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Surface water quality dynamics of river, lakes and dam in Jaipur district, India: Insights from WQI, MANOVA and contour mapping

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ABSTRACT

The present study assesses the surface water quality of Jaipur, Rajasthan, India, by conducting a comprehensive seasonal evaluation of four significant surface water bodies of district. A total of 12 surface water samples in triplicates were taken during pre-monsoon (PRM), monsoon (M) and post-monsoon (POM) seasons and analysed for 12 physicochemical, 3 biological and 2 microbiological parameters, to determine the suitability of these water resources for domestic and ecological use. Water Quality Index (WQI) was employed to provide an overall measure of water status while the significant effects of seasons, sites and their interactions were statistically analysed by Multivariate Analysis of Variance (MANOVA) and post-hoc test. Based on the majority of studied water quality parameters, the results revealed the order of seasonal impact as PRM > M > POM, whereas spatially, Mansagar lake exhibited the highest significance in some parameters (pH, electrical conductivity, TDS, total hardness, chloride, nitrate and carbonates) followed by Dravyavati river (BOD, COD, fluoride and coliforms), Maota lake (D.O and temperature) and Kanota dam (bicarbonates). Contour chats were prepared for each studied parameter, enabling a clear visualization of distributional patterns and trends. The research emphasizes the need for sustainable management techniques to protect surface water resources in semi-arid areas and provides critical insights on how seasonal factors influence the water quality.

Keywords Surface water quality. physicochemical and microbiological parameters. WQI. MANOVA. post-hoc

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Introduction

Surface water is the most preferred source of water to meet the agricultural, industrial and domestic requirements owing to its low cost, hassle-free access, availability on demand in all seasons at the point of use. In future, water scarcity will be one of the biggest challenges in the world. The water bodies, near populated areas, are polluted due to discharge of organic and hazardous pollutants (Pandey et al. 2021). Lakes and reservoirs, throughout the world, are in danger due to excess release of industrial effluents. Similarly, the anthropogenic activities in Jaipur area are increasing day by day (Akhtar et al. 2021; Chahar et al. 2023). Unfortunately, the availability of water resources in the state of Rajasthan is extremely low due to problems with distribution, quality and quantity of water. At the same time, demand for potable water is increasing day by day for purposes like irrigation, industrial and domestic uses. Generally, water resource problems are of three main types, too little water, too much water, and too polluted water (Samiksha & Gupta 2019). Many physicochemical and microbiological parameters of water have deteriorated due to various anthropogenic activities along with direct discharge of domestic waste and industrial effluents into surface water bodies (Jain et al. 2016). Pesticides are substances used to eliminate pathogens, pests and microorganisms. Pesticides along with other pollutants, have direct and immediate detrimental effects on water quality. Also the agricultural ecosystem has jeopardized by the excessive use of pesticides (Sharma & Sharma 2022).

The present study aimed to comprehensive assessment of surface water quality of Jaipur district, Rajasthan, India. The physicochemical, biological and microbiological parameters were evaluated that covers four major surface water bodies (Dravyavati river, Mansagar lake, Maota lake and Kanota dam) and seasonal variations (pre-monsoon, PRM; monsoon, M; and post-monsoon, POM seasons). The statistical analysis such as MANOVA and post-hoc tests were used to determine spatial and temporal variations in water quality, while contour charts were employed for effective spatial visualization. Furthermore, the Water Quality Index (WQI) was also evaluated to provide an integrated measure of water suitability. This study aspires us to generate a holistic understanding of surface water quality in Jaipur district and provide a scientific foundation for sustainable management, actionable insights for long- term preservation of these vital resources.

Materials and Methods

Sites of study and sample collection

The surface water samples were collected and analysed in three different seasons viz, pre-monsoon (PRM), monsoon (M) and post-monsoon (POM) from four different water bodies of Jaipur district, Rajasthan, India. Key sites included river, lakes and reservoir such as Dravyavati river, Mansagar lake, Maota lake and Kanota dam. Jaipur is located in a semi-arid region with extreme seasonal variations, influencing water availability and quality. Two- litre bottles made of High Density Poly Ethylene (HDPE) were used to collect the water samples. Before the water samples were collected, thoroughly cleaned bottles were washed twice with the sample water. Sample bottles were correctly sealed with lids and parafilm as well as labelled with date, time and sample ID.

Studied Parameters

The physicochemical, biological and microbiological parameters viz, odour, temperature, turbidity, electrical conductivity, pH, total dissolved solids, total hardness, chloride, nitrate, fluoride, carbonate, bicarbonate, dissolved oxygen, biological oxygen demand, chemical oxygen demand, total coliforms and faecal coliforms of collected water samples were evaluated.

Physicochemical parameters

The physical and chemical properties of surface water samples were evaluated seasonally (as per APHA 2017). Odour was assessed immediately after sample collection using olfactory evaluation. Temperature was recorded on-site by dipping a laboratory thermometer (Zeal, England, UK) in 30 ml of water sample in a glass beaker. Subsequently, water samples were preserved in an insulated icebox at 4° C and conveyed to the laboratory for further analysis. Turbidity was measured using a nephelometric method with a digital turbidity meter (LABTRONICS: LT-34, Panchkula, India) as per APHA standard methods. The instrument was calibrated by using formazin standard solutions prior to measurement. After calibration, samples were analysed and average of three readings were recorded. The measurement of electrical conductivity (EC) was conducted using a digital conductivity meter (LABTRONICS: LT-16, Panchkula, India). The calibration was performed by a standard KCl (0.01M) solution. Following calibration, 30 ml of each water sample was collected in a cleaned glass beaker and the EC values were recorded.

