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Assessing Seasonal Variations and Anthropogenic Stresses in Water Quality Parameters of Wetlands in Aligarh District

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Abstract: Freshwater ecosystems are vital resources, yet they are increasingly threatened by anthropogenic pressures such as urbanization, industrialization, and agricultural runoff. This study assesses the spatio-temporal variations in the water quality of several key wetlands in the Aligarh district to determine the impact of these human-induced factors. Water samples were collected from multiple sites across six different wetlands during the pre-monsoon (April) and post-monsoon (November) seasons. Twelve physico-chemical parameters, including pH, Dissolved Oxygen (DO), Total Dissolved Solids (TDS), Turbidity, and Total Hardness, were analyzed. A Water Quality Index (WQI) was calculated using a weighted arithmetic method to provide a comprehensive assessment of water quality, and the results were visualized using spatial interpolation maps. The findings reveal that the water quality in the studied wetlands is significantly degraded, with WQI values classifying the water as "poor," "very poor," and in some cases, "unsuitable for drinking." Significant seasonal variations were observed; some wetlands showed an improvement in water quality post-monsoon, likely due to the dilution effect of rainwater, while others showed further deterioration, indicating pollution from surface runoff. The analysis consistently points to anthropogenic activities as the primary driver of water quality decline. The study concludes that the wetlands of Aligarh district are under severe ecological stress, posing a threat to aquatic biodiversity and ecosystem sustainability. These findings underscore the urgent need for implementing robust management strategies and mitigation measures to protect these critical freshwater habitats from further degradation.
Keywords: Wetland; water pollution; WQI; GIS; Anthropogenic Stress.

I. INTRODUCTION

Lakes and marshes are examples of freshwater habitats, which are the most fundamental but unfortunately, rarely found resources. These ecosystems inhabit small portions of the Earth's surface and are considered vital for supporting life. These ecosystems serve various socio-economic and ecological purposes and offer habitat for a wide range of animal, plant and microbial species exclusive to Earth ([11], [12]). Wetlands and lakes are delicate ecosystems with limited self-regulating mechanisms compared to the biosphere's flowing water system. This leads to the accumulation of pollutants in these delicate ecosystems. Human activities like industrialization, population growth, urbanisation, sewage run-off, agricultural practices, climate change, and the use of artificial insecticides and pesticides in and around these ecosystems have led to a decline in water quality and impacted aquatic biodiversity and hydrological cycles. Nutrient enrichment in an aquatic ecosystem is a key factor that contributes to the decline in water quality and changes in biodiversity, ultimately speeding up the process of lake eutrophication. Human activities have led to the reduction and loss of many urban and rural water ecosystems. Aquatic habitats on Earth are scarce and vulnerable to external influences, yet they are often poorly managed and overlooked as natural resources. These water bodies require effective management and careful attention. Currently, these ecosystems are facing significant human-induced pressure. A significant decrease in services has been seen, including reduced or non-portable water supply, decreased food production capacity, and declining fish production, posing a threat to biodiversity [13]. ILEC (2005) states that the majority of difficulties, like delicate natural systems, emerge from their surrounding environments [8]. The degradation of water quality is becoming a global environmental issue [4]. Changes in land use and land cover (LULC) in the surrounding areas, population growth, urbanisation, acidification, climate change, sewage contamination, lack of proper water treatment, sediment accumulation, alterations in water flow and invasion by non-native species all contribute to negative impact on the ecological health of freshwater ecosystems. Due to human activity, the aquatic system in Kashmir is experiencing significant strain at a concerning pace [17]. The changes to the aquatic ecosystems in the Kashmir valley are worsened by weak governmental policies and inadequate enforcement of these policies on the local level.

Recently, the need for freshwater has grown steadily because of its extensive degradation by human activities. Water scarcity has become a significant issue in many nations, as highlighted by various studies ([9], [2], [20], [21]). Therefore, it is crucial to evaluate the water quality of these natural resources. Contaminants in water bodies can harm both water quality and human health. Water quality for domestic use, including drinking and household activities, is assessed based on characteristics such as colour, smell, taste, and levels of inorganic and organic substances [6]. Many studies utilise many water quality indices for water quality assessment. The river habitat survey (RHS), water pollution index (WPI), and water quality index (WQI) are the most favoured indices among these (Milanović et al., 2011). The evaluation of water quality involves measuring several physico-chemical characteristics, generating extensive, intricate and valuable datasets efficiently to extract significant insights that are typically challenging to comprehend ([19], [22]). Water quality assessment techniques aid in determining pollution levels and ensuring efficient water resource management and protection of aquatic ecosystems [15].

The present study aims to analyse the water quality of various water bodies in Aligarh district using statistical methods to determine differences and similarities among different sampling sites. It also seeks to identify the factors responsible for spatial variation and their effect on physico-chemical parameters, including natural and human-induced factors.

II. STUDY AREA

Aligarh, noted for its rich history, cultural variety, and educational institutions, is situated in the northern Uttar Pradesh. It lies between 27°35′ and 28°10′ N and 77°29′ and 78°36′ E, covering part of the fertile Gangetic plain. The district is bounded by major rivers Ganga and Yamuna, from northeast and northwest sides, respectively. The total geographical area of the district Aligarh is 3691.50 sq.km. District Aligarh is administratively divided into 12 blocks namely (i) Tappal (ii) Chandaus (iii) Jawan (iv) Khair (v) Lodha (vi) Dhanipur (vii) Akrabad (viii) Iglas (ix) Gonda (x) Atrauli (xi) Bijouli and (xii) Gangeri [18]. Geologically, Aligarh district forms a part of the Indo-Ganga plain which came into existence in the Pleistocene period. Viewed as a whole, the district is a remarkable fertile plain, sloping gently from the northwest to the southeast. Aligarh district has a typical monsoon type of climate characterized by semi-arid conditions with hot summers, a monsoon season from late June to September, and cool winters. Annual rainfall averages 800–900 mm, most of which falls during the southwest monsoon. The average elevation across the district is approximately 178 meters (587 feet) above mean sea level [3]. According to the Census of India 2011, the district has a total population of 3,673,890. The district witnessed 22.78% of population growth between 2001 to 2011 [5], with high population density indicative of the region's demographic pressures results into the degradation of its natural resources especially limited waterbodies.

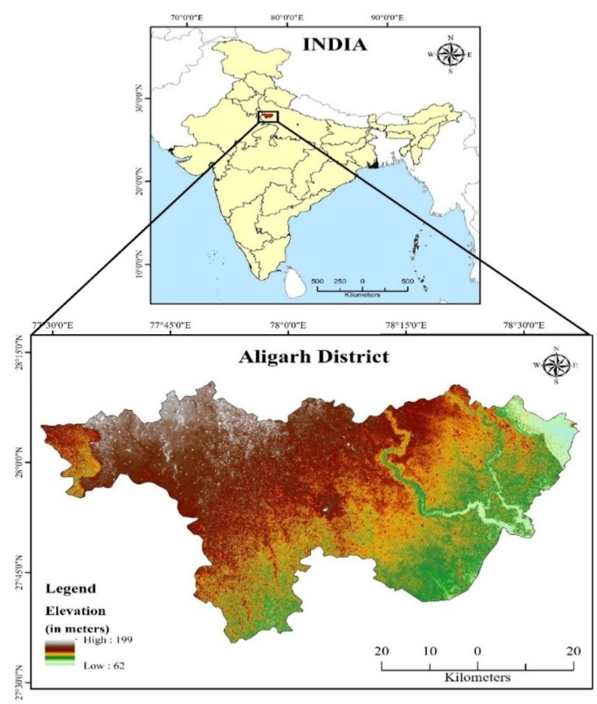

Fig. 1: Layout of the study area

District has many natural water bodies, which are of great importance in maintaining local biodiversity, farming, and livelihoods. The wetlands, however, are under growing anthropogenic pressure from the surrounding settlements and intensive agricultural production . For the purpose of this research, a purposive sampling method was followed to choose six different wetlands having varying environmental conditions in the district: Kaali Deh Talab, Ambedkar Colony Waterbody, Bhamola Fatak Waterbody, Shekha Jheel, Ramgarhi Lake, and the Dabha-Dabhi Wetland (Fig. 2). For every wetland, sampling points were selected strategically in order to consider dominant factors affecting water quality, such as distance to human habitation, distribution of open waters, presence of aquatic vegetation, and location of dominant inlet streams. This way, there was an adequate spatial evaluation of water quality differences in the aquatic ecosystems of the district.

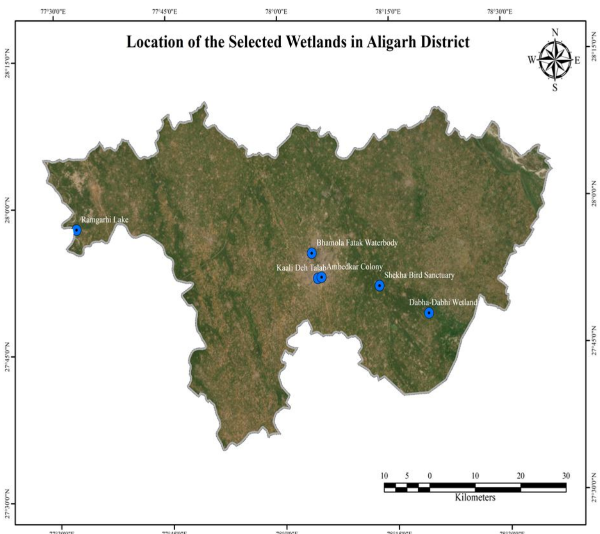

Fig. 2: Selected Wetlands in Aligarh District.

III. MATERIAL & METHODS

The sampling approach for collecting water samples for physico-chemical analysis was designed to consider factors such as proximity to settlements, distribution of open waters, aquatic vegetation, and key mainstream sites (inlet streams). These factors collectively determine the overall water quality of the water bodies. Using the method described earlier, three, two or one specific sites were chosen for collecting water samples. The month of April for pre-monsoon and November for post monsoon has been considered for the collection of samples. A total of 12 parameters of water quality were monitored to evaluate the water quality of the water bodies. Depth, water temperature, pH were measured on-site at specific locations using a graduated metal rod, thermometric technique, pH metre, Secchi disc respectively. Physico-chemical analysis was conducted on various parameters such as calcium hardness, magnesium hardness, total hardness, total dissolved solids, alkalinity, chloride (Cl^-). Water samples were gathered in 1-liter polypropylene bottles that had been washed with acid. Separate 300ml capacity corning glass bottles were utilised for each site to test the dissolved oxygen (DO) parameter. When collecting water samples for dissolved oxygen, precautions were taken to prevent any bubbling of water in Corning glass bottles. The samples were stored at 4°C for transportation and analysed in the laboratory within 48 hours by following approved protocols. Verification of the data was conducted through standardisation, triplicate samples and blank measurements (APHA 2005; [14]). Fig 1 displays the methodological flowchart used to conduct the study.

