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Climate Change Influences on Water Quality Index of Ropar Wetland (Ramsar Site), Punjab, India

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ABSTRACT

Wetlands are invaluable ecosystems that play a crucial role in maintaining eco-hydrological sustainability. They serve as a multifaceted resource, supporting various activities, including industrialization, transportation, agriculture, aquatic fauna habitat, and domestic water supply, as well as serving as a medium for cleaning and waste disposal. However, the increasing influx of debris from corporate activities, residential drainage, and agricultural practices poses a significant threat to the quality of river water. This study focuses on the physico-chemical water parameters of the Ropar wetland, recognized as a Ramsar site, during the period from February 2021 to January 2022. Water samples were collected seasonally from four strategically chosen locations, representing the Pre-monsoon (March-May), Monsoon (June-August), Post monsoon (September-November), and Winter (December-February) seasons. The study assessed a range of water quality parameters, including Dissolved Oxygen (DO), Free Carbon Dioxide (FCO_2), turbidity, alkalinity, hardness, calcium, chloride, pH, temperature, and conductivity, with triplicate measurements at each site. The findings of this research indicate that most water quality parameters, reached their maximum levels during the pre-monsoon season with exception of DO and FCO_2, while DO and FCO_2 maximized during the winter season. These parameters have direct implications for biodiversity loss, imbalanced agricultural practices, and resource depletion. As such, the results underscore the necessity of implementing adaptive strategies to ensure the continued suitability of this water resource for residential purposes over an extended period.

Key words : *Ramsar site, Wetland, Water Quality Index, Physico-Chemical Parameters, Biodiversity, Agriculture, Resource depletion*

Introduction

Wetlands are a vital part of the global ecosystem, playing an essential role in regulating water flow, filtering pollutants, and providing a haven for wildlife. A wetland is a particular biological system that is overflowed by water, either for all time or occasionally (seasonally), flooding brings about oxygen-free ordinary processes prevailing, particularly in the soil. Wetland offers various beneficial types of

([1] Research Scholar, [2]Assistant Professor, [3]Assistant Professor -Guest Faculty) assistance for individuals and natural life (Constanza *et al.*, 1997). Such delicate ecosystems serve as crucial habitats for environmentally significant permanent and migratory aquatic fauna by serving as their breeding and feeding grounds (Jhingran, 1982; Bijoy, 2008). As signs of fast economic development, agro-industries are given more attention than their effects on the local environment and ecosystems that receive waste. In this time of economic expansion, industrialization and subsequent urbanization have led to environmental deterioration and stress on wetland habitats due to change in climate, which negatively affects their innate biota, the physico-chemical composition of water, and output (Stanley, 2004). Therefore, it is crucial to comprehend the current ecological relationships in wetlands among main producers and their surrounding ecosystems. The aquatic environment in wetlands is very fragile, even a small shift in the aquatic environment can result in significant changes to both the abiotic and biotic components of wetlands. In 2002, the Ropar Wetland was recognized as a Ramsar site. The watershed region is undergoing widespread deforestation, which eventually discharges large amounts of sediments into the wetland area. This wetland's reservoir region has developed several small islands, greatly reducing its depth and ability to hold water. The impact of the environment significantly decreases product quality and safety because management choices in aquaculture are influenced by variations in various water quality factors (Akhtar and Brraich, 2020). Due to the simultaneous increase in human activities adjacent to the rivers throughout the previous several years, hazardous chemical compounds are contaminating water resources at a faster rate (Alam *et al.*, 2009, 2010). Wetland habitats offer various services like flood abatement, water quality improvement and carbon sequestration (de Groot *et al.*, 2002; Zedler and Kercher, 2005; Verhoeven *et al.*, 2006). Stormwater management, flood control, improved water quality, aquatic life, helping to sustain food chains, habitats for young marine fish, flora and fauna, carbon storage, and regulation of the climate are among the functions/services frequently carried out/provided by wetlands although not all at the same time or to the same extent (Hassan *et al.*, 2005). Because water pollution directly affects aquatic life and human health, assessing and monitoring it correctly is essential (Saha *et al.*, 2017). Agriculture, residential areas, and some industries like cement factories, thermal power plant, and mills (Sharma *et al.*, 2022) border the Ropar Wetland. The industrial waste and inflow of silt from the upper hills into the river cause the depletion in the depth of the river, which affects the climate of the rivers flora and fauna.

