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Hydro-Edaphic Study For Ecological Significance Of Lokpalsagar Pond Of Panna District Of Madhya Pradesh

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ABSTRACT

The Lokpalsagar pond in Panna district of Madhya Pradesh holds significant ecological and hydrological importance as a key element of the local ecosystem. This study aims to evaluate the hydro-edaphic (soil-water) characteristics of the pond to better understand its ecological role. Parameters such as water quality, soil texture, and nutrient availability were assessed to determine their impact on biodiversity and ecosystem functions. The findings indicate that the pond serves as an important water source, especially during dry periods, and acts as a reservoir of nutrients and moisture. Water quality with balanced pH, adequate dissolved oxygen, and low contamination indicate that the pond is healthy and supportive of aquatic life. The pond plays an important role in maintaining the local ecosystem, contributing to biodiversity, and maintaining ecological balance in the area.

Keywords: Lokpalsagar pond, Hydro-Edaphic, Ecology, Biodiversity.

INTRODUCTION

The scientific study of inland waters such as lakes, rivers, and ponds, is a specialized field within aquatic sciences. Determining the exact number of limnological sources worldwide is quite challenging [1,2,3,4]. Global Limnology Research Community (GLRC), and the International Society of Limnology (SIL), Founded in 1922, are major organizations in the field, consisting of approximately 1,250 members from approximately 70 different countries [5]. The Global Lake Ecological Observatory Network (GLEON) is an international

grassroots network of researchers, educators, and community groups focused on high-frequency observations of lakes and reservoirs [6]. As of January 2021, GLEON has grown to include over 850 individual members from 62 countries on six continents, indicating that several thousand researchers worldwide are engaged in limnological studies, the exact number may vary depending on the scope of the area [6,7].

Limnology is vital to understanding and protecting freshwater ecosystems, which are essential to life on Earth [8, 9]. It supports water resource management by ensuring clean water for drinking, agriculture, and industry, and guides sustainable use. Limnologists study ecosystem health and biodiversity, focusing on how nutrients, pollutants, and invasive species affect aquatic life [10,11, 12]. They also monitor pollution, including eutrophication and acidification, which provides data for environmental regulation and lake restoration. Since lakes and ponds are sensitive to climate change, limnological research helps track changes in temperature, ice cover, and oxygen, predicting and mitigating impacts such as fish kills and water shortages [13, 14]. Limnology increases our understanding of biogeochemical cycles (carbon, nitrogen, phosphorus), informs fisheries and aquaculture management, and supports recreation and tourism by maintaining healthy waters. With nearly 2 billion people dependent on inland fisheries, limnology plays a vital role in ensuring global food and water security [15, 16].

Ponds, as small bodies of inland water, are an important focus within limnology. Research on pond ecosystems covers many aspects, including water quality, biodiversity, and the effects of human activities. Many studies and projects around the world are focused on pond-focused researchers who address pond-related issues [17,18]. The Lokpalsagar Pond is located in the southern part of India, specifically in the Panna district of Madhya Pradesh. Lokpalsagar Pond was constructed by Maharaja Lokpal Singh Judev in the year 1894. This pond is located near Pahari Kheda Road in Panna district at 80°13'129" East longitude and 24°43'2138' North latitude, (Figure 1). It is a relatively small but important water body spread over an area of about 35 hectares. The pond is surrounded by various landscapes, including agricultural fields and forest plots, which contribute to its ecological significance. The pond not only serves as a habitat for various aquatic species but also plays a vital role in local agriculture by supporting irrigation and biodiversity in the region. The main reason why the pond is important is its hydro-edaphic characteristics. Hydro-edaphic means the interaction of water (hydro) and soil (edaphic) [19,20], which together create a specific environment for living organisms, (Figure 2).

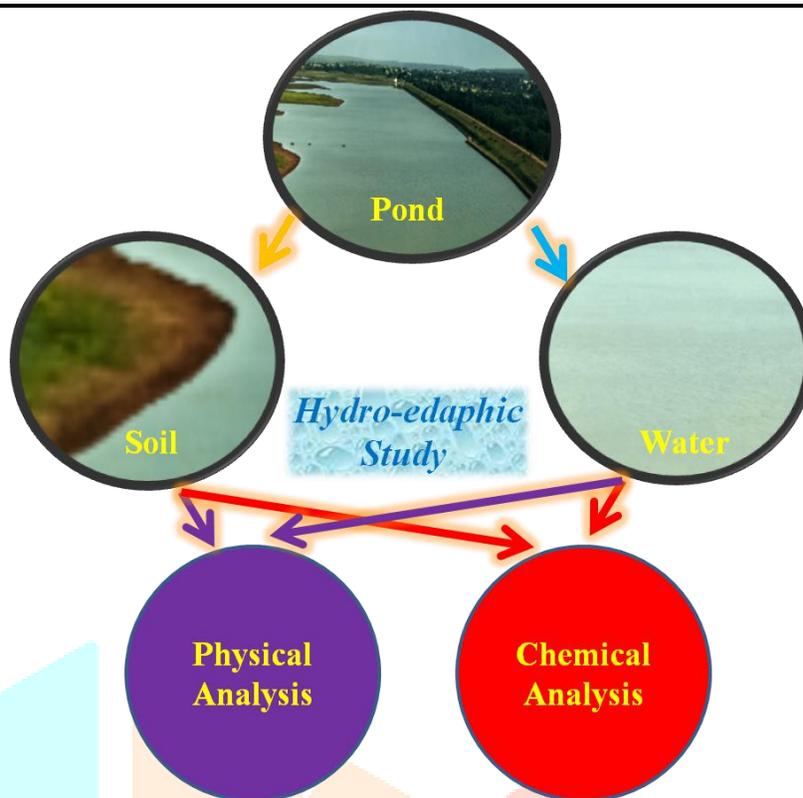


Figure 2: Structural study of Hydro-edaphic.

Water chemistry involves the analysis of various chemical components in water, including parameters such as pH, dissolved oxygen, temperature, and nutrient levels such as nitrogen and phosphorus [25, 26]. A balanced pH, typically between 6.5 and 9, is vital to the health of most fish species, as extreme increases in acidity or alkalinity can be harmful. Dissolved oxygen is vital for fish respiration, with higher oxygen levels promoting better health, diversity, and abundance among fish populations [27, 28]. Nutrients are essential for plant growth, which supports aquatic food webs; however, excessive nutrient levels can lead to problems such as algae blooms that deplete oxygen and negatively affect fish [29].

The composition of the soil at the bottom of a pond includes materials such as sand, silt, clay, and organic matter, which affect the feeding and shelter opportunities for fish. Sandy soils can provide habitat for species that like to lay eggs or hide, while muddy soils support benthic organisms that serve as food for fish. Furthermore, organic matter decomposes to release nutrients into the water, which increases plant growth and improves the habitat for fish.

MATERIALS AND METHODS

Selection of Pond sites

Water and soil samples were collected from four representative locations: Mongha (S1), Aghor (S2), Canal point (S3), and Filter point (S4) from the pond of Lokpalsagar in Panna district of Madhya Pradesh. To avoid contamination, gloves were worn and containers were cleaned before use. The containers were filled to the top

with the water and soil required for the investigation and were tightly sealed to minimize exposure to air. Each sample was labeled with the respective location and other relevant information. This process was carried out in different seasons including winter, summer, and rainy seasons over two years from November 2022 to October 2024.

Pond Water sample analysis

Physico-chemical analysis of pond water usually involves checking various five physical parameters (Temperature, Turbidity, Total dissolved solids, and Electrical conductivity) and chemical parameters (pH, DO, BOD, COD, TH, TA, Cl₂, NO₃, PO₄, SO₄, Fe, F,) properties to understand its quality and suitability for various purposes such as irrigation, drinking, and aquatic life. These properties included parameters such as pH, dissolved oxygen, temperature, hardness, alkalinity, salinity, and levels of various ions.

Physical analysis of water

Temperature was measured to determine the thermal state of the water, which affected the rate of chemical reactions and aquatic life. The temperature of the water sample was measured using a thermometer and recorded in degrees Celsius (°C) [30]. Turbidity measured the cloudiness or turbidity of the water sample due to suspended particles. A water sample was filled in a tube and turbidity was measured using a turbidimeter, which provides readings in nephelometric turbidity units (NTU) [31]. Total dissolved solids (TDS) was the sum of all substances dissolved in water, which was measured by evaporating the water and weighing the residue left. A known volume of water sample was taken and filtered to remove suspended particles. The filtrate was evaporated in a pre-weighed evaporation dish, and the residue was dried in an oven at 105 °C until a constant weight was obtained [32]. TDS was calculated as the difference in weight ' $TDS (mg/L) = (weight\ of\ residue \times 1000) / volume\ of\ sample$ '. The electrical conductivity was measured to directly calibrate the EC meter and analysis values were recorded [32].

Chemical analysis of water

For pH (acidity/alkalinity), a sample of water was taken in a clean beaker. The pH meter was calibrated with standard buffer solutions (pH 4, 7, and 9.2) [32,33]. The pH probe was dipped in the water sample, and the pH value was recorded as ' $pH = -\log [H^+]$ '.

