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Seasonal Variation in Physicochemical Parameters of Kot Dam, Jhunjhunu, Rajasthan, India

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ABSTRACT:
Water is a vital resource for the survival and existence of life on Earth. Lakes and surface water bodies represent vital freshwater resources in the ecosystem and offer several benefits. Lakes and surface water bodies are vital for regulating local climates, serving as natural water storage systems and offering key services to human populations, including irrigation, recreation and potable water supply. Evaluating the physicochemical qualities of water is crucial prior to its use for drinking, residential, agricultural or industrial applications. Consistent assessment of water quality measures, including pH, turbidity, dissolved oxygen and mineral composition, can yield significant insights into its overall status and potential hazards. We conducted current study from summer 2021 to winter 2022-23 to evaluate the seasonal variations in the physicochemical parameters of Kot Dam. We determined three sampling stations to evaluate the physico-chemical parameters of Kot Dam. Summer season had highest temperature as compared to monsoon and winter. Seasonal variation and other climatic factors, such as cloud cover, sunlight and sun positions, also influenced the water transparency. pH limits of Kot dam were observed between 6.84 to 7.45, and higher pH was observed during winter season as compare to other season. Electrical conductivity of Kot Dam ranges from 485 to 592.3 µmhos/cm. TDS value of Kot dam ranges between 320 to 382 mg/l, while hardness values range from 117 to 172 mg/l. Calcium ion concentrations ranged from 24.36 to 38.25 mg/l,and highest magnesium level in winter 2022–23 (17.96 mg/l) was at sampling station I and the lowest level in summer 2022 (11.99 mg/l) was at sampling station III. Concentrations of chloride at Kot Dam ranged from 75.75 to 87.75 mg/l. Value of alkalinity ranges between 114 to 128.75 mg/l. Value of dissolved oxygen ranged between 2.40 mg/l to 4.72 mg/l. Amount of fluoride was observed between 0.1 ppm to 0.11 ppm. During study, we found that highest concentration of BOD was in summer season at all three sampling stations and lowest was in monsoon season. Similarly, during study, we observed the seasonal fluctuations in COD in different seasons as well as

different sampling stations. Understanding these characteristics is critical for implementing appropriate treatment measures and ensuring the health of ecosystems, crops and human populations that rely on water sources. Furthermore, modern technology, such as bio-monitoring and remote sensing, can improve conventional water quality assessment procedures, resulting in a more comprehensive understanding of aquatic ecosystem health and its potential long-term implications for water resources.

Keywords:
Fresh water, physicochemical parameter, Kot dam, Season, Variation, Water quality.

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1. INTRODUCTION

Water is an essential resource for the survival and existence of life on earth. Lakes and surface water are important freshwater resources in the environment and they provide several advantages. People use lakes and surface water reservoirs for household and irrigation needs, and they also function as habitats for aquatic organisms especially fish, which not only provide essential protein but also add to the world's biological diversity. Fresh water is necessary for the maintenance of human life, agriculture, industry and consumption. An adequate supply and purity of fresh water are essential for sustainable development (Mahananda *et al.,* 2005). On Earth, fresh water is scarce, with 69.9% hidden beneath continental glaciers and 30.1% subterranean. Dams, rivers, lakes and other reservoirs comprise only 0.26% of the freshwater supply. In lakes, water comprises approximately 0.007% of the global freshwater supply. Freshwater environment is currently facing significant threats due to several issues, such as the overexploitation of biodiversity, alterations in water flow, contamination of water, destruction or deterioration of habitat and invasion of non-native species. Contamination of various chemicals and pollutants can have detrimental effects on the health of freshwater ecosystems, such as eutrophication, acidification and pesticide contamination (Dudgeon *et al.,* 2006). It is essential to assess physicochemical properties of water before using it for drinking, home, agricultural or industrial purposes. The intended use of water and desired level of quality and purity solely determine the selection of the tested criteria. Rapid process of industrialization and uncontrolled use of chemical fertilizers and pesticides in agriculture result in significant and diverse contamination in aquatic ecosystems. This pollution is leading to a decline in water quality and depletion of aquatic organisms and overall biodiversity of aquatic ecosystem. Use of polluted water causes a variety of health issues in the human population, including waterborne diseases. It is necessary to regularly monitor water quality (Lilly Florence, 2013). Various factors, including the physicochemical qualities of the habitat, biotic factors and climatic change, influence occurrence and distribution of plankton fauna (Rajagopal *et al.,* 2010; Ahmad *et al.,* 2011; Chishty and Choudhary, 2022 a & b).

Bio-monitoring is now a crucial component of water pollution research and significantly adds to the investigation of water quality assessment. Physicochemical properties and stability of an aquatic environment significantly dictate its way of life. Any aquatic system's physicochemical condition intimately links to its biological productivity (Sharma *et al.,* 2013). Physicochemical parameters are the optimal indicators for assessing the water quality of any aquatic environment. Even a small change in physicochemical characteristics impacts diversity of the ecosystem. Elements such as temperature, light, dissolved oxygen, pH, electric conductivity and nutrients influence phytoplankton composition, biomass and diversity in tropical reservoirs (Padisak *et al.*, 2010; Stomp *et al.*, 2011). Gannon and Stemberger (1978) and Neves *et al.* (2003) found that regular monitoring of specific physicochemical parameters is necessary to maintain a suitable habitat for organisms in terms of water quality. Climate, physicochemical and biological factors influence the structure and distribution of plankton communities (Gannon and Stemberger, 1978; Neves *et al.*, 2003; Chishty and Choudhary 2022 a&b). Ayoade *et al.* (2006), Oso and Fagbauro (2008) and Idowu *et al.* (2013) have demonstrated the potential correlation between these fluctuations and factors like temperature and rainfall. In present study, we conducted an assessment of seasonal variation in physicochemical parameters of Kot Dam, Jhunjhunu, Rajasthan. During study, we analyze the following physicochemical parameters: water temperature, transparency or depth of visibility, pH, electrical conductivity, total dissolved solids, hardness, calcium ions, magnesium ions, chloride ions, alkalinity, dissolved oxygen, fluoride, biochemical oxygen demand (BOD) and chemical oxygen demand (COD).