Materials and Methods

Study site

Due to the industrialization around the wetland, climate changes very frequently. These changes can be judged by various biotic and abiotic factors that affect the wetland biodiversity. In the present manuscript, authors observed the abiotic physico-chemical parameters to calculate the loss of biodiversity due to this industrialization. This important ecological zone is located in the Shivalik foothills of the Lower Himalayas and was created artificially in 1952 on the Sutlej River, in the Punjab state of India. Ropar Wetland is located at about 45 Km. in the North-West of Chandigarh. The geographic location of the wetland is 30°57N310 06' latitude and 76°25'-76°36'E longitude at an elevation of 275 m AMSL. The total area covered by the Wetland is 1365 ha, which includes an 800 ha area of the river and the reservoir, 30 ha of forest area named Sadavarat Forest and 30 ha under marshy plants. The wetland is surrounded by hills in the northwest Himalayas and by plain areas in the South and South East

Sampling methodology

Seasonally sampling was performed for a period of one year from Feb 2021 to Jan 2022 representing four seasons Pre-monsoon (March-May), Monsoon (June-August), Post-monsoon (September-November) and winter (December-February). The specific sample sites were fixed by using Global Positioning System (GPS) four sampling sites S1, S2, S3 and S4 (Figure 1) were related to the objective of acquiring tests for the examination of physico-chemical parameters from this wetland. For sampling, 2 liters of plastic bottles were used to collect the samples from the various sites. Sampling was done in triplicates from each site and physico-chemical water parameters like air and water temperature, pH and conductivity were performed on the spot with the help of digital meters. Water temperature was determined by using a degree centigrade (" 10 to 50 °C) thermometer (P-601466), pH with a digital pH meter

(HM Digital PH-80), electric conductivity was measured with a digital conductivity meter (Thermo ECO- ECTEST). Similarly, dissolved oxygen (Winkler, 1888), free carbon dioxide (APHA, 2017), alkalinity (APHA, 2012), total hardness (APHA, 2017), calcium and chloride were also analyzed with titrimetric methods in the laboratory by using standard methodology (Trivedy and Goel, 2012). Transparency was measured by employing a Secchi disk (Trivedy and Goel, 1984).

Statistical Analysis

Kruskal Wallis and post-hoc Dunn's test using a Bonferroni was performed using the online statistical tool of Statistics Kingdom to observe any statistical difference in the variable between the different seasons followed with a mean rank score for different seasons.

Results and Discussion

Seasonal variations in the water quality parameters of the Ropar wetland were carried out from February 2021 to January 2022 at four representative sites (S1, S2, S3 and S4). The seasons were typically split into Pre-monsoon (March-May), Monsoon (June-August), Post-monsoon (September-November) and winter (December-February). Seasonal variations between physico-chemical water parameters at four different sites (S1, S2, S3 and S4) were observed and mean and standard deviations were calculated. These water parameters are: Air Temperature (°C), Water temperature (°C), Conductivity (ìS/cm), Dissolved oxygen (mg/l), Free CO_2 (mg/l), pH, Alkalinity (mg/l), Chlorides (mg/l), Total Hardness (mg/l), Ca++Hardness (mg/l).

Physicochemical Parameters

Air Temperature (°C)

Seasonally variations in the air temperature at all four sites were recorded and maximum values were observed during the present research. In the Winter season, the air temperature is ranged from 16.5 ± 0.38 °C – 19.8 ±0.04 °C, pre-monsoon 30.5 ± 0.22 °C – 32.5 ± 0.33°C, monsoon 27.5 ± 0.31 °C – 30.5 ± 0.19 °C and in post-monsoon 24.5 ± 0.40 °C – 26.2 ± 0.15 °C (Table 2). The maximum temperature was observed in the pre-monsoon season (31.82 ± 0.06 °C) and minimum temperature was observed in the winter season (18.49 ± 0.12 °C). The Kruskal-Wallis test indicated that there is a significant difference in the dependent variable between the different groups, $\chi 0^2(3) = 14.12$, $p = .003$, with a mean rank score of 2.5 for Winter season, 14.5 for Pre-monsoon season, 10.5 for Monsoon season, 6.5 for Post-monsoon season.

Water Temperature (°C)

At all the sites, water temperatures were recorded seasonally. In the winter season, the air temperature is ranged from 15.4 ± 0.32 °C – 17.3 ± 0.04 °C, pre-monsoon 23.7 ± 0.04 °C – 26.3 ± 0.25 °C, monsoon 24.5 ± 0.10 °C – 27.6 ± 0.25 °C and in post-monsoon 22.3 ± 0.13 °C – 22.8 ± 0.05 °C (Table 2). The maximum temperature was observed in the pre-monsoon season (26.21 ± 0.07 °C) and the minimum temperature was observed in the winter season (16.44 ± 0.12 °C). The Kruskal-Wallis H test indicated that there is a significant difference in the dependent variable between the different groups, $\chi^2(3) = 13.26$, $p = .004$, with a mean rank score of 2.5 for Winter season, 11.25 for Pre-monsoon season, 13.75 for Monsoon season, 6.5 for Post-monsoon season. Depending on when the water was collected, the season, and air temperature might all have an impact on the water temperature. Because suspended particles absorb heat from sunlight, the greater water temperature throughout the summer may also be a result of the increased turbidity (Sharma and Cooper, 2010; Thirupathaiah, 2012). Our conclusions concur with the results of another researcher (Akhtar and Brraich, 2020).