A digital pH meter (HI9812-51, HANNA instruments, Romania) and a TDS meter (HIMEDIA: WT018, Thane, India) were used to test the pH and TDS of water samples. Each sample (25 ml) were taken in a cleaned glass beaker for the measurement of their value. Total hardness of

water samples was determined by using EDTA complexometeric titration method (Gupta et al. 2016). This method involves titrating the surface water samples with standardized solution of ethylene diamine tetra acetic acid (EDTA) using eriochrome black-T as an indicator at pH 10. The appearance of colour change from wine red to blue indicates the endpoint. The argentometric titration technique was used to measure the chloride concentration. The water samples (10 ml each) were titrated with standardized silver nitrate ($AgNO_3$) solution using potassium chromate (as an indicator). The appearance of persistent reddish-brown colour in each sample was recorded as an endpoint (Kicińska & Caba 2021). Fluoride was estimated using a zirconium-alizarin red S colorimetric method. In this method, 50 ml of water sample was mixed with 2.5 ml of zirconyl oxychloride and 2.5 ml of alizarin red S. the sample was incubated at 37 C for 1 hr to allow the formation of zirconium-alizarin complex. Fluoride displaces the dye from this complex, causing a measurable colour change. The absorbance was recorded at 550 nm by using a MS-UV Plus double beam spectrophotometer (Motras Scientific, Gurugram, India). Nitrate concentration was determined using the UV spectrophotometric method. For sample preparation, 5 ml of each water sample was transferred into a 50 ml of volumetric flask followed by the addition of 1 ml concentrated hydrochloric acid. Then the volumetric flask filled up to the mark with distilled water and gently inverted 6-8 times to ensure homogenization. A blank solution (control) was prepared similarly using 1 ml of HCl diluted to 50 ml with distilled water, without any sample. The absorbance of samples and blank was measured at 220 nm using a MS-UV Plus double beam UV-visible spectrophotometer (Motras Scientific, Gurugram, India). A calibration curve was constructed using standard nitrate solution i.e., control and then nitrate concentrations in water samples were calculated accordingly (Bairwa et al. 2024). The acid-base titration method was used to measure the amount of carbonate and bicarbonate ions in surface water samples. A 20 ml of water sample was titrated with standard HCl (99%, Fisher Scientific). The sample was first titrated using phenolphthalein indicator until the disappearance of pink colour, indicates neutralization of carbonate ions. Then the titration continued with methyl orange (indicator) and the colour changes from yellow to orange-red as an endpoint for bicarbonate ions.

Biological Parameters

Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD) were determined as per the protocol of APHA standard methods, (APHA 2017). The procedures were supported by established limnological principles (Wetzel 2001; Boyd 2020). Water samples were filled into 300 ml air tight BOD bottles without air bubbles to prevent oxygen exchange. For Dissolved

Oxygen (DO) determination, the samples were promptly fixed with manganous sulfate and alkaline iodide azide reagents, followed by titration using sodium thiosulfate solution (Winkler titration method). Furthermore, for BOD evaluation, collected water samples were incubated in the dark (27± 1°C) for 3 days, after which final DO was measured following the same titration method to calculate BOD. This method was performed in triplicate to reduce the errors and record the readings. Results were expressed in mg/l.

BOD_3 was calculated as: $BOD_3 = DO_{initial} - DO_{final}$

Chemical Oxygen Demand (COD) was determined using the closed reflux titrimeteric method (APHA 2017). Water samples were digested with potassium dichromate and concentrated sulfuric acid (containing silver sulfate and mercuric sulfate) in COD digestion tubes. The COD digester was adjusted at 150°C for 2 h (Chemtech: Ambay biotech, Noida). After 2 h, water samples were placed at room temperature for 30 minutes, the water samples were titrated against standardized 0.1N ferrous ammonium sulfate (FAS) solution followed by addition of ferroin solution (as an indicator) until the colour changes from blue-green to reddish brown (as endpoint). The samples were titrated in triplicate to reduce standard errors.

COD calculated as: $$COD\ (mg/L) = \frac{(A-B)\times N\times 8000}{\text{Volume of sample (ml)}}$$

Where, A = Volume of FAS used for blank (ml)

B = Volume of FAS used for sample (ml)

N = Normality of FAS

8000 = Milliequivalent weight of oxygen x 1000

Microbiological Parameters

The total coliforms and faecal coliforms (*Escherichia coli*) in all water samples were determined by using the Compact Dry EC chromogenic plate method (Nissui Pharmaceutical Co., Ltd., Japan; Mizuochi et al. 2016). This standardized, ready-to-use medium was used for simultaneous detection and differentiation of coliform groups based on characteristic colony coloration. The aliquot (1 ml) of each water sample was aseptically pipetted and placed at the centre of the Compact Dry EC plate. Through capillary action, each sample was let to diffuse uniformly throughout the surface of dehydrated medium. After that, the plates were incubated for 24 h at 35 ± 1°C in an aerobic environment.

Statistical Analysis

A Multivariate Analysis of Variance (MANOVA) was employed to assess the spatio-temporal variations in water quality. MANOVA is a statistical method that enables the concurrent analysis of multiple dependent variables to assess whether statistically significant differences exist among groups defined by categorical independent variables. The physicochemical, biological and microbiological parameters in water samples were used as dependent variables. Whereas, 3 different seasons (PRM, M and POM) and areas/locations (Dravyavati river, Mansagar lake, Maota lake and Kanota dam) as independent variables. This approach accounts for possible interactions between seasons and locations, thereby highlighting whether seasonal changes affect all study sites uniformly or certain locations exhibit distinct patterns of variation. Post-hoc multiple comparison tests (Tukey's HSD) were further employed to identify specific group differences when significant MANOVA results were obtained. The statistical analyses were performed using IBM SPSS software version 26.

Water Quality Index (WQI)

The water quality indexes provide dependable assessments of surface water quality (Chakravarty & Gupta 2021). The WQI serves as a systematic approach to classify water sources by evaluating water quality parameters against established national or international standards (Azhari et al. 2023). Its importance is illustrated by integrating all of the water quality metrics into one number that is easy to understand and use (Azzirgue et al. 2022). A WQI typically comprises four processes or components. First, the water quality parameters of interest are selected. Second, the water quality data are read and for each water quality parameter the concentrations are converted to a single-value dimensionless sub-index. Third, the weighting factor for each water quality parameter is determined and fourth, a final single value water quality index is calculated by an aggregation function using the sub-indices and weighting factors for all water quality parameters. Many different WQI models have been developed with variations in model structure, the parameters included and their associated weightings, and the methods used for sub-indexing and aggregation (Jha et al. 2015; Uddin et al. 2021).

