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Assessment of water quality of Kot Dam, Rajasthan, India, using water quality index

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Abstract

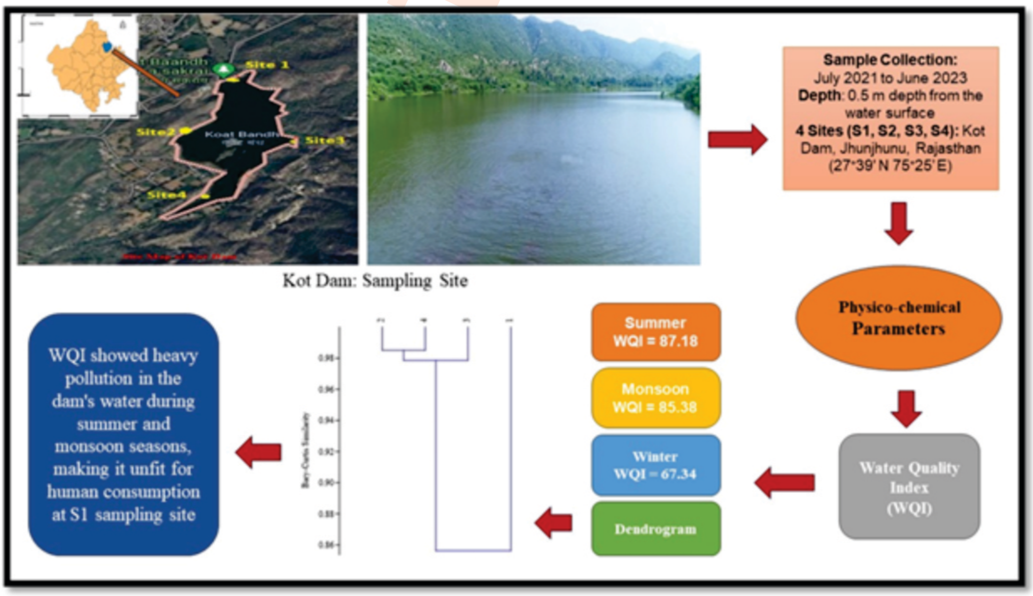
Aim: To assess the water quality of Kot Dam, located in the Jhunjhunu district of Rajasthan, India.

Methodology: Physico-chemical parameters of water quality were monitored for two years (July 2021 to June 2023). The Water Quality Index (WQI), a widely accepted mathematical expression used to understand the trend in the quality of water bodies, was calculated based on the analysis of physicochemical parameters, including pH, total dissolved solids, hardness, alkalinity, dissolved oxygen, biological oxygen demand, chloride, sulphate, nitrate, calcium, magnesium, conductivity, and fluoride.

Results: The site-wise and season-wise analysis of WQI revealed that Dam water was polluted due to organic pollutants, agricultural runoff, and waste disposal by local people, especially during summer (WQI=87.18) and monsoon seasons (WQI=85.38).

Interpretation: Anthropogenic activities adversely affected the water quality at sample station (S1) of Kot Dam.

Key words: Anthropogenic activities, Bray-Curtis Similarity Index, Dendrogram, Kot dam, Water quality



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Introduction

A dam is a wall-like construction placed over a stream or river to stop water flow through the surrounding area. It is a crucial part of India's energy and water security since it offers a variety of advantages, including irrigation, drinking water supply, flood control, hydropower generation, and recreation (Bassi, 2022). According to Zielinski *et al.* (2022) Central Water Commission, India has more than 5,000 major dams, which collectively produce 13% of the nation's total energy and nearly 18% of its total capacity for water storage.Natural and human factors impact the quality and composition of dam water (Peters *et al.,* 2000).

Understanding the characteristics of aquatic systems water is crucial for ecosystem sustainability, including physical, chemical, and biological attributes (Brauman, 2015). Recent studies have shed light on the varied water quality status across different reservoirs in Rajasthan. A comprehensive study conducted by Sharma and Sharma (2023) on Man Sagar Lake, located at Jal Mahal in Jaipur, has highlighted that the excessive use and disposal of synthetic chemicals have been deteriorating the water quality of this crucial lake. They assessed this deterioration by analysing various physico-chemical parameters and evaluating algal counts, phytoplankton and zooplankton. Kavindra *et al.* (2019) studied the water quality and productivity metrics at Jawai Dam in Pali, Western Rajasthan, and found that the dam's waters were "low to medium productive." In another interesting study, Gothwal and Gupta (2019) studied the limnological characteristics and planktonic diversity on Sant-Sarover Pond in Mount Abu, Rajasthan. They found that the pond was eutrophic due to the release of sewage into the lake but had a high level of biodiversity in plankton and fish.

Water quality is a critical aspect that requires proper monitoring and assessment. Various indices have been developed to make summarising water quality data much easier. For instance, National Sanitation Foundation Water Quality Index (NSFWQI) and Oregon Water Quality Index (OWQI) indices use logarithmic transforms to convert water quality variable results into subindex values (Brown *et al.,* 1970; Cude, 2001). The River Ganga Index assesses water quality and identifies highly polluted areas requiring immediate pollution control measures (Sharma and Kansal, 2011). The contamination index (CI) method also assess and map groundwater contamination levels (Backman *et al.,* 1998). Water quality index (WQI) is a mathematical tool that condenses complex water quality data into a single number to express overall water quality at a specific location and time. These indices provide a comprehensive representation of water quality and facilitate the evaluation of its susceptibility to potential hazards (Soni and Thomas, 2014).