2. MATERIAL AND METHODS

Shakambhari hills are located opposite the Sarju Sagar Dam, often known as the Kot Dam. Shakambhari hills are located in Jhunjhunu, Rajasthan, India and are thirteen kilometers away from the town of Udaipurwati. Constructed between 1923 and 1924, the dam was constructed to retain water and facilitate irrigation for the adjacent region. "Saptrupi River" originates from the Kot Dam and extends to Udaipurwati. We conducted study from summer 2021 to winter 2022-23 to evaluate seasonal fluctuations in the physicochemical parameters of various sampling stations at Kot Dam. During course of study, water samples were collected from three sampling stations, namely sampling stations I, II and III. Physicochemical assessments were performed following the guidelines established by APHA (2012). On location temperature measurements were conducted with a Celsius thermometer to ensure accuracy. A calibrated digital pH meter was utilized to measure pH levels and a portable conductivity meter was employed to evaluate electrical conductivity. These measurements are essential for assessing overall water quality and possible environmental effects. Water transparency was assessed using a standard 20 cm diameter Secchi disk, while water pH was measured in situ with a digital pH meter. A digital WTW meter was employed to measure total dissolved solids, electrical conductivity and temperature in situ. Standardized tools and techniques, including the Secchi disk for measuring water clarity and digital meters for assessing pH, conductivity and temperature, ensure consistent and reliable data collection across sampling sites. These parameters are essential indicators of water quality, providing insights into nutrient content, pollution levels and the health of aquatic ecosystems. On-going assessment of these parameters aids in detecting temporal variations and informing water management strategies for the protection of aquatic environments. Total hardness, chlorides, alkalinity and dissolved oxygen were measured through titration methods. Field measurements yield critical data regarding the physicochemical properties of aquatic environments. Titration method used for assessing total hardness, chlorides, alkalinity and dissolved oxygen enables precise measurement of these important water quality parameters.

3. RESULT AND DISCUSSION

1. Water Temperature: Water temperature is a critical determinant in the growth of organisms and, thus, overall quality of the water (Pandey *et al.*, 2012). Water is susceptible to various types of contamination, including particulate matter, dissolved oxygen, suspended solids, microbiological agents and bacterial contamination. Water temperature plays a crucial role in regulating various abiotic factors and biotic activities within an aquatic ecosystem (Sharma and Sarang, 2004; Radhika *et al.*, 2004). This also represents the dynamics of living organisms, including metabolic and physiological behavior in aquatic habitats (Sahni and Yadav, 2012). Summer 2022 recorded the highest temperature at station I (28.87°C) followed by summer 2021 (27.86°C), monsoon 2022 (27°C) and monsoon 2021 (26.09°C) (Table 1). Winter season recorded the lowest temperature (winter 2022-23 = 17.9°C; winter 2021-22 = 16.2°C). Station II recorded the highest temperature in summer 2022 (28.97°C) followed by summer 2021 (28.94°C), monsoon 2021 (27.14°C), monsoon 2022 (27.12°C) and lowest temperature in winter season (winter 2022-23 = 18.22°C; winter 2021-22 = 17.78°C) (Table 1). Station III recorded the highest temperature in summer 2021 (27.36°C) followed by summer 2022 (27.32°C), monsoon (monsoon 2021= 26.30°C; monsoon 2022 =24.70°C) and lowest temperature in the winter season (winter 2022-23 = 18.4°C; winter 2021-22 = 17.82°C) (Table 1). Soni and Thomas (2013) conducted a study on physicochemical parameters of Dakor sacred wetland, Anand, Gujarat. They found that summer season has the highest water temperature compared to monsoon. Kumar *et al.* (2010) observed similar trends at the Sabarmati River and Kharicat Canal, Ahmedabad, while Chishty and Choudhary (2022a) also found similar temperature trends in the Berach River of Udaipur district.

2. Water Transparency: According to Ewebiyi *et al.* (2015) the water transparency serves as an indicator of overall water quality, revealing presence or absence of suspended matter, whether living or inert. Monsoon 2021 recorded the highest transparency at station I (33.15cm) followed by monsoon 2022 (33.12cm), winter 2022-23 (31.97cm) and winter 2021-22 (31.45cm). Summer season recorded the lowest transparency (summer 2021 = 30.32cm; summer 2022 = 29.175cm) (Table 1). Monsoon 2022 (28.97cm) recorded the highest transparency at station II followed by monsoon 2021 (32.71cm), winter 2022-23 (31.55cm) and winter 2021-22 (30.67cm). Summer season (summer 2022 = 28.60cm; summer 2021 = 28.59cm) recorded the lowest transparency (Table 1). At station III, the winter season (winter 2022-23 = 31.75cm; winter 2021-22 = 31.63cm) had the highest water transparency followed by the monsoon 2022 (29.28cm), summer 2021 (28.93cm), summer 2022 (28.62cm) and monsoon 2021 (27.95cm), which had the lowest transparency (Table 1). Water transparency, as measured by the Secchi disk, exhibited the highest turbidity in November (Ewebiyi *et al.,* 2015). Decrease in sunlight intensity may result from heavy cloud cover in the atmosphere, which subsequently reduces the amount of light reaching the water, thereby diminishing light penetration (Anetekhai, 1986; Oso and Fagbuaro, 2008). Minimum turbidity occurred in December, February and March, indicating higher transparency. Ibrahim *et al.* (2009) attribute this phenomenon to a decrease in allochthonous substances entering the reservoir. During study, we observed distinct trends in water transparency at three separate stations. We found the highest water transparency in monsoon seasons at sampling stations I and II, while at sampling station III we observed the highest water transparency in winter season. Variations in water transparency occur due to the presence of daylight variations and cloudy environments during the sampling process. Presence of daylight and climatic conditions, as well as cloud cover availability, also influenced the overall transparency of the water body (Anetekhai, 1986; Oso and Fagbuaro, 2008).