Surface water quality maps for each parameter was created using the neighbour interpolation (NN) approach in Arc GIS 10.8, ([7], [16]). The nearest neighbour interpolation (NN) approach is utilised to determine the value at any unknown place. It selects the nearest group of points and assigns weights based on their relative areas. To calculate the value at a specific position ƛ for any parameter, the values of the nearest set of points or neighbours of ƛ and their respective weights are used. The weight of the nearest set of points is equivalent to the nearest neighbour coordination of ƛ with respect to its neighbouring or closest point. If each point in a set of points has a scalar attribute, denoted as x_i, nearest neighbour interpolation can be defined as (**Error! Reference source not found.**):

$$f(ƛ) = \sum_{i=1}^{n} w_i \times x_i \quad (1)$$

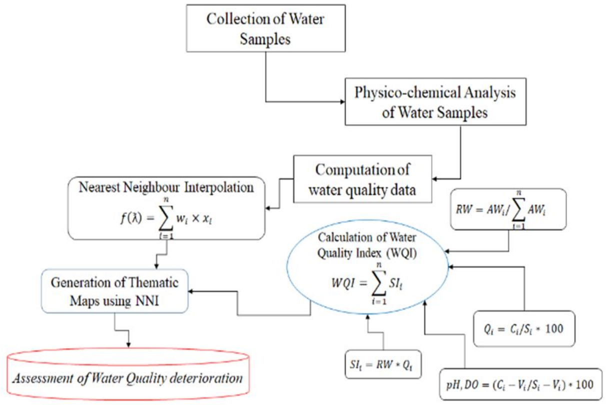

Fig. 3: Flowchart of the methods adopted for the study

A. *Water Quality Index*

Optimising water quality requires precise and timely data on water quality for successfully implementing appropriate public policies. Data trends and indices, such as the water quality index, are key ways for assessing water quality effectively. Water quality data may be condensed into a single value using a water quality index, which combines many water quality parameters. The WQI is a mathematical tool utilised to assess standardised water quality data. Arithmetic measurements of various physico-chemical parameters are weighted differently for different water uses (Pesce & Wunderlin, 2000). The Water Quality Index (WQI) was initially created by Horton in 1965 and later enhanced by Tiwari & Mishra in 1985. Calculating the Water Quality Index (WQI) for specific waterbodies requires following a 5-step process.

Step First: The initial step in determining the Water Quality Index (WQI) involved assigning a weight (AWi) to each of the 10 water quality parameters (out of 12, except Depth and Temperature) on a scale of 1-5 based on their significance in overall water quality for drinking purposes. This was done by gathering expert opinions from different studies (Table 1). Ph, Dissolved Oxygen (DO) were allocated a relative weight of 5 (maximum) due to its significance in water quality evaluation. Excessive acidic or basic water and DO level are not suitable for drinking as well as aquatic lives and is detrimental to human health. Hardness of Calcium (Ca) was assigned a minimum weight of 2 due to their comparatively low level of harm. The examination deemed a relative weight of 5 as the most significant and 2 as the least significant.

Step Second: The Relative weight (RW) for each parameter in the Water Quality Index was determined using the given equation (**Error! Reference source not found.**).

$$RW = AW_i / \sum_{i=1}^{n} AW_i \qquad (2)$$

Where; RW = Relative Weight
AW = Assigned Weight of each parameter
n = number of parameters

Step Third: A quality scale (Qi) was assigned to each parameter of physico-chemical examination, excluding Dissolved Oxygen (DO) and pH. The Quality Scale was determined by dividing the concentration of each water quality parameter by its corresponding standard as per the recommendations set by BIS (Bureau of Indian Standards: 10500-2012). After obtaining the results, they were multiplied by 100 using the formula (**Error! Reference source not found.**).

$$Q_i = C_i / S_i * 100 \qquad (3)$$

The quality rating for parameters DO and pH was determined using the following equation (**Error! Reference source not found.**):

$$pH, DO = (C_i - V_i / S_i - V_i) * 100 \qquad (4)$$

Where; Qi = Quality rating
Ci= Concentration of each parameter obtained from laboratory analysis.
Si = WHO and Indian recommended standards for corresponding parameters
Vi = Ideal value, 7.0 for pH and 14.6 for DO.

Step Fourth: The Water Quality Index (WQI) was computed by first calculating Si (Sub-indices) for each water quality parameter (**Error! Reference source not found.**) and then using them in the equation for WQI ()).

$$SI_i = RW * Q_i \qquad (5)$$
$$WQI = \sum_{i=1}^{n} SI_i \qquad (6)$$

Where; SI_i = Sub-index of ith parameter
Qi = rating based on concentration of ith parameter
n = number of parameters

Step Fifth: The calculated water quality index (WQI) values were categorised into five classes.

I. < 50 = least polluted zone
II. 50-100 = moderately polluted zone
III. 100-200 = highly polluted zone
IV. 200-300 = very high polluted zone
V. > 300 = extremely polluted zone

Table 1: Relative Weight of Parameters with BIS/WHO Standard

Parameters	Units	BIS: 10500 (2012)/WHO (2006) Desirable limits	Weight (w_i)	Relative weight (W_i)
pH	-	6.5-8.5	5	0.1389
E. Conductivity	µS cm^{-1}	500	3	0.0833
TDS	mg L^{-1}	500	4	0.1111
D.O	mg L^{-1}	5	5	0.1389
Turbidity	NTU	5	4	0.1111
T. Hardness	mg L^{-1}	200	4	0.1111
Calcium	mg L^{-1}	75	3	0.0833
Magnesium	mg L^{-1}	30	3	0.0833
Chloride	mg L^{-1}	250	2	0.0556
Alkalinity	mg L^{-1}	200	3	0.0833

Source: BIS (Bureau of Indian Standards) 10500, Indian standard drinking water-specification, Second revision, 2012

IV. RESULT AND DISCUSSION

This section is divided into three primary parts based on the methods employed to accomplish the study objectives. The three components include measuring concentration levels of water quality parameters at specific locations, calculating the Water Quality Index, and assessing human activities in proximity to water sources.

A. Physcio-chemical Analysis of the selected wetlands (Pre-Monsoon and post Monsoon)

1) Kaali Deh Talab

Kaali de talab shows slightly high temperatures, with S1 measuring 32.2°C and S2 recording 31.0°C. In post Monsoon, Kaali de talab exhibits relatively stable temperatures, with S1 recording 30.3°C and S2 measuring 29.6°C. The water depth (in meters) measured at different sites within wetlands before the onset of the monsoon season. Kaali de talab shows a considerable difference in depth between its two sites, with S2 having a much deeper water column (4.7 meters) compared to S1 (2.5 meters). Kaali de talab shows an increase in depth, with S1 measuring 2.9 meters and S2 recording 4.9 meters. Kaali de talab shows slightly alkaline conditions, with pH values ranging from 8.66 to 8.75 across its sites. In the Post-monsoon, Kaali de talab shows a slight decrease in pH, with S1 measuring 8.69 and S2 recording 8.02. Kaali de talab shows relatively high EC levels, with readings of 2048 µS/cm at S1 and 2182 µS/cm at S2. Kaali de talab shows a slight increase in EC, with S1 measuring 1901 µS/cm and S2 recording 1979 µS/cm. (Fig. 4 & Table 2).

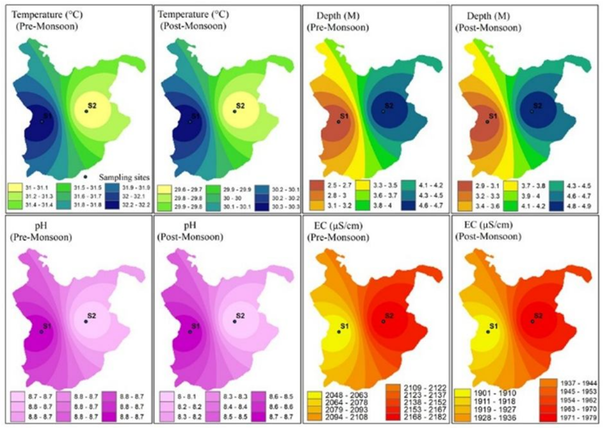

Fig. 4: Spatial distribution of water parameters in Kaali Deh Talab

The Total Dissolved Solids (TDS) concentrations at various sites within the wetlands offer valuable insights into the water quality and environmental conditions of these ecosystems. Kaali de talab demonstrates varying TDS levels between its sites, with S1 recording 983 mg/L and S2 slightly higher at 1053 mg/L. Kaali de talab shows a moderate increase in TDS, with S1 measuring 841 mg/L and S2 recording 938 mg/L. Kaali de talab shows relatively low DO levels, with values ranging from 0.37 to 0.41 mg/L across its sites. In Post Monsoon, Kaali de talab shows relatively stable DO levels, with S1 measuring 0.47 mg/L and S2 recording 0.51 mg/L. Kaali de talab displays moderate turbidity levels, with readings of 17 NTU at S1 and 22 NTU at S2. In the Post Monsoon, Kaali de talab shows an increase in turbidity, with S1 measuring 22 NTU and S2 recording 29 NTU. Kaali de talab shows consistent TH levels, with readings of 500 mg/L at both S1 and S2. Kaali de talab shows a decrease in TH, with S1 measuring 435 mg/L and S2 recording 400 mg/L (Fig. 5 & Table 2).

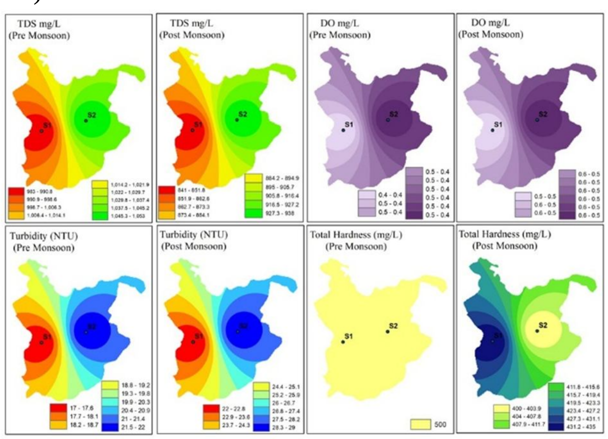

Fig. 5: Spatial distribution of water parameters in Kaali Deh Talab

Kaali de talab demonstrates consistent TH Ca levels, with both S1 and S2 recording concentrations of 250 mg/L. In the Post-monsoon, Kaali de talab shows a decrease in TH Ca, with S1 measuring 234 mg/L and S2 recording 220 mg/L. Kaali de talab displays consistent TH Mg levels, with both S1 and S2 recording concentrations of 250 mg/L. Kaali de talab shows a decrease in magnesium hardness, with S1 measuring 201 mg/L and S2 recording 180 mg/L. Kaali de talab shows varying Chloride levels, with S1 recording 249.92 mg/L (under prescribed limit by BIS, Table 2) and S2 measuring 324.90 mg/L. In the post monsoon, Kaali de talab shows an increase in chloride levels, with S1 measuring 232.45 mg/L (under prescribed limit by BIS, Table 2) and S2 recording 309.80 mg/L (exceeds standard limit set by BIS, Table 2). Kaali de talab shows consistent Alkalinity levels, with both S1 and S2 recording concentrations of 750 mg/L. In the post monsoon season, Kaali de talab shows a decrease in alkalinity, with S1 measuring 680 mg/L and S2 recording 660 mg/L (Fig. 6 & Table 2).

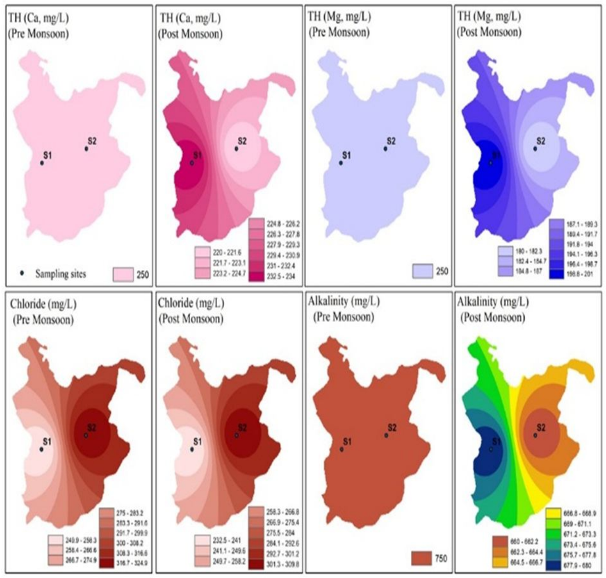

Fig. 6: Spatial distribution of water parameters in Kaali Deh Talab

2) Ambedkar Colony waterbody

Ambedkar colony shows a lower temperature range, with a reading of 29.0°C at S1 during Pre-monsoon. However, in post-monsoon it shows slightly lower temperatures, with a reading of 27°C at S1. Ambedkar colony has a moderate depth of 3.6 meters at site S1, indicating a relatively stable water level before the monsoon. Ambedkar col also demonstrates a rise in depth, with a reading of 3.9 meters at S1. Ambedkar col exhibits a similar trend, with a pH of 8.7 at site S1. Ambedkar col also demonstrates a decrease in pH, with a reading of 8.6 at S1. Ambedkar col demonstrates a similar pattern, with an EC of 2091 µS/cm at S1. Ambedkar col also demonstrates an increase in EC, with a reading of 2091 µS/cm at S1 (Table 2).