It efficiently communicates water quality trends to the public and policymakers and implements water quality improvement programs (Gitau *et al.,* 2016). The current study was conducted to determine the water quality index (WQI) of Kot Dam. Kot Dam is located near the world-famous Shakambhari Mata Temple. The temple attracts devotees from all over the country during the Navratri festival for the Darshan of deity, making the dam a popular recreational site. The dam water is also used for daily household activities and agricultural purpose by the villagers. As it is located in an arid zone, it is crucial to assess the water quality of Kot Dam. The study will aid in managing the lotic water habitat and making policy decisions on the ecologically and culturally significant Kot dam.

Materials and Methods

Study area: The study aimed to evaluate the water quality of Kot Dam, located in the village of Kot (27°39' N 75°25' E), approximately 65 km from Jhunjhunu into Udaipurwati Sub division of Rajasthan. The Dam, also known as Sarju Sagar Bandh, was constructed in 1924 under the rule of Raja Bhoop. Shakambari Mata temple on the dam's banks is revered in the region. Kot Dam lies on the western edge of the Aravalli range in Rajasthan. The water in Kot Dam is derived from a gross catchment area of 11.65 km^2. The gross command area of dam is 52 ha and is used for growing crops such as wheat, gram, and mustard. The population of the Kot Dam area is around 2000. There are several other famous temples and ashrams located nearby, such as the Paniwale Bheruji Temple, Yogeshwar Mahadev Siddha Peeth, Manu Ashram, Munni Baba Ka Ashram, Bhuvaneshwari Ashram, and Nag Kund. The area has an arid climate with limited resources, including water and food. Intense solar radiation, powerful dry winds, regular dust storms, and significant temperature fluctuations characterise it. Rainfall mainly occur during in July and August, resulting in brief but intense downpours. To study the water quality of Kot Dam, four sampling stations, Tourist site (S1), Manu Ashram site (S2), Shakambhari Conservation Reserve site (S3) and Water entry site (S4) were identified. These stations were selected to cover the entire ecosystem, provide seasonal physico-chemical characterisation, and represent varied dam conditions. Station S1 is highly disturbed due to tourist activity and its roadside location, S2 is disturbed due to agricultural activity, S3 is the least disturbed site, and S4 is the water entry point in the dam area (Fig. 1).

Water sampling and analysis: Water samples were collected and analysed every month from July 2021 to June 2023 to examine the monthly changes in water quality. Samples were collected from~0.5 m below the water's surface using pre-cleaned 2 l plastic containers. The water quality index (WQI) was derived by analysing the physico-chemical properties. A portable hand meter was used for measuring the pH, while the modified Winkler's method was employed to measure the dissolved oxygen. The other water quality parameters estimated (total dissolved solids, hardness, total alkalinity, dissolved oxygen, biological oxygen demand, chloride, sulphate, nitrate, calcium, magnesium, conductivity, and fluoride) were analysed as per the standard methods of APHA (2017) in the Rajasthan State Pollution Control Board, Jaipur Laboratory.

Statistical analysis: Analysed physico-chemical data was tabulated and presented as Mean±SD. One-way ANOVA was calculated to test the significant difference among the parameters of the sampling stations. A dendrogram was derived from the Bray-Curtis similarity index. The correlation coefficient analysis was performed between physico-chemical parameters analysed and were presented graphically using Origin Pro 2016 software.

WQI was calculated using the "Weighted arithmetic Index" method (Brown *et al.,* 1972). All the physico-chemical parameters estimated were utilised to calculate the Water Quality Index.The term "weighting" refers to the importance of a factor in overall water quality, which is determined by the permissible level of drinking water recommended by the CPCB (Central Pollution Control Board) and the Bureau of Indian Standards (BIS:10500) (Harinagaraj *et al.,* 2021). Factors with higher permissible limits pose less harm and have lower weightings.

Each parameter's unit weight (Wn) factors were calculated by the WQI Formula (Brown *et al.,*1972).

$$W_n = \frac{K}{Sn}$$

Where, $$K = \frac{1}{1/S1+1/S2+1/S3+1/S4+\ldots+1/Sn)} = \frac{1}{\sum \frac{1}{Sn}}$$

Sn = Standard desirable value for the nth parameter.

When all selected parameters were summed, the unit weight factor Wn equals 1 (unity).

The Sub-Index (Q_n) value was calculated by the formula.

$$Q_n = \frac{[(Vn\text{-}Vo)]}{[(Sn\text{-}Vo)])} \times 100$$

Where, Vn = mean concentration of the nth parameters; Sn = Standard desirable value of the nth parameters; Vo = Actual values of the parameters in Pure water.

WQI was calculated using the values of W_n and Q_n

$$\text{Overall WQI} = \frac{\sum WnQn}{\sum Wn}$$

Using the Water Quality Index, samples were categorised into five classes based on their quality: Excellent (0-25), Good (26-50), Moderate Polluted (51-75), Severe Polluted (76-100), and unfit for human consumption (above 100).

Results and Discussion

The water quality of selected sampling sites at ecologically and culturally significant Kot Dam was examined in the current study between July 2021 and June 2023, covering summer, monsoon and winter seasons. In this study, the important physico-chemical parameters of dam water, like, pH, total dissolved solids, hardness, total alkalinity, dissolved oxygen, BOD, chloride, sulphate, nitrate, calcium, magnesium, conductivity, and fluoride were analyzed. The mean values of the parameters with standard deviation are presented in Table 1 and 2. Overall, the results showed that the total alkalinity and mean magnesium concentration were higher than the prescribed limits at Site S1. Water samples from all the sites had higher BOD and conductivity than the prescribed limits. However, the mean values of other nine parameters (pH, total dissolved solids, hardness, dissolved oxygen, chloride, sulphate, nitrate, calcium and fluoride) were within the permissible limits of Central Pollution Control Board (CPCB) and Bureau of Indian Standards (BIS:10500), as presented in Table 1.

