figure-8. This result is supported by the findings of Rao *et al.* (1990), Narayana *et al.* (2005), and Kedar *et al.* (2007). In the present study EC showed high significant positive correlation ( $p < 0.01$ ) with water temperature, turbidity, FCO, TDS, TSS, BOD and COD whereas EC showed negative correlation ( $p < 0.01$ ) with pH, DO, TA and Nitrate table-2.

### Total Suspended Solids (TSS)

In the present study period i.e. March 2022–February 2024 total suspended solids showed high significant positive relationship ( $p < 0.01$ ) with Water Temperature ( $r = 0.787$ ), turbidity ( $r = 0.671$ ), TDS ( $r = 0.664$ ), FCO ( $r = 0.793$ ), COD ( $r = 0.601$ ), it showed high significant negative relationship ( $p < 0.01$ ) with DO ( $r = -0.785$ ) and total alkalinity ( $r = -0.675$ ), it showed significant negative relationship with pH ( $r = -0.440$ ) table-2. The maximum value of T.S.S was observed in the month of April 2022 (118.62 mg/L). Minimum value was recorded in December 2022 (40 mg/l) during the two years study period. The overall mean was  $77.44 \pm 24.5$  (mg/L). The present study displayed that, the average TSS values were maximum during monsoon and minimum during winter in the first year and TSS recorded maximum concentration in summer season and minimum value of TSS was obtained during winter season in the second year of observation figure-6. This investigation is in close conformity with the finding of Parikh and Mankodi (2012).

### Dissolved Solids (TDS)

Total a dissolved solid is the measure of the combined content of all inorganic and organic substances in a water sample. In the first year of investigation (March 2022- Feb 2023), the TDS displayed a wide range of variations with a minimum value of 80 mg/L and maximum of 216 mg/L. Whereas during the second year period (March 2023- Feb. 2024), the range of the concentration of TDS of Nawabganj wetland obtained, was 100 – 216 mg/L. The TDS of water during the study period shows high significant positive relationship ( $p < 0.01$ ) with Water temperature ( $r = 0.784$ ), turbidity ( $r = 0.765$ ), carbon dioxide ( $r = 0.795$ ), EC ( $r = 0.572$ ), TSS ( $r = 0.664$ ), chloride ( $r = 0.571$ ), BOD ( $r = 0.689$ ), and

COD ( $r = 0.758$ ) and high significant negative correlation ( $p < 0.01$ ) with DO ( $r = -0.761$ ) and total alkalinity ( $r = -0.784$ ) table-2. In the present investigation, the total dissolved solids of Nawabganj wetland was found maximum during the summer season and least TDS was obtained during winter figure-7. Narayana *et al.* (2005) also reported maximum concentration of TDS during summer.

### Chloride (Cl)

Chloride is considered as one of the most important inorganic anion in water. It occurs naturally in all types of water due to its high solubility. Its concentrations in freshwater is generally taken as an indicator of sewage pollution. In the present investigation, minimum chloride was recorded during monsoon season and maximum during the summer season table-02. Abir Shib (2014), Chaturbhuj *et al.* (2004), Mishra *et al.* (2008), and Arya *et al.* (2011) also reported similar results in their study.

### Biological Oxygen Demand (BOD)

BOD is an indication of the organic load and it is a pollution index especially for water bodies receiving organic effluent (Ndimele, P E 2012). In the first year of investigation (March 2022- Feb 2023), the BOD value ranges between 1.22 to 4.2 mg/L. Whereas during the second year period (March 2023- Feb 2024), the range of the concentration of BOD of Nawabganj wetland obtained, was 2.28 to 3.11 mg/L. The overall mean was  $2.52 \pm 0.51$  for the entire two year of study (March 2022 to February 2024) table-2. The BOD of water during the study period shows high significant positive correlation ( $p < 0.01$  level) with Water temperature ( $r = 0.690$ ), turbidity ( $r = 0.723$ ), carbon dioxide ( $r = 0.368$ ), EC ( $r = 0.732$ ) and TDS ( $r = 0.689$ ) and high significant negative correlation with DO ( $r = -0.563$ ), COD ( $r = 0.618$ ) and total alkalinity ( $r = -0.712$ ). BOD showed significant negative correlation with Nitrate ( $r = -0.508$ ) during the study period (table-2). In the present investigation (March 2022 to Feb 2024) B.O.D. values of Nawabganj wetland was reported high during summer season followed by monsoon and least in winter season figure-5. These findings are also in accordance with Pal (2008) and Paul and Mukherjee (2006).