Conductivity (µS/cm)

The lowest electrical conductivity may result from rainfall, which raises the amount of water in wetlands, while higher electrical conductivity may result from evaporation and a rise in organic matter, such as plant debris, which causes wetlands to lose water and raise electrical conductivity. In the winter season, the conductivity is ranged from 235.33 ± 0.47 – 240 ± 0.81 µS/cm, pre-monsoon 357.81 ± 0.36 – 436.98 ± 0.11 µS/cm, monsoon 305.33 ± 0.47 – 353.64 ± 0.16 µS/cm and in post-monsoon 298.84 ± 0.29 –332.72 ± 0.11 µS/cm (Table 2). The maximum Conductivity was observed in the pre-monsoon season (391.39 ± 0.26 µS/cm) and the minimum temperature was observed in the winter season (237.75 ± 0.21 µS/cm). The Kruskal-Wallis H test indicated that there is a significant difference in the dependent variable between the different groups, $\chi^2(3) = 12.86$, p = .005, with a mean rank score of 2.5 for Winter season, 14.25 for Pre-monsoon season, 10 for Monsoon season, 7.25 for Post-monsoon season. Our findings are consistent with those of the workers, who recorded EC ranges of 296 to 723 mhos/cm and 115.11 to 212.13 mhos/cm, respectively (Kataria *et al*, 2011; Shrivastava *et al*, 2013).

pH

At every site, the seasonal fluctuations in pH were noted; in the winter season, the pH ranged from 6.39 ± 0.01 - 6.81 ± 0.01, pre-monsoon 7.82 ± 0.01 - 7.97 ± 0.01, monsoon 7.18 ± 0.01 - 7.37 ± 0.02, and in post-monsoon season 7.25 ± 0.01 - 7.48 ± 0.02 (Table 2). The winter season has the lowest pH values (6.57 ± 0.01) and the pre-monsoon season has the highest values (7.92 ± 0.01). All of the locations were found to have pH values that were slightly acidic and slightly alkaline throughout the investigation. The Kruskal-Wallis H test indicated that there is a significant difference in the dependent variable between the different groups, $\chi^2(3) = 12.81$, p = .005, with a mean rank score of 2.5 for Winter season, 14.5 for Pre-monsoon season, 8 for Monsoon season, 9 for Post-monsoon season. pH shows the acidity and basicity degree of the water (Kamboj and Kamboj, 2019). Our results are almost similar to the other research, which gave results of pH during different seasons between 6.5 to 8 (Shrivastava *et al.*, 2013). Throughout the study period, the observed pH at all the sites was marginally acidic and slightly alkaline in nature.

Dissolved Oxygen (mg/l)

DO values show the seasonal variations at all the sites (S1, S2, S3 and S4) during the present study. In the winter season, the DO ranged from 8.45 ± 0.02 – 8.53 ± 0.02 mg/l, pre-monsoon 6.53 ± 0.01 – 6.74 ± 0.01 mg/l, monsoon 7.25 ± 0.01 - 7.28 ± 0.01 mg/l, and in post-monsoon season 8.14 ± 0.02 – 8.17 ± 0.01 mg/l (Table 1). The minimum amount of DO was recorded during the pre-monsoon season (6.62 ± 0.01 mg/l) and the maximum value was recorded during the winter season (8.48 ± 20.2 mg/l). The Kruskal-Wallis H test indicated that there is a significant difference in the dependent variable between the different groups, $\chi^2(3) = 14.18$, p = .003, with a mean rank score of 14.5 for Winter season, 2.5 for Pre-monsoon season, 6.5 for Monsoon season, 10.5 for Post-monsoon season. Dissolve oxygen (DO) determines how much oxygen is present in the water body, which in turn affects how healthy the ecosystems are. Due to the surrounding water's substantial biological and physicochemical characteristics, it is a crucial water quality metric to maintain (Kumar *et al.*, 2019). In the water bodies, the degree