The average mean pH values did not show significant variation between the sampling sites during the study period. The pH remained close to neutral and within the standard range of CPCB and IS (10500). However, water at Site S1 was slightly alkaline during winter season, with the highest pH level reaching up to 7.8 (Table 2). The pH was neutral during monsoon season at this site, which may be due to the inflow of acidic rainwater into the dam during the monsoon season. Human activities, such as agriculture, mining, metal smelting, and chemical manufacturing, are linked to the change in the pH of water bodies (Kaushal *et al.,* 2013; Lal and Lal, 2023). Mild alkaline pH during summers, as observed in the current study, may be due to increased photosynthesis by phytoplanktons and aquatic plants, leading to higher consumption of dissolved carbon dioxide, which results in higher pH. Meanwhile, alkaline pH during winter might be due to the accumulation of agricultural run-off during monsoon months (Rey-Romero *et al.,* 2022).

In the first year of sampling (2021-22), the maximum alkalinity (278.7 mg l^{-1}) was recorded at Site S1 during winter, while the minimum (133 mg l^{-1}) was recorded at Site S3 during monsoon. For the next sampling year (2022-23), the maximum alkalinity was reported at Site S1 in winter (248.2 mg l^{-1}), while the minimum was reported at Site S2 in monsoon (126.7 mg l^{-1}) (Table 2).The alkalinity levels were highest during winter and lowest during monsoon throughout the sampling period. During winter, the total alkalinity of Kot Dam water may increase due to reduced biological activity and slow decomposition processes, allowing the accumulation of alkaline substances. On the other hand, during summer, higher microbial activity and vegetation growth may lead to increased consumption of alkaline compounds, resulting in lower total alkalinity of Dam water (Chauhan *et al.,* 2020). Sharma *et al.* (2022) made similar observations in the Chambal River and Anasagar Lake, reporting that the alkalinity of the water was due to dissolved minerals microbial and anthropogenic activities. It is worth noting here that the basic human activities observed around the Kot Dam were agriculture, tourism and disposal of organic wastes from nearby temples and residential areas.

Dissolved oxygen (DO) is an excellent indicator of water quality. DO values are greatly influenced by natural causes, such as temperature, as well as anthropogenic causes, like organic pollution (Jeelani *et al.,* 2018). In the current study, seasonal variation was observed in the DO levels. During the sampling year 2021-2022, the highest and lowest dissolved oxygen values were

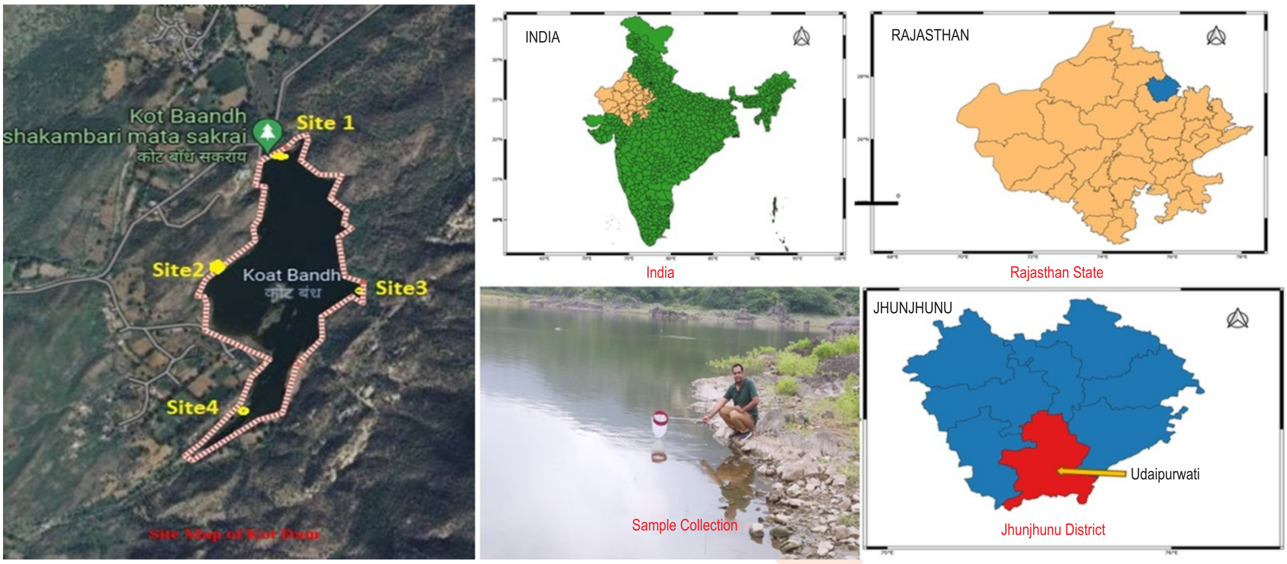

Fig. 1: Geographical map of the study area (Kot Dam) and sample collection sites (Designed by author, using Google Earth and QGIS software).

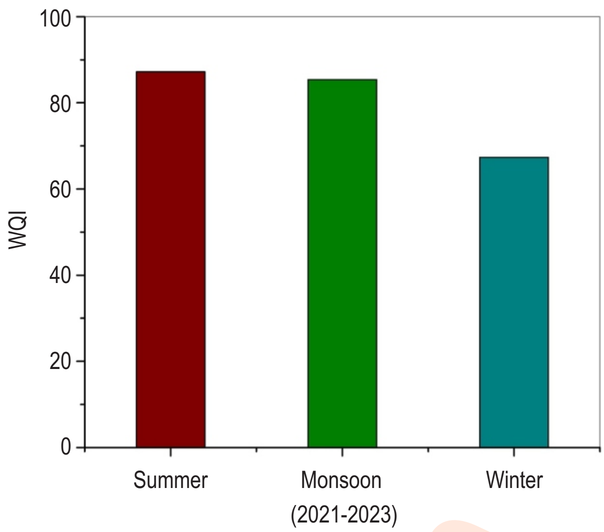

Fig. 2: Seasonal water quality index (WQI) variation in Kot Dam Water (2021-23).