The WQI was employed according to the classical method to assess the impact of natural and anthropogenic factors on water quality, utilizing 10 physicochemical and biological parameters of surface water chemistry of Jaipur district. Parameters were as follows- DO, pH, TDS, turbidity, electrical conductivity, total hardness, chloride, BOD, COD and nitrate.

The WQI was computed following the methodology outlined by (BROWN et al. 1972), the WAWQI is calculated as follows:

$$WQI = \frac{\sum_i^n WiQi}{\sum Wi} \quad \text{..... (i)}$$

Where, Wi = weight of each metric used to evaluate the quality of water is determined in the manner shown below:

$$Wi = \frac{K}{Sstd} \quad \text{..... (ii)}$$

And,

$$K = \frac{1}{\sum \frac{1}{Sstd}} \quad \text{..... (iii)}$$

K = proportionality constant

Sstd = standard value applied for different parameters.

Qi = quality rating scale of the i^{th} parameter, for all the n parameters of quality of water.

It is calculated as follows:

$$Qi = \frac{Q-Qi}{Sstd-Qi} \quad \text{..... (iv)}$$

Where,

Qi = optimal parameter value in pure water.

Qi = 0 for all parameters, except foe DO and pH. (Qi for DO = 14.6 mg/l and pH = 7.0).

Result and Discussion

Multivariate analysis of variance

A multivariate analysis of variance (MANOVA) was conducted to examine the effects of seasons (pre-monsoon, monsoon, post-monsoon) and areas (Dravyavati river, Mansagar lake, Maota lake and Kanota dam) on the combined water quality parameters. All 4 multivariate tests (Pillai's, Wilks, Hotelling's, and Roy's) showed the significant effects of areas and seasons on the dependent variables (water quality parameters). The results revealed a significant multivariate effects of seasons on the dependent variables, Wilks' $\Lambda = 0.002$, $F(32, 30) = 20.31$, $p < 0.001$. Similarly, a significant multivariate effect of area was observed, Wilks' $\Lambda \approx$

0.000, F (48, 45.41) = 36.83, $p < 0.001$ (Table 1). These findings indicate that both seasonal variation and site differences contribute significant changes in the overall water quality profile.

In present study, it was observed that the seasons showed significant effects on various dependent variables such as pH, temperature, total dissolved solids, total hardness, turbidity, nitrate, carbonate, bicarbonate, faecal coliforms, biochemical oxygen demand and chemical oxygen demand ($p<0.05$). No significant effects were observed on electrical conductivity, chloride, fluoride, total coliforms and dissolved oxygen ($p>0.05$). On the other hand, for areas, all the dependent variables showed significant effects in all cases ($p<0.05$). This confirm that spatial differences among sites/ areas were strongly influence the water quality across most physicochemical and microbiological parameters.

Physicochemical parameters

The odour of water is used to detect the contaminants or unwanted compounds that may compromise its quality, usage and acceptance. The unpleasant smell was present in tested surface water samples that were collected from Dravyavati river and Maota lake while the smell was mildly unpleasant in the samples collected from Mansagar lake and Kanota dam in all three seasons. Odour provide early warning of pollution and give clues about the type of contamination in water bodies. This unpleasant smell indicates organic pollution, sewage, industrial and chemical discharge (Shirin & Yadav 2014; Czarnota et al. 2023).

Temperature has considerable impact on biological water quality by influencing macroinvertebrate abundance, species composition and biodiversity. Higher temperatures alter the metabolic rates and growth patterns in aquatic life. Recognizing the importance of temperature is critical in monitoring water quality and forecasting ecological responses to climate change (Khaliq et al. 2024). The temperature of tested surface water samples was recorded in the range of 30 °C to 32 °C (PRM), 22 °C to 28.2 °C (M) and 17 °C to 26 °C (POM). Statistical study revealed that temperature show significant effects on the water samples analysed in 3 seasons and 4 areas (Table 2). Through a post-hoc test, among 3 seasons PRM had the highest of temperature (Table 3). In area-wise study, Maota lake had the maximum temperature (Table 4). The contour chart illustrated the spatial and seasonal variation in water temperature at the four studied sites across three seasons (Fig 1a). The minor cooling was observed in the post- monsoon season which reveals that seasonal variations occur due to high rainfall and low temperatures. Higher summer temperature and solar radiations directly

affect the surface water temperature of selected water bodies of Jaipur during pre-monsoon and monsoon seasons.

Turbidity is an essential parameter for evaluating the water quality and the quantity of suspended particles. It correlates with the water pollution and anthropogenic activities (Joshi & Agrawal 2022). Graphical representation of spatial and temporal variation of a turbidity is depicted in contour chart (Fig 1b). In Kanota dam and Mansagar lake higher turbidity was found during monsoon and post- monsoon seasons but, in Maota lake and indicated sites of the Dravyavati river the turbidity levels were lower (0-20 NTU) in PRM season. The observed values at all studied sites substantially exceeded from the BIS permissible limit (5 NTU). The significant effects of turbidity were observed on tested surface water samples during seasonal variations ($p<0.05$; Table 2). In our study, the rainfall and surface water runoff affected the levels of turbidity in tested water samples during monsoon season (Table 3).

Electrical conductivity (EC) is a measurement for how much a water body can transmit electric current. The fluctuations in EC depends on the concentration of total dissolved solids in water, encompassing both organic and inorganic materials such as salts, minerals and metals. Elevated EC values influence the taste, odour and also salinity which might negatively impact on aquatic organisms, irrigation methods and overall acceptability of water (Kumar et al. 2023). Statistically study displayed, area-wise significant differences ($p<0.05$) in surface water samples of electrical conductivity rather than studied seasons (Table 2). A post-hoc test was applied to find out maximum and minimum values of EC in water samples among significant areas. Maximum value of EC was recorded in the water samples of Mansagar lake whereas minimum value found in Maota lake (Table 4). The contour chart distribution showed marked spatial differences with Mansagar and Maota lake with a larger proportion of measurements falling within the 2000-3000 µS/cm range when compared with Dravyavati river and Kanota dam. While, seasonally the highest concentrations were observed during the PRM season, reflecting evaporative concentration and limited dilution (Fig 1c).