Dissolved oxygen (DO) was measured, which is the amount of oxygen dissolved in water and is essential for aquatic life. It was measured using the Winkler method, which involved titration [32, 34]. A BOD bottle was filled with the water sample, manganese sulfate solution was added to the sample and shaken well, the alkali-iodide-azide reagent was added to the bottle and mixed, and concentrated sulfuric acid was added to the bottle and mixed again. The sample was titrated to the endpoint (yellow to colorless) with sodium thiosulfate solution,

and DO was calculated using the formula ' $DO \text{ in mg/L} = V1 * N * 8 / V2$ ', where $V1$ = volume of $Na_2S_2O_3$, N = normality of $Na_2S_2O_3$, and $V2$ = volume of sample. Biochemical oxygen demand (BOD) measures the oxygen consumed by microorganisms in water to decompose organic matter for 5 days. A BOD bottle was filled with a known volume of sample, initial dissolved oxygen (DO) was measured, the bottle was incubated at 20°C for 5 days, and the final DO was measured after 5 days [32,35,36]. BOD was calculated as the difference in oxygen levels ' $BOD \text{ in mg/L} = (DO_0 - DO_5) \times \text{dilution factor}$ '. Chemical oxygen demand (COD) was a measure of the oxygen required to chemically oxidize organic matter using a strong oxidizing agent such as potassium dichromate [32, 35, 37]. A known volume of water sample was taken, a known volume of potassium dichromate solution ($K_2Cr_2O_7$) was added in an acidic medium, the sample was heated for a specified time, and the excess dichromate was titrated with ferrous ammonium sulfate solution ' $COD \text{ (mg/L)} = (\text{volume of } K_2Cr_2O_7 \times N \times 8) / \text{volume of sample}$ '.

Total hardness (TH) was due to the presence of calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions in water. A known volume of water sample was taken and a few drops of Eriochrome Black T indicator were added to the sample. The sample was titrated with standard EDTA solution (disodium ethylenediaminetetraacetate) to the endpoint color change from wine red to blue [32,34, 37]. Total hardness was calculated using the formula ' $TH \text{ (mg/L)} = (V \times N \times 1000) / \text{volume of sample (mL)}$ '. Alkalinity measured the ability of water to neutralize acids and was mainly due to bicarbonate (HCO_3^-), carbonate (CO_3^{2-}), and hydroxide (OH^-). A known volume of water sample was taken, and a few drops of phenolphthalein indicator were added. The sample was titrated with standard sulfuric acid solution until the solution became colorless (for phenolphthalein alkalinity). Then, methyl orange was added, and titration was done again with acid to reach the endpoint (for total alkalinity) [32, 38]. Alkalinity was calculated from the titration as ' $Alkalinity \text{ (as } CaCO_3 \text{ in mg/L)} = (V \times N \times 1000) / \text{volume of sample}$ '.

Nitrate (NO_3^-) was measured by colorimetry method where nitrate reacted with reagents to form a colored complex, which was measured spectrophotometrically. A known volume of the sample was taken, a nitrate reagent (e.g., sulfanilic acid and NED reagent) was added, and the absorbance was measured at 540 nm using a spectrophotometer [32, 37, 39]. The nitrate concentration was calculated from a standard curve ' $Nitrate \text{ (mg/L)} = (\text{absorbance of sample}/\text{absorbance of standard}) \times \text{concentration of standard}$ '. Phosphates (PO_4^{3-}) reacted with ammonium molybdate and antimony potassium tartrate to form a blue color, which was measured spectrophotometrically. A known volume of water sample was taken. Solutions of ammonium molybdate and antimony potassium tartrate were added. Ascorbic acid was added to reduce phosphate. Absorbance was measured at 880 nm using a spectrophotometer [32, 35, 37]. Phosphate concentrations were calculated using a standard curve ' $Phosphate \text{ (mg/L)} = (\text{absorbance of sample}/\text{absorbance of standard}) \times \text{concentration of standard}$ '. Sulfates (SO_4^{2-}) were measured by precipitation with barium chloride ($BaCl_2$), forming barium sulfate ($BaSO_4$). A known volume of sample was taken. Barium chloride ($BaCl_2$) was added to precipitate

barium sulfate (BaSO_4) [32]. The precipitate was filtered and washed, then dried and weighed, and the sulfate concentration was calculated as '*Sulfate (mg/liter) = (weight of $\text{BaSO}_4 \times 1000) / \text{volume of sample}$* '.

Water samples were collected in clean, acid-washed bottles. The sample contained suspended solids; it was filtered through a $0.45 \mu\text{m}$ filter to remove the particles. The pH of the water sample was measured and adjusted to 4.5 using hydrochloric acid. In a clean beaker, 25 mL of the filtered water sample was added, 1.0 mL of ammonium acetate buffer solution, and 1 mL of 1,10-phenanthroline solution, which formed a colored complex with iron (Fe) [32,33,38]. The solution was stirred using a magnetic stirrer for approximately 5 min to ensure a complete reaction. After allowing the solution to stand for 10 min to develop color, the absorbance of the solution was measured at 510 nm using a spectrophotometer. The calibration curve was then used to determine the iron concentration in the water sample based on the absorbance. Collect water samples in clean, acid-washed bottles. Ensure samples are preserved if not analyzed immediately. Filter the sample with a $0.45 \mu\text{m}$ filter to remove particles. Measure the pH of the water sample. Adjust the pH to approximately 4.5 to 5.0 using a buffer solution. Calibrate the fluoride ion-selective electrode using a standard fluoride (F) solution of known concentration [32, 39, 40].

Pond Soil sample analysis

To analyze the physicochemical properties of the pond soil, several tests were carried out to assess parameters such as pH, Texture, Organic Carbon, and Nutrients (Nitrate, phosphorus, and Potassium).

Soil pH measures the acidity or alkalinity of the soil, which affects nutrient availability and microbial activity. Soil pH was measured using a pH meter or indicator solution. A sample of soil was taken and mixed with distilled water in a 1:1 ratio. The mixture was stirred and allowed to settle for about 15-30 minutes. The pH of the suspension was measured using a pH meter or pH indicator paper [32, 36].

Soil texture (particle size distribution) was determined by the relative proportions of sand, silt, and clay particles, which affected water retention, aeration, and nutrient availability. A sample of dry soil was collected, and either the hydrometer method or the sedimentation method was performed. The soil was mixed with water and a dispersing agent (such as sodium hexametaphosphate), and the soil particles were allowed to settle. The sand particles settled first, followed by the silt, while the clay remained suspended [41]. The distribution of particles was measured at different time intervals. Texture was expressed using the formula: *Sand (%) = (weight of sand/total weight of sample) × 100*, *Silt (%) = (weight of silt/total weight of sample) × 100*, *Clay (%) = (weight of clay/total weight of sample) × 100*.

The amount of organic matter in soil affects nutrient and water retention and was estimated using the Walkley-Black method or loss on ignition. One gram of soil was put into a beaker, followed by the addition of 10 mL of 1 N $\text{K}_2\text{Cr}_2\text{O}_7$ solution (potassium dichromate) and 20 mL of concentrated H_2SO_4 . The mixture was stirred

and allowed to react for 30 min. Excess dichromate was titrated with ferrous ammonium sulfate (FAS), and the organic carbon content was calculated using the formula '*Organic carbon (%) = (titration value × 0.003 × 100)/sample weight*'.

Soil electrical conductivity (EC) measures the soluble salts in the soil, which indicates the salinity of the soil. The higher the EC, the higher the solute concentration. Twenty grams of soil was mixed with 40 mL distilled water, stirred for 30 min, and allowed to settle [32]. The EC of the supernatant was measured using a conductivity meter, whose formula was '*EC ($\mu\text{S}/\text{cm}$) = (conductivity reading) × (dilution factor)*'.

Nutrient estimation for nitrogen (N) indicated that nitrogen in the soil was mainly present as nitrate (NO_3^-). It was measured using the Kjeldahl method or colorimetry methods. Soil samples were digested with sulfuric acid and a catalyst to convert organic nitrogen to ammonium. The ammonium was distilled off and then titrated with a standard acid [32, 36]. Total nitrogen was calculated using the formula as '*total nitrogen (mg/kg) = (titration value × normality of HCl × volume of sample) / weight of soil*'. Phosphorus (P) in soil was usually measured using the colorimetry method, where phosphorus reacted with molybdate to form a blue complex. Phosphorus was extracted from the soil using a dilute acid solution (Bray-1/Olsen), and ammonium molybdate reagent was added [32, 35]. The color intensity was measured at 880 nm using a spectrophotometer, with the formula as '*phosphorus (mg/kg) = (absorbance of sample/absorbance of standard) × concentration of standard*'. Potassium (K) in soil was measured by flame photometry, where potassium ions emit a specific light at a specific wavelength when heated. Potassium was extracted from the soil using an ammonium acetate solution, and the concentration of potassium in the extract was measured using a flame photometer [32]. The formula used was '*potassium (mg/kg) = (emission intensity of sample/emission intensity of standard) × concentration of standard*'.

RESULTS AND DISCUSSIONS

Analysis of pond water

Physico-chemical analysis of the Lokpalasagar pond water was carried out to assess its quality and determine its suitability for various purposes including irrigation, drinking, and supporting aquatic life. The study focused on both physical and chemical parameters to gain a comprehensive understanding of the pond water quality. Physico-chemical analysis of pond water usually involves checking various five physical parameters (Temperature, Turbidity, Total dissolved solids, and Electrical conductivity) and chemical parameters (pH, DO, BOD, COD, TH, TA, N, P, S, Fe, F).

Physical analysis of water

The pond water temperature was analyzed during the years 2022-23 and 2023-24. In the year 2022-23, the highest average temperature was recorded at site S1 (25.64°C), while the lowest average temperature was

observed at site S4 (24.63°C). In contrast, during 2023-24, site S1 again showed the highest average temperature (25.72°C). The lowest average temperature of that year, 25.68°C, was recorded at three sites: S2, S3, and S4. The investigation found that the maximum temperature was observed at site S1 in 2023-24, while the lowest temperature was recorded at site S4 in 2022-23, (Figure 3).