3. pH= Globally, people use the term "pH" to describe how acidic or alkaline a solution. The majority of the waters exhibit a slight acidity. pH is a widely recognized analysis in soil and water testing, serving as the standard measure of the acidity or alkalinity of a solution. The measurement is on a scale from 0 to 14. The pH scale indicates that a pH of 7 is neutral, while a pH below 7 signifies acidity and a pH above 7 indicates basicity. Aquatic organisms require the pH levels of their aquatic environments to remain within a specific range to ensure optimal growth and survival. Acid rain can decrease the pH levels of lakes, resulting in increased acidity. Boyd and Lichtkoppler (1979) indicated that the optimal pH range for supporting aquatic life, including fish is between 6.09 and 8.45.

At station I, we recorded the maximum pH in winter season (winter 2021-22 and winter 2022-23 = 7.14 at each station) followed by monsoon 2021 (7.09), monsoon (7.08) and minimum pH in summer season (summer 2022 = 6.95; summer 2021 = 6.84) (Table 1). At station II, winter season recorded the highest pH (winter 2022-23 = 7.33; winter 2021-22 = 7.32) followed by summer (summer 2022= 7.27; summer 2021=7.24), while monsoon season recorded the lowest pH (monsoon 2022 = 7.13; monsoon 2021 = 7.12) (Table 1). At station III, the winter season recorded the highest pH value (winter 2021-22 = 7.45; winter 2022-23 = 7.42) followed by summer 2021 (7.35), monsoon 2022 (7.31), summer 2022 (7.29) and monsoon 2021 (7.16) (Table 1). During observation, we found that the highest pH value was in winter season at all three stations and the lowest pH value in monsoon season. Other studies, including Tiwari and Chauhan (2006), Aher *et al.* (2007) and Samrat *et al.* (2012) also observed similar trends. Heavy inflow of fresh water into the water body during the monsoon caused the low pH value (Samrat *et al.*, 2012; Chishty and Choudhary 2022 a). Higher pH value in winter might be due to high photosynthetic activity. Furthermore, origin of the water and the characteristics of the landscape affect pH level. It plays a significant role in the physicochemical balance of water and varies in accordance with the dissolution and precipitation of minerals (Belghiti *et al.*, 2013; Benrabah *et al.*, 2016).

4. Electrical conductivity: Electrical conductivity quantifies the ability of water to transmit electric current. This indicates the total concentration of dissolved salts (Dahiya and Kaur, 1999). Electrical conductivity (EC) quantifies the capacity of a solution to conduct electric current. Electrical conductivity serves as a rapid method for estimating the concentration of ions or soluble salts in soils, water supplies, fertilizer solutions and chemical solutions. We conduct the measurement using an EC meter, which evaluates the resistance water presents between two platinized electrodes. We calibrate the instrument using established conductance values from a standard KCl solution. Ewebiyi *et al.* (2015) define electrical conductivity as a measure of a material's capacity to conduct electric current. Conductivity serves as the most effective indicator of water pollution, functioning as an indirect measure of total dissolved solids or nutrients (Pandey *et al.*, 2012). Electrical conductivity of water of Kot dam was measured in micromhos per centimeter (µmhos/cm). At station I, we measured the highest electrical conductivity in summer 2021 (592.3 µmhos/cm) followed by summer 2022 (587.5 µmhos/cm), winter 2021-22 (523 µmhos/cm) and winter 2022-23 (520 µmhos/cm), with the monsoon season recording lowest conductivity (monsoon 2021 = 487 µmhos/cm; monsoon 2022 = 485 µmhos/cm) (Table 1). At station II, we measured the highest electrical conductivity during summer season (summer 2022 = 550 µmhos/cm; summer 2021 = 546 µmhos/cm) followed by winter season (winter 2022-23 = 520 µmhos/cm; winter 2021-22 = 519.65 µmhos/cm) and the lowest during monsoon season (monsoon 2022 = 517.50 µmhos/cm; monsoon 2021 = 516.76 µmhos/cm) (Table 1). At station III, we measured the highest electrical conductivity during the summer season (summer 2021 = 563.41 µmhos/cm; summer 2022 = 562.50 µmhos/cm) followed by the monsoon (monsoon 2021 = 561.42 µmhos/cm; monsoon 2022 = 548.37 µmhos/cm) and the lowest electrical conductivity during the winter season (winter 2021-22 = 506.15 µmhos/cm; winter 2022-23 = 505 µmhos/cm) (Table 1). Dirican (2015) studied the water conductivity of Camligoze Lake and found that the conductivity ranged from 335 to 342 µmhos/cm at surface level, whereas it was 339 µmhos/cm to 341 µmhos/cm at the 10-meter water of Camlıgoze Dam Lake. During study, we found the value of electrical conductivity ranges between 485 to 592.3 µmhos/cm at sampling station I, 516.76 to 550 µmhos/cm at sampling station II and 505 to 563.41 µmhos/cm at sampling station III (Table 1). Polat (1997) asserts that a lake becomes contaminated or polluted when its conductivity surpasses 1000 µmhos/cm. Conductivity value of Kot dam was within normal and low ranges, as per established norms. Conductivity and mineral buildup fluctuated significantly based on the season and the aquatic environment (Baijot *et al.*, 1997).