### Chemical Oxygen Demand (COD)

The high COD values indicate that some degree of non-biodegradable oxygen demanding pollutants were present in the water. In the present investigation, the maximum COD value recorded 66.75 mg/L and minimum value of COD obtained was 21.32 mg/L in the first year. During the second year COD value ranged

between 26.63 to 101.6 mg/L. The overall mean value obtained was 48.27 mg/L during the two year observation (table-2). COD showed highly significant negative correlation ( $p < 0.01$ ) with DO ( $r = -0.880$ ), total alkalinity ( $r = -0.835$ ) and pH ( $r = -0.477$ ) and high significant positive correlation ( $p < 0.01$ ) with Water temperature ( $r = 0.832$ ), turbidity ( $r = 0.745$ ), CO ( $r = 0.787$ ), EC ( $r = 0.787$ ), TDS ( $r = 0.758$ ) and BOD ( $r = 0.618$ ) during the investigation (table-02). Seasonal variation revealed that COD values were higher during summer seasons and lower during winter. This result is supported by the findings of Abir Shib (2014).

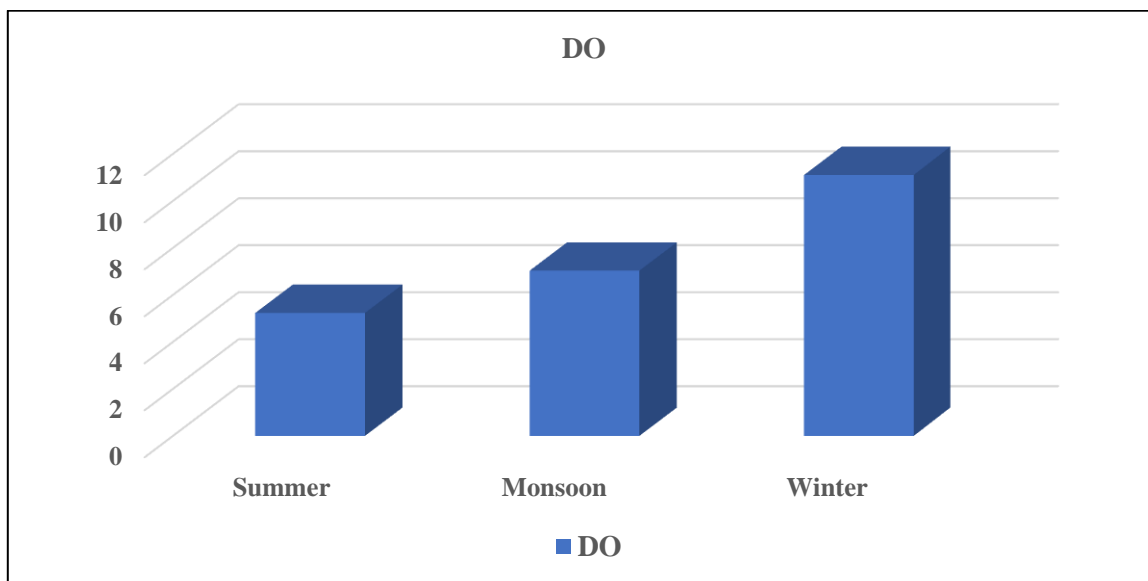
**Turbidity**

Turbidity reduces the amount of light penetrating the water due to the presence of various suspended particles such as clay, silt, plankton, algae etc. These suspended particles absorb more light and results in rising of the water temperature. In the first year of investigation, turbidity revealed a wide range of variation with a minimum of 15.75 NTU and that of maximum of 51.0 NTU. Whereas during the second year of observation the range obtained was 14.86 to 47.0 NTU. The Turbidity of water during the study period shows high significant positive relationship ( $p < 0.01$ ) with water temperature ( $r = 0.830$ ), Carbon dioxide ( $r = 0.907$ ), EC ( $r = 0.564$ ), TSS ( $r = 0.671$ ), TDS ( $r = 0.765$ ), BOD ( $r = 0.723$ ), and COD ( $r = 0.745$ ) and high significant negative correlation ( $p < 0.01$ ) with DO ( $r = -0.823$ ) and total alkalinity ( $r = -0.876$ ) table-02. In the present investigation, the turbidity of water was found

maximum during the summer season and least turbidity was obtained during winter. Similar findings have been projected by Offem *et al.* (2011).