Ambedkar colony's waterbody single measurement at S1 shows a TDS concentration of 1026 mg/L, indicating a relatively consistent mineral content in its waters. Ambedkar col also demonstrates a rise in TDS, with a reading of 954 mg/L at S1. Ambedkar col exhibits even lower DO concentrations, with a value of 0.21 mg/L at site S1. Ambedkar col also demonstrates stable DO levels, with a reading of 0.42 mg/L at S1. Ambedkar col shows a similar pattern, with a turbidity of 18 NTU at S1. Ambedkar col also demonstrates increased turbidity, with a reading of 25 NTU at S1. Ambedkar col demonstrates a slightly lower TH at S1, with a measurement of 450 mg/L. Ambedkar col also demonstrates a decrease in TH, with a reading of 450 mg/L at S1 Table 2).

Ambedkar col exhibits a slightly lower TH Ca concentration at S1, measuring 190 mg/L. Ambedkar col also demonstrates a decrease in TH Ca, with a reading of 190 mg/L at S1. Ambedkar colony waterbody shows a slightly higher TH Mg concentration at S1, measuring 260 mg/L. Ambedkar col also demonstrates a decrease in magnesium hardness, with a reading of 260 mg/L at S1. Ambedkar col exhibits a similar trend, with a Chloride concentration of 269.92 mg/L at S1 (exceeds standard limit set by BIS, Table 2). Ambedkar colony waterbody also demonstrates an increase in chloride, with a reading of 257.32 mg/L at S1 (exceeds standard limit set by BIS, Table 2). Ambedkar col exhibits a higher Alkalinity at S1, measuring 1050 mg/L. Ambedkar col also demonstrates a decrease in alkalinity, with a reading of 960 mg/L at S1 (Table 2)

3) Bhamola Fatak Waterbody

Bhamola demonstrates a minor temperature difference between its sites, with S1 at 31.1°C and S2 at 29.0°C. Bhamola demonstrates minor temperature differences between its sites, with S1 at 29.8°C and S2 at 28.7°C. Bhamola waterbody records a moderate depth range, with site S1 at 2.8 meters and site S2 at 3.7 meters. Bhamola displays a moderate increase in depth, with S1 at 3.0 meters and S2 at 4.1 meters. Bhamola displays a slightly higher alkalinity, with pH values of 8.86 at S2 and 9.03 at S1, suggesting a more alkaline environment. Bhamola displays a slight increase in pH, with S1 at 8.7 and S2 at 9.16. Bhamola exhibits moderately high EC levels, with S1 at 1840 µS/cm and S2 at 1850 µS/cm, indicating significant dissolved salt content. Bhamola displays variability in EC levels, with S1 at 2034 µS/cm and S2 at 1923 µS/cm (Exceeds the standard limit set by BIS), (Fig. 7; Table 2).

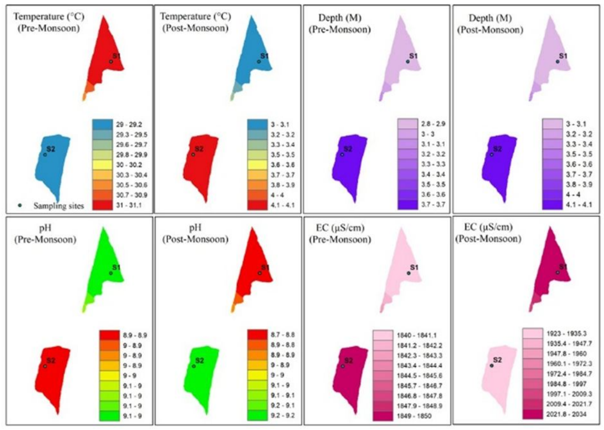

Fig. 7: Spatial distribution of water parameters in Bhamola Fatak Waterbody

Waterbody at Bhamola presents moderate TDS concentrations, with S1 at 868 mg/L and S2 at 894 mg/L, suggesting stable dissolved mineral levels. Bhamola displays a slight increase in TDS, with S1 at 902 mg/L and S2 at 908 mg/L. Bhamola, on the other hand, demonstrates a wide variation in DO levels between its sites, with S1 at 0.5 mg/L and S2 at a higher 1.01 mg/L, indicating potential differences in oxygen availability within the wetland. Bhamola displays a significant increase in DO, with S1 at 1.09 mg/L and S2 at 2.0 mg/L. Bhamola demonstrates a range of turbidity levels, with S1 at 6 NTU and S2 at 12 NTU, indicating relatively clear water compared to other sites. Bhamola displays variability in turbidity levels, with S1 at 9 NTU and S2 at 15 NTU. Bhamola fatak waterbody, shows variability in TH levels, with S1 at 480 mg/L and S2 at a lower 400 mg/L. Bhamola displays a slight decrease in TH levels, with S1 at 375 mg/L and S2 at 360 mg/L (Fig. 8; Table 2).

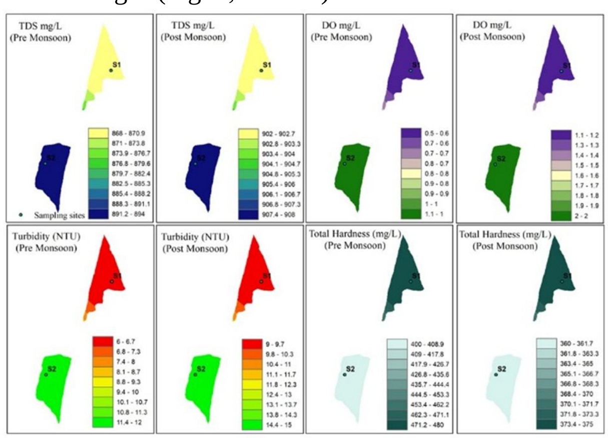

Fig. 8: Spatial distribution of water parameters in Bhamola Fatak Waterbody

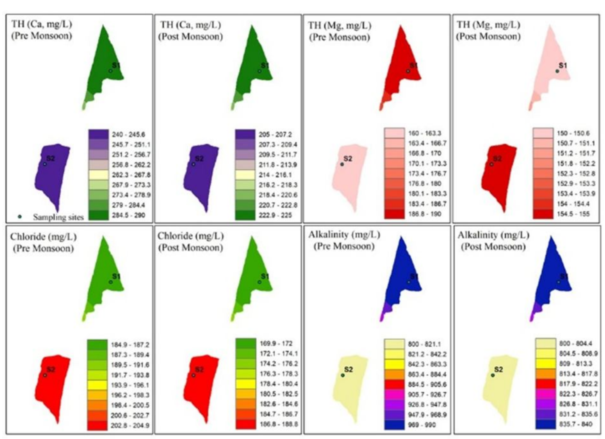

Fig. 9: Spatial distribution of water parameters in Bhamola Fatak Waterbody

Bhamola displays variability in TH Ca levels, with S1 at 290 mg/L and S2 at a slightly lower 240 mg/L. Bhamola displays a slight decrease in TH Ca levels, with S1 at 225 mg/L and S2 at 205 mg/L. Bhamola shows variability in TH Mg levels, with S1 at 190 mg/L and S2 at 160 mg/L (exceeds permissible limit set by BIS, Table 2). Bhamola displays a slight decrease in magnesium hardness levels, with S1 at 150 mg/L and S2 at 155 mg/L. Bhamola demonstrates moderate Chloride levels, with S1 at 184.94 mg/L and S2 at 204.94 mg/L (under prescribed limit by BIS, Table 2). Bhamola displays variability in chloride levels, with S1 at 169.89 mg/L and S2 at 188.78 mg/L. Bhamola demonstrates variability in Alkalinity levels, with S1 at 990 mg/L and S2 at 800 mg/L. Bhamola displays a slight decrease in alkalinity levels, with S1 at 840 mg/L and S2 at 800 mg/L (Fig. 9; Table 2).

4) Shekha Jheel

Shekha Jheel displays a similar pattern, with temperatures ranging from 29.7°C at S3 to 30.2°C at S1 and 30.0°C at S2, indicating relatively consistent thermal conditions within the wetland. During Post-monsoon Shekha Jheel displays a similar pattern, with temperatures ranging from 27.8°C at S3 to 29.0°C at S1 and 28.3°C at S2, indicating relatively consistent thermal conditions within the wetland. Shekha Jheel shows a range of depths across its sites, from 0.8 meters at S1 to 2.3 meters at S3. The shallow depth at S1 may indicate a more ephemeral or shallow-water habitat, while the deeper depths at S2 and S3 can support a more permanent aquatic ecosystem. Shekha Jheel shows varied depth changes, ranging from 1.1 meters at S1 to 2.4 meters at S2 and 2.9 meters at S3, indicating fluctuations in water levels within the wetland. . In contrast, Shekha Jheel shows a wider range of pH values, from 9.18 at S3 to 9.49 at S1, indicating variability in alkalinity across its sites. Shekha Jheel shows varied pH changes, ranging from 8.03 at S3 to 8.88 at S2 and 8.62 at S1, indicating fluctuations in water acidity or alkalinity within the wetland. Shekha Jheel, in contrast, shows much lower EC levels, ranging from 120.3 µS/cm at S2 to 281 µS/cm at S3, suggesting lower dissolved salt concentrations in its waters. Shekha Jheel shows varied EC changes, ranging from 90.7 µS/cm at S2 to 312 µS/cm at S3 and 158 µS/cm at S1, indicating fluctuations in dissolved salt content within the wetland (Fig. 10; Table 2).

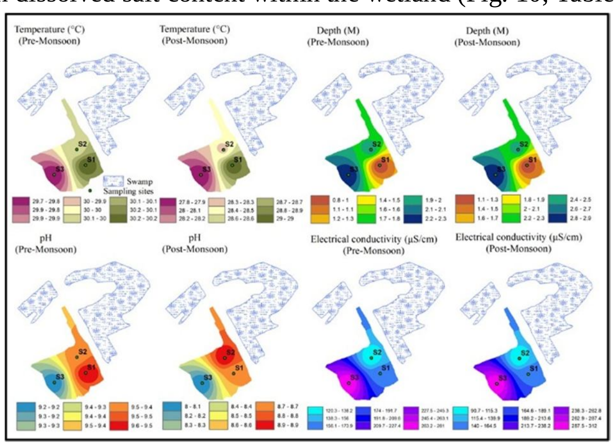

Fig. 10: Spatial distribution of water parameters in Shekha Jheel

In contrast, Shekha Jheel displays a wide range of TDS values across its sites, from 74.2 mg/L at S1 to 126.9 mg/L at S3, indicating potential variations in water quality and mineral composition within the wetland. Shekha Jheel shows varied TDS changes, ranging from 52.5 mg/L at S2 to 148 mg/L at S3, indicating fluctuations in dissolved mineral content within the wetland. Shekha Jheel shows a similar trend, with DO concentrations ranging from 2.81 to 7.56 mg/L across its sites (S1, exceeding the permissible limit set BIS), suggesting varying oxygen conditions. Shekha Jheel shows varied DO changes, ranging from 3.8 mg/L at S3 to 8.36 mg/L at S1 (exceeding the range set by BIS) and 3.9 mg/L at S2, indicating fluctuations in oxygen levels within the wetland. Shekha Jheel exhibits higher turbidity levels, ranging from 24 NTU at S1 to 54 NTU at S3, suggesting higher suspended particle content and potentially lower water clarity. Shekha Jheel shows varied turbidity changes, ranging from 19 NTU at S1 to 28 NTU at S2 and 47 NTU at S3, indicating fluctuations in suspended particle content within the wetland. Shekha Jheel displays relatively low TH levels, ranging from 150 mg/L at S1 to 180 mg/L at S2 and 170 mg/L at S3, indicating softer water compared to other sites. Shekha Jheel shows varied TH changes, ranging from 115 mg/L at S1 to 190 mg/L at S2 and 130 mg/L at S3, indicating fluctuations in mineral content within the wetland (Fig. 11; Table 2).