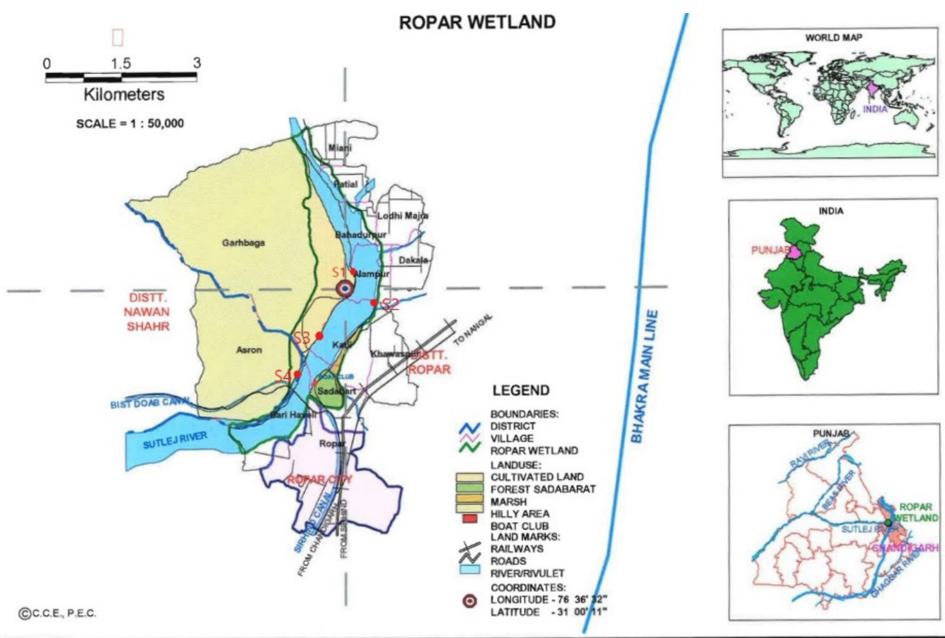


Fig. 1. Map of the study area Ropar Wetland (Ramsar site) with experimental sites for sampling and observations.

Table 1. Seasonal variations observed during different seasons at Ropar Wetland experimental sites

Parameter	Sites	Winter season		Pre-monsoon season		Monsoon season		Post-monsoon season	
		Mean ± S.E.	Seasonal Mean ± S.E.	Mean ± S.E.	Seasonal Mean ± S.E.	Mean ± S.E.	Seasonal Mean ± S.E.	Mean ± S.E.	Seasonal Mean ± S.E.
Dissolved Oxygen (mg/l)	S1	8.45 ± 0.02	8.48 ± 0.01	6.74 ± 0.01	6.62 ± 0.01	7.25 ± 0.01	7.26 ± 0.01	8.14 ± 0.02	8.16 ± 0.01
	S2	8.45 ± 0.02		6.53 ± 0.01		7.28 ± 0.01		8.16 ± 0.02	
	S3	8.53 ± 0.02		6.56 ± 0.01		7.25 ± 0.01		8.17 ± 0.01	
	S4	8.49 ± 0.03		6.65 ± 0.01		7.27 ± 0.01		8.17 ± 0.01	
Free Carbon Dioxide (mg/l)	S1	9.38 ± 0.02	9.39 ± 0.01	7.36 ± 0.01	7.38 ± 0.01	7.85 ± 0.01	7.85 ± 0.01	8.74 ± 0.01	8.77 ± 0.01
	S2	9.47 ± 0.01		7.47 ± 0.01		7.83 ± 0.01		8.78 ± 0.01	
	S3	9.37 ± 0.01		7.38 ± 0.01		7.88 ± 0.01		8.79 ± 0.01	
	S4	9.32 ± 0.01		7.33 ± 0.02		7.86 ± 0.01		8.79 ± 0.01	
Alkalinity (mg/l)	S1	85.73 ± 0.52	79.39 ± 0.03	137.87 ± 0.01	135.71 ± 0.02	110.66 ± 0.94	103.48 ± 0.28	90.75 ± 0.06	87.86 ± 0.01
	S2	67.63 ± 0.44		133.68 ± 0.02		98.35 ± 0.24		80.37 ± 0.03	
	S3	86.6 ± 0.43		139.46 ± 0.02		108.30 ± 0.22		89.78 ± 0.05	
	S4	77.63 ± 0.44		131.83 ± 0.06		96.6 ± 0.43		90.53 ± 0.07	
Total Hardness (mg/l)	S1	176.26 ± 0.47	173.51 ± 0.02	358.55 ± 0.41	352.15 ± 0.20	249.51 ± 0.37	244.96 ± 0.01	223.81 ± 0.36	226.43 ± 0.05
	S2	182.52 ± 0.40		344.88 ± 0.69		238.68 ± 0.39		228.95 ± 0.38	
	S3	169.63 ± 0.44		363.27 ± 0.41		256.74 ± 0.38		231.87 ± 0.25	
	S4	165.66 ± 0.46		341.88 ± 0.11		234.92 ± 0.41		221.10 ± 0.29	

of pollution was also estimated by the level of DO (Gopalkrushna, 2011), in the present study the DO obtained s greater than the recommended value of 5 mg/l by BIS/ICMR. If the level of DO less than 5.0 mg/l affects the aquatic fauna and if the level of DO concentration is below the 2.0 mg/l may be lethal to the fish fauna (Islam *et al.*, 2021). Moreover, similar results were supported by Kumar *et al.*, 2019

Free Carbon Dioxide (mg/l)