**Dissolved Oxygen (DO<sub>2</sub>)**

Dissolved oxygen is regarded as one of the best indicator to assess the health of a water body. Minimum DO<sub>2</sub> of water was recorded in the month of May 2022 (4.26 mg/L) and maximum in December 2022 (8.6 mg/L) during the first year of investigation. During the second year of study, the minimum DO<sub>2</sub> value obtained was 3.8 mg/L (March 2022) and maximum of 8.6 mg/L (December 2023). The overall mean during the entire study period was 6.22 mg/mL. The DO<sub>2</sub> of water of Nawabganj wetland was high in winter months and comparatively lower during monsoon and lowest concentration of DO<sub>2</sub> recorded in the summer months in both the year of investigation figure-4. Abir Shib (2014) stated that, the maximum dissolved oxygen in winter may be due to low atmospheric temperature and minimum dissolve oxygen in summer may be due to high metabolic rate of organisms. This was supported by the observations made by Tara *et al.* (2011), Parikh and Mankodi (2012) and Pathak and Mankodi (2013). In the present investigation, dissolved oxygen of Nawabganj wetland shows high significant negative correlation ( $p < 0.01$ ) with Water temperature ( $r = -0.890$ ), turbidity ( $r = -0.826$ ), FCO ( $r = -0.906$ ), TDS ( $r = -0.761$ ), TSS ( $r = -0.785$ ), BOD ( $r = -0.563$ ), COD ( $r = -0.880$ ) and high significant positive relation ( $p < 0.01$ ) with pH ( $r = 0.554$ ), total alkalinity ( $r = 0.895$ ) as shown in table 3.