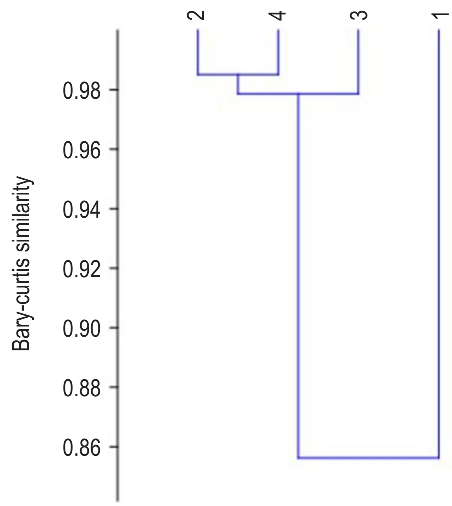

Fig. 3: Dendrogram shows the Bray-Curtis Similarity Index of sampling site-Wise WQI of Kot Dam in 2021-23.

observed at S4 and S1 sites, which were 8.72 mg l^{-1} in winter and 4.87 mg l^{-1} in monsoon, respectively (Table 2). In winter, colder water holds more dissolved oxygen due to lower temperatures. Increased water mixing and reduced biological activity contribute to higher oxygen levels. During the next sampling year (2022-23), the highest DO value (9.37 mg l^{-1}) was recorded during winter at S4 site, while the lowest (6.02 mg l^{-1}) was observed in summer at S1 Site (Table 2). A higher DO value showed better water quality at Site S4, which is the entry point of water into the dam. The lowest DO values at Site S1 during summer showed poor water quality both due to natural and human factors. Oxygen-holding capacity of water decreases during summer. Higher tourist activity at Site S1 and organic waste released from temples nearby may be the anthropogenic factors responsible for reduced DO.Makwana and Rathore (2021) recorded the lowest DO values in Nakki Lake during summer due to sewage and high pollution load.

Dissolved oxygen values also correspond with the levels of biological oxygen demand. Analysis of variance showed significant variation in BOD levels between the sites. During the sampling year 2021-2022, the BOD values at S1 site reached