At all the research sites, seasonal variations in free CO_2 concentrations were also recorded during the present study. In the winter season, the FCO_2 is ranged from 9.32 ± 0.01 – 9.47 ± 0.01 mg/l, pre-monsoon 7.33 ± 0.02 – 7.47 ± 0.01 mg/l, monsoon 7.83 ± 0.01 - 7.88 ± 0.01 mg/l, and in post-monsoon season 8.74 ± 0.01 – 8.79 ± 0.01 mg/l (Table 1). The minimum amount of free CO2 was recorded during the pre-monsoon season (7.38 ± 0.01 mg/l) and the maximum value was recorded during the winter season (9.39 ± 0.01 mg/l). The Kruskal-Wallis H test indicated that there is a significant difference in the dependent variable between the different groups, $\chi^2(3) = 14.14$, $p = .003$, with a mean rank score of 14.5 for Winter season, 2.5 for Pre-monsoon season, 6.5 for Monsoon season, 10.5 for Post-monsoon season. A water body's sources of carbon dioxide can include the atmosphere, biotic respiration, seeping groundwater, bacterial decomposition of organic matter, and the water body itself in combination with other elements, primarily calcium and magnesium (Abir, 2014). Due to this, the lowest value of FCO_2 is in the month of May (pre-monsoon season) and the highest is during the month of February (winter season). Similar results were recorded by Tara *et al.*, 2011 and Jain and Seethapati, 1996.

Alkalinity (mg/l)

The seasonal variations in the alkalinity were recorded during the present study from all the sites (S1, S2, S3 and S4). In the winter season, the alkalinity is ranged from 67.63 ± 0.44 – 86.6 ± 0.43 mg/l, pre-monsoon 131.83 ± 0.06 – 139.46 ± 0.02 mg/l, monsoon 96.6 ± 0.43 – 110.66 ± 0.94 mg/l, and in post-monsoon season 80.37 ± 0.03 – 90.75 ± 0.06 mg/l (Table 1). Due to sewage outflow and runoff from catchment regions, the amount of carbonates and bicarbonates rise throughout the summer, so the maximum value of alkalinity was in pre-monsoon season (135.71± 0.02 mg/l) and the minimum value was recorded during the winter season (79.39 ±0.03 mg/l). The Kruskal-Wallis H test indicated that there is a significant difference in the dependent variable between the different groups, $\chi^2(3) = 13.5$, $p = .004$, with a mean rank score of 3 for Winter season, 14.5 for Pre-monsoon season, 10.5 for Monsoon season, 6 for Post-monsoon season.Alkalinity is caused by the existence of different bicarbonates, hydroxides, and carbonates in water which shows the capacity to neutralize a strong acid (Kamboj and Kamboj, 2019). As in the summer season, the alkalinity shows the maximum level and minimum in the winter season, our results are similar to other researchers Akhtar and Brraich, 2020, also gave supportive results.

Total Hardness (mg/l)

The seasonal variations in the total hardness were recorded at all four sites during the different seasons. In the winter season, the total hardness is ranged from 165.66 ± 0.46 – 182.52 ± 0.40 mg/l, pre-monsoon 341.88 ± 0.11 – 363.27 ± 0.69 mg/l, monsoon 234.92 ± 0.41 – 256.74 ± 0.32 mg/l, and in post-monsoon season 221.10 ± 0.29 – 231.87 ± 0.25 mg/l (Table 1). The maximum value was recorded during the pre-monsoon season (352.15 ± 0.20 mg/l) and the minimum value was recorded during the winter season (173.51 ± 0.02 mg/l). The Kruskal-Wallis H test indicated that there is a significant difference in the dependent variable between the different groups, $\chi^2(3) = 14.12$, $p = .003$, with a mean rank score of 2.5 for Winter season, 14.5 for Pre-monsoon season, 10.5 for Monsoon season, 6.5 for Post-monsoon season. The natural deposit of salts in water via interaction with the soil and geological formations or direct human activity pollution are the two main causes of hardness (Joseph and Jacob, 2010). In the present study, due to the inflow of pollutants from the cement factory and domestic wastes, the total hardness of the water of the selected wetland is high and similar results were supported by Jayangouder 1980.

Calcium (mg/l)

The seasonal variations in the calcium hardness were recorded during the present study at all four sites (S1, S2, S3 and S4). In the winter season,

Table 2. Seasonal variations reported during different seasons at Ropar Wetland experimental sites.