5. Total dissolved solid (TDS): Total dissolved solids (TDS) are the total amount of positively or negatively charged ions, such as minerals, salts, or metals, dissolved in a given volume of water in mg/l. TDS closely correlates with water purity and the quality of a water purification system, influencing everything that consumes, inhabits, or uses water, whether organic or inorganic, to varying degrees. Calcium, magnesium, potassium and sodium are cations, while carbonates, nitrates, bicarbonates, chlorides and sulfates are anions. Total dissolved solids indicate the salinity of groundwater Rao and Venkateswaralu (2000) recommend against using water with TDS levels above 500 mg/l for drinking water sources, but they tolerate levels up to 1500 mg/l in exceptional cases. Carbonate, bicarbonate, chloride, sulfate, phosphate, nitrate, Ca, Mg, Na, K, Fe and Mn, among others, make up the majority of total dissolved solids (TDS) in natural water (Esmaeili and Johal, 2005). Pond water samples with a high total dissolved solids concentration had a greater ionic concentration, which has a lower mobility and may have an adverse physicochemical effect on consumers. We recorded the highest TDS value in summer (summer 2021=382 mg/l; summer 2022 =380 mg/l) followed by winter (winter 2021-22= 327 mg/l; winter 2022-23= 326 mg/l) and lowest TDS value in monsoon season (monsoon 2021 = 324 mg/l; monsoon 2022 = 320 mg/l) (Table 1). At station II, we observed the highest TDS value during summer season (summer 2022 = 355 mg/l; summer 2021 = 351 mg/l) followed by monsoon season (monsoon 2022 = 340.50 mg/l; monsoon 2021 = 339.81 mg/l) and lowest value during the winter season (winter 2022-23 = 325 mg/l; winter 2021-22 = 324.11 mg/l) (Table 1). At station III, we observed the highest TDS value during monsoon 2021 (364.20 mg/l) followed by the summer season (summer 2021 = 364.10 mg/l; summer 2022 = 362.50 mg/l), monsoon 2022 (353.04 mg/l) and winter season (winter 2022-23 = 321.50 mg/l; winter 2021-22 = 321.34 mg/l) (Table 1). Dwivedi, A.P. (2017) studied total dissolved solid content in the Mandakini River and they found that the TDS ranged from 118 to 548 mg/l at different sampling stations. During study, we found the value of TDS of Kot dam ranges between 320 to 382 mg/l for sampling station I, 324.11 to 355 mg/l at sampling station II, and 321.34 to 364.20 mg/l at sampling station III(Table 1). Sharma *et al.* (2017) carried out a study on the hardness of different lentic water bodies in the Himalayan region of Himachal Pradesh and found that the total hardness ranged from 12 mg/l (pond-1) to 84 mg/l (pond-3). Except for Pond 1 (monsoon), the winter season yielded the highest value, while the summer season reported the lowest. Current study revealed that sampling stations I (summer 2021 = 382 mg/l; summer 2022 = 380 mg/l) and II (summer 2022 = 355 mg/l; summer 2021 = 351 mg/l) recorded the highest TDS values during the summer season. Meanwhile, at sampling station III, we recorded the highest TDS value during the monsoon of 2021 (364.20 mg/l) (Table 1). Dhanze *et al.* (2002) and Kaur and Sharma (2001) also documented the peak TDS value in summer.

6. Hardness: The sum of the calcium and magnesium hardness, expressed in milligrams per liter as $CaCO_3$, is the total hardness. As $CaCO_3$, total hardness in fresh water typically ranges from 15 to 375 mg/l. At station I, winter season had the highest hardness value (winter 2021-22 = 172 mg/l; winter 2022-23 = 169 mg/l) followed by monsoon season (monsoon 2022 = 158.5 mg/l; monsoon 2021 = 157.36 mg/l) and summer season (summer 2022 = 126 mg/l; summer 2021 = 123 mg/l) had lowest hardness (Table 1). At station II, winter season (winter 2021-22 = 163 mg/l; winter 2021-22 = 162.40 mg/l) had highest hardness value followed by the monsoon season (Monsoon 2022 = 151.5 mg/l; monsoon 2021 = 150.69 mg/l) and summer season (summer 2021 = 121 mg/l; summer 2022 = 119 mg/l) had lowest hardness (Table 1). At station III, winter (winter 2021-22 = 156.01 mg/l; winter 2022-23 = 154 mg/l) had highest hardness value followed by monsoon 2022 (127.22 mg/l), summer 2021 (118.03 mg/l) and monsoon 2021 (117.82 mg/l), with summer 2022 (117 mg/l) having the lowest hardness (Table 1). Dwivedi, A.P. (2017) found that the maximum total hardness of water bodies in the Mandakini River was 621 mg/l and minimum value was 249 mg/l. Sharma *et al.* (2013) conducted a study on the physicochemical analysis of surface and ground water in the Abhanpur block of Raipur district, Chhattisgarh and found that the water hardness ranged from 130 to 280 mg/l. In current study, we observed hardness values ranging from 123 to 172 mg/l at sampling station I, 119 to 163 mg/l at sampling station II, and 117 to 156.01 mg/l at sampling station III (Table 1).