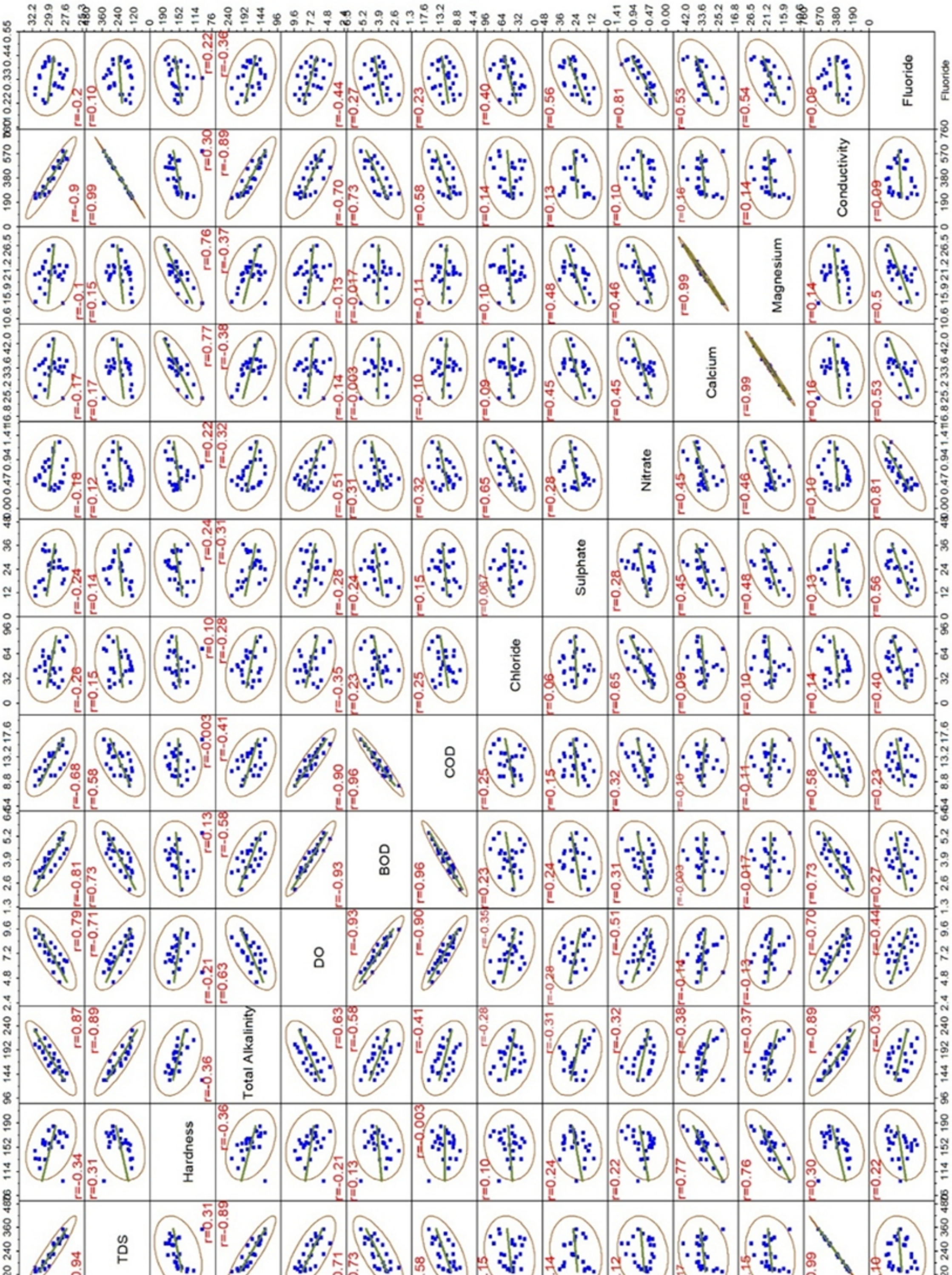

Fig. 4: Correlation graph displaying Pearson correlation coefficient (r) between thirteen physico-chemical parameters of Kot Dam water.

Table 1: Displaying the recommended permissible values for various parameters in drinking water, expressed in mg l^{-1}, (except for pH and Conductivity), as recommended by the Central Pollution Control Board (CPCB) and Indian Standards and Mean values of physicochemical parameters at four selected sites of Kot Dam during 2021-23

Parameters	CPCB	IS (10500)	S1	S2	S3	S4
pH	6.5-8.5	6.5-8.5	7.52±0.374	7.38±0.282	7.37±0.309	7.36±0.30
TDS	500	500	289.5±118.0	208.8±48.4	206.3±64.8	203.4±54.2
Total hardness	300	300	199.7±21.3	133.9±14.5	140.9±10.8	148.04±11.8
Total Alkalinity	200	200	227.3±33.07	151.08±19.7	144.62±14.9	178.58±33.62
DO	6	-	6.11±0.94	7.5±1.24	7.55±1.16	7.81±1.07
BOD	2	-	5.15±0.46	3.53±0.75	3.72±0.707	3.45±0.62
Chloride	250	250	44.6±5.32	51.9±7.15	49.7±9.46	51.6±9.25
Sulphate	200	200	27.5±7.35	23.3±5.76	25.5±6.26	21.54±6.16
Nitrate	20	45	0.71±0.25	0.69±0.29	0.63±0.22	0.67±0.22
Calcium	75	75	50.1±1.67	26.5±5.82	26.8±3.18	29.4±5.29
Magnesium	30	30	30.5±0.83	16.2±3.55	16.5±2.05	17.9±3.3
Conductivity	300	300	489.1±198.3	349.7±81.31	345±109.57	340.41±92.02
Fluoride	1	1	0.35±0.063	0.334±0.068	0.335±0.066	0.329±0.068

their highest point during the monsoon season (6.32 mg l^{-1}) and their lowest point during the winter season (3.05 mg l^{-1}) at S2 site. BOD values ranged from 2.2 to 5.12 mg l^{-1} in the following sampling year, with the highest value observed at S1 silte in summer and the lowest at S2 site in winter. Jeelani *et al.* (2018) attributed increased BOD levels to animal waste deposition. Similarly, Kan (2019) reported higher BOD in Pali water bodies during monsoon due to agricultural runoff. We suggest that agricultural and tourist activities, along with organic waste from temples and households, have contributed to increased organic pollution in the water of Kot Dam at S1 site.

During monsoon season, the run-off from rural areas may further increase the organic content in dam water. In summer, higher temperatures can speed up decomposition, leading to higher BOD levels in the Kot Dam. In the case of TDS, site-wise variation was not statistically significant. However, significant seasonal variation was observed. During the first year of sampling, high TDS (431.5 mg l^{-1}) was found during the monsoon season at S1 site while the lowest TDS (144.7 mg l^{-1}) during winter at S3 site. In the second year, the highest TDS (419.5 mg l^{-1}) was found at S1 site during the monsoon season, the lowest TDS (148.7 mg l^{-1}) was reported at Site S3 during the winter season (Table 2). Heavy rainfall in monsoon season can lead to increase in water runoff, which carries minerals and salts into the dam water. This can elevate the TDS levels. Qureshi and Dube (2021) noted high TDS levels in Chandrasarovar Pond during the monsoon season due to the mixing of wastewater, garbage and sewage. A similar pattern was observed with conductivity. The highest conductivity was measured at S1 site during monsoon (729.7 μmho cm^{-1}) in 2021-22 and at the same (S1) location during monsoon (705.75 μmho cm^{-1}) in 2022-23. The lowest conductivity value was recorded at S4 site during winter (242.5 μmho cm^{-1}) in 2021-22 and at S3 site during winter (249.25 μmho cm^{-1}) in 2022-23 (Table 2). Monsoon season runoff increases conductivity in Kot Dam due to ions and minerals. Winter season reduces conductivity due to less runoff and dissolved substances. Chauhan *et al.* (2020) reported high electrical conductivity in the Chambal River during monsoon due to dissolved minerals.

The hardness of water is another important indicator of water quality which shows the amount of calcium and magnesium ions in the water (Singodia and John, 2023). The current study clearly correlates hardness values with Ca and Mg ions. Hardness varied significantly across the sites and seasons. In the first year of sampling, site S1 had the highest total hardness during summer (196.2 mg l^{-1}), and the lowest was at sites S3 and S4 during monsoon season (119 mg l^{-1}). The highest calcium content was reported in winter at S1 site (49.5 mg l^{-1}), while the lowest was at S3 site (18.5 mg l^{-1}) in winter, the magnesium concentration was highest at S1 (31.25 mg l^{-1}) and lowest at S3 (11.5 mg l^{-1}) sites. During the sampling year (2022-23), total hardness in the monsoon season was highest at S1 site (228.7 mg l^{-1}) and lowest (127 mg l^{-1}) at S2 during winter. Calcium levels showed similar trend, with highest value (54.25 mg l^{-1}) at S1 site and the lowest (24.75 mg l^{-1}) at S2 site. Magnesium level was maximum (33 mg l^{-1}) at S1 site during monsoon, and minimum (15 mg l^{-1}) at S2 site in winter (Table 2). In winter, water hardness decreases due to low temperature, slowing mineral dissolution, reducing rainfall, limiting mineral runoff, and decreasing biological activity. The fluctuations in water discharge and waste disposal from Kot village may cause variations in total hardness between seasons in all stations. Temporary hardness results due to the presence of carbonates, while permanent hardness is due to sulphates and chlorides, which can affect water quality (Hundal, 2011).