Shekha Jheel shows relatively low TH Ca levels, ranging from 130 mg/L at S1 to 140 mg/L at both S2 and S3, suggesting softer water compared to other sites. Shekha Jheel shows varied TH Ca changes, ranging from 80 mg/L at S1 to 120 mg/L at S2 and 90 mg/L at S3, indicating fluctuations in calcium ion content within the wetland. Shekha Jheel demonstrates relatively low TH Mg levels, ranging from 20 mg/L at S1 (under prescribed limit by BIS, Table 2) to 40 mg/L at S2 and 30 mg/L at S3 (under prescribed limit by BIS, Table 2), indicating softer water compared to other sites. Shekha Jheel shows varied magnesium hardness changes, ranging from 35 mg/L at S1 to 70 mg/L at S2 and 40 mg/L at S3, indicating fluctuations in magnesium ion content within the wetland. Shekha Jheel displays a wide range of Chloride concentrations, ranging from 49.98 mg/L at S2 to 124.96 mg/L at S3, suggesting variability in salinity across its sites. Shekha Jheel shows varied chloride changes, ranging from 47.76 mg/L at S2 to 100.54 mg/L at S3 and 56.42 mg/L at S1, indicating fluctuations in chloride content within the wetland. Shekha Jheel displays relatively low Alkalinity levels, ranging from 250 mg/L at S3 to 330 mg/L at S2 and 280 mg/L at S1, indicating lower buffering capacity compared to other sites. Shekha Jheel shows varied alkalinity changes, ranging from 250 mg/L at S1 to 310 mg/L at S2 and 170 mg/L at S3, indicating fluctuations in alkaline content within the wetland (Fig. 12; Table 2).

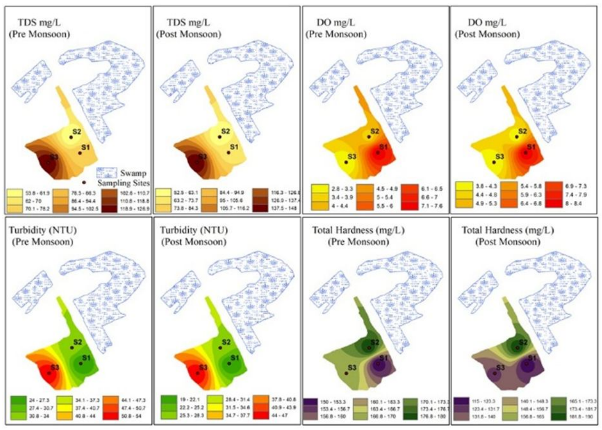

Fig. 11: Spatial distribution of water parameters in Shekha Jheel

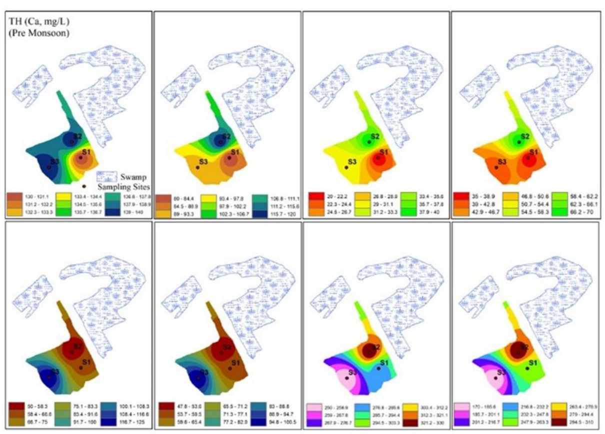

Fig. 12: Spatial distribution of water parameters in Shekha Jheel

5) Ramgarhi Lake

Ramgarhi Lake shows slight variations in temperature, with readings ranging from 29.6°C to 31.5°C across its sites. Ramgarhi Lake shows slight variations in temperature, with readings ranging from 29.3°C to 30.0°C across its sites. Ramgarhi Lake displays a wide range of depths, from 2.5 meters at S1 to 5.6 meters at S3. Ramgarhi Lake exhibits notable changes in depth, with readings ranging from 3.2 meters to 7.2 meters across its sites. Ramgarhi Lake demonstrates relatively stable pH levels, with values ranging from 8.45 to 8.48 across its sites. Ramgarhi Lake exhibits minor changes in pH, with readings ranging from 7.98 to 8.46 across its sites. Ramgarhi Lake displays relatively low to moderate EC levels, with readings ranging from 394 µS/cm to 405 µS/cm across its sites. Ramgarhi Lake exhibits notable changes in EC, with readings ranging from 385 µS/cm to 454 µS/cm across its sites (Fig. 13; Table 2).

Ramgarhi Lake exhibits relatively higher TDS concentrations, ranging from 214.6 mg/L to 226 mg/L across its sites. Shekha Jheel, shows 74.2 mg/L at S1, 53.8 mg/L at S2 and 126.9 at S3. Ramgarhi Lake exhibits notable changes in TDS, with readings ranging from 209.9 mg/L to 250 mg/L across its sites. Ramgarhi Lake displays a diverse range of DO concentrations, from 0.15 to 2.34 mg/L across its sites. Ramgarhi Lake exhibits notable changes in DO, with readings ranging from 0.23 mg/L to 2.79 mg/L across its sites. Ramgarhi Lake shows variability in turbidity, with readings ranging from 11 NTU at S1 to 52 NTU at S2, indicating differences in suspended solids between these sites. Ramgarhi Lake exhibits notable changes in turbidity, with readings ranging from 9 NTU to 43 NTU across its sites. Ramgarhi Lake shows a moderate increase in TH levels, with readings ranging from 190 mg/L to 250 mg/L across its sites. Ramgarhi Lake exhibits minor changes in TH, with readings ranging from 176 mg/L to 215 mg/L across its sites (Fig. 14; Table 2).

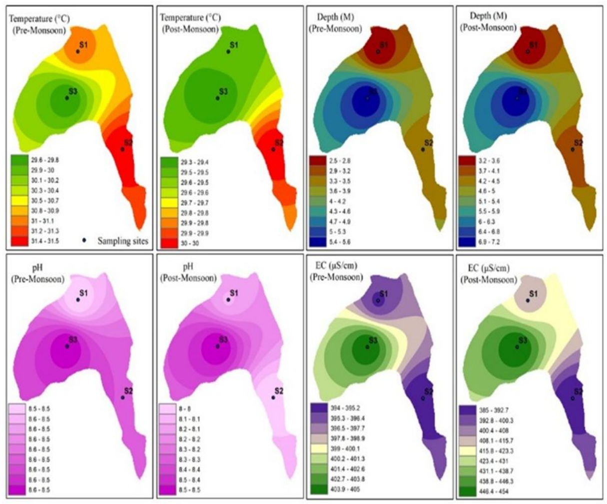

Fig. 13: Spatial distribution of water parameters in Ramgarhi Lake

Ramgarhi Lake demonstrates a moderate range of TH Ca levels, with readings ranging from 120 mg/L to 180 mg/L across its sites. It exhibits minor changes in TH Ca, with readings ranging from 112 mg/L to 155 mg/L across its sites. It displays a moderate range of TH Mg levels, with readings ranging from 50 mg/L to 100 mg/L across its sites. It exhibits minor changes in magnesium hardness, with readings ranging from 60 mg/L to 64 mg/L across its sites. Ramgarhi Lake shows variability in Chloride levels, with readings ranging from 49.98 mg/L to 89.97 mg/L across its sites.

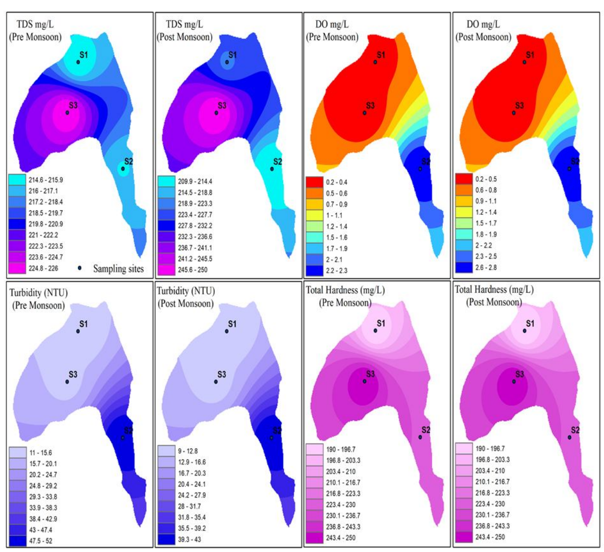

Fig. 14: Spatial distribution of water parameters in Ramgarhi Lake

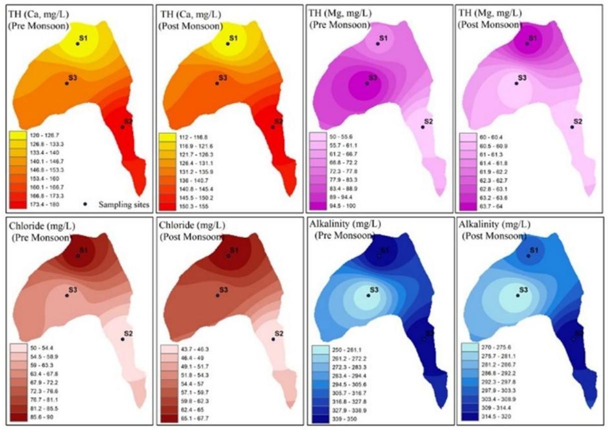

Fig. 15: Spatial distribution of water parameters in Ramgarhi Lake

Ramgarhi Lake exhibits notable changes in chloride, with readings ranging from 43.68 mg/L to 67.66 mg/L across its sites. It shows relatively stable Alkalinity levels, with readings ranging from 250 mg/L to 350 mg/L across its sites. Ramgarhi Lake exhibits minor changes in alkalinity, with readings ranging from 270 mg/L to 320 mg/L across its sites (Fig. 15; Table 2).

6) Dabha - Dabhi

Dabha Dabhi also demonstrates variability, with temperatures at S1 measuring 32.0°C and at S2 measuring 29.7°C. It also demonstrates variability, with temperatures at S1 measuring 30.6°C and at S2 measuring 29.1°C. It also shows depth differences between its sites, with S1 at 2.4 meters and S2 at 3.0 meters. It also shows variability, with depths at S1 measuring 2.5 meters and at S2 measuring 3.2 meters. However, it shows a more significant variation, with a pH of 8.67 at S1 and 8.18 at S2, suggesting differences in water chemistry or environmental conditions between these sites. It also shows variability, with pH at S1 measuring 8.1 and at S2 measuring 8.13. It also shows a similar trend, with EC levels at S1 measuring 179 µS/cm and at S2 measuring 186.7 µS/cm. It also shows variability, with EC at S1 measuring 189 µS/cm and at S2 measuring 212.65 µS/cm (under the prescribed limit of BIS), (Fig. 16; Table 2).

It shows variability in TDS concentrations, with S1 at 64.2 mg/L and S2 at 50.3 mg/L, indicating potentially different sources or processes influencing the dissolved mineral content in these locations. It also shows variability, with TDS at S1 measuring 73 mg/L and at S2 measuring 68 mg/L. It also shows variability, with DO levels at S1 measuring 1.69 mg/L and at S2 measuring 0.94 mg/L, indicating differences in oxygen availability between these sites. It also shows variability, with DO at S1 measuring 2.02 mg/L and at S2 measuring 1.06 mg/L. It also displays variability, with turbidity levels at S1 measuring 30 NTU and at S2 measuring 22 NTU. In pre-monsoon the range of turbidity of each site has crossed the set limit by BIS. It also shows variability, with turbidity at S1 measuring 32 NTU and at S2 measuring 27 NTU. It also demonstrates variability, with TH levels at S1 measuring 350 mg/L and at S2 measuring 380 mg/L. It also shows variability, with TH at S1 measuring 330 mg/L and at S2 measuring 300 mg/L (Fig. 17; Table 2).