**Figure 4: Showing DO of wetland pond water in different seasons**

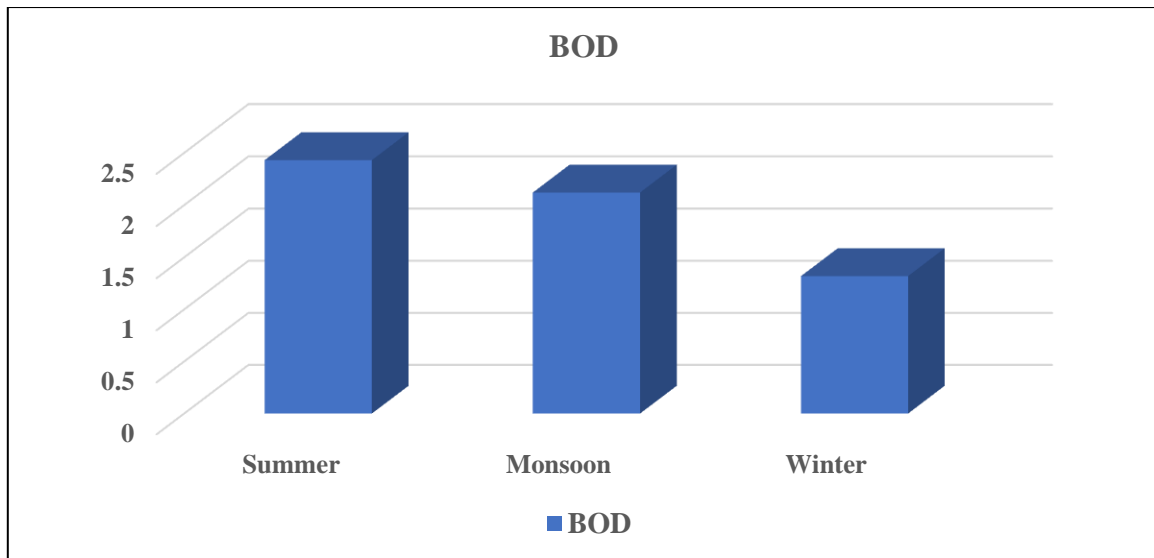


Figure 5: Showing BOD of wetland pond water in different seasons

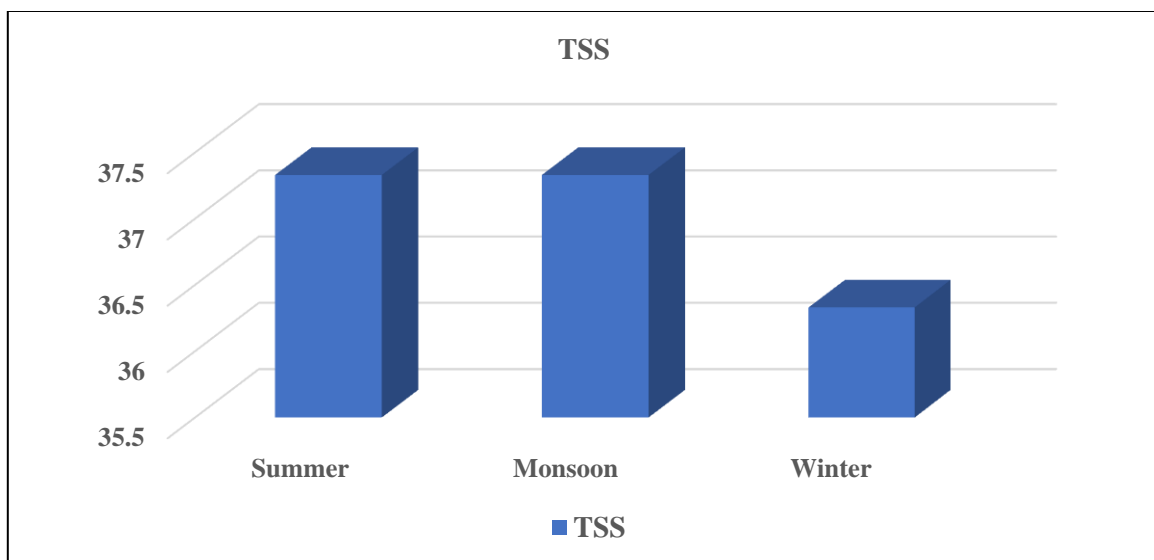


Figure 6: Showing TSS of wetland pond water in different seasons

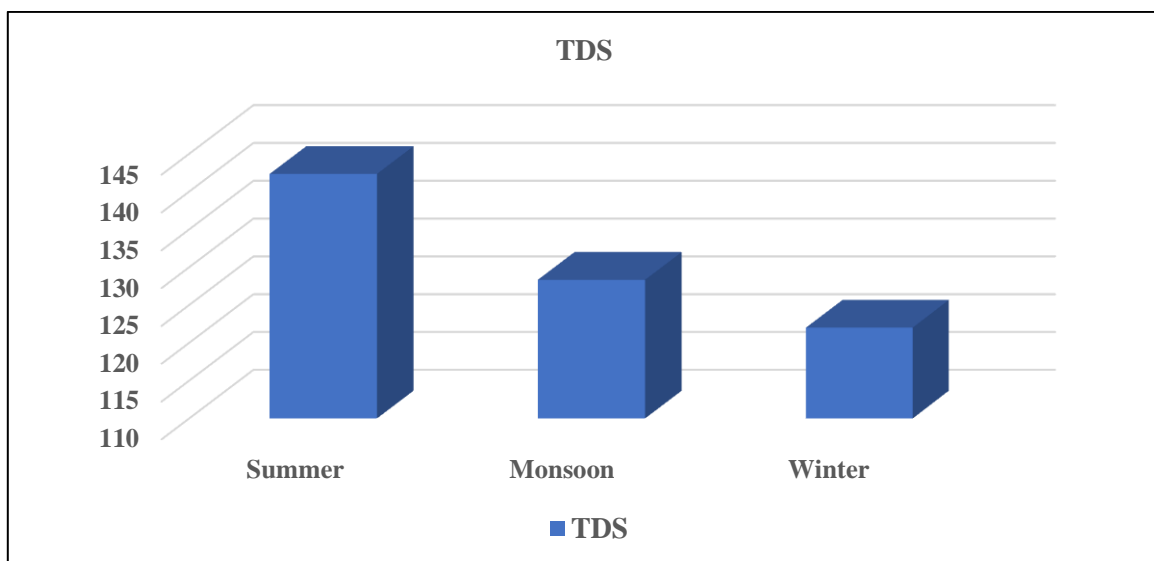
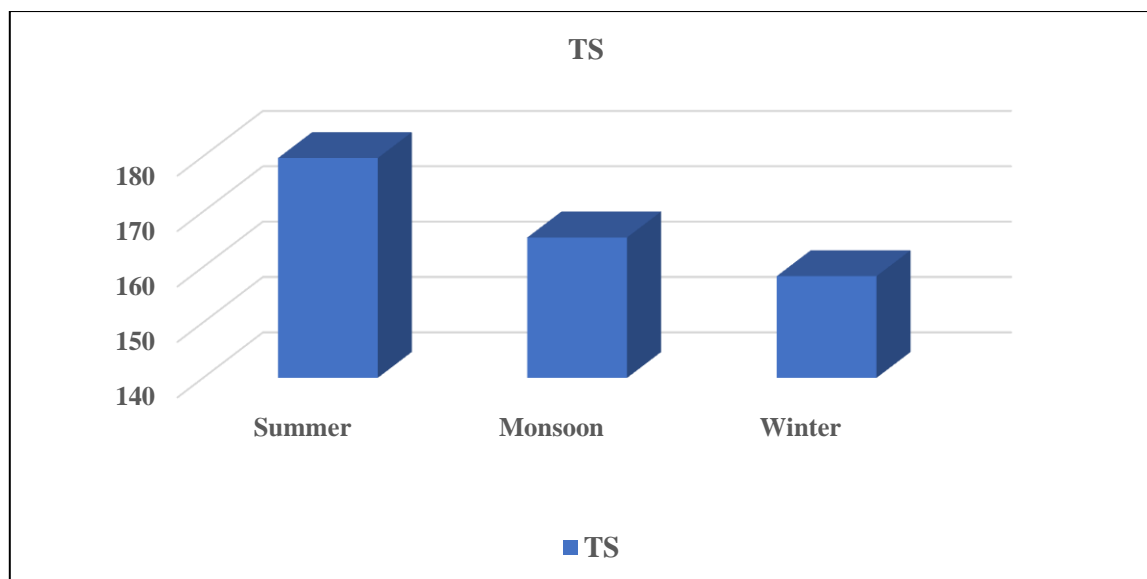