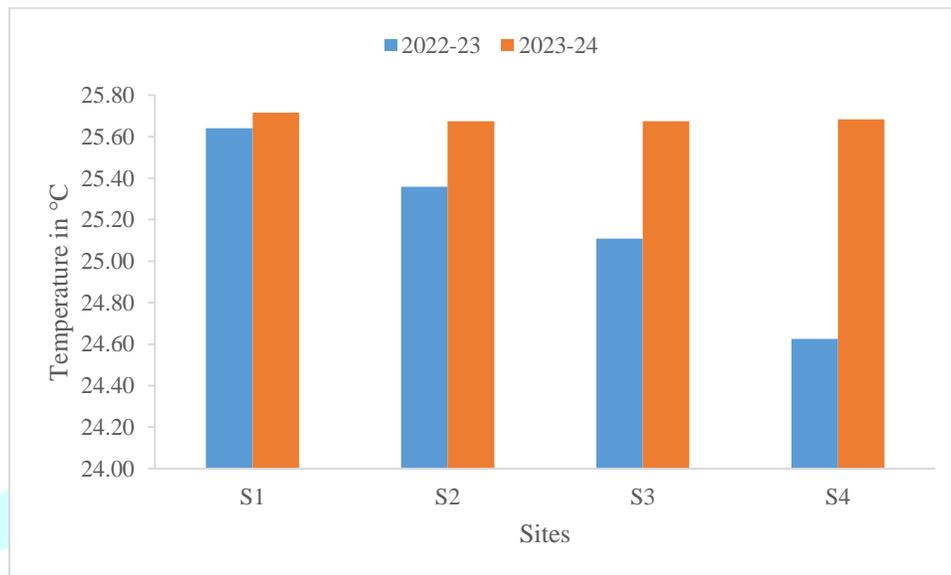


Figure 3: Analysis of water temperature (°C) from different sites of the pond over two years.

The pond water turbidity was analyzed for the years 2022-23 and 2023-24. In 2022-23, the highest average turbidity was recorded at site S1 of 3.08 NTU, while the lowest turbidity was observed at site S4 of 2.71 NTU. The following year, 2023-24, the highest average turbidity was shared by sites S2 and S3, both at 3.02 NTU. The lowest average turbidity during this period was again recorded at site S4, with a value of 2.75 NTU. The investigation concluded that in both years, the highest turbidity was observed at site S1 in the year 2022-23, while the lowest turbidity was observed at site S4, (Figure 4).

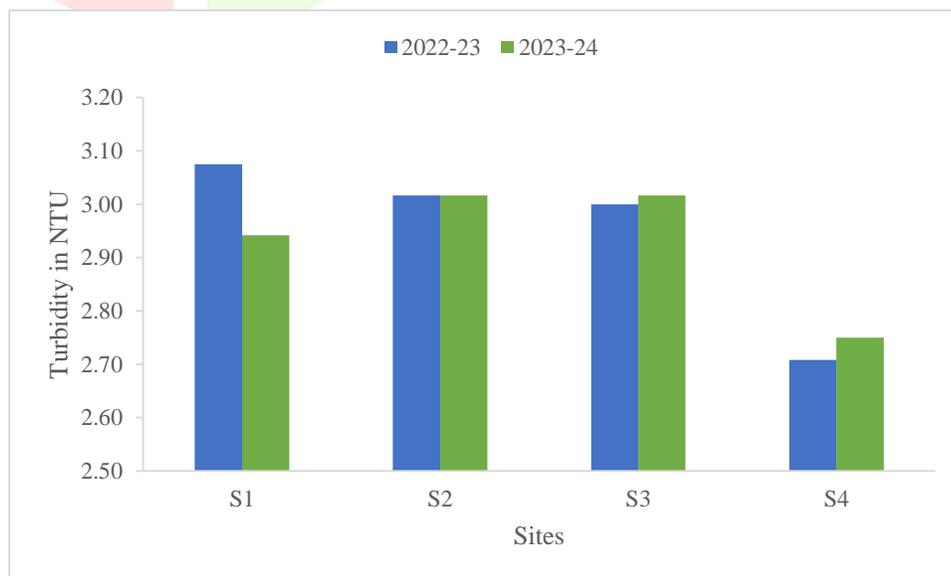


Figure 4: Analysis of water turbidity (NTU) from different sites of the pond over two years.

Total dissolved solids (TDS) in the pond water were analyzed over two years (2022-23 and 2023-24). TDS was a key indicator of water quality, indicating the concentration of dissolved substances such as minerals, salts, and organic matter. In 2022-23, the highest average TDS was recorded at site S4, with a value of 190.42 mg/L, indicating a relatively higher concentration of dissolved substances at this location. The lowest average TDS was observed at site S1, which was 171.0 mg/L. In 2023-24, the TDS value declined at all sites compared to the previous year. Interestingly, site S1, which had the lowest TDS last year, showed the highest average TDS this time at 159.92 mg/L. The lowest average TDS was recorded at site S2, with a value of 145.08 mg/L. This change showed a decrease in TDS levels from one year to another, possibly due to improved water quality, less pollution, or seasonal and environmental factors affecting the ponds. Based on the data, the maximum TDS was observed at site S4 in 2022-23, and the minimum TDS was at site S2 in 2023-24, (Figure 5).

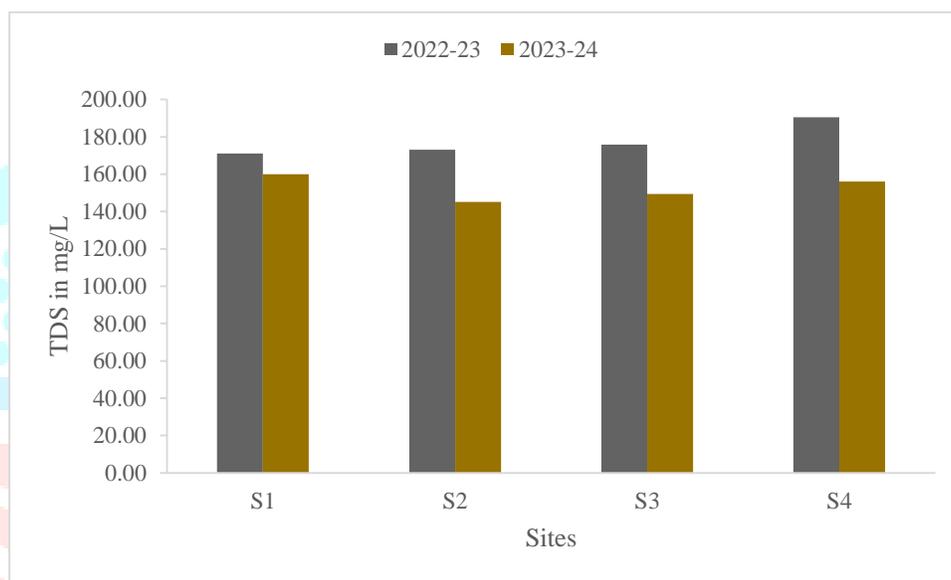


Figure 5: Analysis of water TDS from different sites of the pond over two years.

The electrical conductivity (EC) of the pond water was analyzed during the years 2022-23 and 2023-24. In 2022-23, the highest average EC was recorded at site S4, with a value of 418.54µS/cm, while the lowest average was observed at site S1, measuring 365.29µS/cm. In contrast, during 2023-24, site S4 again exhibited the highest average EC at 435.01µS/cm, while the lowest average EC was recorded at site S1 with a value of 398.63µS/cm. Overall, the investigation found that the maximum EC was observed at site S4 in 2023-24, while the lowest EC was recorded at site S1 in 2022-23, (Figure 6).

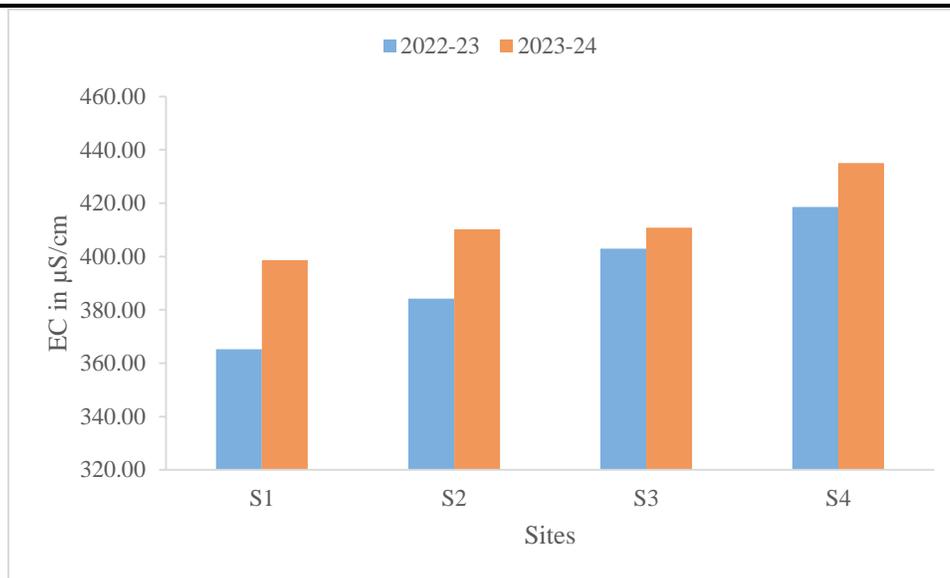


Figure 6: Analysis of water EC from different sites of the pond over two years.

Chemical analysis of water

The pH of pond water was analyzed in two years from 2022-23 and 2023-24. The pH is a key indicator of water quality, which reflects the quality of water with dissolved substances such as minerals, salts, and organic matter. In 2022-23, the highest average pH of 7.50 was recorded at site S4, and the lowest average pH of 7.23 was recorded at site S1. In 2023-24, the highest average pH of 7.75 was recorded at site S2, and the lowest average pH of 7.22 was recorded at site S4. Based on the analysis data of both years, the highest pH was found at site S2 in the year 2023-24 and the lowest pH was found at site S4 in the same year, (Figure 7).



Figure 7: Analysis of water pH from different sites of the pond over two years.

The dissolved oxygen (DO) of pond water was analyzed in two years from 2022-23 and 2023-24. The DO is a key indicator of oxygen amount in water, which reflects the quality of water with dissolved oxygen with

minerals, salts, organic matter, and living organisms. In 2022-23, the highest average DO of 7.19 mg/L was recorded at site S2, and the lowest average DO of 7.13 mg/L was recorded at site S4. In 2023-24, the highest average DO of 7.18 mg/L was recorded at site S2, and the lowest average DO of 7.08 mg/L was recorded at site S3. Based on the analysis data of both the years, the highest DO was found at site S2 in the year 2022-23 and the lowest DO was found at site S3 in 2023-24, (Figure 8).