The pH level serves as a critical indicator of water quality, representing the extent of acidity or alkalinity. A balanced pH of water is essential for living being because it influences the availability of nutrients, solubility of minerals and the toxicity of pollutants in water. On the basis of pH, the quality of water is determined that it is suitable for drinking, farming, aquatic life and other environmental purposes (Vohra et al. 2023). A MANOVA test of pH showed significant effect for both seasons and areas, among the 4 areas or water bodies.

Mansagar lake had highest significance while Maota lake had lowest (Table 4). And seasonally, pre-monsoon had highest value and monsoon had lowest (Table 3). The pattern of contour chart indicated that Dravyavati river and Mansagar lake typically presented elevated pH levels, leaning towards alkaline conditions throughout the majority of seasons whereas Maota lake and Kanota dam relatively lower pH values, within neutral spectrum. The levels of alkalinity were slight higher in PRM and POM seasons while moderate to lower in monsoon season (Fig 2a). Overall, the pH values across all sites majorly fall within acceptable range of freshwater systems (6.5 to 8.5 as per BIS/WHO guidelines), suggesting that spatial and temporal fluctuations exist, the water remains appropriate for the majority of domestic and ecological applications.

Total dissolved solids (TDS) describe the overall concentration of dissolved substances, encompassing both organic and inorganic components present in water (Singh et al. 2024). The contour chart illustrates (Fig 2b) considerable variations among selected water bodies across seasons (PRM, M and POM). Elevated TDS levels were notably recorded in Mansagar lake and Dravyavati river, especially in PRM and POM seasons. This indicating the effects of lower dilution and potential human contributions. Conversely, reduced TDS levels were observed in Maota lake during monsoon season, likely due to surface runoff and rainfall causing dilution. Similarly, statistical analysis revealed that both areas and seasons were significant for total dissolved solids (as their $p<0.05$; Table 2). Seasonally, PRM had maximum value and monsoon season had minimum values of TDS (Table 3). Furthermore, area-wise statistical analyses revealed that Mansagar lake present highest value and Maota lake had lowest value of TDS (Table 4). The observed seasonal variations highlight dynamic nature of TDS. Its increased levels are associated with evaporation and pollutant accumulation during pre-monsoon season while decreased level of TDS were noted in monsoon season due to natural dilution (Banyal et al. 2020).

Total hardness characterizes the property of water and its tendency to form insoluble precipitates with soaps and detergents. It is primarily caused by the presence of divalent cations, namely magnesium and calcium (Gupta et al. 2016). Statistically, total hardness of water showed significance in both seasons and areas (Table 2). Furthermore, contour chart distribution patterns (Fig 2c) reflected that Mansagar lake and Maota lake frequently exhibit elevated water hardness values, particularly during pre- monsoon and post- monsoon respectively. This showed reduced dilution and increased mineral concentration in stagnant conditions. In contrast, Dravyavati river demonstrates wider fluctuations ranging from lower

hardness in monsoon season to elevated levels during pre- monsoon season, due to varying inflow and pollution load. Kanota dam mostly falls within moderate to high range (200-400 mg/l) with seasonal shift. So, the levels of total hardness of water in several water bodies were found exceeded when compare with desirable limits (BIS, 200 mg/l). This indicating moderate to high mineralization in the surface waters of the study. Total hardness in lakes and dams influence the water chemistry; by scaling and corrosion, affect ecological health and plays a crucial role in the long-term sustainability of surface water resources (Gholizadeh et al. 2017; Porsan et al. 2020).

Chloride ions (Cl^-) are often found in natural water bodies, mainly in the form of calcium, magnesium and sodium salts (Wu et al. 2021). Chloride levels of surface water samples were analysed in 3 different seasons. A MANOVA test stated that chloride showed its significance ($p<0.05$) to the studied areas (water bodies) not to the studied seasons (Table 2). Among all the studied sites Mansagar lake had maximum values of chloride while Maota lake had minimum value, determined by a post-hoc test (Table 4). A contour chart (Fig 3a) described distinct spatial heterogeneity with Maota lake and Kanota dam showed relatively higher chloride fluctuations as compare to Dravyavati river and Mansagar lake. Moreover, contour chart reflected seasonal distribution that demonstrates noticeable variation between PRM, M and POM seasons. This indicate the observed patterns were probably governed by anthropogenic activities, dilution factors and hydrological inputs. Pre- monsoon circumstances showed higher chloride levels, whereas monsoon conditions showed more dilution, indicating the impact of runoff and rainfall. The fluctuating nature of chloride levels in these aquatic ecosystems was highlighted. This emphasizing the need of ongoing monitoring to evaluate the changes in water quality. Exceeded chloride concentration in studied water bodies (esp. Mansagar lake) act as an indicator of sewage pollution (Gupta et al. 2016).

Fluoride is the most prevalent element in the Earth's crust, exhibiting a beneficial and detrimental effect on human health. A small quantity (0.60 mg/l) is essential for preventing dental decay whereas concentrations below this can lead to tooth decay. On the other hand, elevated doses (exceeding 1.5 mg/l) can cause dental fluorosis (Tiwari et al. 2020; Wang et al. 2020) Fluoride had significance in studies areas rather than studied seasons (Table 2). A post-hoc test revealed maximum and minimum significant values of fluoride among four studied surface water bodies/ areas i.e., Dravyavati river > Kanota dam > Mansagar lake > Maota lake (Table 4). The contour chart displayed slightly elevated levels of fluoride in the sample water of Dravyavati river, particularly during PRM season more like due to groundwater influence

or anthropogenic inputs (Fig 3b). Fluoride ions (F^-) of all water samples were found within permissible limit of BIS and WHO i.e., 1.5 mg/l.