7. Calcium ion: Calcium is more abundant in natural waters, primarily sourced from the weathering of rocks through leachate (Jemi and Balasingh, 2011). Calcium functions as a crucial micronutrient for many organisms in aquatic environments. At station I, we found the highest value of calcium ions in winter (winter 2021-22 = 38.25 mg/l; winter 2022-23 = 37.50 mg/l) followed by monsoon (monsoon 2022 = 36.30 mg/l; monsoon 2021 = 36.15 mg/l) and the lowest value in summer (summer 2022 = 28.62 mg/l; summer 2021 = 27.93 mg/l) (Table 1). At station II, we found highest concentration of calcium ions in winter (winter 2022–23 = 37.15 mg/l; winter 2021–22 = 39.61 mg/l) followed by monsoon (monsoon 2022 = 35.05 mg/l; monsoon 2021 = 34.95 mg/l) and lowest concentration in summer (summer 2022 = 26.65 mg/l; summer 2021 = 24.36 mg/l) (Table 1). At station III, we observed highest value of calcium ions during winter (winter 2021-22 = 37.62 mg/l; winter 2022-23 = 37.57 mg/l) followed by monsoon 2022 (30.66 mg/l), summer 2022 (28.37 mg/l) and monsoon 2021 (28.36 mg/l) and lowest value during summer 2022 (28.3 mg/l) (Table 1). Soni and Thomas (2013) studied calcium hardness across various sampling stations in the Dakor sacred wetland, reporting concentrations of 84–361 mg/l at station D1, 63–384 mg/l at station D2 and 73.59–357 mg/l at station D3. Sampling station D2 recorded a maximum concentration of 384 mg/l during winter, while same station recorded a minimum concentration of 63 mg/l during hot summer days. In present study, we observed calcium ion concentrations ranging from 36.15 to 38.25 mg/l at sampling station I, 24.36 to 37.15 mg/l at sampling station II, and 28.3 to 37.62 mg/l at sampling station III(Table 1). As per Soni and Thomas (2013), we also observed the highest calcium concentration in the winter season at all three stations and lowest in the summer season. Elevated magnesium levels may result from the infiltration of anthropogenic or domestic waste or from cationic exchange with sodium ions (Thompson *et al.*, 1999).

8. Magnesium ion: Various water sources typically contain magnesium in association with calcium, but its concentration is generally lower than that of calcium (Venkatasubramani and Meenambal, 2007). Magnesium is crucial for chlorophyll development, serving as a limiting factor for significant phytoplankton growth (Dagaonkar and Saksena, 1992). Elevated magnesium concentration may result from the infiltration of anthropogenic or domestic waste, or it may arise from cationic exchange with sodium (Na). At station I, winter had the highest magnesium ion values (winter 2022-23 = 17.96 mg/l; winter 2021-23 = 17.93 mg/l) followed by monsoon (monsoon 2022 = 17.15 mg/l; monsoon 2021 = 17.11 mg/l) and summer had the lowest values (summer 2022 = 12.47 mg/l; summer 2021 = 12.36 mg/l) (Table 1). At station II, we observed the highest value of magnesium ions during monsoon (monsoon 2022 = 16.20 mg/l; monsoon 2021 = 16.19 mg/l) followed by winter (winter 2022-23 = 16.07 mg/l; winter 2021-22 = 16.04 mg/l) and lowest value during summer (summer 2022 = 12.49 mg/l; summer 2021 = 12.37 mg/l). At station III, winter season (winter 2021-22=16.34 mg/l; winter 2022-23=15.99 mg/l) had the highest value of magnesium ions followed by monsoon (monsoon 2022=13.11 mg/l; monsoon 2021=12.06 mg/l) and summer season (summer 2021=12.03 mg/l; summer 2022=11.99 mg/l) had lowest value (Table 1). Sajitha and Vijayama (2016) observed magnesium concentrations ranging from 0 to 7.24 mg/l in the pond water of Athiyannoor Panchayath, Kerala State. The maximum permissible limit of calcium hardness is 30 mg/l (BIS, 1991). According to BIS (1991), magnesium levels in Kot dam are below the desirable limits. Study found the highest magnesium level in winter 2022–23 (17.96 mg/l) at sampling station I and the lowest level in summer 2022 (11.99 mg/l) at sampling station III. Magnesium is often associated with calcium in all kinds of water, but its concentration remains generally lower than that of calcium (Venkatasubramani and Meenambal, 2007). A decrease in the level of Mg reduces phytoplankton production.

9. Chloride ion: Chloride concentration indicates sewer pollution. People who are accustomed to higher levels of chloride in their water may experience laxative effects (Dahiya and Kaur, 1999). Chloride, the ionized form of chlorine, is one of the most common inorganic ions in natural water and wastewater. All types of water naturally contain chloride. Chloride dissolves in water and flows freely through soil and rocks. Chloride levels in excess of 100 mg/l give water a salty taste. At station I, summer 2021 had the highest chloride ion value (83.50 mg/l) followed by monsoon 2022 (83.50 mg/l), monsoon 2021 (82.08 mg/l), winter 2021-22 (81.34 mg/l) and winter 2022-23 (81 mg/l). Summer 2022 had the lowest chloride ion value (80.5 mg/l) (Table 1). At station II, monsoon (monsoon 2022=87.75 mg/l; monsoon 2021=86.93 mg/l) had highest concentration of chloride ions followed by winter (winter 2022-23=81.75 mg/l; winter 2021-22=80.94 mg/l) and the summer season (summer 2022=79.25 mg/l; summer 2021=78.32 mg/l) had lowest concentration (Table 1). At station III, the monsoon 2021 had highest value of chloride ions (80.33 mg/l) followed by summer 2021 (79.22 mg/l), monsoon 2022 (78.34 mg/l) and summer 2022 (77 mg/l). Winter had the lowest value of chloride ions (winter 2021-22 = 76.82 mg/l; winter 2022-23 = 75.75 mg/l) (Table 1). Tripathi *et al.* (2013) studied the characterization of diffuse chemical contamination in the Satna district of India's Vindhya region. Chloride values in bodies of water ranged between 5.0 and 82.0 mg/l. It is believed that a higher chloride concentration signifies increased pollution due to an increase in animal-derived organic waste. Sahu *et al.* (2007) noted that elevated chloride concentrations during the summer may result from increasing temperatures, reduced water levels and sewage contamination. Chloride concentrations of Kot dam were ranges between 80.5 to 83.50 mg/l at station I, 78.32 to 87.75 mg/l at station II and 75.75 to 80.33 mg/l at station III. Chlorides are significant inorganic anions found in diverse amounts in natural waterways and serve as a pollution indicator (Makhoukh *et al.,* 2011). Their presence in lake water may signify anthropogenic contamination due to their occurrence in urine and maintenance products (Matini *et al.,* 2009). Human-made sources of chloride in surface water include salt runoff, wastewater from cities and farms and wastewater from wastewater treatment plants (Dickman and Gochnauer, 1978; Sonzogni *et al.,* 1983; Birge *et al.,* 1985).