During the first year of sampling (2021-22), the highest nitrate concentration (1.07 mg l^{-1}) was observed in summer at S1 site, and the lowest (0.45 mg l^{-1}) in winter at S3 site. The highest sulphate concentration (33 mg l^{-1}) was recorded in summer at S1 site, and the lowest (15 mg l^{-1}) was observed in summer at the same S1 site. The highest concentration of fluoride (0.416 mg l^{-1}) was

Table 2: Physico-chemical parameters mean value (in mg l^{-1} and µmho cm^{-2} for conductivity) observed in four sampling stations of Kot Dam during 2021-2023

Physico-chemical parameters	2021-2022			2022-2023		
	Summer	Monsoon	Winter	Summer	Monsoon	Winter
pH (S1)	7.4925±0.25	7.1875±0.22	7.8925±0.29	7.665±0.17	7.0525±0.19	7.83075±0.28
pH (S2)	7.365±0.18	7.105±0.14	7.6475±0.21	7.4475±0.18	7.065±0.16	7.65±0.21
pH (S3)	7.345±0.19	7.085±0.15	7.635±0.23	7.48±0.16	7.0075±0.16	7.6875±0.21
pH (S4)	7.3125±0.23	7.075±0.11	7.62±0.19	7.4925±0.11	7.02±0.17	7.67±0.15
TDS (S1)	227.75±58.2	431.5±57.2	192.5±53.3	233.5±62.82	419.5±55	232.5±54.4
TDS (S2)	196±53.7	257.75±24.7	151.5±27.9	215±28.4	260±23	172.75±29.4
TDS (S3)	199.5±70.7	286.75±118.2	144.75±26	194.25±64.7	264±48.8	148.75±31.4
TDS (S4)	191.5±57.4	253±34.2	146.5±31.2	201.5±53.5	268.75±40	159.5±25
Hardness (S1)	196.25±46.3	220±75.8	192.25±33.5	181.5±12.4	228.75±13.04	179.75±44.1
Hardness (S2)	138±12.1	120.5±20.9	126.25±9.6	163.5±21.8	128.5±10.4	127±8.5
Hardness (S3)	139.25±14.4	119±20.4	122.5±16.5	166±12.1	158.75±10.07	140±12.3
Hardness (S4)	151.75±13.1	119±17.08	127±8.6	170±12.2	172.25±4.5	148.25±9.8
Total Alkalinity (S1)	239.75±27	212.75±17.5	278.75±26.7	200±31.6	184.5±7	248.25±17.9
Total Alkalinity (S2)	150.75±6.8	133.75±13.5	173.5±18.8	156.25±31.6	126.75±11.9	165.5±9.8
Total Alkalinity (S3)	138.75±6.7	133±20.7	174.75±3.4	142.5±9.4	131.25±5.8	147.5±8.7
Total Alkalinity (S4)	185.5±27.4	157±47.6	231±18.2	172.5±11.9	132.5±13.1	193±15.7
DO (S1)	5.025±0.86	4.875±0.8	6.6±0.4	6.025±1.02	6.35±0.5	7.8±0.3
DO (S2)	5.975±1.3	6.175±0.6	8.525±0.6	7.825±0.99	7.2±0.5	9.35±0.59
DO (S3)	6.175±1.4	6.225±0.55	8.45±0.5	8.025±0.99	7.125±0.6	9.3±0.69
DO (S4)	6.475±1.3	6.9±0.51	8.725±0.5	8.175±0.91	7.225±0.7	9.375±0.57
BOD (S1)	4.85±0.6	6.325±0.2	5.4±0.3	5.125±0.5	5.025±0.3	4.175±1.5
BOD (S2)	4.3±0.5	4.375±0.6	3.05±0.8	3.45±0.4	3.75±0.4	2.275±0.2
BOD (S3)	4.35±0.59	4.675±0.5	3.325±0.3	3.475±0.48	3.95±0.4	2.55±0.3
BOD (S4)	4.075±0.53	4.225±0.5	3.075±0.2	3.3±0.3	3.625±0.3	2.4±0.17
Chloride (S1)	57.5±11.3	27.975±19.7	40.75±14.7	44±12.6	56±21.6	41.5±6.8
Chloride (S2)	66±12.5	41.15±20.6	45.5±18.9	51.25±9.1	64.25±18.3	43.25±5.1
Chloride (S3)	65.75±9.1	36.475±18.6	45±20.3	54.5±8.3	58.25±19.3	38.25±5.1
Chloride (S4)	67.75±14.6	39.05±23.8	44.75±22.5	56±11.1	59.25±28.4	43±6.1
Sulphate (S1)	33±13.2	29.5±13.6	15±11.2	33.75±7.9	30.25±14.3	23.5±9.2
Sulphate (S2)	30±3.3	23.75±6.9	16.25±4.2	27.75±2.8	24±5.7	18.5±4.5
Sulphate (S3)	32.5±7.3	25.75±8.7	18.25±5.4	30.5±6.4	26.25±5.7	19.75±5.8
Sulphate (S4)	27.5±6.7	19.25±8.6	15.75±3.1	29±4.5	21.25±8.4	16.5±3.3
Nitrate (S1)	1.075±0.2	0.58±0.2	0.5475±0.10	0.92±0.08	0.685±0.19	0.4725±0.1
Nitrate (S2)	1.06±0.3	0.4625±0.1	0.4725±0.13	1.0075±0.2	0.5925±0.16	0.57±0.1
Nitrate (S3)	0.8625±0.18	0.4725±0.2	0.455±0.1	0.92875±0.15	0.61175±0.15	0.5035±0.08
Nitrate (S4)	0.9695±0.34	0.528±0.2	0.4725±0.1	0.86625±0.16	0.672±0.39	0.516±0.11
Calcium (S1)	49.5±3.6	48.5±20.1	51.5±6	47±2.9	54.25±2.6	50.25±7.3
Calcium (S2)	28.25±1.7	24.25±2.2	18.75±2.5	37.75±6.1	25.25±1.8	24.75±2.7
Calcium (S3)	25.75±0.9	22.5±2.08	18.5±5	35.25±3.7	28±2.1	31±3.5
Calcium (S4)	33.75±3.2	27.25±1.2	19.5±2.9	36.5±4.2	30±2.9	29.75±3.6
Magnesium (S1)	30.25±2.2	29.5±12.5	31.25±3.8	29±1.4	33±1.4	30.25±4.3
Magnesium (S2)	17.25±1.7	14.75±1.5	11.75±1.4	23.25±3.5	15.75±0.9	15±1.7
Magnesium (S3)	15.75±0.5	14±1.4	11.5±2.9	22±2.3	16.75±0.9	19±2.3
Magnesium (S4)	20.5±1.7	16.25±0.5	11.75±1.7	22.5±2.3	18.25±1.8	18.25±2.2
Conductivity (S1)	384.5±96	729.75±94.1	333.75±88.1	390±104.6	705.75±93.1	391±93.7
Conductivity (S2)	329±86.6	432.75±40.1	251.75±47.5	360±45.4	434.5±38.2	290.75±50.5
Conductivity (S3)	329.5±118.5	483.5±200.6	243.25±44.7	322.25±105.2	442.25±83.1	249.25±56.2
Conductivity (S4)	314.75±90.3	426.5±60.5	242.5±50.4	337.5±92.7	451±69.6	270.25±42.5
Fluoride (S1)	0.4165±0.02	0.3665±0.04	0.36975±0.09	0.422±0.04	0.3235±0.03	0.2155±0.03
Fluoride (S2)	0.40175±0.01	0.289±0.02	0.24375±0.02	0.4135±0.01	0.35975±0.02	0.2985±0.05
Fluoride (S3)	0.4115±0.01	0.293±0.05	0.25275±0.04	0.4015±0.01	0.3595±0.02	0.29475±0.06
Fluoride (S4)	0.39375±0.01	0.277±0.03	0.246±0.05	0.4145±0.01	0.3535±0.02	0.2945±0.05