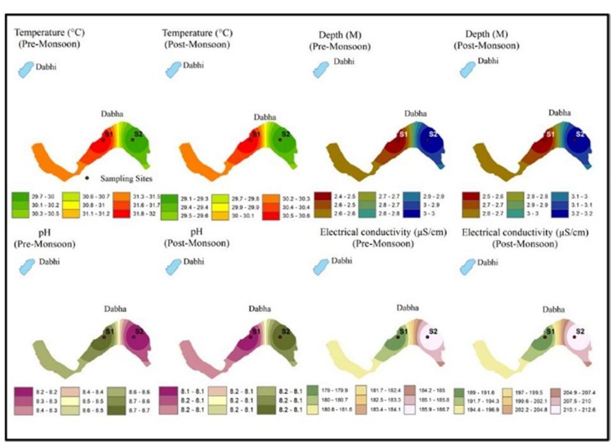

Fig. 16: Spatial distribution of water parameters in Dabha-Dabhi

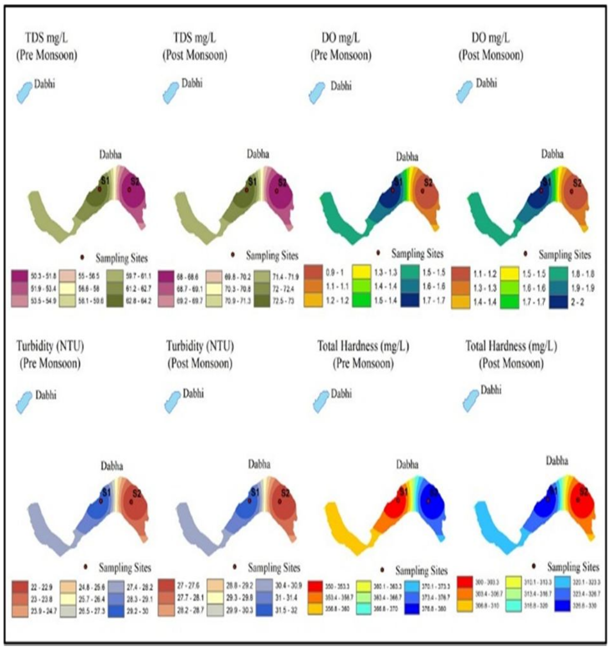

Fig. 17: patial distribution of water parameters in Dabha-Dabhi

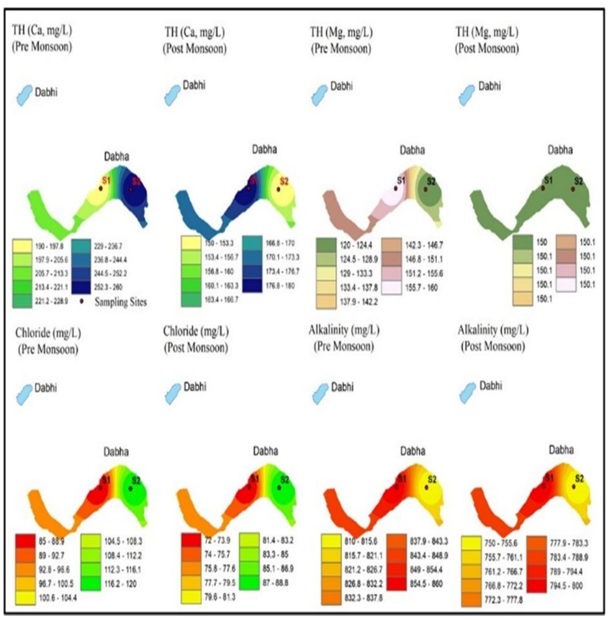

Fig. 18: Spatial distribution of water parameters in Dabha-Dabhi

Dabha Dabhi also shows variability, with TH Ca levels at S1 measuring 190 mg/L and at S2 measuring 260 mg/L. It also shows variability, with TH Ca at S1 measuring 180 mg/L and at S2 measuring 150 mg/L. It also shows variability, with TH Mg levels at S1 measuring 160 mg/L and at S2 measuring 120 mg/L (exceeds permissible limit set by BIS, Table 2). It also shows stability, with magnesium hardness at S1 and S2 measuring 150 mg/L. It also demonstrates variability, with Chloride levels at S1 measuring 84.97 mg/L and at S2 measuring 119.96 mg/L (under prescribed limit by BIS, Table 2). It also shows variability, with chloride at S1 measuring 72.00 mg/L and at S2 measuring 88.77 mg/L (under prescribed limit by BIS, Table 2). It also demonstrates variability, with Alkalinity levels at S1 measuring 860 mg/L and at S2 measuring 810 mg/L. It also shows stability, with alkalinity at S1 measuring 800 mg/L and at S2 measuring 750 mg/L. (Fig. 18; Table 2).

Table 2: Physico-Chemical Concentration Values of Water Quality Parameters at Selected Sites

Pre-Monsoon													
WL	KDT		ACP	BFW		SJ			RL			DD	
SITE	S1	S2	S1	S1	S2	S1	S2	S3	S1	S2	S3	S1	S2
Temp (°C)	32.2	31	29	31.1	29	30.2	30	29.7	31	31.5	29.6	32	29.7
DEPTH (M)	2.5	4.7	3.6	2.8	3.7	0.8	1.9	2.3	2.5	3.2	5.6	2.4	3
TDS mg/L	983	1053	1026	868	894	74.2	53.8	126.9	214.6	215.8	226	64.2	50.3
Ph	8.75	8.66	8.7	9.03	8.86	9.49	9.4	9.18	8.45	8.47	8.48	8.67	8.18
DO mg/L	0.37	0.41	0.21	0.5	1.01	7.56	3.6	2.81	0.31	2.34	0.15	1.69	0.94
Turbidity (NTU)	17	22	18	6	12	24	32	54	11	52	14	30	22
EC (µS/cm)	2048	2182	2091	1840	1850	166.2	120.3	281	395	394	405	179	186.7
TH mg/L	500	500	450	480	400	150	180	170	190	230	250	350	380
TH ca (mg/L)	250	250	190	290	240	130	140	140	120	180	150	190	260
TH mg (mg/L)	250	250	260	190	160	20	40	30	70	50	100	160	120
Chloride mg/L	249.9225	324.8993	269.9163	184.9427	204.9365	64.97985	49.9845	124.9613	89.9721	49.9845	59.9814	84.97365	119.9628
Alkalinity mg/L	750	750	1050	990	800	280	330	250	350	350	250	860	810
Post Monsoon													
Temp (°C)	30.3	29.6	27	29.8	28.7	29	28.3	27.8	29.4	30	29.3	30.6	29.1
DEPTH (M)	2.9	4.9	3.9	3	4.1	1.1	2.4	2.9	3.2	3.8	7.2	2.5	3.2
TDS mg/L	841	938	954	902	908	69	52.5	148	222.56	209.9	250	73	68
Ph	8.69	8.02	8.6	8.7	9.16	8.62	8.88	8.03	8.08	7.98	8.46	8.1	8.13
DO mg/L	0.47	0.51	0.42	1.09	2	8.36	3.9	3.8	0.42	2.79	0.23	2.02	1.06
Turbidity (NTU)	22	29	25	9	15	19	28	47	9	43	11	32	27
EC (µS/cm)	1901	1979	2091	2034	1923	158	90.7	312	412	385	454	189	212.65
TH mg/L	435	400	450	375	360	115	190	130	176	215	200	330	300
TH ca (mg/L)	234	220	190	225	205	80	120	90	112	155	140	180	150
TH mg (mg/L)	201	180	260	150	155	35	70	40	64	60	60	150	150
Chloride mg/L	232.45	309.8	257.32	169.89	188.78	56.42	47.76	100.54	67.66	43.68	57.98	72	88.7683
Alkalinity mg/L	680	660	960	840	800	250	310	170	300	320	270	800	750

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B. Water quality index (WQI) of the studied wetlands

1) Kaali Deh Talab

In the pre-monsoon period, S1 has a pH WQI score of 11.34, indicating highly alkaline water, while S2 has a slightly lower pH of 10.09, also alkaline. TDS levels are 21.84 for S1 and slightly higher at 23.40 for S2. DO remains stable around 20.75 and 20.69 for S1 and S2, respectively. Turbidity is higher at S2 with a WQI score of 48.89 compared to 37.78 at S1. Electrical Conductivity measures are 34.13 for S1 and 36.37 for S2. Total Hardness, Total Hardness of Calcium, and Total Hardness of Magnesium are the same at 27.78, 27.78, and 69.44, respectively, for both S1 and S2. Chloride levels are higher at S2 with a WQI score of 7.22 compared to 5.55 at S1. Alkalinity is the same at 31.25 for both sites. The total WQI score is 287.65 for S1 and 302.91 for S2 (Table 3; Fig. 19).

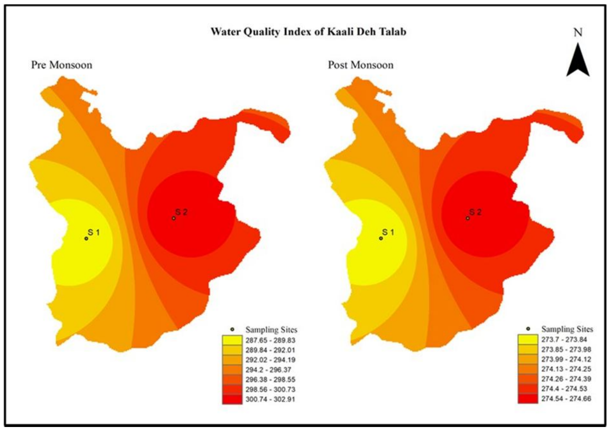

Fig. 19: WQI for the selected sites of Kaali Deh Talab

In the post-monsoon period, S1's pH drops to 10.51, remaining alkaline, while S2 becomes highly acidic with a pH of 1.20. TDS decreases to 18.69 for S1 and 20.84 for S2. DO remains stable at around 20.44 and 20.38 for S1 and S2, respectively. Turbidity remains high at both sites, with S1 at 48.89 and S2 at 64.44. Electrical Conductivity decreases to31.68 for S1 and 32.98 for S2. Total Hardness decreases to 24.17 for S1 and 22.22 for S2. Total Hardness of Calcium increases to 30.00 for S1 and decreases to 28.20 for S2. Total Hardness of Magnesium decreases to 55.83 for S1 and 50.00 for S2. Chloride level decrease to 5.17 for S1 and 6.88 for S2. Alkalinity decreases to 28.33 for S1 and 27.50 for S2. The total WQI score is 273.70 for S1 and 274.66 for S2 (Table 4; Fig. 19).

In Kaali deh talab, the overall Water Quality Index (WQI) scores show a mixed trend between the pre-monsoon and post-monsoon periods. In the pre-monsoon period, the total WQI score is higher, with S2 having a score of 302.91 compared to S1's score of 287.65. This indicates that S2 has poorer water quality than S1 during this period. However, in the post-monsoon period, the total WQI scores decrease for both sites, with S1 having a score of 273.70 and S2 having a score of 274.66. This suggests an improvement in water quality at both sites post-monsoon, with S1 having a slightly lower WQI score than S2. Overall, the post-monsoon period shows better water quality at both sites compared to the pre-monsoon period, with S1 displaying a more significant improvement than S2 (Table 3; Table 4; Fig 16).