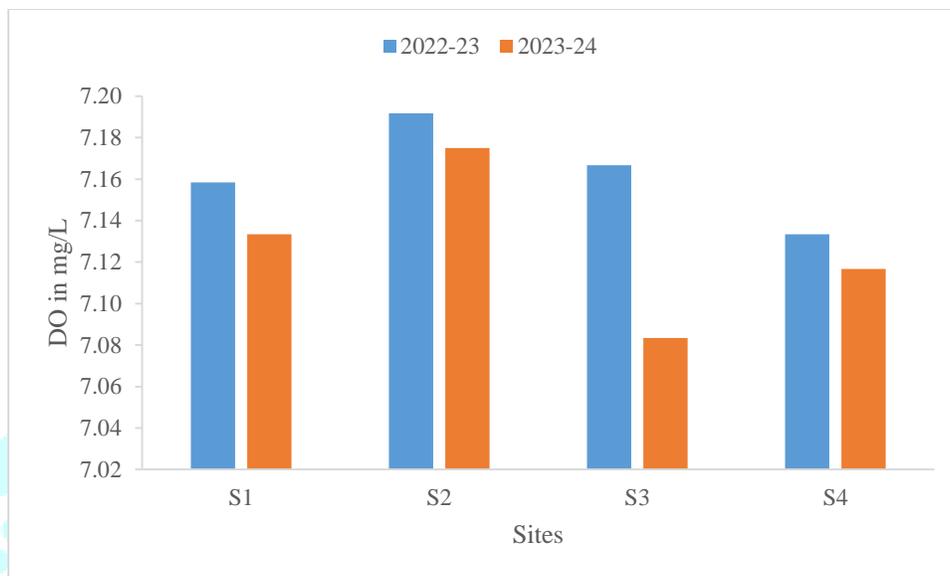


Figure 8: Analysis of water DO from different sites of the pond over two years.

The biological oxygen demand (BOD) of pond water was analyzed in two years from 2022-23 and 2023-24. The BOD is a key indicator of water quality, which reflects the quality of water with dissolved oxygen with minerals, salts, organic matter, and living organisms. In 2022-23, the highest average BOD of 1.92 mg/L was recorded at site S1, and the lowest average BOD of 1.62 mg/L was recorded at site S3. In 2023-24, the highest average BOD of 1.76 mg/L was recorded at site S1, and the lowest average BOD of 1.62 mg/L was recorded at site S3. Based on the analysis data of both years, the highest BOD was found at site S1 in the year 2022-23 and the lowest BOD was found at site S3 in both years, (Figure 9).

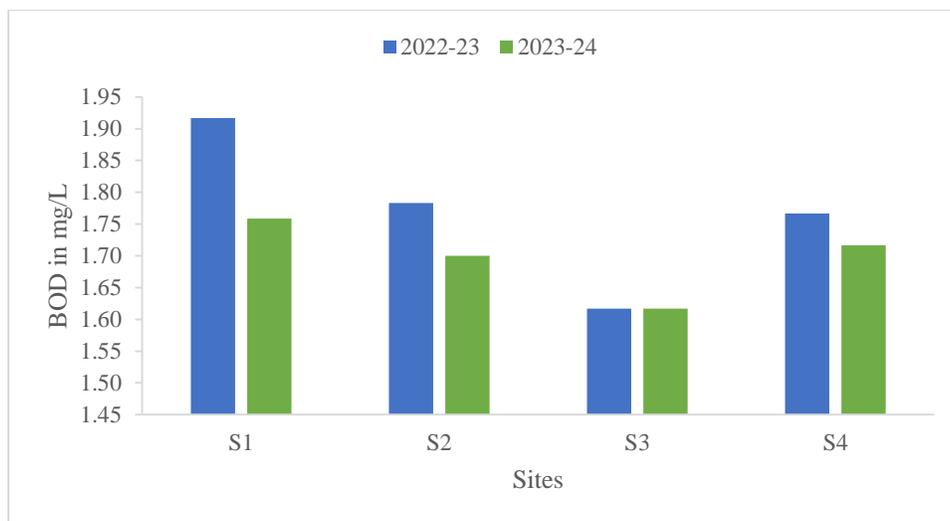


Figure 9: Analysis of water BOD from different sites of the pond over two years.

The chemical oxygen demand (COD) of pond water was analyzed in two years from 2022-23 and 2023-24. The COD is a key indicator of oxygen amount in water, which reflects the quality of water with dissolved oxygen with organic matter. In 2022-23, the highest average COD of 12.13 mg/L was recorded at site S2, and the lowest average COD of 11.68 mg/L was recorded at site S3. In 2023-24, the highest average COD of 12.11 mg/L was recorded at site S3, and the lowest average COD of 11.27 mg/L was recorded at site S1. Based on the analysis data of both the years, the highest COD was found at site S2 in the year 2022-23 and the lowest COD was found at site S1 in 2023-24, (Figure 10).

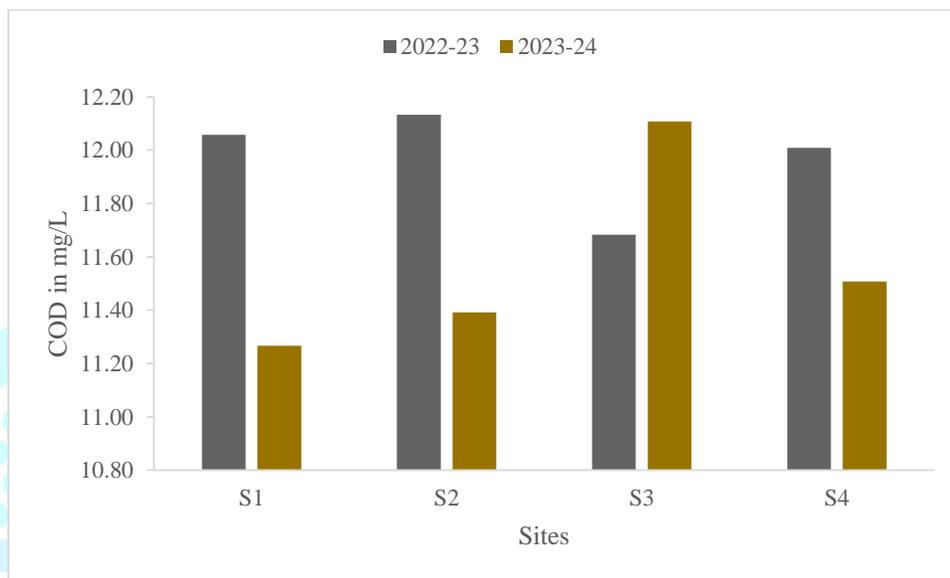


Figure 10: Analysis of water COD from different sites of the pond over two years.

The total hardness (TH) of pond water was analyzed in two years from 2022-23 and 2023-24. In 2022-23, the highest average TH of 131.17 mg/L was recorded at site S1, and the lowest average TH of 86.92 mg/L was recorded at site S4. In 2023-24, the highest average TH of 128.33 mg/L was recorded at site S1, and the lowest average TH of 103.58 mg/L was recorded at site S4. Based on the analysis data of both years, the highest TH was found at site S1 in the year 2022-23 and the lowest TH was found at site S4 in the same year, (Figure 11).

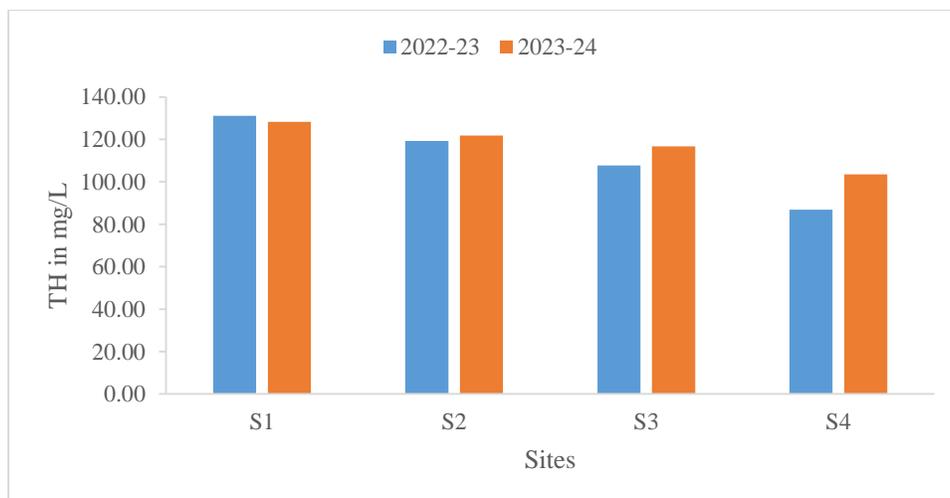


Figure 11: Analysis of water TH from different sites of the pond over two years.

The total alkalinity (TA) of pond water was analyzed in two years from 2022-23 and 2023-24. In 2022-23, the highest average TA of 164.92 mg/L was recorded at site S1, and the lowest average TA of 73.83 mg/L was recorded at site S4. In 2023-24, the highest average TA of 144.0 mg/L was recorded at site S1, and the lowest average TA of 80.33 mg/L was recorded at site S4. Based on the analysis data of both years, the highest TA was found at site S1 in the year 2022-23 and the lowest TA was found at site S4 in the same year, (Figure 12).