Parameter	Sites	Winter season		Pre-monsoon season		Monsoon season		Post-monsoon season	
		Mean ± S.E.	Seasonal Mean ± S.E.	Mean ± S.E.	Seasonal Mean ± S.E.	Mean ± S.E.	Seasonal Mean ± S.E.	Mean ± S.E.	Seasonal Mean ± S.E.
Air Temperature	S1	19.73 ± 0.04	18.49 ± 0.12	32.45 ± 0.33	31.82 ± 0.06	29.73 ± 0.24	29.02 ± 0.07	25.43 ± 0.32	25.19 ± 0.12
	S2	18.36 ± 0.28		31.51 ± 0.37		27.76 ± 0.31		24.69 ± 0.49	
	S3	19.33 ± 0.23		30.83 ± 0.22		30.12 ± 0.19		26.09 ± 0.15	
	S4	16.53 ± 0.38		32.5 ± 0.21		28.48 ± 0.40		24.55 ± 0.40	
Water Temperature	S1	17.23 ± 0.04	16.44 ± 0.15	26.27 ± 0.25	24.64 ± 0.08	27.6 ± 0.25	26.21 ± 0.07	22.76 ± 0.05	22.59 ± 0.06
	S2	17.65 ± 0.46		23.89 ± 0.14		24.58 ± 0.10		22.56 ± 0.08	
	S3	15.43 ± 0.32		24.70 ± 0.06		26.86 ± 0.08		22.34 ± 0.13	
	S4	15.47 ± 0.35		23.71 ± 0.04		25.79 ± 0.08		22.70 ± 0.23	
pH	S1	6.81 ± 0.01	6.57 ± 0.01	7.82 ± 0.01	7.92 ± 0.01	7.37 ± 0.02	7.31 ± 0.01	7.25 ± 0.01	7.375 ± 0.01
	S2	6.45 ± 0.02		7.97 ± 0.01		7.18 ± 0.01		7.44 ± 0.02	
	S3	6.65 ± 0.02		7.97 ± 0.01		7.35 ± 0.02		7.48 ± 0.02	
	S4	6.39 ± 0.01		7.92 ± 0.01		7.36 ± 0.01		7.31 ± 0.04	
Conductivity	S1	235.33 ± 0.47	237.75 ±0.21	422.96 ± 0.77	391.39 ± 0.26	335.61 ± 0.43	331.83 ± 0.11	325.66 ± 0.46	321.97 ± 0.12
	S2	237.33 ± 0.94		357.81 ± 0.36		332.73 ± 0.34		298.84 ± 0.29	
	S3	240 ± 0.81		436.98 ± 0.11		353.64 ± 0.16		332.72 ± 0.11	
	S4	238.33 ± 0.47		347.81 ± 0.16		305.33 ± 0.47		330.66 ± 0.38	

the total hardness is 23.64 ± 0.15 – 25.65 ± 0.21 mg/l, pre-monsoon 34.04 ± 0.11 – 39.72 ± 0.08 mg/l, monsoon 24.80 ± 0.29 – 26.96 ± 0.11 mg/l, and in post-monsoon season 27.71 ± 0.27 – 30.09 ± 0.11 mg/l (Figure 2). The maximum value of the calcium hardness was recorded during the pre-monsoon season (36.61 ± 0.01 mg/l) and the minimum value was recorded during the winter season (24.50 ± 0.03 mg/l). The Kruskal-Wallis H test indicated that there is a significant difference in the dependent variable between the different groups, $\chi^2(3) = 13.5$, $p = .004$, with a mean rank score of 3 for Winter season, 14.5 for Pre-monsoon season, 6 for Monsoon season, 10.5 for Post-monsoon season. Calcium plays an important role in the metabolism and growth of aquatic flora (Krishna Kumar, 2015). The level of calcium in the wetland area varies due to the sedimentation of silt and the inflow of waste material from industries and agricultural runoff. Due to this pre-monsoon season has recorded the highest value and the winter season was recorded as the lowest value and our results are also supported by Subhashini, Saradhamani, 2005. Patil, 2013.

Chloride (mg/l

During the present study, the chloride shows the different seasonal variations from all four sites (S1, S2, S3 and S4). In the winter season, the chloride ranged from 16.74 ± 0.10 – 19.37 ± 0.03 mg/l, pre-monsoon 34.26 ± 0.19 – 38.35 ± 0.22 mg/l, monsoon 18.92 ± 0.08 – 25.73 ± 0.14 mg/l, and in post-monsoon season 23.46 ± 0.34 – 24.67 ± 0.25 mg/l (Figure 3). The maximum value of the chlorides was recorded during the Pre-monsoon season (36.52 ± 0.04 mg/l) and the minimum value was recorded during the winter season (18.35 ± 0.02 mg/l). The Kruskal-Wallis H test indicated that there is a significant difference in the dependent variable between the different groups, $\chi^2(3) = 12.46$, $p = .006$, with a mean

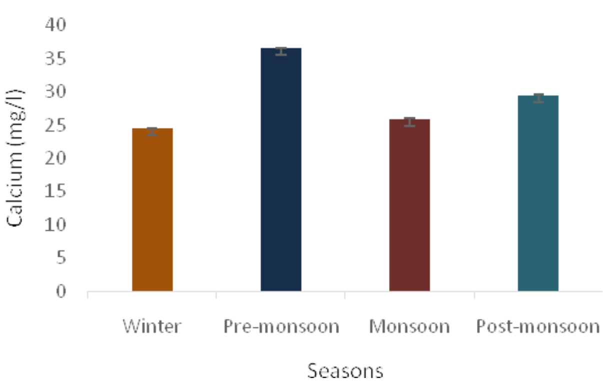


Fig. 2. Graphical representation of Calcium (mg/l) levels recorded during different experimental seasons at Ropar Wetland.