Nitrate significantly influences surface water systems through its quick dissolution and subsequent interactions with groundwater. Multiple natural elements and anthropogenic activities play a role in its occurrence, including septic tank leakage, fertilizers and drainage from poultry waste (Camargo & Alonso 2006; Jandu et al. 2021). Nitrate levels range from 7 to 26.34 mg/l throughout all the studied areas, which is within the acceptable range (45 mg/l) of BIS (as per IS 10500:2012). Statistically, nitrate showed significance for both studied seasons as well as sites (Table 2). Afterwards, a post-hoc test was applied on obtained significant values and found which season or site had maximum and minimum values, reflected as: seasonally, PRM > M > POM (Table 3) while area-wise, Mansagar lake > Kanota dam > Dravyavati river > Maota lake (Table 4). The distribution pattern of contour chart highlights the spatiotemporal trends and interaction between hydrological systems and human influences on water quality. As higher nitrate concentrations frequently observed in pre-monsoon season, probably because reduced dilution and greater accumulation of agricultural runoff. In contrast, monsoon season reflected significant dilution effects from rainfall, leading to relatively lower nitrate levels across most sites (esp. Maota lake). Tested values from post- monsoon season demonstrated moderate to elevated concentrations, indicating leaching and residual impacts of fertilizers. Area-wise, the chart showed site-specific influences such as land use and catchment activities (Fig 3c).

Carbonates and bicarbonates play a crucial role in determining the alkalinity of water bodies in Jaipur, primarily resulting from the dissolution of carbon dioxide and its interaction with minerals found in the soil and bedrock. The surface and ground water in the area are mainly defined by carbonate-bicarbonate hydro-chemical groups, which have an essential role in influencing the overall water chemistry (Dadhich et al. 2016). By adding to the alkalinity and overall hardness of the water, these substances alter its appropriateness for irrigation as well as its potability by buffering the pH. Carbonate level in the analysed water samples ranged from 0.01 to 84 mg/l. It showed significance for both studied seasons as well as areas (Table 2). A post-hoc analysis revealed that carbonate concentration was comparatively lower during POM season, whereas higher values were observed in PRM season (Table 3). Conversely, Maota lake exhibited lowest concentration while Mansagar lake marked highest concentrations of carbonate (Table 4). Contour chart pattern indicated that carbonate dynamics were strongly site-specific, with Mansagar lake and Dravyavati river reflecting hydrological variability, while

Maota lake and Kanota dam maintain persistent levels, possibly due to catchment geology and groundwater contributions (Fig 4). Bicarbonate levels ranged from 341 to 435 mg/l in pre-monsoon, 171 to 391 mg/l in monsoon and 220 to 500 mg/l in post-monsoon season. Statistically both seasons and areas (Table 2) were significant and their maximum and minimum concentrations found as: PRM > POM > M (Table 3) and area-wise, Kanota dam > Dravyavati river > Mansagar lake > Maota lake (Table 4). As per BIS limits, the water samples of all the studied sites among 3 seasons were found under the desirable limits of carbonate and bicarbonate. Such conditions make the aquatic life more prone to pH fluctuations and metal toxicity, which can adversely affect the overall ecosystem stability (Z. Wang et al. 2016; Kerr et al. 2021).

Biological Parameters

Dissolved oxygen (DO) describes the concentration of free molecular oxygen in water, which is influenced by temperature and biological activity (Piatka et al. 2021). The dissolved oxygen levels in lakes and rivers are influenced by complex interaction of various environmental occurrences and biological activities (Zhang et al. 2024). Analysed values of DO in PRM, M and POM seasons were reported as: 0.4 to 1.8 mg/L in Dravyavati river, 2.9 to 5.6 mg/L in Mansagar lake, 3.5 to 5.9 mg/L in Maota lake and 0.6 to 5.1 mg/L in Kanota dam. As shown in Table 2, MANOVA revealed that DO differ significantly among the studied areas (p<0.05) whereas no significant difference was observed with studied seasons. The results of contour chart and post-hoc test indicated that Dravyavati river experience critically low DO concentrations (0-2 mg/L; Fig 5a) esp. during pre-monsoon season reflecting high organic loading and oxygen depletion. Surface water bodies often have low DO levels (hypoxia), which may adversely affect aquatic ecosystems in variety of ways such as causing physiological stress in living organisms and altering the composition of biological communities (Weinke & Biddanda 2018; Xu et al. 2021).

Biochemical Oxygen Demand is an essential parameter for evaluating contamination levels in surface water, resulting from industrial and domestic wastewater. Elevated BOD levels signify a higher biochemical pollutant load. Reducing BOD is necessary for minimizing its detrimental effects on aquatic ecosystems (Das 2024). BOD levels varied from 37.4 to 45.2 mg/l in Dravyavati river, 6.5 to 28 mg/l in Mansagar lake, 8.5 to 11.2 mg/l in Maota lake and 5.5 to 22 mg/l in Kanota dam throughout all 3 seasons. The MANOVA test determined the p-value less than 0.05 in both cases i.e., studied seasons and studied areas. A post-hoc test and contour chart (Fig 5b) indicated that Dravyavati river and Mansagar lake showing consistently

elevated BOD levels (Table 4) during pre- monsoon season (Table 3). This reflecting heavy organic pollution from sewage, domestic waste, agricultural runoff and reduced dilution. Maota lake and Kanota dam recorded relatively lower BOD values during monsoon and post-monsoon seasons (Table 3), suggesting comparatively better water quality.