10. Alkalinity: Alkalinity, ability of water to neutralize a strong acid, typically results from the presence of calcium, sodium and potassium hydroxide, bicarbonate and carbonate molecules in the water. Alkalinity chemically measures water's ability to neutralize acid. Alkalinity is another indicator of water's buffering capacity, or its resistance to pH shifts caused by the addition of bases or acids. Although strong bases, such as OH^-, may also play a role (in extreme settings), weak acid salts are the main cause of natural water alkalinity. At station I, the monsoon season had the highest alkalinity (monsoon 2022 = 128.75 mg/l; monsoon 2021 = 128.57 mg/l) followed by winter (winter 2021-22 = 125.78 mg/l; winter 2022-23 = 125.75 mg/l) and summer season had lowest alkalinity (summer 2021 = 126.01 mg/l; summer 2022 = 126 mg/l) (Table 1). At station II, winter had highest alkalinity value (winter 2022-23 = 124.25 mg/l; winter 2021-22 = 124.03 mg/l) followed by summer (summer 2022 = 120 mg/l; summer 2021 = 119 mg/l) and monsoon season had lowest alkalinity (monsoon 2022 = 112.75 mg/l; monsoon 2021 = 112.65 mg/l). Monsoon 2021 (123.50 mg/l) had highest alkalinity value at station III followed by summer 2022 (121.44 mg/l), summer 2022 (120.75 mg/l) and monsoon 2022 (120.23 mg/l) (Table 1). Winter season (winter 2021-22 = 115.22 mg/l; winter 2022-23 = 114 mg/l) had lowest alkalinity value (Table 1). Alkalinity quantifies the concentration of ions in water that can react to neutralize hydrogen ions. Excessively high alkalinity renders water unpleasant and unappealing. Dwivedi, A.P. (2017) determined that the minimum alkalinity value was 210 mg/l, while the maximum value was 500 mg/l. During study we measure alkalinity between 126 to 128.75 mg/l at sampling station I, 112.65 to 124.25 mg/l at station II and 114 to 121.44 mg/l at station III of Kot Dam (Table 1). Surface water with an alkalinity below 200 mg/l is possibly susceptible to significant acid deposition. Alkalinity is not detrimental to humans; static water with an alkalinity level below 100 mg/l is preferable for residential use. Water with a pH over 8.3 is characterized by "phenolphthalein alkalinity," mostly attributed to the presence of carbonate or hydroxide ions. The optimal total alkalinity for drinking water must remain below 200 ppm (IS, 1991). Carbonates and bicarbonates constitute the primary constituents of surface water alkalinity (Muhammad *et al.,* 2000).

11. Dissolved oxygen (DO): Dissolved oxygen serves as a critical indicator of water body health and its ability to sustain a balanced aquatic ecosystem comprising both flora and fauna.

Warm water discharged from industrial outlets, flowages, or storm sewers can decrease dissolved oxygen levels. Dissolved oxygen significantly impacts the survival of aquatic organisms in lakes and reservoirs during the summer. Sahni and Yadav (2012) assert that dissolved oxygen is a critical parameter of water quality, significantly influencing the survival and distribution of flora and fauna within an ecosystem. At station I, monsoon season (monsoon 2021 = 4.06 mg/l; monsoon 2022 = 4.02 mg/l) had the highest value of dissolved oxygen followed by summer season (summer 2022 = 2.08 mg/l; summer 2021 = 2.76 mg/l) and winter season (winter 2022-23 = 2.72 mg/l; winter 2021-22 = 2.67 mg/l) had lowest amount (Table 1). At station II, monsoon season had highest dissolved oxygen value (monsoon 2022 = 4.72 mg/l; monsoon 2021 = 4.71 mg/l) followed by summer (summer 2022 = 3.67 mg/l; summer 2021 = 3.64 mg/l) and winter (winter 2022-23 = 2.75 mg/l; winter 2021-22 = 2.67 mg/l). At station III, the monsoon 2021 had highest dissolved oxygen content (3.06 mg/l) followed by summer 2021 (3.05 mg/l), summer 2022 (3 mg/l) and monsoon 2022 (2.88 mg/l). Winter had lowest dissolved oxygen content (winter 2021-22 = 2.41 mg/l; winter 2022-23 = 2.40 mg/l) (Table 1). Similarly, Sahni and Yadav (2012) studied DO content in Bharawas pond in Rewari, Haryana and observed DO values between 4.73 to 5.34 mg/l. During study, we observed DO values between 2.67 to 4.06 mg/l at sampling station I, 2.67 to 4.72 mg/l at station II and 2.40 to 3.06 mg/l at station III. Water temperature, air partial pressure and other factors directly or indirectly affect the amount of DO in water (Saloom and Ducan, 2005; Chaurasia and Pandey, 2007). Low dissolved oxygen levels are associated with the self-purification capacity of moving water, the photosynthetic efficiency of aquatic plants, airflow, and other variables (Singh and Trivedi, 1979). Dirican (2015) suggests that deep water bodies have lower dissolved oxygen concentrations than surface water.