Table 3: Water Quality Index (WQI) of Kot Dam was computed for the study period (2021-23)

Sampling Stations	Summer	Monsoon	Winter
S1	102.2	105.65	92.43
S2	84.06	80.61	59.24
S3	84.17	83.89	63.21
S4	81.07	77.98	60.22

Table 4: Water Quality Index (WQI) of Kot Dam in Summer Season (2021-23)

Parameters	Vi	Si	Wi	Qi	WiQi
pH	7.45	8.5	0.061801	30	1.854026
TDS	207.3	500	0.001051	41.46	0.043558
Total Hardness	163.2	300	0.001751	54.4	0.095256
Total Alkalinity	173.2	200	0.002627	86.6	0.227458
DO	6.7	6	0.087551	91.86047	8.042498
BOD	4.1	2	0.262654	205	53.84401
Chloride	57.8	250	0.002101	23.12	0.04858
Sulphate	30.5	200	0.002627	15.25	0.040055
Nitrate	0.94	20	0.026265	4.7	0.123447
Calcium	36.7	75	0.007004	48.93333	0.342734
Magnesium	22.5	30	0.01751	75	1.313269
Conductivity	345.9	300	0.001751	115.3	0.201893
Fluoride	0.4	1	0.525307	40	21.0123

WQI=87.18

noted in summer at S1 site, and the lowest (0.243 mg l^{-1}) in winter at S2 site. Chloride concentration was highest (67.7 mg l^{-1}) in summer at S4 site and lowest (27.9 mg l^{-1}) at S1 site during monsoon. During the sampling year (2022-23), the nitrate and sulphate levels were highest in summer at S2 (1.007 mg l^{-1}) and S1 site (33.75 mg l^{-1}), and lowest in winter (0.47 mg l^{-1}) at S1 and (16.5 mg l^{-1}) S4 sites. Fluoride levels were highest in summer (0.42 mg l^{-1}) and lowest in winter (0.21mg l^{-1}) at S1 site, while chloride levels were highest in monsoon (64.25 mg l^{-1}) at S2 site and lowest (38.2 mg l^{-1}) in winter at S3 site, respectively (Table 2). During summer, the chemical concentrations of nitrate, sulphate, phosphate, chloride, and fluoride increase in water bodies due to human activities and also evaporation (Nayar, 2020). Nitrate, Chloride and phosphate levels are linked to agriculture, animal waste and detergents. High temperatures promote evaporation, thereby concentrating these chemicals (Dey *et al.,* 2021). Fluoride levels increase due to industrial discharges, emphasising human impact on water quality during summer (Gupta *et al.,* 2021). Kumar *et al.* (2022) noted high concentrations of nitrate, sulphate, and chloride ions in water bodies attributed to agricultural runoff, industrial waste, municipal sewage, and synthetic detergents.