Chemical Oxygen Demand quantifies the oxygen needed to oxidize organic compounds that resist biological degradation. The total organic material in water samples, encompassing both biodegradable and non-biodegradable components (Abdullahi et al. 2021). 100 to 125 mg/L in Dravyavati river, 35 to 99 mg/L in Mansagar lake, 28.6 to 37 mg/L in Maota lake and 23.3 to 79 mg/L in Kanota dam throughout 3 seasons. Studied areas as well as studied seasons showed the *p*-value less than 0.05, analysed through MANOVA test. Post-hoc comparisons and contour mapping (Fig 5c) demonstrates that Dravyavati river and Mansagar lake had high COD levels (Table 4), often within moderate to high range (50-150 mg/L), particularly during pre- monsoon season. This indicating substantial organic and chemical pollution from human sources. On the other hand, Kanota dam and Maota lake maintain relatively stable and lower COD levels. Seasonal variability is apparent with COD levels (Table 3), as reaching their highest levels in PRM period due to decreased dilution and increased organic matter load, whereas monsoon period leads to lower values through the process of dilution. POM period indicate moderate level of COD, reflecting the presence of organic inputs from sewage and industrial effluents along with inorganic contaminants like sulphides and nitrates (Rosid et al. 2025).

Microbiological Parameters

Total coliform (TC) counts in the surface water samples revealed extensive contamination from various sources including anthropogenic inputs (Ramteke et al. 1992). TC counts ranged from 7900 to 10,000 cfu/100mL in Dravyavati river, 350 to 920 cfu/100mL in Mansagar lake, 475 to 650 cfu100/mL in Maota lake and 350 to 920 cfu/100mL in Kanota dam. MANOVA test determined that only studies areas showed significance for total coliform counts (Table 2). Furthermore, a post-hoc test comparison revealed that Dravyavati river had highest total coliform contamination followed by Mansagar lake > Kanota dam > Maota lake, shown in Table 4. Similar results were also displayed in contour mapping (Fig 6a). The observed elevated TC levels in all studied surface waters indicate significant microbial contamination with the influence of domestic sewage discharge and improper waste disposal in surrounding catchment areas.

Faecal coliforms (FC) are the particular biomarker of recent thermotolerant enteric bacteria derived from animal or human excreta (Paruch & Mæhlum 2012). FC values reported as: 6890 to 9000 cfu/100mL (Dravyavati river), 170 to 350 cfu/100mL (Mansagar lake), 12 to 52 cfu/100mL (Maota lake) and 170 to 430 cfu/100mL (Kanota dam). Significant differences in faecal coliform counts were observed across both studies seasons and areas based on MANOVA results (p<0.05). Post-hoc analysis identified Dravyavati river (Table 4) and PRM season had highest FC counts while Maota lake and POM season had lowest (Table 3). While contour mapping provided spatial visualization of FC hotspots and seasonal variability (Fig 6b).

Water Quality Index (WQI)

The assessment of the WQI reveals that all four examined surface water bodies of Jaipur-Dravyavati river, Mansagar lake, Maota lake and Kanota dam exhibit extremely high WQI values in pre-monsoon, monsoon and post-monsoon seasons. All water samples were consistently exceeding the >100 threshold that denotes water "unfit for consumption". This indicated significant degradation of water quality, mainly influenced by ongoing human activities such as untreated household waste and agricultural contributions. Seasonal variations also showed higher WQI during monsoon season, which indicate enhanced pollutant transport through surface runoff (Table 5). Overall, WQI findings highlighted the critical necessity for implementing effective pollution measures, regular monitoring and employ suitable treatment strategies to restore the surface water resources of Jaipur district.

Conclusion

This research offers a comprehensive assessment of surface water quality in Jaipur, Rajasthan, by integrating physicochemical, biological and microbiological water quality parameters across four major surface water bodies i.e, Dravyavati river, Mansagar lake, Maota lake and Kanota dam during pre-monsoon, monsoon and post-monsoon seasons. A multivariate statistical analysis (MANOVA), spatial contour mapping and Water Quality Index (WQI) were employed to robust the evaluation of water quality status and analyse the key factors for surface water quality degradation.

The results of MANOVA test indicated that both studied areas and seasons had statistically significant effect on several tested parameters. Along with this, a post-hoc test resulted that, which water quality parameter showed the highest and the lowest values of studied season or area. The values of pH, temperature, TDS, nitrates, carbonates, bicarbonates, BOD, COD and

faecal coliforms were recorded as the maximum during pre-monsoon season while values of turbidity and total hardness were observed in monsoon and post-monsoon seasons, respectively. Similarly, in area-wise study, the water samples of Dravyavati river contained the highest concentration of fluoride, BOD, COD, total coliforms and faecal coliforms. The values of pH, total hardness, chloride, nitrates, electrical conductivity, total dissolved solids and carbonates were found in maximum levels in the water samples of Mansagar lake. Dissolved oxygen and temperature variations were majorly observed in Maota lake and Kanota dam had highest concentration of bicarbonates in its water samples.

Spatial distribution patterns generated through contour mapping effectively illustrated pollution hotspots and gradients within and among studied water bodies. As per Water Quality Index findings, water samples from all surface water bodies classified as “unfit for consumption”. This showed a significant decline in water quality across different seasons. Among all sites, Dravyavati river and Mansagar lake exhibited comparatively poor water quality likely due to discharge of untreated or partially treated sewage, urban runoff and anthropogenic pressures.

Overall, the study highlights critical degradation of Jaipur’s surface water resources and emphasizes urgent need for effective wastewater management, routine monitoring and site-specific restoration strategies are needed. In order to restore and protect surface water quality in rapidly urbanizing areas, policymakers and water resource managers find the comprehensive analytical framework used in this research that will be a useful tool for assessing urban surface water quality.

References

Abdullahi AB, Siregar AR, Pakiding W, Mahyuddin (2021) The analysis of BOD (Biological Oxygen Demand) and COD (Chemical Oxygen Demand) contents in the water of around laying chicken farm The analysis of BOD (Biological Oxygen Demand) and COD (Chemical Oxygen Demand) contents in the water of around lay. Earth and Environmental Science 788. https://doi.org/10.1088/1755-1315/788/1/012155

Akhtar N, Syakir Ishak MI, Bhawani SA, Umar K (2021) Various natural and anthropogenic factors responsible for water quality degradation: a review. Water 13, 2660. https://doi.org/10.3390/w13192660

APHA (2017) Standard methods for the examination of water and wastewater, 23rd Edition. American Public Health Association Washington, D.C.