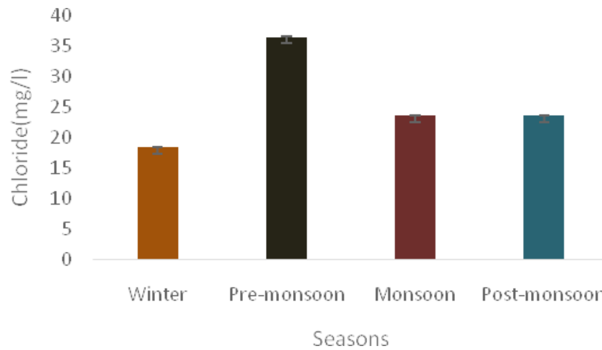


Fig. 3. Graphical representation of Chloride (mg/l) levels recorded during different experimental seasons at Ropar Wetland.

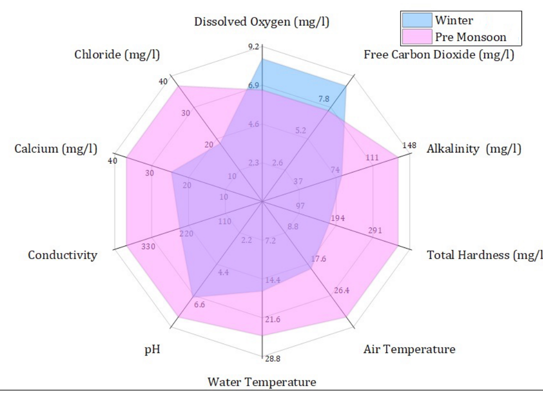


Fig. 4. Graphical representation of Physico-chemical parameters during the season Winter and Pre Monsoon.

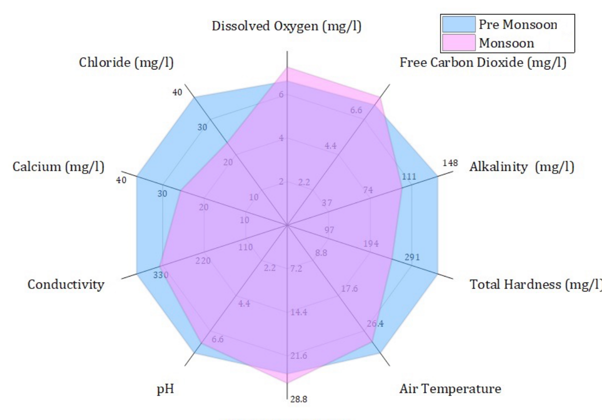


Fig. 5. Graphical representation of Physico-chemical parameters during the Pre Monsoon and Monsoon season.

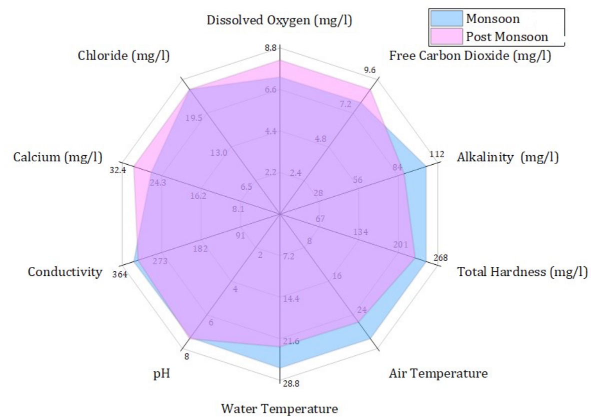


Fig. 6. Graphical representation of Physico-chemical parameters during the Monsoon and Post Monsoon season.

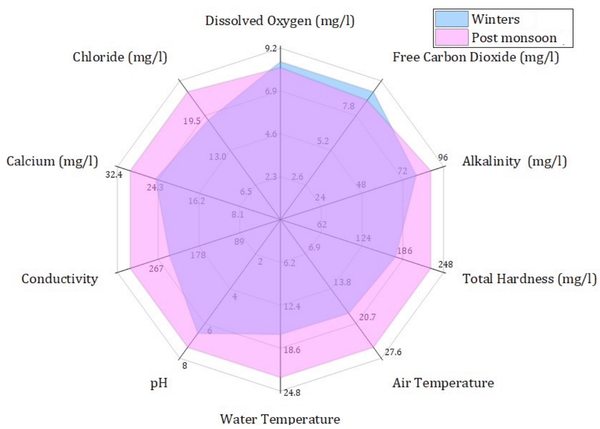


Fig. 7. Graphical representation of Physico-chemical parameters during the Winter and Post Monsoon season.