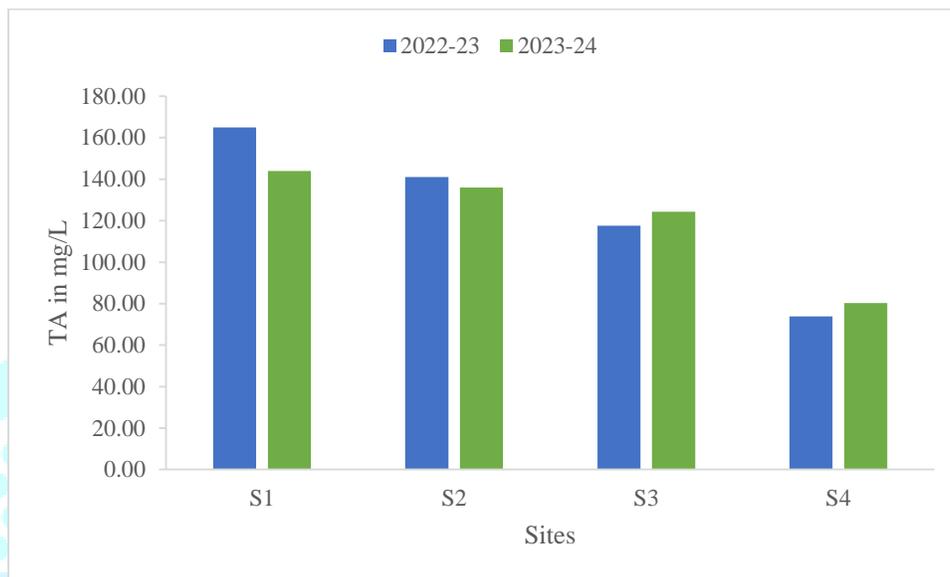


Figure 12: Analysis of water TA from different sites of the pond over two years.

The nitrate of pond water was analyzed in two years from 2022-23 and 2023-24. In 2022-23, the highest average nitrate of 10.50 mg/L was recorded at site S1, and the lowest average nitrate of 3.88 mg/L was recorded at site S4. In 2023-24, the highest average nitrate of 10.08 mg/L was recorded at sites S1 and S3, and the lowest average nitrate of 7.77 mg/L was recorded at site S4. Based on the analysis data of both years, the highest nitrate was found at site S1 in the year 2022-23 and the lowest nitrate was found at site S4 in the same year, (Figure 13).

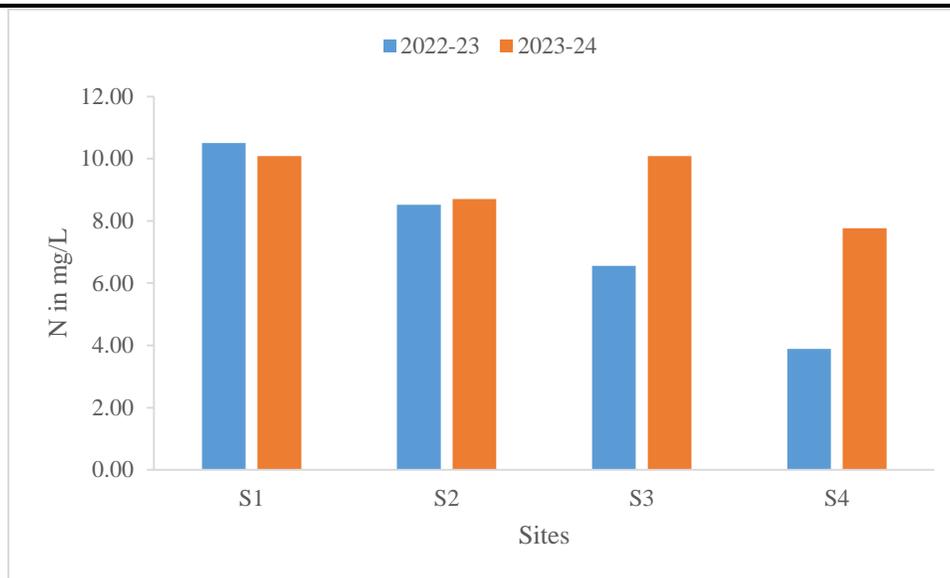


Figure 13: Analysis of water nitrate from different sites of the pond over two years.

The phosphorous of pond water was analyzed in two years from 2022-23 and 2023-24. In 2022-23, the highest average phosphorous of 0.02 mg/L was recorded at site S2, and the lowest average phosphorous of 0.01 mg/L was recorded at sites S1, and S4. In 2023-24, the highest average phosphorous of 0.03 mg/L was recorded at site S2, and the lowest average phosphorous of 0.01 mg/L was recorded at site S4. Based on the analysis data of both years, the highest phosphorous was found at site S2 in the year 2023-24 and the lowest nitrate phosphorous was found at site S4 in the same year, (Figure 14).



Figure 14: Analysis of water phosphorous from different sites of the pond over two years.

In the years 2022-23 and 2023-24, sulfate (S) concentrations were measured in four water samples (S1, S2, S3, and S4), with values recorded in milligrams per liter (mg/L). The data revealed varying sulfate levels in the two years. In the year 2022-23, S1 had the highest sulfate concentration at 123.17 mg/L, suggesting significant sulfate presence due to industrial discharge or natural mineral weathering. S2 showed a concentration of 90.50

mg/L, which was also high but lower than S1, possibly indicating a different source or dilution factor. S3 had a sulfate concentration of 58.17 mg/L, which was still relatively high but possibly reflects a natural level or some dilution. S4 had the lowest concentration at 15.25 mg/L, indicating either a naturally low sulfate environment or minimal pollution impact. In 2023-24, sulfate levels decreased in most samples. S1 decreased to 54.00 mg/L, indicating a significant decrease due to changes in industrial activity, and environmental regulations improved water treatment. S2 decreased to 41.50 mg/L, which may indicate a reduction in sulfate sources or changes in water flow. S3 saw a sharp decrease to 29.25 mg/L, possibly due to improved water quality management or seasonal effects. S4 saw a slight increase to 15.58 mg/L, possibly due to natural variation or minor changes in water chemistry. Most samples (S1, S2, and S3) saw a significant decrease in sulfate concentrations from 2022-23 to 2023-24, indicating improvements in water quality or a reduction in industrial discharges, (Figure 15). The slight increase in S4 may be due to natural fluctuations. These changes reflect broader environmental changes or adjustments in local water management practices.

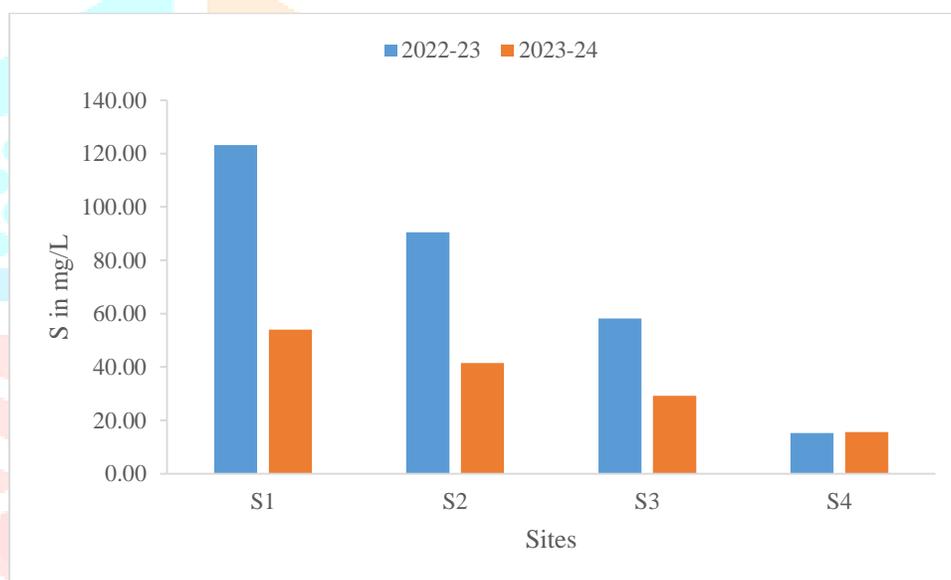


Figure 15: Analysis of water sulfate from different sites of the pond over two years.

In the years 2022-23 and 2023-24, iron (Fe) concentrations were measured in four samples (S1, S2, S3, and S4), recorded in milligrams per liter (mg/L). The data showed a significant decrease in iron levels over the two years. In the year 2022-23, iron concentration in S1 was 0.25 mg/L, which was close to the upper limit of the normal range, indicating a moderate presence of iron. S2 had a slightly lower concentration of 0.22 mg/L, which was still within the same range, indicating moderate levels of iron. S3 had the lowest concentration of 0.20 mg/L but was still within the acceptable range. S4 was similar to S3, with a concentration of 0.23 mg/L, suggesting slightly higher iron levels than S3, but was still within the normal range. In 2023-24, all samples showed a decrease in iron concentrations. S1 decreased to 0.18 mg/L, indicating a slight decrease, possibly due to changes in water composition or improvements in treatment methods. S2 decreased to 0.14 mg/L, indicating a decrease influenced by better water treatment or fewer pollution sources. S3 showed a further decrease to 0.12 mg/L, continuing the downward trend, possibly due to better water quality control. S4 showed

the smallest decrease, dropping to 0.11 mg/L, the lowest concentration recorded in both years, which may reflect natural variation or slight improvements in water quality. During the years 2022-23 to 2023-24, iron concentrations decreased in all four samples, indicating a decrease in the presence of iron, (Figure 16). These changes, although small, reflect possible improvements in water treatment, environmental conditions, or reduction in sources of iron contamination.