Azhari HEl, Cherif EK, Sarti O, Azzirgue EM, Dakak H, Yachou H, Esteves da Silva JCG, Salmoun F (2023) Assessment of surface water quality using the water quality index (IWQ), multivariate statistical analysis (MSA) and geographic information system (GIS) in oued laou mediterranean watershed, Morocco. Water (Switzerland) 15 (1). https://doi.org/10.3390/w15010130

Azzirgue EM, Cherif EK, Tchakoucht TA, Azhari HEl, Salmoun F (2022) Testing groundwater quality in jouamaa hakama region (north of morocco) using water quality indices (WQIs) and fuzzy logic method: an exploratory study. Water (Switzerland) 14 (19). https://doi.org/10.3390/w14193028

Bairwa AK, Gupta AK, Mishra V, Gupta K (2024) Physico-chemical and correlation study of ground drinking water of Tonk district of Rajasthan (India). Discover Water 4 (1). https://doi.org/10.1007/s43832-024-00077-x.

Banyal S, Aggarwal RK, Bharadwaj SK (2020) Effects of national highway expansion activities on physicochemical characteristics of surface water along NH-22, India. International Journal of Ecology and Environmental Sciences 2 (4), 347-354

BIS (1984) Indian standard methods of sampling and test (physical and chemical) for water and wastewater.

Boyd CE (2020) Water quality: an introduction (3rd ed.). Springer Nature, cham.

Brown RM, Mcclelland NI, Deininger RA, O'connor MF (1972) A water quality index – crashing the psychological barrier. Advances in Water Pollution Research 787–797. https://doi.org/10.1016/b978-0-08-017005-3.50067-0

Camargo JA, Alonso Á (2006) Ecological and toxicological effects of inorganic nitrogen pollution in aquatic ecosystems: A global assessment. Environment International 32 (6), 831–849. https://doi.org/10.1016/j.envint.2006.05.002

Chahar R, Mukherji R, Chakraborty S, Chug R, Chauhan MK, Mukherji MD (2023) Impact of temporal variation in macrophyte composition on importance value index (IVI), diversity indices a study at bandhbaretha wild life sanctuary, Rajasthan. International Journal of Science, Mathematics and Technology Learning 31 (2).

https://doi.org/10.5281/zenodo.8327904

Chakravarty T, Gupta S (2021) Assessment of water quality of a hilly river of south assam, north east india using water quality index and multivariate statistical analysis. Environmental Challenges 5, 100392. https://doi.org/10.1016/j.envc.2021.100392

Czarnota J, Masłoń A, Pajura R (2023) Wastewater treatment plants as a source of malodorous substances hazardous to health, including a case study from Poland. International Journal of Environmental Research & Public Health 20 (7), 5379. doi: 10.3390/ijerph20075379

Dadhich PN, Jain H, Meena J, Meena H, Meena CS (2016) Water resource management based on GIS- a case study of municipality of sanganer, Jaipur. International Journal of Engineering Research & Technology 4 (23), 1–2

Das A (2024) An innovative approach for quality assessment and its contamination on surface water for drinking purpose in Mahanadi River Basin , Odisha of India , with the integration of BA - WQI , AHP - TOPSIS , FL - DWQI , MOORA , and RF methodology. Applied Water Science 14 (12). https://doi.org/10.1007/s13201-024-02326-9

Gholizadeh A, Mokhtari M, Naimi N, Shiravand B, Ehrampoush MH, Miri M, Ebrahimi A (2017) Assessment of corrosion and scaling potential in groundwater resources; a case study of Yazd-Ardakan Plain, Iran. Groundwater for Sustainable Development 5, 59–65. https://doi.org/https://doi.org/10.1016/j.gsd.2017.04.002

Gupta A, Bhatnagar P, Bakre PP, Pradeep Bhatnagar C (2016) Physicochemical properties of water and heavy metals (lead and zinc) in water and sediment of a reservoir and drainage of Jaipur (Rajasthan)-A comparative study. International Journal of Fisheries and Aquatic Studies 4 (5), 407-412

Jain R, Bnasal AK, Sharma R (2016) Comparative assessment of physico-chemical parameters of surface water and ground water of Dravyavati river of Jaipur (Rajasthan, India). International Journal of Innovative Research in Science, Engineering and Technology 5 (12), 21153-21160. doi:10.15680/ijirset.2016.0512043

Jandu A, Malik A, Dhull SB (2021) Fluoride and nitrate in groundwater of rural habitations of semiarid region of northern Rajasthan, India: a hydrogeochemical, multivariate statistical, and human health risk assessment perspective. Environmental Geochemistry and Health 43 (10), 3997–4026. https://doi.org/10.1007/s10653-021-00882-6

Joshi A, Agrawal S (2022) Reduction in turbidity of Indian lakes through satellite imagery

during COVID-19 induced lockdown. Spatial Information Research 30 (6), 715–727. https://doi.org/10.1007/s41324-022-00468-z

Kerr DE, Brown PJ, Grey A, Kelleher BP (2021) The influence of organic alkalinity on the carbonate system in coastal waters. Marine Chemistry 237, 104050. https://doi.org/10.1016/j.marchem.2021.104050

Khaliq I, Chollet Ramampiandra E, Vorburger C, Narwani A, Schuwirth N (2024) The effect of water temperature changes on biological water quality assessment. Ecological Indicators 159, 111652. https://doi.org/10.1016/j.ecolind.2024.111652

Kicińska A, Caba G (2021) Leaching of chlorides, sulphates, and phosphates from ashes formed as a result of burning conventional fuels, alternative fuels, and municipal waste in household furnaces. Energies 14 (13). https://doi.org/10.3390/en14133936

Kumar D, Singh VK, Abed SA, Tripathi VK, Gupta S, Al-Ansari N, Vishwakarma DK, Dewidar AZ, Al-Othman AA, Mattar MA (2023) Multi-ahead electrical conductivity forecasting of surface water based on machine learning algorithms. Applied Water Science 13 (10), 1–20. https://doi.org/10.1007/s13201-023-02005-1