2) Ambedkar Colony Waterbody

In the Ambedkar Colony Pond, the water quality parameters show notable variations between the pre-monsoon and post-monsoon periods. The WQI scores of pre-monsoon period reveals that (Table 3) the water at S1 demonstrates a pH Water Quality Index (WQI) score of 10.65, indicating slightly alkaline conditions. Total Dissolved Solids (TDS) have a WQI score of 22.80, while Dissolved Oxygen (DO) levels have a WQI score of 20.99, indicating good oxygenation. Turbidity has a WQI score of 40.00 and Electrical Conductivity measures 34.85. Total Hardness has a WQI score of 25.00 with Total Hardness of Calcium at 21.11 and Total Hardness of Magnesium at 72.22. Chloride levels have a WQI score of 6.00 and Alkalinity has a WQI score of 43.75. The total WQI score is 297.36 in the pre-monsoon period (Table 4). In the post-monsoon period, the pH drops to 9.26, remaining alkaline. TDS decreases slightly to 21.20 and DO remains stable at 20.51. Turbidity increases to 55.56 and Electrical Conductivity remains the same at 34.85. Total Hardness, Total Hardness of Calcium and Total Hardness of Magnesium remain constant at 25.00, 24.36 and 72.22 respectively. Chloride level decrease to 5.72 and Alkalinity decreases to 40.00. The total WQI score increases to 308.67 in the post-monsoon period (Table 4). The post-monsoon period shows a slight improvement in water quality at the Ambedkar Colony Pond, as indicated by the increase in the total WQI score. However, some parameters, such as pH and turbidity, show less favourable conditions post-monsoon, suggesting a need for continued monitoring and management of water quality in the area.

3) Bhamola Fatak Waterbody

The water quality of the waterbody Bhamola Fatak area, as indicated by the Water Quality Index (WQI), shows some variations between the pre-monsoon and post monsoon periods. In the pre-monsoon period, the pH was relatively high at 15.23 for S1 and 12.87 for S2, indicating alkaline water. Total Dissolved Solids (TDS) were similar between the two sites, with values of 19.29 and 19.87 respectively. Dissolved Oxygen (DO) levels were also similar, around 20.56 for S1 and 19.82 for S2. Turbidity was low, with values of 13.33 and 26.67. Electrical Conductivity was around 30.67 for S1 and 30.83 for S2. Total Hardness, both overall and in terms of Calcium and Magnesium, showed some differences between the two sites but remained within acceptable levels. Chloride levels were relatively low at 4.11 for S1 and 4.55 for S2 and Alkalinity was higher, around 41.25 for S1 and 33.33 for S2 (Table 3; Fig. 20).

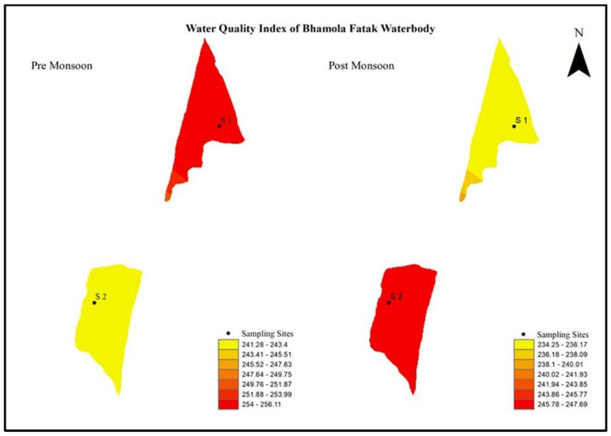

Fig. 20: WQI for the selected sites of Bhamola Fatak waterbody

In the post monsoon period, there were some changes in water quality parameters. The pH dropped to more neutral levels, with values of 10.65 for S1 and 17.04 for S2. TDS remained stable, DO decreased slightly to around 19.54 for S1 and 18.23 for S2 and turbidity increased to 20.00 for S1 and 33.33 for S2. Electrical Conductivity increased slightly to 33.90 for S1 and 32.05 for S2. Total Hardness showed some decrease, especially in terms of Magnesium, which decreased to 41.67 for S1 and 43.05 for S2. Chloride levels remained relatively stable and Alkalinity decreased to 35.00 for S1 and remained at 33.33 for S2. The total WQI score for the post-monsoon period was 234.25, showing a slight decrease compared to the pre-monsoon period (Table 4; Fig. 20).

Overall, the Bhamola Fatak area experienced some changes in water quality between the pre-monsoon and post-monsoon periods, with variations in pH, turbidity and some other parameters. Regular monitoring and management of water quality are essential to ensure the health and sustainability of the waterbody in this area.

4) Shekha Jheel

In Pre-monsoon, S1 displays a pH WQI score of 131.08, TDS WQI score of 1.65, DO WQI score of 10.27, turbidity WQI score of 53.33, EC WQI score of 2.77, total hardness WQI score of 8.33, total hardness (calcium) WQI score of 14.44, total hardness (magnesium) WQI score of 5.56, chloride WQI score of 1.44 and alkalinity WQI score of 11.67, resulting in a total WQI score of 131.08. At S2 demonstrates WQI scores of 162.25 for pH, 1.20 for TDS, 16.04 for DO, 71.11 for turbidity, 2.00 for EC, 10.00 for total hardness, 15.56 for total hardness (calcium), 11.11 for total hardness (magnesium), 1.11 for chloride and 13.75 for alkalinity, resulting in a total WQI score of 162.25. At S3, the WQI scores are 17.32 for pH, 2.82 for TDS, 17.19 for DO, 120.00 for turbidity, 4.68 for EC, 9.44 for total hardness, 15.56 for total hardness (calcium), 8.33 for total hardness (magnesium), 2.78 for chloride and 10.42 for alkalinity, resulting in a total WQI score of 208.54 (Table 3; Fig. 21).

In the post monsoon, S1 shows WQI scores of 9.54 for pH, 1.53 for TDS, 9.03 for DO, 42.22 for turbidity, 2.63 for EC, 6.39 for total hardness, 10.26 for total hardness (calcium), 9.72 for total hardness (magnesium), 1.25 for chloride and 10.42 for alkalinity, resulting in a total WQI score of 102.99. S2 displays WQI scores of 13.15 for pH, 1.17 for TDS, 15.48 for DO, 62.22 for turbidity, 1.51 for EC, 10.56 for total hardness, 15.38 for total hardness (calcium), 19.44 for total hardness (magnesium), 1.06 for chloride and 12.92 for alkalinity, resulting in a total WQI score of 152.89. At S3, the WQI scores are 1.34 for pH, 3.29 for TDS, 15.62 for DO, 104.44 for turbidity, 5.20 for EC, 7.22 for total hardness, 11.54 for total hardness (calcium), 11.11 for total hardness (magnesium), 2.23 for chloride and 7.08 for alkalinity, resulting in a total WQI score of 169.09 (Table 4; Fig. 21).

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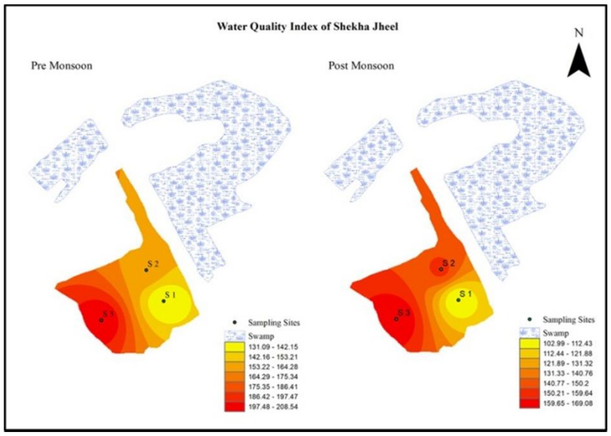

Fig. 21: WQI for the selected sites of Shekha Jheel

The overall Water Quality Index (WQI) total scores for Shekha Jheel before and after the monsoon season indicates a significant improvement in water quality post-monsoon. Before the monsoon, the total WQI scores for the three sites (S1, S2, and S3) were 131.08, 162.25 and 208.54 respectively. After the monsoon, these scores decreased to 102.99, 152.89 and 169.09 for the same sites. This decrease in total WQI scores suggests an enhancement in water quality, with lower scores reflecting better water quality. Factors contributing to this improvement may include dilution of pollutants due to increased water flow and flushing of contaminants, as well as the replenishment of dissolved oxygen levels. Overall, the post-monsoon period presents a more favourable water quality scenario for Shekha Jheel, highlighting the seasonal variability in water quality dynamics.

5) Ramgarhi Lake

In the Pre-Monsoon season, S1 exhibits a total WQI score of 123.73, with a pH WQI score of 7.18, TDS WQI score of 4.77, DO WQI score of 20.84, turbidity WQI score of 24.44, EC WQI score of 6.58, total hardness WQI score of 10.56, total hardness (calcium) WQI score of 13.33, total hardness (magnesium) WQI score of 19.44, chloride WQI score of 2.00 and alkalinity WQI score of 14.58. Site S2 displays a total WQI score of 214.61, with pH WQI score of 7.45, TDS WQI score of 4.80, DO WQI score of 17.88, turbidity WQI score of 115.55, EC WQI score of 6.57, total hardness WQI score of 12.78, total hardness (calcium) WQI score of 20.00, total hardness (magnesium) WQI score of 13.89, chloride WQI score of 1.11 and alkalinity WQI score of 14.58. At site S3, the total WQI score is 141.63, with pH WQI score of 7.59, TDS WQI score of 5.02, DO WQI score of 21.07, turbidity WQI score of 31.11, EC WQI score of 6.75, total hardness WQI score of 13.89, total hardness (calcium) WQI score of 16.67, total hardness (magnesium) WQI score of 27.78, chloride WQI score of 1.33, and alkalinity WQI score of 10.42 (Table 3; Fig. 22).

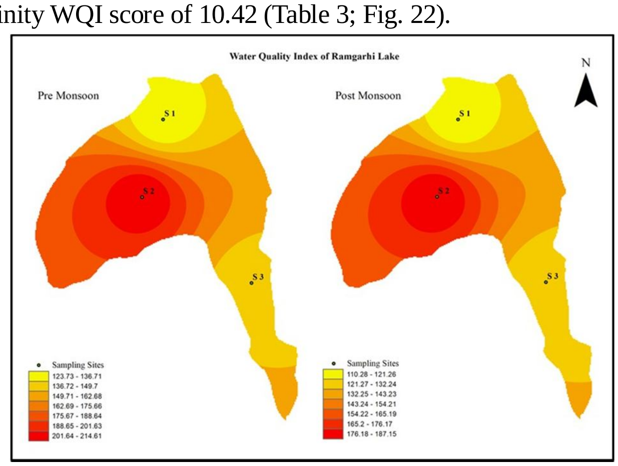

Fig. 22: WQI for the selected sites of Ramgarhi Lake

In the Post monsoon, S1 shows a total WQI score of 110.28, with a pH WQI score of 2.04, TDS WQI score of 4.95, DO WQI score of 20.51, turbidity WQI score of 20.00, EC WQ score of 6.87, total hardness WQI score of 9.78, total hardness (calcium) WQI score of 14.36, total hardness (magnesium) WQI score of 17.78, chloride WQI score of 1.50 and alkalinity WQI score of 12.50.

The S2 displays a total WQI score of 187.15, with a pH WQI score of 0.65, TDS WQI score of 4.66, DO WQI score of 17.09, turbidity WQI score of 95.55, EC WQI score of 6.42, total hardness WQI score of 11.94, total hardness (calcium) WQI score of 19.87, total hardness (magnesium) WQI score of 16.67, chloride WQI score of 0.97 and alkalinity WQI score of 13.33. At S3, the total WQI score is 123.93, with a pH WQI score of 7.32, TDS WQI score of 5.56, DO WQI score of 20.79, turbidity WQI score of 24.44, EC WQI score of 7.57, total hardness WQI score of 11.11, total hardness (calcium) WQI score of 17.95, total hardness (magnesium) WQI score of 16.67, chloride WQI score of 1.29 and alkalinity WQI score of 11.25 (Table 4; Fig. 22).
Ramgarhi Lake shows varied total Water Quality Index (WQI) scores in pre-monsoon and post monsoon across its sites. In the pre-monsoon, the total WQI scores for sites S1, S2, and S3 are 123.73, 214.61 and 141.63 respectively. In the post monsoon, these scores decrease to 110.28, 187.15 and 123.93 for the same sites. This indicates an overall improvement in water quality of post-monsoon, with lower WQI scores reflecting better water quality.