The water quality index (WQI) of Kot Dam was calculated based on the analysis of physicochemical parameters of the water sample collected during the year 2021 to 2023. The analysis of water quality at each station of Kot Dam is shown in Table 3, providing a clear understanding of its status. During summer and monsoon seasons, the WQI value at sampling site S1 exceeded the upper limit of 100, indicating the unsuitability of water for human use. The WQI value for sampling site S1 during winter and S2, S3 and S4 sites during summer and monsoon indicates severely polluted water quality of Kot Dam. Throughout the winter season, the WQI value suggests a moderately polluted water condition for sampling S2, S3 and S4 sites. The water at sampling site S1 is unsuitable for human consumption due to anthropogenic activities, tourism, and its roadside location. The WQI was 87.18 in summer (Table 4), 85.38 in monsoon (Table 5), and 67.34 in winter (Table 6). The results showed that the water was severely polluted in summer and monsoon, while in winter, the water was moderately polluted (Fig. 2). Several studies on Indian dams have utilised WQI in assessing the water quality. For instance, Mishra *et al.* (2008) studied dam water quality based on the Water Quality Index (WQI) in Kohargaddi Dam in the Balrampur district. Similarly, Panda *et al.* (2016) examined water quality in Hadagada Dam, Odisha.

The dendrogram displays the hierarchical relationships between sampling sites based on their Bray-Curtis distances. S2 and S4 site are closest to each other regarding Bray-Curti's distance. This indicates that these two sites share relatively similar water quality characteristics across three seasons during the study period. Site S3 has some water quality similarities with the cluster containing Site S2 and site S4, as measured by the Bray-Curtis distance. Site S1 shares some water quality

Table 5: Water Quality Index (WQI) of Kot Dam in Monsoon Season (2021-23)

Parameters	Vi	Si	Wi	Qi	WiQi
pH	7.07	8.5	0.061801	4.666667	0.288404
TDS	305.1	500	0.001051	61.02	0.064109
Total Hardness	158.3	300	0.001751	52.76667	0.092396
Total Alkalinity	151.4	200	0.002627	75.7	0.198829
DO	6.5	6	0.087551	94.18605	8.246105
BOD	4.4	2	0.262654	220	57.78382
Chloride	47.8	250	0.002101	19.12	0.040176
Sulphate	25	200	0.002627	12.5	0.032832
Nitrate	0.55	20	0.026265	2.75	0.07223
Calcium	32.5	75	0.007004	43.33333	0.303511
Magnesium	19.78	30	0.01751	65.93333	1.154509
Conductivity	513.25	300	0.001751	171.0833	0.299571
Fluoride	0.32	1	0.525307	32	16.80984

WQI= 85.38

Table 6: Water Quality Index (WQI) of Kot Dam in Winter Season (2021-23)

Parameters	Vi	Si	Wi	Qi	WiQi
Ph	7.7	8.5	0.061801	46.66667	2.884041
TDS	168.5	500	0.001051	33.7	0.035406
Total Hardness	145.3	300	0.001751	48.43333	0.084808
Total Alkalinity	201.5	200	0.002627	100.75	0.264624
DO	8.5	6	0.087551	70.93023	6.21003
BOD	3.2	2	0.262654	160	42.0246
Chloride	42.7	250	0.002101	17.08	0.035889
Sulphate	17.9	200	0.002627	8.95	0.023508
Nitrate	0.49	20	0.026265	2.45	0.06435
Calcium	30.5	75	0.007004	40.66667	0.284833
Magnesium	18.5	30	0.01751	61.66667	1.079799
Conductivity	284.06	300	0.001751	94.68667	0.165799
Fluoride	0.27	1	0.525307	27	14.1833

WQI =67.34

characteristics with the combined cluster, which includes Site S3 and the previous cluster formed by Site S2 and site S4 (Fig. 3). Harinagaraj *et al.* (2021) analysed physical, chemical, and nutrient parameters in Muthirapuzha River of Kerala, using the Bray-Curtis Similarity Index, which corroborates with this study in establishing hierarchical relationships between sampling sites.

Correlation coefficient analysis of physico-chemical parameters at four sampling stations in Kot Dam water showed significant relationships in both sampling years. There was a negative correlation between DO and BOD across the study period, while total hardness was positively correlated with alkalinity, BOD, nitrate, sulphate, calcium, magnesium, fluoride and total dissolved solids. Additionally, DO and chloride showed a significant negative correlation with these parameters, while total hardness positively correlated with pH, conductivity and TDS. Fig. 4 showed that there was a positive correlation between total dissolved solids and total hardness, BOD and conductivity. This correlation was also observed in prior studies conducted by Sumitra *et al.* (2007), Gaur *et al.* (2001), Mishra *et al*. (2017) and Kavindra *et al.* (2019) in Lake Pichola, Rana Pratap Sagar Dam and Jawai Dam, respectively.

Kot Dam, situated on the western fringe of the Aravalli range in Rajasthan's Jhunjhunu district, lies in close proximity to the Indian desert region, giving the area its predominantly arid climate. An evaluation of the Kot Dam water revealed marked spatio-temporal variations over the study period. Using the water quality index (WQI), it was determined that the dam water was heavily polluted during summer and monsoon seasons, rendering the water at S1 sampling site unfit for human consumption. However, in winters, the water quality improved slightly, indicating its potential use for irrigation, though it still showed moderate pollution levels. Insights into water quality are paramount for the sustainable management of surface water sources, especially in arid regions where water is scarce. The current study will prove significant for devising appropriate strategies to treat and conserve these water bodies while maintaining the cultural and economic activities around the dam.

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