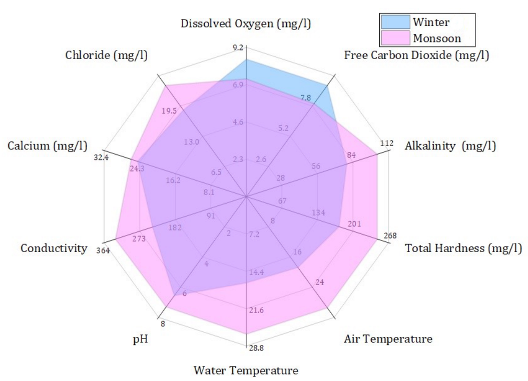


Fig. 8. Graphical representation of Physico-chemical parameters during the Winter and Monsoon season.

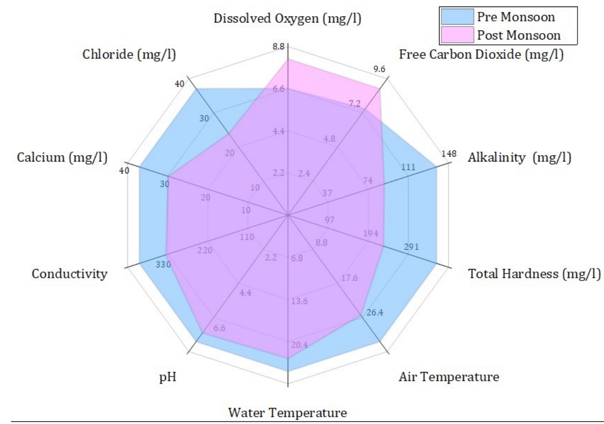
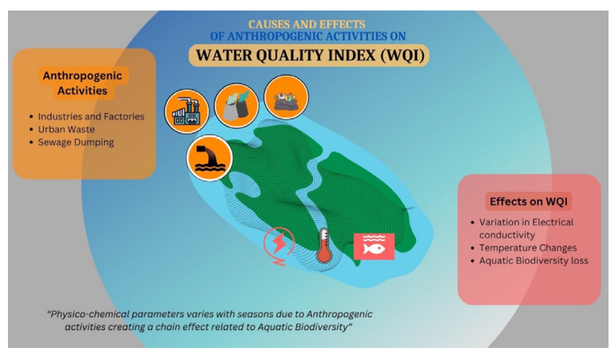


Fig. 9. Graphical representations of Physico-chemical parameters during the Pre Monsoon and Post Monsoon season

rank score of 2.75 for Winter season, 14.5 for Pre-monsoon season, 9.25 for Monsoon season, 7.5 for Post-monsoon season. Chloride naturally occurs in all types of water bodies due to its high solubility. Its concentrations in freshwater are generally taken as an indicator of sewage pollution. Its presence in freshwater is typically considered a sign of sewage contamination (Zafar, 1964 and Abir, 2014). The inflow of domestic sewage and influent from industries near the wetland from Rupnagar city is the major cause of the contamination. Due to this, the



value of the chloride in different season's shows variations in the water quality of the Ropar wetland which is also supported by Akhtar and Brraich, 2020.

Graphical Representation

Management and Legislation

Multiple legislation and efforts at the national and state levels control wetland management and protection of Ramsar sites including Ropar Wetland.

The Ramsar Convention encourages the responsible use of wetland resources and offers a framework for wetland management and conservation. The central legislation in India Wildlife Protection Act, 1972; ensures the safety of wildlife and their natural habitats. Wetlands (Conservation and Management) Rules (India) 2017, have been described to regulate the preservation and long-term management of wetlands, especially Ropar Wetland. Legislations and policies deal with matters including identifying and defining wetlands, controlling activity there, and creating a framework for monitoring (Ministry of Environment, Forest and Climate Change, India, 2017). Punjab State Wetland Authority, in Ropar and other wetland regions in Punjab, collaborates with numerous departments and organizations to enforce laws and promote sustainable wetland management techniques.

Conclusion

The major cause of water pollution at Ropar Wetland is the untreated discharge of home sewage, agricultural runoff, and industrial effluents into the water body. Due to the inflow of waste material from the industries like NFL, cement factories, and thermal power plants leads to both short-term and long-term consequences for the aquatic ecosystem. These effects can be detrimental and disruptive to the health and diversity of the river ecosystem. During the current phase of the study, the fluctuation in physico-chemical parameters has been recorded. All the physico-chemical parameters except DO and FCO_2 have shown maximum values during the premonsoon season and the minimum value during the winter seasons.Due to the low level of DO, the number and type of surface water invertebrates decreases. Certain species of stoneflies, caddisflies, mayflies and beetles are intolerant to the low DO.

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Conflict of Interest: None

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