12. Fluoride: The World Health Organization recommends 1.5 mg/L or ppm fluoride in drinking water to prevent dental fluorosis and tooth decay (Sushella *et al.,* 1999; Harrison, 2005; Jagtap *et al.,* 2012; Ali *et al.,* 2016). Different water fluoride levels may influence public health considerations regarding fluoridation. US guidelines indicate 0.7 mg/L. Fluoride salts' water solubility affects their availability and dispersion. Climate, food, and water use can affect community fluoride levels. The fluoride chemical used in water treatment systems may also affect fluoridation program efficiency and cost (Jagtap *et al.,* 2012; Ali *et al.,* 2016). Water pH affects fluoride's reactivity and bioavailability. Water ions like calcium and magnesium can interact with fluoride and influence its concentration and effectiveness (Sushella *et al.,* 1999; Ali *et al.,* 2016). Additionally, the water source (groundwater, surface water or precipitation) may influence natural fluoride levels, necessitating modifications to artificial fluoridation. In places with complicated infrastructure or different water sources, monitoring and maintaining fluoride levels in water distribution systems is difficult. In water, fluoride might be sodium fluoride, fluorosilicic acid, or fluorosilicate. Fluoride may form complexes or precipitates with other water ions. Water temperature affects fluoride's solubility and chemistry. We measure the concentration of fluoride ions in milligrams per liter. During the study, the amount of fluoride was observed between 0.1 mg/l to 0.11 mg/l at station I, 0.1 mg/l to 0.9 mg/l and fluoride content at station III was observed between 0.1 mg/l to 0.11 mg/l (Table 1).

13. Biochemical oxygen demand (BOD): Bacteria and other microbes utilize organic compounds as sustenance. They use oxygen while metabolizing organic material (APHA, 2012; Tchobanoglous *et al.,* 2003). Organic materials are decomposed into simpler chemicals, including CO_2 and H_2O, which microorganisms need for energy in growth and reproduction (Tchobanoglous *et al.,* 2003). When this process transpires in water, oxygen utilized is the dissolved oxygen (DO) present in the water. If oxygen is not perpetually replenished by natural or artificial methods in the water, the dissolved oxygen concentration will diminish as microorganisms degrade organic matter. Requirement for oxygen is referred to as biochemical oxygen demand (BOD). An increase in organic content in the water correlates with a higher biochemical oxygen demand (BOD) exerted by bacteria. BOD serves as an indicator of sewage strength; robust sewage exhibits a high BOD, whereas dilute sewage displays a low BOD (Tchobanoglous *et al.,* 2003). Breakdown of organic matter by microbes often requires aduration of 20 days or longer under normal conditions (Tchobanoglous *et al.,* 2003). Biochemical oxygen demand (BOD) serves as an index for organic pollution, quantifying the dissolved oxygen (DO) needed by microbial communities to decompose organic matter in a water sample through aerobic biochemical processes (Boyd, 2000). At station I, we observed the highest biochemical oxygen demand during summer season (summer 2021 = 17.02 mg/l; summer 2022 = 16.85 mg/l) followed by monsoon (monsoon 2022 = 15.15 mg/l; monsoon 2021 = 15.11 mg/l) and lowest biochemical oxygen demand during winter (winter 2022-23 = 12.62 mg/l; winter 2021-22 = 12.34 mg/l) (Table 1). At station II, we observed highest BOD value during summer (summer 2022 = 13.67 mg/l; summer 2021 = 13.22 mg/l) followed by monsoon (monsoon 2022 = 13.15 mg/l; monsoon 2021 = 13.11 mg/l) and lowest BOD value during winter (winter 2022-23 = 12.92 mg/l; winter 2021-22 = 12.78 mg/l) (Table 1). At station III, we observed the highest BOD value in summer 2022 (14.59 mg/l) followed by monsoon 2021 (14.52 mg/l), summer 2022 (14.22 mg/l) and monsoon 2022 (13.94 mg/l) and lowest BOD value during winter (winter 2021-22 = 12.43 mg/l; winter 2022-23 = 12.40 mg/l) (Table 1). Singh and Rai (1999) noted that elevated BOD levels served as a marker for organic pollution in the river Ganga at Varanasi. During study, we found that the highest concentration of BOD was in the summer season at all three sampling stations and lowest was in the monsoon season. High wind velocity during summer season allows various pollutants to infiltrate water body. Another reason was the decrease in water levels at all three sampling stations, which led to an increase in the BOD level.

14. Chemical oxygen demand (COD): Conventional approach for assessing the level of pollution in a water sample is through chemical oxygen demand analysis. Chemical oxygen demand test procedure depends on the chemical breakdown of both organic and inorganic contaminants, regardless of their suspension or dissolution in water. We can link the release of effluents and diffuse pollution sources in the coastal region and mangrove site to the reduced levels of dissolved oxygen and elevated biochemical and chemical oxygen demand (Kumar and Prabhahar, 2012). Chemical oxygen demand (COD) is a parameter that quantifies all organics, both biodegradable and non-biodegradable (Tchobanoglou *et al.,* 2003). It is a chemical test that uses powerful oxidizing chemicals (potassium dichromate), sulfuric acid and heat to produce results in as little as two hours (APHA, 2005). COD readings are consistently greater than BOD values for the same sample (Tchobanoglous *et al.,* 2003). At station I, summer had the highest COD value (summer 2021 = 44.3 mg/l; summer 2022 = 44.2 mg/l) followed by monsoon (monsoon 2022 = 42.74 mg/l; monsoon 2021 = 41.34 mg/l) and winter season had the lowest COD value (winter 2022-23 = 39.48 mg/l; winter 2021-22 = 39.19 mg/l) (Table 1). At station II, winter had the highest COD value (winter 2022-23 = 43.97 mg/l; winter 2021-22 = 42.41 mg/l) followed by monsoon (monsoon 2022 = 37.91 mg/l; monsoon 2021 = 37.54 mg/l) and summer had lowest COD value (summer 2022 = 34.125 mg/l; summer 2021 = 33.89 mg/l) (Table 1). At sampling station III, the winter season (winter 2021-22 = 40.84 mg/l; winter 2022-23 = 40.77 mg/l) had the highest COD value followed by monsoon (monsoon 2022 = 38.61 mg/l; monsoon 2021 = 38.22 mg/l) and summer season (summer 2021 = 38.12 mg/l; summer 2022 = 37.26 mg/l) had the lowest COD value (Table 1). Singh, K. (2020) studied physicochemical parameters of different water bodies located in Pali district. They found that the value of COD ranges between 830 mg/l to 1545 mg/l in different periods of the year. Similarly, during study, we observed the seasonal fluctuations in COD in different seasons as well as different sampling stations. Assessing the physical characteristics of a substance, such as its temperature, turbidity, pH and total dissolved solids (TDS), is necessary during certain examinations. Additionally, chemical tests are required to measure its biochemical oxygen demand (BOD), chemical oxygen demand (COD), dissolved oxygen (DO), hardness and alkalinity. In order to enhance the level of quality and purity, it is necessary to conduct tests on water for the presence of trace metals, heavy metals and organic pollutants. Physical and chemical properties of a freshwater body have a significant impact on its living organisms. Several studies in India have comprehensively studied the physicochemical characteristics and biotic communities of standing and running water bodies (Gopal and Zutshi, 1998; Esmaeili and Johal, 2005).