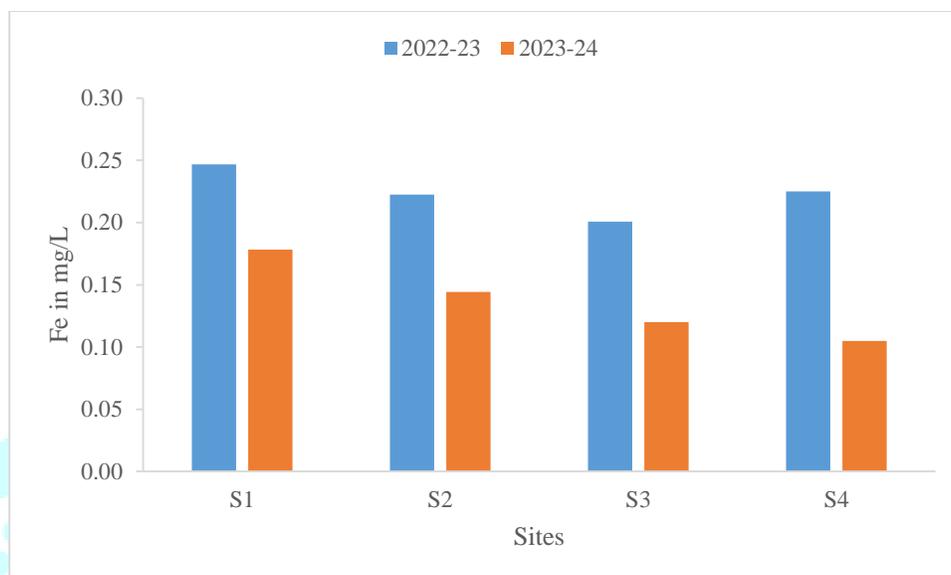


Figure 16: Analysis of water iron from different sites of the pond over two years.

In the years 2022-23 and 2023-24, fluoride (F) concentrations were measured in four samples (S1, S2, S3 and S4), recorded in milligrams per liter (mg/L). The data showed that there was a marginal increase in fluoride levels over the two years. In the year 2022-23, the fluoride concentration in S1 was 0.51 mg/L, which was at the lower end of the normal range (1.0-1.5 mg/L), indicating a moderate presence of fluoride. S2 had a similar concentration of 0.50 mg/L, suggesting fluoride levels comparable to S1. S3 had a slightly lower concentration of 0.49 mg/L, which was still within the acceptable limit, indicating relatively low fluoride presence. S4 had the lowest fluoride concentration at 0.48 mg/L, which was still within the normal range, but slightly lower than the other samples. In 2023-24, all samples showed a slight increase in fluoride concentrations. S1 increased to 0.53 mg/L, indicating a small increase that may reflect changes in local water sources or adjustments in water treatment processes. S2 increased to 0.52 mg/L, slightly higher than its previous value of 0.50 mg/L. S3 saw a more significant increase to 0.56 mg/L, while S4 also increased to 0.53 mg/L, a slight increase from 0.48 mg/L. From 2022-23 to 2023-24, fluoride concentrations increased in all four samples, indicating a gradual increase in fluoride levels in samples, possibly due to changes in water sources, treatment processes, or environmental factors, (Figure 17).

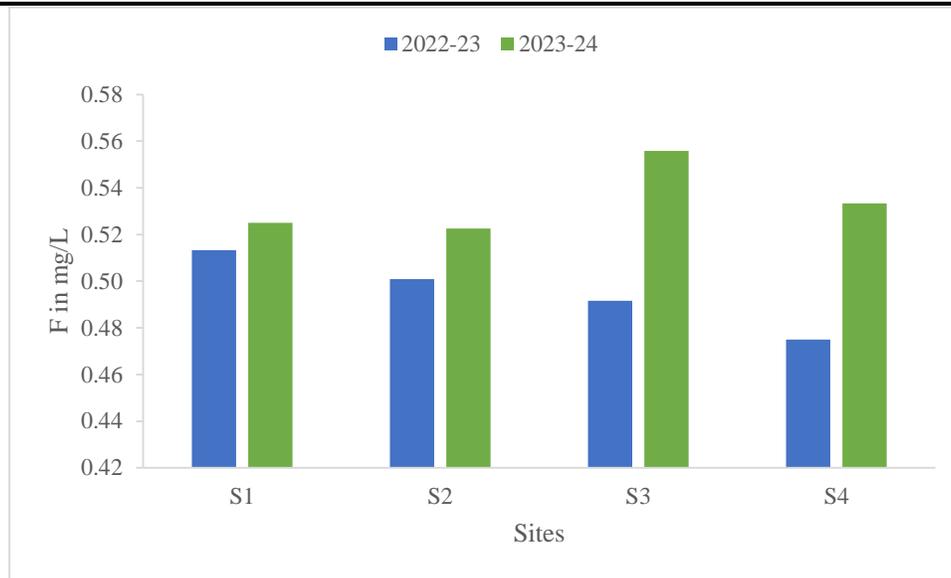


Figure 17: Analysis of water fluoride from different sites of the pond over two years.

Analysis of pond soil

Analysis of the physicochemical properties of the soil of the Lokpalasagar pond provided important information about its suitability for supporting biodiversity and ecological functions of the pond. The following parameters were tested pH, soil texture, organic carbon content, and concentrations of essential nutrients such as nitrate, phosphorus, and potassium [41].

Physical analysis of soil

There were significant changes in soil texture from the pre-monsoon to the post-monsoon period. The decrease in clay and silt and the increase in fine sand and silt at most locations probably reflect the effects of rainfall, erosion, and sediment redistribution. These changes indicate color changes in soil structure and composition, possibly influenced by the monsoon effect on the soil environment from four selected sites, (Figure 18).

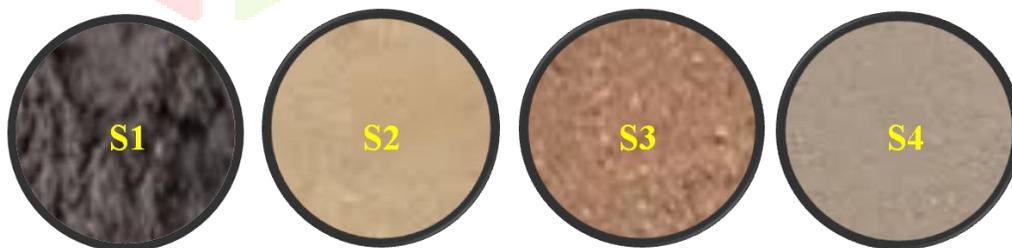


Figure 18: Soil samples of selected sites.

Soil texture analysis was carried out on 10-gram samples from four locations (S1, S2, S3, and S4), which recorded data for both pre-monsoon and post-monsoon periods, (Table 1). The analysis focused on the percentage of clay, silt, fine sand, and sand in the samples. In the pre-monsoon analysis, S1 contained 34% clay, 24% silt, 22% fine sand and 20% sand. S2 contained 38% clay, 27% silt, 20% fine sand and 15% sand. S3 contained 42% clay, 23% silt, 22% fine sand and 13% sand. S4 contained 36% clay, 22% silt, 24% fine

sand, and 18% sand, (Figure 19). In the post-monsoon analysis, S1 showed a decrease in clay (29%) and silt (21%), while fine sand increased to 31% and sand to 19%. S2 showed a decrease in clay (35%) and silt (15%), while fine sand increased to 23% and sand to 27%. S3 showed a decrease in clay (39%) and silt (13%), while fine sand increased to 24% and sand to 24%. S4 showed a marginal decrease in clay (35%) and silt (17%), while fine sand increased to 21% and sand to 27%, (Figure 20).

A decrease in clay content was observed at all locations in the post-monsoon period, indicating possible leaching effects and changes in the water-holding capacity of the soil [41]. Silt content also decreased, except at S1, where it decreased slightly, indicating structural changes in the soil between the two periods. Fine sand content increased at most locations, especially at S1 and S2, which may be attributed to changes in sedimentation or runoff patterns after monsoon rains. The sand content also increased at most locations, especially at S2, S3, and S4, which may indicate that the soil became more coarse due to the transfer of fine particles during rainfall, (Figure 21).

Table 1: Soil texture analysis from 10 gm samples of each site

Soil types	Size's	Pre-monsoon				Post-monsoon			
		S1	S2	S3	S4	S1	S2	S3	S4
Clay %	0.00-0.05 mm	34	38	42	36	29	35	39	35
Silt %	0.05-0.10 mm	24	27	23	22	21	15	13	17
Fine sand %	0.10-0.20 mm	22	20	22	24	31	23	24	21
Sand %	0.20-1.00 mm	20	15	13	18	19	27	24	27