6) Dabha-Dabhi

In Dabha-Dabhi wetland, the water quality parameters display a notable variation between the pre-monsoon and post-monsoon periods. In the pre-monsoon period, the water at S1 demonstrates a pH Water Quality Index (WQI) score of 10.23, indicating slightly alkaline conditions, while S2 shows a significantly lower pH score of 3.43, suggesting acidic conditions. Total Dissolved Solids (TDS) are relatively low at both sites, with S1 at 1.43 and S2 at 1.12. Dissolved Oxygen (DO) levels are high, indicating good oxygenation, with S1 at 18.83 and S2 at 19.92. Turbidity is higher at S1 with a score of 66.67 compared to 48.89 at S2. Electrical Conductivity values are also relatively low, with S1 at 2.98 and S2 at 3.11. Total Hardness is higher at S2 with a score of 21.11 compared to 19.44 at S1. Total Hardness of Calcium and Total Hardness of Magnesium follow a similar trend, being higher at S2 than at S1. Chloride levels are slightly higher at S2 with a score of 2.67 compared to 1.89 at S1. Alkalinity is higher at S1 with a score of 35.83 compared to 33.75 at S2. The total WQI score is 222.86 for S1 and 196.21 for S2 in the pre-monsoon period (Table 3; Fig. 23).
In the post-monsoon period, both sites show a decrease in pH, with S1 at 2.31 and S2 at 2.73, indicating highly acidic conditions. TDS levels increase slightly, with S1 at 1.62 and S2 at 1.51. DO levels remain relatively stable, with S1 at 18.20 and S2 at 19.59. Turbidity increases at both sites, with S1 at 71.11 and S2 at 60.00. Electrical Conductivity values increase slightly, with S1 at 3.15 and S2 at 3.54. Total Hardness decreases at both sites, with S1 at 18.33 and S2 at 16.67. Total Hardness of Calcium and Total Hardness of Magnesium follow a similar trend, decreasing at both sites. Chloride levels decrease at both sites, with S1 at 1.60 and S2 at 1.97. Alkalinity also decreases at both sites, with S1 at 33.33 and S2 at 31.25. The total WQI score is 214.40 for S1 and 198.16 for S2 in the post-monsoon period (Table 4; Fig. 23).

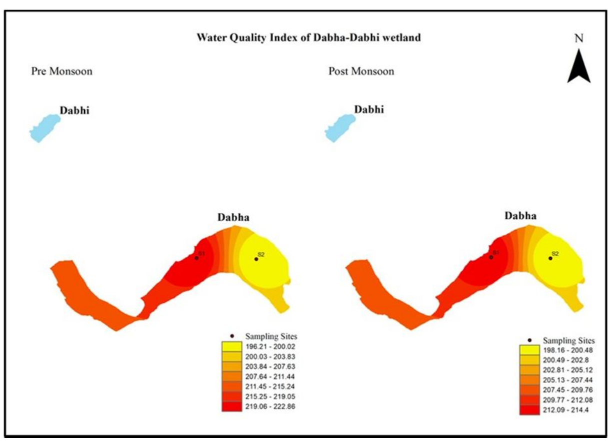

Fig. 23: WQI for the selected sites of Dabha-Dabhi wetland

In the Dabha-Dabhi wetland, the post-monsoon period shows a deterioration in water quality at both sites compared to the pre-monsoon period, with S2 displaying poorer water quality than S1 in both periods. The changes in pH, turbidity and Total Hardness are particularly noteworthy, indicating a shift towards more acidic and turbid conditions with lower levels of hardness during post-monsoon.

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Table 3: Statistics of WQI for the selected sites of the sampled wetlands (Pre-monsoon)

WL	SITE	pH		TDS (mg/L)		DO (mg/L)		Turbidity (NTU)		EC (µS/cm)		TH (mg/L)		TH ca (mg/L)		TH mg (mg/L)		Chloride (mg/L)		Alkalinity (mg/L)	
		qi	wiqi	qi	wiqi	qi	wiqi	qi	wiqi	qi	wiqi	qi	wiqi	qi	wiqi	qi	wiqi	qi	wiqi	qi	wiqi
Kaali de talab	S1	81.67	11.34	196.60	21.84	148.23	20.75	340	37.78	409.60	34.13	250	27.78	333.33	27.78	833.33	69.44	99.97	5.55	375	31.25
	S2	72.67	10.09	210.60	23.40	147.81	20.69	440	48.89	436.40	36.37	250	27.78	333.33	27.78	833.33	69.44	129.96	7.22	375	31.25
Ambedkar col	S1	76.67	10.65	205.20	22.80	149.90	20.99	360	40.00	418.20	34.85	225	25.00	253.33	21.11	866.67	72.22	107.97	6.00	525	43.75
Bhamola	S1	109.67	15.23	173.60	19.29	146.88	20.56	120	13.33	368.00	30.67	240	26.67	386.67	32.22	633.33	52.78	73.98	4.11	495	41.25
	S2	92.67	12.87	178.80	19.87	141.56	19.82	240	26.67	370.00	30.83	200	22.22	320.00	26.67	533.33	44.44	81.97	4.55	400	33.33
Shekha Jheel	S1	155.67	21.62	14.84	1.65	73.33	10.27	480	53.33	33.24	2.77	75	8.33	173.33	14.44	66.67	5.56	25.99	1.44	140	11.67
	S2	146.67	20.37	10.76	1.20	114.58	16.04	640	71.11	24.06	2.00	90	10.00	186.67	15.56	133.33	11.11	19.99	1.11	165	13.75
	S3	124.67	17.32	25.38	2.82	122.81	17.19	1080	120.00	56.20	4.68	85	9.44	186.67	15.56	100.00	8.33	49.98	2.78	125	10.42
Ramgarhi Lake	S1	51.67	7.18	42.92	4.77	148.85	20.84	220	24.44	79.00	6.58	95	10.56	160.00	13.33	233.33	19.44	35.99	2.00	175	14.58
	S2	53.67	7.45	43.16	4.80	127.71	17.88	1040	115.55	78.80	6.57	115	12.78	240.00	20.00	166.67	13.89	19.99	1.11	175	14.58
	S3	54.67	7.59	45.20	5.02	150.52	21.07	280	31.11	81.00	6.75	125	13.89	200.00	16.67	333.33	27.78	23.99	1.33	125	10.42
Dabha Dabhi	S1	73.67	10.23	12.84	1.43	134.48	18.83	600	66.67	35.80	2.98	175	19.44	253.33	21.11	533.33	44.44	33.99	1.89	430	35.83
	S2	24.67	3.43	10.06	1.12	142.29	19.92	440	48.89	37.34	3.11	190	21.11	346.67	28.89	400.00	33.33	47.99	2.67	405	33.75

Table 4: Statistics of WQI for the selected sites of the sampled wetlands (Post-monsoon)

WL	**SITE**	**pH**		**TDS (mg/L)**		**DO (mg/L)**		**Turbidity (NTU)**		**EC (µS/cm)**		**TH (mg/L)**		**TH ca (mg/L)**		**TH mg (mg/L)**		**Chloride (mg/L)**		**Alkalinity (mg/L)**	
		qi	**wiqi**	**qi**	**wiqi**	**qi**	**wiqi**	**qi**	**wiqi**	**qi**	**Wiqi**	**qi**	**wiqi**	**qi**	**wiqi**	**qi**	**wiqi**	**qi**	**wiqi**	**qi**	**wiqi**
Kaali de talab	*S1*	75.67	10.51	168.20	18.69	147.19	20.44	440	48.89	380.20	31.68	217.50	24.17	360.00	30.00	670.00	55.83	92.98	5.17	340	28.33
	S2	8.67	1.20	187.60	20.84	146.77	20.38	580	64.44	395.80	32.98	200.00	22.22	338.46	28.20	600.00	50.00	123.92	6.88	330	27.50
Ambedkar col	*S1*	66.67	9.26	190.80	21.20	147.71	20.51	500	55.56	418.20	34.85	225.00	25.00	292.31	24.36	866.67	72.22	102.93	5.72	480	40.00
Bhamola	*S1*	76.67	10.65	180.40	20.04	140.73	19.54	180	20.00	406.80	33.90	187.50	20.83	346.15	28.85	500.00	41.67	67.96	3.77	420	35.00
	S2	122.67	17.04	181.60	20.18	131.25	18.23	300	33.33	384.60	32.05	180.00	20.00	315.38	26.28	516.67	43.05	75.51	4.19	400	33.33
Shekha Jheel	*S1*	68.67	9.54	13.80	1.53	65.00	9.03	380	42.22	31.60	2.63	57.50	6.39	123.08	10.26	116.67	9.72	22.57	1.25	125	10.42
	S2	94.67	13.15	10.50	1.17	111.46	15.48	560	62.22	18.14	1.51	95.00	10.56	184.62	15.38	233.33	19.44	19.10	1.06	155	12.92
	S3	9.67	1.34	29.60	3.29	112.50	15.62	940	104.44	62.40	5.20	65.00	7.22	138.46	11.54	133.33	11.11	40.22	2.23	85	7.08
Ramgarhi Lake	*S1*	14.67	2.04	44.51	4.95	147.71	20.51	180	20.00	82.40	6.87	88.00	9.78	172.31	14.36	213.33	17.78	27.06	1.50	150	12.50
	S2	4.67	0.65	41.98	4.66	123.02	17.09	860	95.55	77.00	6.42	107.50	11.94	238.46	19.87	200.00	16.67	17.47	0.97	160	13.33
	S3	52.67	7.32	50.00	5.56	149.69	20.79	220	24.44	90.80	7.57	100.00	11.11	215.38	17.95	200.00	16.67	23.19	1.29	135	11.25
Dabha Dabhi	*S1*	16.67	2.32	14.60	1.62	131.04	18.20	640	71.11	37.80	3.15	165.00	18.33	276.92	23.08	500.00	41.67	28.80	1.60	400	33.33
	S2	19.67	2.73	13.60	1.51	141.04	19.59	540	60.00	42.53	3.54	150.00	16.67	230.77	19.23	500.00	41.67	35.51	1.97	375	31.25

C. Water Quality Range of the Studied Sites

1) Pre-Monsoon

The Table 5 presents the Water Quality Index (WQI) scores for various sites across Kaali Deh Talab (KDT), Ambedkar Colony Pond (ACP), Bhamola Fatak Waterbody (BFW) and Shekha Jheel (SJ) during the pre-monsoon period. In KDT, the water quality at S1 is categorized as "Very Poor," with a WQI score of 287.65, while at S2, the water is classified as "Unsuitable for drinking" with a score of 302.91. ACP's S1 water quality falls under the "Very Poor" category with a WQI score of 297.36. while, BFW's S1 and S2 are classified as with a score of 256.11 and 241.28. In SJ, the water quality at S1 and S2 are rated as "poor water" with a WQI score of 131.08 and 162.25 respectively. The S3 of SJ categorised as "very Poor water" with a score of 208.54. For RL, at S1 and S3, the water quality falls under the "Poor water" category with a WQI score of 123.73 and 141.63 respectively. At S2, the score is 214.61 under "very poor" category. For DD, at S1, the water quality is categorized as "Very Poor water" with a WQI score of 222.86 and at S2, it is classified as "Poor water" with a score of 196.21.