Table 1: Seasonal variation in physico-chemical parameters of Kot Dam, Jhunjhunu, Rajasthan, India

Sampling Station I of Kot dam						
Parameters	**Summer 2021**	**Monsoon 2021**	**Winter 2021-22**	**Summer 2022**	**Monsoon 2022**	**winter 2022-23**
Temperature	28.86	26.09	16.2	28.87	27.0	17.9
Transparency	30.32	33.15	31.45	29.175	33.125	31.975
pH	6.84	7.09	7.14	6.9525	7.08	7.145
EC	592.3	487	523	587.5	485	520
TDS	382	324	327	380	320	326
Hardness	123	157.36	172	126	158.5	169
Ca+	27.93	36.15	38.25	28.625	36.3	37.5
Mg+	12.36	17.11	17.93	12.475	17.15	17.96
Cl-	83.5	82.08	81.34	80.5	83.5	81
Alkalinity	126.01	128.57	125.78	126	128.75	125.75
DO	2.76	4.06	2.67	2.8	4.025	2.725
FL	0.11	0.09	0.1	0.1	0.1	0.1
BOD	17.02	15.11	12.34	16.85	15.15	12.625
COD	44.3	41.34	39.19	44.2	42.7475	39.48
Sampling station II of Kot Dam						
Parameters	**Summer 2021**	**Monsoon 2021**	**winter 2021-22**	**Summer 2022**	**Monsoon 2022**	**Winter 2022-23**
Temperature	28.94	27.14	17.78	28.97	27.125	18.225
Transparency	28.59	32.71	30.67	28.6	32.725	31.55
pH	7.24	7.12	7.32	7.27	7.135	7.3325
EC	546	516.76	519.65	550	517.5	520
TDS	351	339.81	324.11	355	340.5	325
Hardness	121	150.69	162.64	119	151.5	163
Ca+	24.36	34.95	36.91	25.65	35.05	37.15
Mg+	12.37	16.19	16.04	12.49	16.2075	16.075
Cl-	78.32	86.93	80.94	79.25	87.75	81.75
Alkalinity	119	112.65	124.03	120	112.75	124.25
DO	3.64	4.71	2.67	3.675	4.725	2.75
FL	0.1	0	0.09	0.1	0	0.1
BOD	13.22	13.11	12.78	13.675	13.15	12.925
COD	33.89	37.54	42.21	34.125	37.915	43.97

Sampling station III of Kot dam						
Parameters	**Summer 2021**	**Monsoon 2021**	**Winter 2021-22**	**Summer 2022**	**Monsoon 2022**	**Winter 2022-23**
Temperature	27.36	26.3	17.82	27.325	24.70	18.4
Transparency	28.93	27.95	31.63	28.625	29.28	31.75
pH	7.35	7.16	7.45	7.295	7.31	7.4225
EC	563.41	561.42	506.15	562.5	548.37	505
TDS	364.1	364.2	321.34	362.5	353.04	321.5
Hardness	118.03	117.82	156.01	117	127.22	154
Ca+	28.37	28.36	37.62	28.3	30.66	37.575
Mg+	12.03	12.06	16.34	11.9925	13.11	15.9925
Cl-	79.22	80.33	76.82	77	78.34	75.75
Alkalinity	121.44	123.5	115.22	120.75	120.23	114
DO	3.05	3.06	2.41	3	2.88	2.4
FL	0.11	<0.1	0.09	0.1	<0.1	0.1
BOD	14.59	14.52	12.43	14.225	13.94	12.4
COD	38.12	38.22	40.84	37.26	38.61	40.775

4. CONCLUSION

Meteorological, geochemical, geomorphological and pollution factors interact complexly to influence the quality of freshwater bodies. These elements interact complexly, influencing characteristics such as water temperature, pH levels, nutrient composition and load of sediment. The interplay among these elements can profoundly affect aquatic ecosystems, shaping biodiversity and overall health of freshwater environments. Understanding these linkages is crucial for the efficient management and conservation of water resources. Quality of water is vital for the health of aquatic species and immediately influences human activities such as water supply, agriculture and recreation. Changes in water quality can lead to economic implications, especially for sectors reliant on pristine water resources. Furthermore, the geographical and temporal fluctuations in these elements necessitate continuous monitoring and adaptable management strategies to guarantee the long-term sustainability of freshwater ecosystems. To achieve adequate fish production in freshwater ecosystems, it is essential to perform a thorough analysis of the physicochemical characteristics that affect the biological productivity of the water. The intricate balance of these physicochemical parameters influences both the immediate health of aquatic organisms and the long-term dynamics and resilience of ecosystems. By overseeing and regulating these factors, one can foresee and alleviate potential hazards to freshwater ecosystems, such as algal blooms, oxygen deprivation, or habitat deterioration. Moreover, comprehending the distinct water quality prerequisites of different aquatic species helps direct focused conservation initiatives and enhance sustainable aquaculture approaches.

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