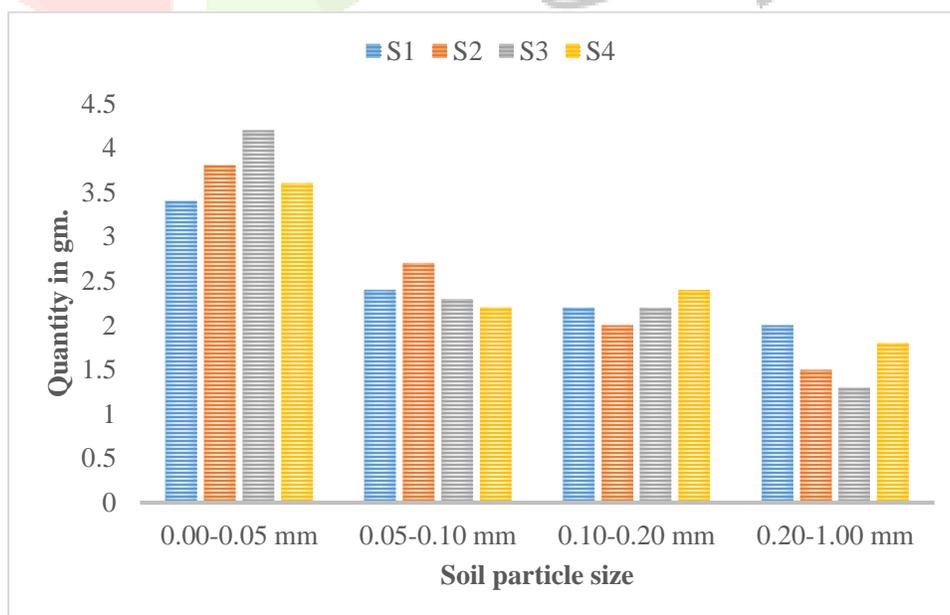


Figure 19: Soil texture from pre-monsoon

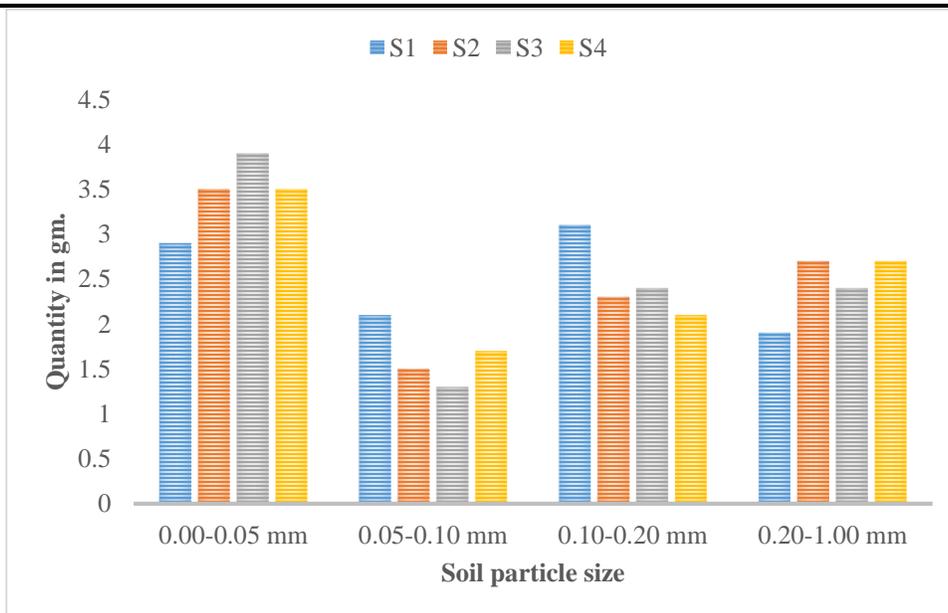


Figure 20: Soil texture from post-monsoon

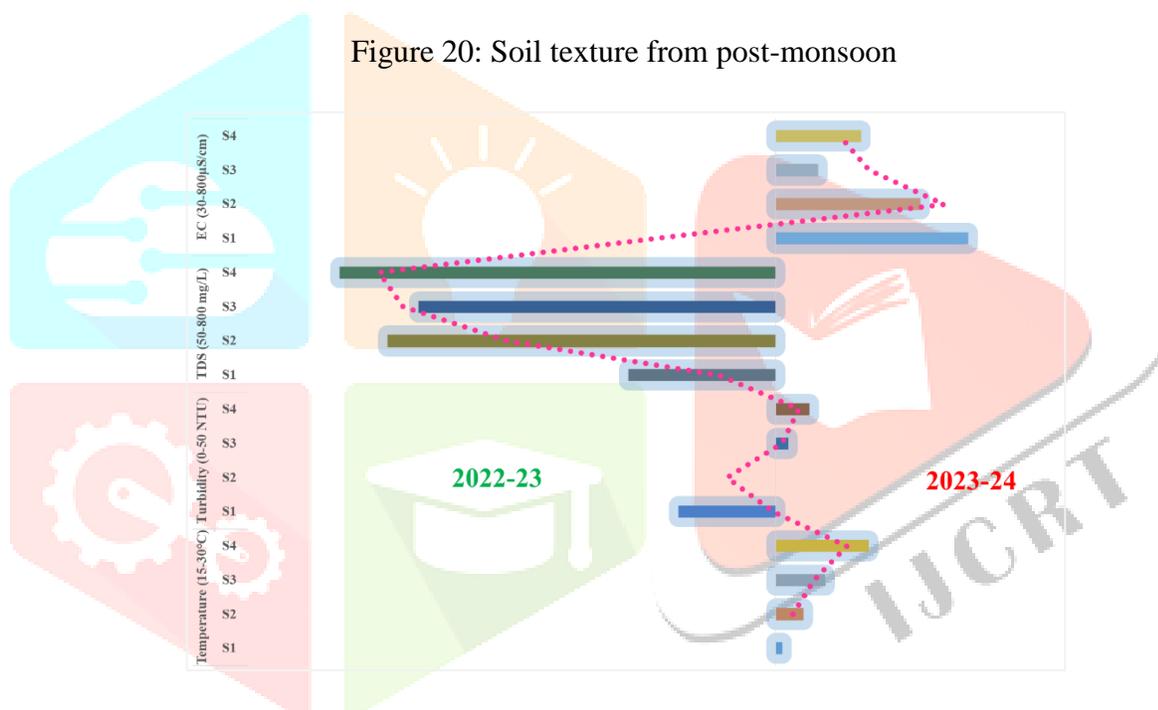


Figure 21: Segregation of physical parameters analysis of water b/w two years.

Soil pH was measured in samples taken from four locations (S1, S2, S3, and S4) during the periods 2022-23 and 2023-24. The pH values were within the acceptable range of 6.5 to 8.5, indicating slightly acidic to neutral conditions. In 2022-23, soil pH at S1 was 6.80, which was slightly alkaline but still within the normal range, indicating relatively neutral soil conditions. S2 had a pH of 6.71, slightly lower than S1, indicating a tendency towards slightly acidic conditions. S3 had a pH of 6.73, which was similar to S2, indicating slightly acidic to neutral conditions. S4 had a pH of 6.72, which was very close to S3 and S2, indicating similar neutral-to-slightly acidic conditions. In 2023-24, S1 showed a slight decrease in pH, dropping to 6.72, indicating a small shift towards a more neutral condition. S2 increased slightly to 6.73, remaining in the slightly acidic to neutral range. S3 decreased slightly to 6.66, indicating a move towards more acidic conditions. S4 had the lowest pH at 6.65, slightly lower than S3, indicating a shift towards more acidic soil conditions. From 2022-23 to 2023-

24, pH values decreased slightly in all four samples, (Figure 22). These changes were small but indicated a trend towards slightly more acidic conditions over the year.

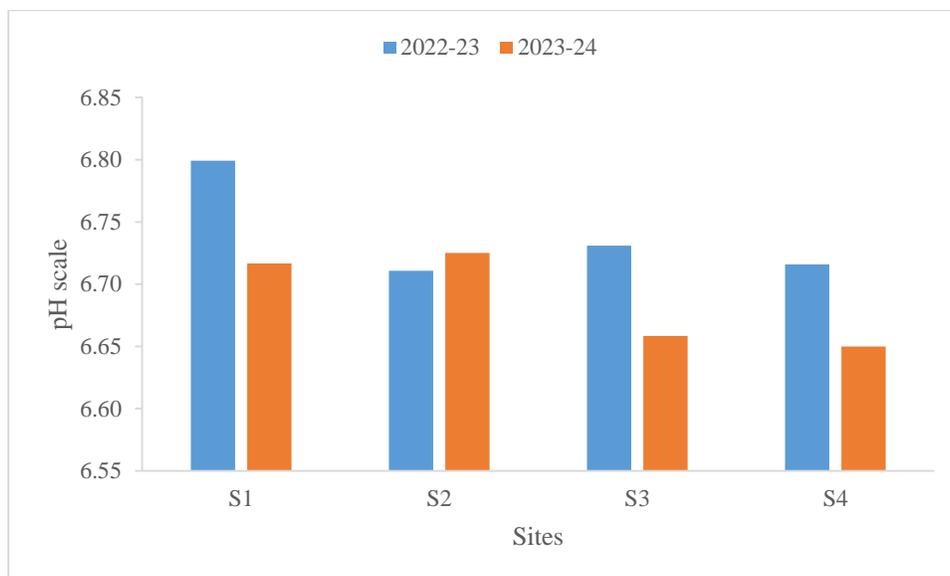


Figure 22: Analysis of soil pH from different sites of the pond over two years.

Organic carbon (OC) content in pond soil was measured for four different locations (S1, S2, S3, and S4) during the period 2022-23 and 2023-24. In the year 2022-23, the organic carbon content in S1 was 0.75%, which indicates a relatively moderate amount of organic matter in the pond soil. S2 had 0.79% organic carbon, which was slightly higher than S1, indicating that the pond soil in this area had slightly more organic matter. S3 had 0.78% organic carbon, which was very close to S2, indicating similar organic matter content in the soil. S4 had 0.74% organic carbon. S2 showed a decrease of 0.73%, slightly lower than the previous year's 0.79%. The most significant decrease was observed in S3, which fell to 0.67%, significantly lower than its previous value of 0.78%, indicating a more significant decrease in organic carbon content. S4 remained stable with 0.74% organic carbon, showing no change from the previous year, indicating similar levels of organic matter in pond soil at this site. From 2022-23 to 2023-24, organic carbon content decreased in three of the four samples (S1, S2, and S3), with the largest decrease observed in S3. The decrease in organic carbon may reflect changes in environmental conditions. S4 showed no change, indicating stability in organic matter content at this location, (Figure 23).

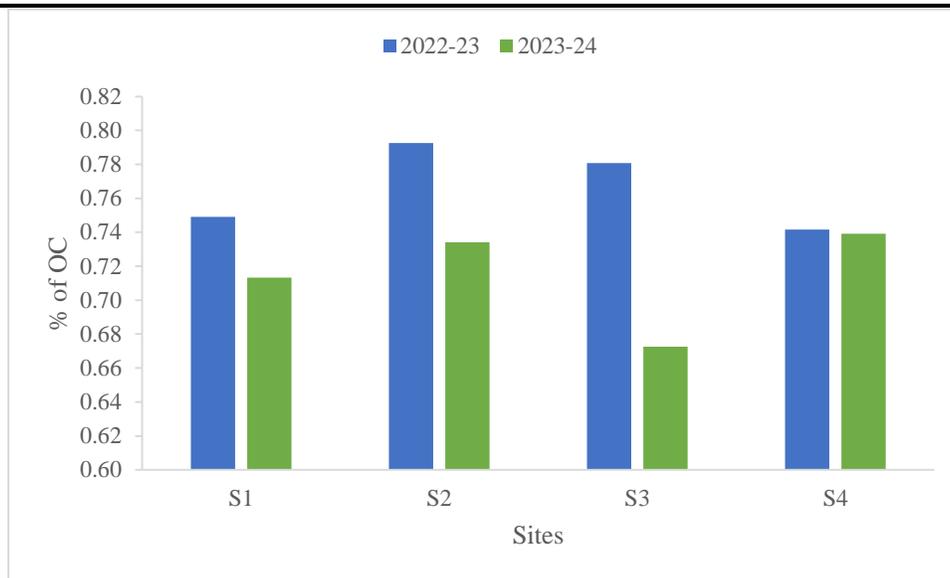


Figure 23: Analysis of soil OC from different sites of the pond over two years.