Figure 7: Showing TDS of wetland pond water in different seasons



**Figure 8: Showing TS of Nawabganj pond water in different seasons**

### Phosphate ( $\text{PO}_4^{3-}$ )

Present investigations displayed that phosphate obtained in the range of 0.894 to 4.78 mg/L in the first year and 0.52 to 5.36 mg/L during the second year of observation. The overall mean value obtained as  $2.68 \pm 1.44$  table-2. The value of phosphate was found maximum during monsoon and it falls down during the winter season. The study also supports the findings of, Mishra *et al.* (2008) and Parikh & Mankodi (2012). In the present investigation phosphate of Nawabganj wetland showed high significant positive correlation with TSS ( $r=0.601$ ) and significant positive correlation with water temperature ( $r=0.457$ ) and shows significant negative correlation with DO ( $r=-0.436$ ) table-2.

### Nitrate ( $\text{NO}_3$ )

The most chemically stable form of nitrogen is nitrate. High nitrate concentration can result in excess algal blooms in water body. Fertilizers, decayed vegetables and animal matter are the principle sources of nitrates in a water body. In the present study (March 2022 – Feb 2024), the maximum value of nitrate was recorded as 8.1 mg/L in the month of August 2022 and minimum value observed in May 2023 (2.4 mg/L) with a mean value of 5.54 table-2. Seasonal observations revealed that, values of nitrate were maximum during monsoon and minimum during summer season table -02. Similar results have been reported by Pathak and Mankodi (2013).

### CONCLUSION

The physico-chemical studies on water of Chandra Shekhar Azad Bird Sanctuary revealed that it has nutrient rich environment, neutral pH and favourable BOD value. Fluctuations in various physico-chemical

parameters were observed during summer, monsoon and winter seasons. The study shows that the water of Nawabganj wetland exhibits high concentration of TSS, TDS, nitrate, phosphate etc. High phosphate and nitrate value indicates that the wetland is moderately eutrophicated. Fluctuations in various physico-chemical parameters were observed during summer, monsoon and winter seasons. Comparatively it has been observed in rainy season pond water has optimum quality, that is accountable for its rich diversity. The main water source of the wetland is rainwater. The correlation coefficient indicates positive and negative correlation of physico-chemical parameters with each other. This study may be helpful in optimum utilization and sustainable management of the wetland. Chlorination of water bodies of the Nawabganj wetland is also suggested time to time to disinfect the water quality and weeding management should be also practiced at regular intervals to control the nutrients level and silt deposition. Thus the present study may be helpful in optimum utilization and sustainable management of the wetland.

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