Table 5: Water Quality status of selected sites of sampled wetlands (Pre-Monsoon)

Pre-Monsoon						
WLs	WQI	> 50	50-100	100-200	200-300	> 300
	Water quality	Excellent	Very good	Poor water	Very poor	Unsuitable
KDT	S1	-	-	-	287.65	-
	S2	-	-	-	-	302.91
ACP	S1	-	-	-	297.36	-
BFW	S1	-	-	-	256.11	-
	S2	-	-	-	241.28	-
SJ	S1	-	-	131.08	-	-
	S2	-	-	162.25	-	-
	S3	-	-	-	208.54	-
RL	S1	-	-	123.73	-	-
	S2	-	-	-	214.61	-
	S3	-	-	141.63	-	-
DD	S1	-	-	-	222.86	-
	S2	-	-	196.21	-	-

2) Post Monsoon

For KDT, the Table 6 shows that both S1 and S2 falls under the "Very poor water" category, with WQI scores of 273.7 and 274.66 respectively. In ACP, S1 is classified as "Unsuitable for drinking" with a WQI score of 308.67. For BFW, the table indicates that S1 and S2 are in the "Very poor water" category, with WQI scores of 234.25 and 247.69, respectively. In SJ, S1, S2, and S3 are all classified as "poor water" with WQI scores of 102.99, 152.89 and 169.09 respectively. For RL, at S1, the water quality falls under the "Poor water" category with a WQI score of 110.28, while at S2, it is categorized as "Poor water" with a score of 187.15. For S3, the water quality is again "Poor water" with a score of 123.93. For DD, the table indicates that at S1, the water quality is "Very poor water" with a WQI score of 214.4, while at S2, the score for S1 is 198.16.

Table 6: Water Quality Status of Selected Sites of Sampled Wetlands (Post-Monsoon)

WLs	WQI	> 50	50-100	100-200	200-300	> 300
	Water quality	Excellent	Very good	Poor water	Very poor	Unsuitable
KDT	S1	-	-	-	273.7	-
	S2	-	-	-	274.66	-
ACP	S1	-	-	-	-	308.67
BFW	S1	-	-	-	234.25	-
	S2	-	-	-	247.69	-
SJ	S1	-	-	102.99	-	-

	S2	-	-	152.89	-	-
	S3	-	-	169.09	-	-
RL	S1	-	-	110.28	-	-
	S2	-	-	187.15	-	-
	S3	-	-	123.93	-	-
DD	S1	-	-	-	214.4	-
	S2	-	-	198.16	-	-

The research findings reveal that the wetlands in Aligarh district are currently experiencing water quality conditions categorized as poor, very poor, and unsuitable. This poses a serious threat to the health and sustainability of these aquatic environments. Urgent measures are required to address this issue and restore the ecological balance of the wetlands.

The assessment of water quality reveals a significant difference in the parameters of water quality between pre- and post-monsoon seasons suggest that human activity has an impact on these wetlands. In the case of in Kaali Deh Talab, there is a notable variation in the water quality between the pre monsoon and post monsoon season. During the post-monsoon period, there is a noticeable enhancement in the water quality. This improvement can be attributed to the dilution of pollutants and the removal of contaminants through higher water flow that occurs during the rainy season. This implies that human activities causing pollution are more prevalent during the dry season. Similarly, there are significant differences in water quality parameters between the two periods in Ambedkar Colony waterbody. During the post-monsoon season, there is a marginal rise in the overall Water Quality Index (WQI) score, suggesting a minor decline in water quality. This phenomenon can be ascribed to anthropogenic activities, such as the disposal of waste and the runoff from nearby households and agricultural fields, which become more noticeable in the aftermath of the monsoon season. The pH, turbidity, and other characteristics in the Bhamola Fatak Waterbody show significant variations between the pre-monsoon and post-monsoon periods, indicating the impact of human activities. The decline in pH and rise in turbidity after the monsoon season may be attributed to activities such as agricultural runoff, sewage discharge, and other anthropogenic influences. Shekha Jheel exhibits notable variations in water quality units during the two time periods, suggesting the influence of human activity. The enhancement in water quality during the post monsoon season can be ascribed to natural mechanisms such as the dilution and removal of pollutants, which underscores the impact of human activities on the deterioration of water quality. The WQI ratings of Ramgarhi Lake show significant variations between the pre-monsoon and post-monsoon periods, indicating changes in water quality that are influenced by human activities. The decline in overall WQI ratings after the monsoon season suggests an enhancement in water quality, potentially resulting from a decrease in human activity during this period. The analysis of water quality measures in the Dabha-Dabhi wetland reveals the influence of human activities on the deterioration of water quality, as observed during both the pre-monsoon and post-monsoon periods. The pH reduction and turbidity rise observed after the monsoon season indicate the impact of anthropogenic factors, such as sewage and domestic garbage disposal.

Human activities are likely causing the decline in the water quality in wetlands of the district. The WQI values suggest that the majority of the wetlands studied have poor to very poor water quality, with some sites even being deemed unfit for drinking. The parameters such as increased pH levels, turbidity, and decreased Dissolved Oxygen (DO) levels indicate the presence of contamination and pollution, which are frequently associated with human activities.

Industrial discharge, agricultural runoff, and households' sewage discharge can introduce pollutants into the wetlands, which can cause a decline in water quality. These contaminants may consist of toxic metals, essential minerals and organic substances, all of which can cause significant impacts on the well-being of aquatic organisms and the general health of the environment.

The analysis of water quality parameters during the pre-monsoon and post-monsoon periods in the wetlands under study demonstrates that human activities are responsible for the decline in water quality. Implementing measures to mitigate these activities and safeguard wetlands is crucial to guarantee their long-term viability and the well-being of ecosystems that rely on them.

V. CONCLUSION

The temperature data suggests relatively stable thermal conditions in the wetlands, with minor variations between sites. Monitoring water temperatures is crucial for understanding the ecological dynamics of these ecosystems, as temperature influences various biological and chemical processes essential for their functioning. The depth variations in these wetlands indicate the diverse habitat conditions present in these ecosystems. Understanding these depth differences is crucial for managing and conserving wetlands to ensure their ecological integrity and the services they provide to both wildlife and humans.

The TDS data highlights the diverse chemical composition of the wetland waters, which can impact aquatic life, water treatment processes, and overall ecosystem health. TDS levels is crucial for understanding and managing these wetland environments effectively. The pH values suggests that most of the wetland sites exhibit alkaline conditions, which can influence nutrient availability, metal toxicity, and biological processes in these ecosystems. Understanding pH variations is essential for managing and conserving wetlands to ensure their ecological integrity and the services they provide to both wildlife and humans. DO range suggests that some wetland sites may have low oxygen levels, which can impact the health of aquatic organisms and the overall ecosystem. Monitoring DO concentrations is important for assessing water quality and the ecological health of wetlands, as it directly affects the survival and behaviour of aquatic life. The turbidity ranges suggest varying levels of suspended particles and water clarity in the wetlands, which can impact light penetration, aquatic plant growth, and overall ecosystem health. Monitoring turbidity is essential for understanding and managing these wetland environments to ensure their ecological integrity and the services they provide to both wildlife and humans. The EC suggests varying levels of dissolved salts and minerals in the wetlands, which can impact water quality, nutrient availability, and overall ecosystem health. Monitoring EC is crucial for understanding and managing these wetland environments to ensure their ecological integrity and the services they provide to both wildlife and humans. Overall, the TH data suggests varying degrees of water hardness in the wetlands, which can impact water quality, aquatic life, and ecosystem health. Monitoring TH levels is crucial for understanding and managing these wetland environments to ensure their ecological integrity and the services they provide to both wildlife and humans. The TH Ca data provides insights into the calcium content in the wetland waters, which is important for understanding water hardness and its impact on aquatic organisms and ecosystem dynamics. Monitoring TH Ca levels is crucial for managing and conserving wetlands to ensure their ecological integrity and the services they provide to both wildlife and humans. The TH (Mg) data provides insights into the magnesium content in the wetland waters, which is important for understanding water hardness and its impact on aquatic organisms and ecosystem dynamics. Monitoring TH Mg levels is crucial for managing and conserving wetlands to ensure their ecological integrity and the services they provide to both wildlife and humans. Chloride data suggests varying levels of salinity in the wetlands, which can impact water quality, aquatic life, and ecosystem health. Monitoring Chloride concentrations is crucial for understanding and managing these wetland environments to ensure their ecological integrity and the services they provide to both wildlife and humans. Alkalinity range suggests varying levels of buffering capacity in the wetlands, which can impact water quality and the stability of aquatic ecosystems. Monitoring Alkalinity concentrations is crucial for understanding and managing these wetland environments to ensure their ecological integrity and the services they provide to both wildlife and humans.

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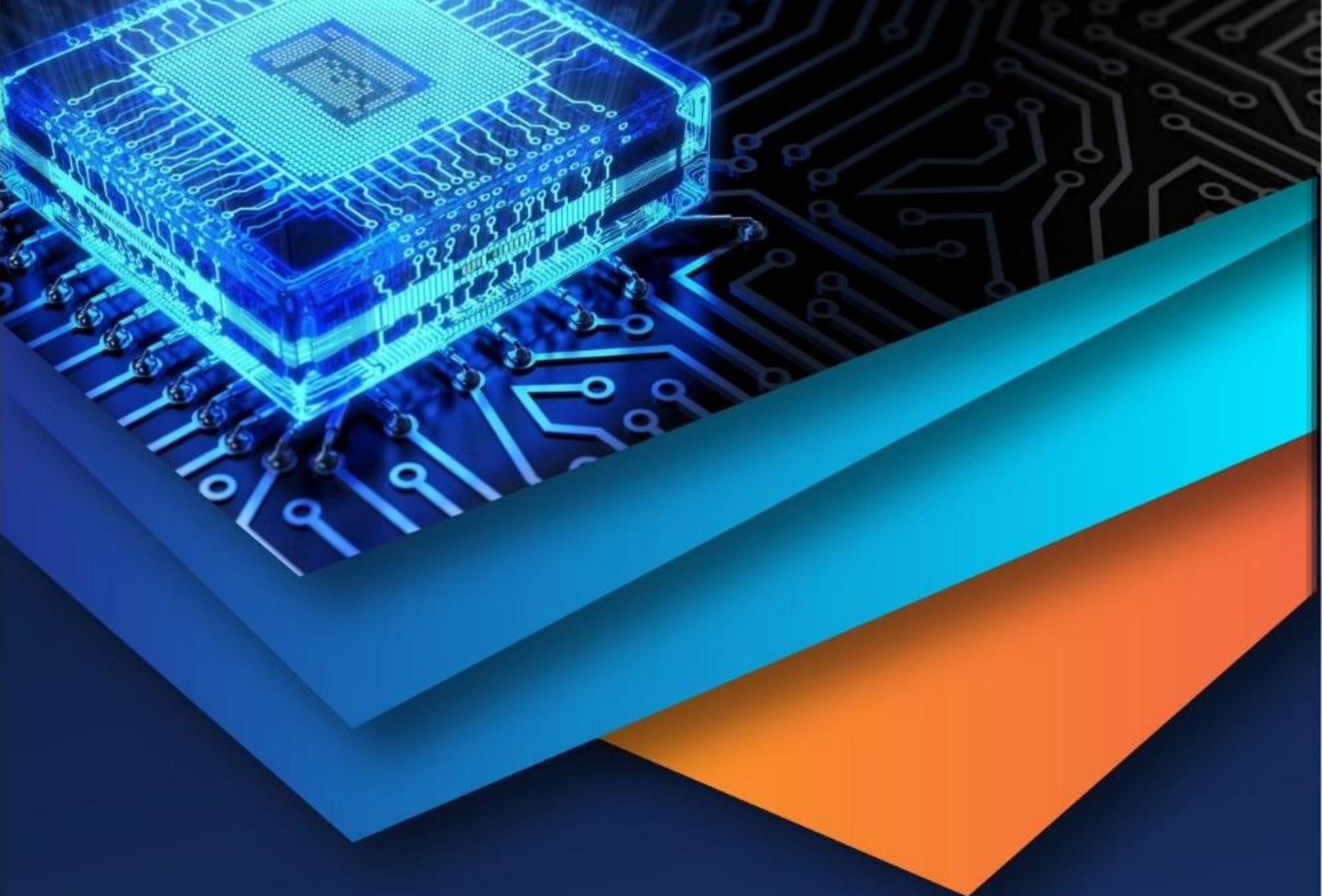

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