Nitrate concentrations in pond soil were measured for four locations (S1, S2, S3, and S4) during the period 2022-23 and 2023-24. In 2022-23, the nitrate concentration in S1 was 220.26 mg/kg, indicating relatively high levels of nitrate in the pond soil. The nitrate concentration in S2 was 213.32 mg/kg, slightly lower than S1, indicating moderate nitrate levels. S3 had the lowest nitrate concentration at 204.96 mg/kg, indicating low levels of nitrate. S4 showed a nitrate concentration of 217.05 mg/kg, which was higher than S3 but lower than S1, indicating moderate nitrate levels. In 2023-24, a slight increase was observed in S1 which was 224.05 mg/kg, indicating a slight increase in nitrate levels. S2 increased to 226.89 mg/kg, a significant increase over the previous year's 213.32 mg/kg. S3 increased to 215.70 mg/kg, showing an increase from 204.96 mg/kg. S4 increased marginally to 218.01 mg/kg. From 2022-23 to 2023-24, nitrate concentrations increased in all four samples, although the increases were relatively small, indicating a slight overall increase in nitrate levels in pond soil, (Figure 24).

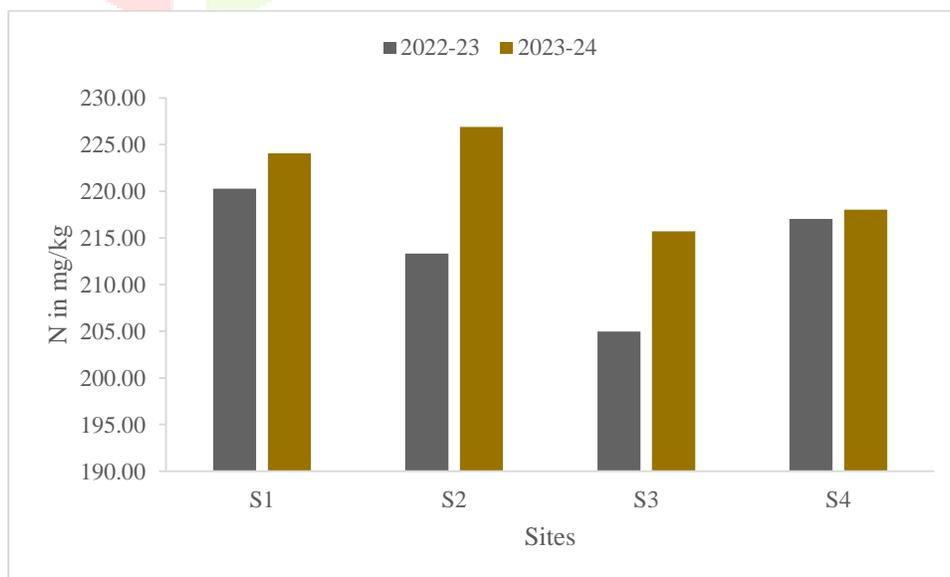


Figure 24: Analysis of soil nitrate from different sites of the pond over two years.

Phosphorus (P) concentrations in pond soil were measured at four locations (S1, S2, S3, and S4) during the periods 2022-23 and 2023-24. In 2022-23, the phosphorus concentration in S1 was 14.90 mg/kg, indicating relatively high amounts of phosphorus. The concentration in S2 was 14.34 mg/kg, which was slightly lower than S1, but still high. S3 was 13.67 mg/kg, which was slightly lower than S1 and S2, indicating moderate phosphorus levels. S4 was 13.90 mg/kg, which was similar to S3, indicating moderately high levels of phosphorus. In 2023-24, phosphorus concentrations decreased slightly in all samples. S1 decreased to 14.83 mg/kg, S2 decreased to 14.31 mg/kg, S3 decreased to 13.63 mg/kg, and S4 decreased to 13.87 mg/kg. These decreases were minimal, but indicate a slight decrease in phosphorus concentrations at all locations. From 2022-23 to 2023-24, phosphorus concentrations decreased slightly at all four locations, indicating a small but noticeable decrease in phosphorus levels in pond soil throughout the year, (Figure 25).

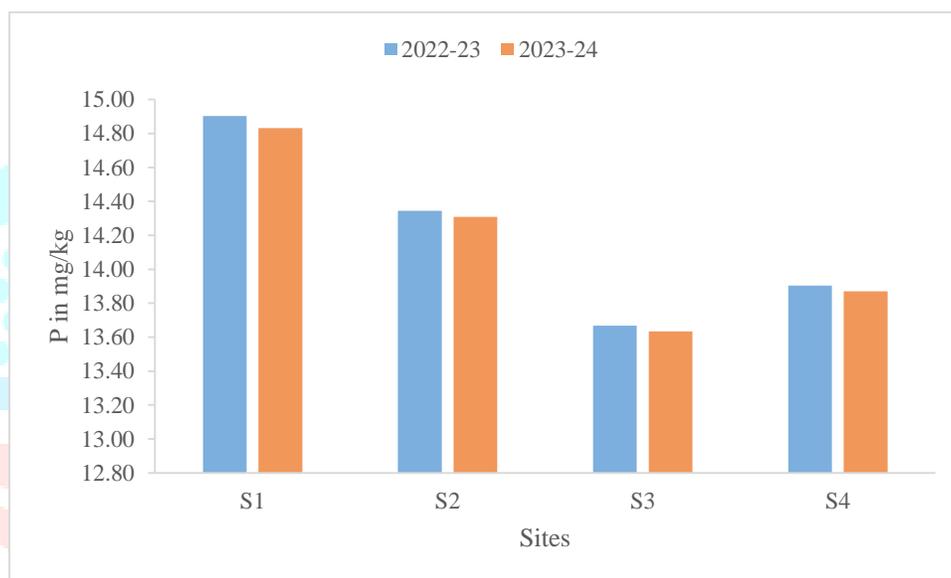


Figure 25: Analysis of soil phosphorous from different sites of the pond over two years.

Potassium (K) concentrations were measured in pond soil at four different locations (S1, S2, S3, and S4) during the periods 2022-23 and 2023-24. In 2022-23, the potassium concentration at S1 was 214.28 mg/kg, indicating relatively high levels of potassium in the soil. At S2, the potassium concentration was 212.88 mg/kg, slightly lower than S1, but still high. S3 showed 212.24 mg/kg, similar to S2, indicating moderate levels of potassium. The concentration at S4 was 199.61 mg/kg, the lowest among the samples, indicating low potassium levels. In 2023-24, a slight increase in potassium concentration was observed at S1, increasing from 214.28 mg/kg to 216.19 mg/kg. A more significant increase was observed in S2, which increased from 212.88 mg/kg the previous year to 219.68 mg/kg. A slight increase was also observed in S3, which increased from 212.24 mg/l to 217.61 mg/kg. A slight increase was observed in S4, which increased from 199.61 mg/kg to 200.08 mg/kg. From 2022-23 to 2023-24, potassium concentrations increased marginally in all four samples, indicating a general increase in potassium levels in pond soils at all locations, (Figure 26).

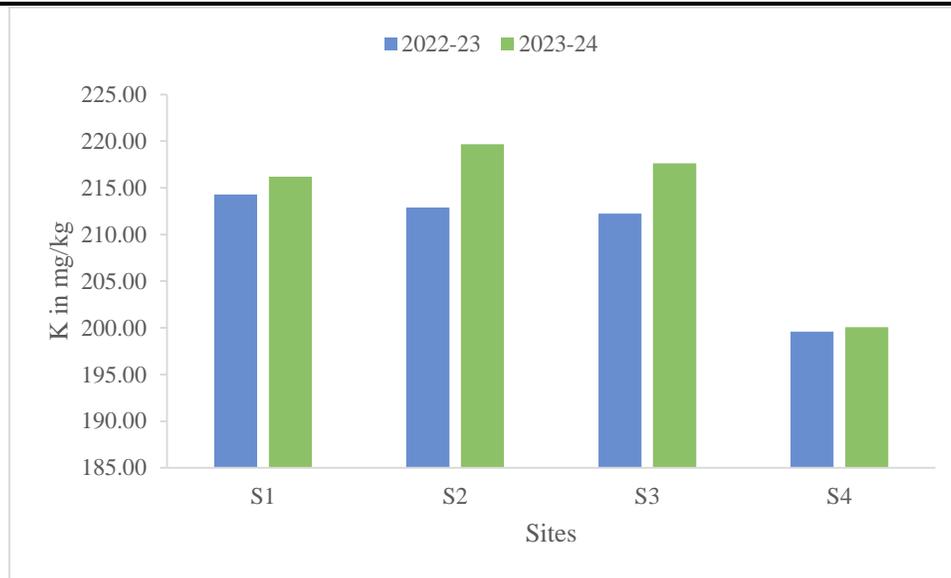


Figure 26: Analysis of soil potassium from different sites of the pond over two years.

CONCLUSION

The present investigation focuses on the hydro-edaphic properties of the Lokpalasagar pond, examining various physical and chemical parameters of both water and soil. The investigation highlights the important role of hydro-edaphic properties in supporting biodiversity and promoting sustainable development within the pond ecosystem. Despite some fluctuations in the data, it is clear that maintaining stable water and soil quality sustainability of the pond. Based on a comparative analysis of pond water and soil over two consecutive years (2022-2023 and 2023-2024) at four sampling sites (S1, S2, S3, and S4), several important observations have been made regarding both the physicochemical properties of water and soil quality.

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