Mizuochi S, Nelson M, Baylis C, Green B, Jewell K, Monadjemi F, Chen Y, Salfinger Y, Fernandez MC (2016) Matrix extension study: validation of the compact dry EC method for enumeration of Escherichia coli and non-E. coli Coliform bacteria in selected foods. Journal of AOAC International 99 (2), 451–460. https://doi.org/10.5740/jaoacint.15-0268

Pandey N, Sharma C, Punia MP (2021) Status of groundwater water quality in bhilwara district of rajasthan: a geospatial approach. Geospatial Technology and Smart Cities, The Urban Book Series Springer, Cham. https://doi.org/10.1007/978-3-030-71945-6_24

Paruch AM, Mæhlum T (2012) Specific features of Escherichia coli that distinguish it from coliform and thermotolerant coliform bacteria and define it as the most accurate indicator of faecal contamination in the environment. Ecological Indicators 23, 140–142. https://doi.org/10.1016/j.ecolind.2012.03.026

Piatka DR, Wild R, Hartmann J, Kaule R, Kaule L, Gilfedder B, Peiffer S, Geist J, Beierkuhnlein C, Barth JAC (2021) Transfer and transformations of oxygen in rivers as catchment reflectors of continental landscapes: a review. Earth-Science Reviews 220, 103729. https://doi.org/https://doi.org/10.1016/j.earscirev.2021.103729

Porsan ZP, Zarei , Alimohammadi M (2020) Evaluation of corrosion and scaling potential of

drinking groundwater in Gonbad-e Kavus. Desalination and Water Treatment. 195, 19–25. https://doi.org/https://doi.org/10.5004/dwt.2020.25895

Ramteke PW, Bhattacharjee JW, Pathak SP, Kalra N (1992) Evaluation of coliforms as indicators of water quality in India. The Journal of applied bacteriology 72 (4), 352–356. https://doi.org/10.1111/j.1365-2672.1992.tb01846.x

Rosid A, Satria H, Artika E (2025) Results in chemistry study of water pollution parameters in the dry and rainy seasons on the pollution index of the Mesuji River , Lampung , Indonesia. Results in Chemistry 13, 101906. https://doi.org/10.1016/j.rechem.2024.101906

Samiksha, Gupta P (2019) Comparative statistical analysis of surface and underground water of Ramgarh, Alwar, Rajasthan. Think India. 22 (4), 3360-3368

Sharma S, Sharma G (2022) A survey on water pollution and prevention techniques: a case study of man sagar lake, Jaipur. Journal of Pharmaceutical Negative Results 13 (5), 1772–1780. https://doi.org/10.47750/pnr.2022.13

Shirin S, Yadav AK, (2014) Physico-Chemical analysis of municipal wastewater discharge in Ganga river, Haridwar district of Uttarakhand, India. Current World Environment 9 (2), 536-543. http://dx.doi.org/10.12944/CWE.9.2.39

Singh R, Singh A, Majumder CB, Vidyarthi AK (2024) Impact of pH, TDS, chloride, and nitrate on the groundwater quality using entropy-weighted water quality index and statistical analysis: a case study in the districts of north india. Water Conservation Science and Engineering 9 (2), 1–17. https://doi.org/10.1007/s41101-024-00317-0

Tiwari KK, Krishan G, Anjali, Prasad G, Mondal NC, Bhardwaj V (2020) Evaluation of fluoride contamination in groundwater in a semi-arid region, Dausa District, Rajasthan, India. Groundwater for Sustainable Development 11, 100465. https://doi.org/10.1016/j.gsd.2020.100465

Uddin MdG, Nash S, Olbert AI (2021) A review of water quality index models and their use for assessing surface water quality. Ecological Indicators 122 https://doi.org/10.1016/j.ecolind.2020.107218

Vohra P (2023) Review on physicochemical characteristics of ground water and their health effects. Journal of Mechanical and Construction Engineering 3 (1), 1–8. https://doi.org/10.54060/jmce.v3i1.30

Wang T, Shao Z, Yu H, Bah H (2020) Distribution of fluoride in surface water and a health risk assessment in the upper reaches of the Yongding River. Journal of Geographical Sciences 30 (6), 908–920. https://doi.org/10.1007/s11442-020-1761-4

Wang Z, Meador JP, Leung KMY (2016) Chemosphere Metal toxicity to freshwater organisms as a function of pH : A. Chemosphere 144, 1544–1552. https://doi.org/10.1016/j.chemosphere.2015.10.032

Weinke AD, Biddanda BA (2018) From bacteria to fish : ecological consequences of seasonal hypoxia in a great lakes estuary. Ecosystems 21 (3), 426–442. https://doi.org/10.1007/s10021-017-0160-x

Wetzel RG (2001) Limnology: lake and river ecosystems (3rd ed.). Academic press, San Diego

Wu D, Hu Y, Liu Y, Zhang R (2021) Review of chloride ion detection technology in water. Applied Sciences 124–134. https://doi.org/10.4324/9781315232140-14

Xu Wenzhao, Collingsworth PD, Richard K, Minsker B (2021) Spatio-temporal analysis of hypoxia in the central basin of lake erie of north america. Water Resources Research 57. https://doi.org/10.1029/2020WR027676

Zhang F, Shi X, Zhao S, Hao R, Sun B, Song S (2024) Science of the total environment hypoxia cycle in shallow lakes during winter (ice-covered to melting period): stable and decay , hypoxia , and recovery phases. Science of the Total Environment 954, 176625. https://doi.org/10.1016/j.scitotenv.2024.176625

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CRediT authorship contribution statement

Anuja Saxena: Writing – original draft, Writing – review & editing, Methodology, Investigation, Formal analysis, Software, Data curation. **Rakhi Chahar:** Software,

Conceptualization and Resources. **Afroz Alam:** Supervision. **Bharat Singh:** Writing – review and editing, validation, Supervision.

Ethical Approval

No ethical approval is required in this study.

Consent to Participate

Participants are agreed voluntarily to take part in this study.

Consent to Publish

Participants are agreed to the publication of the data, findings or any identifiable information included in the manuscript.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Mandatory if your study involves humans and/or animals

No humans and/or animals are involved in this study.

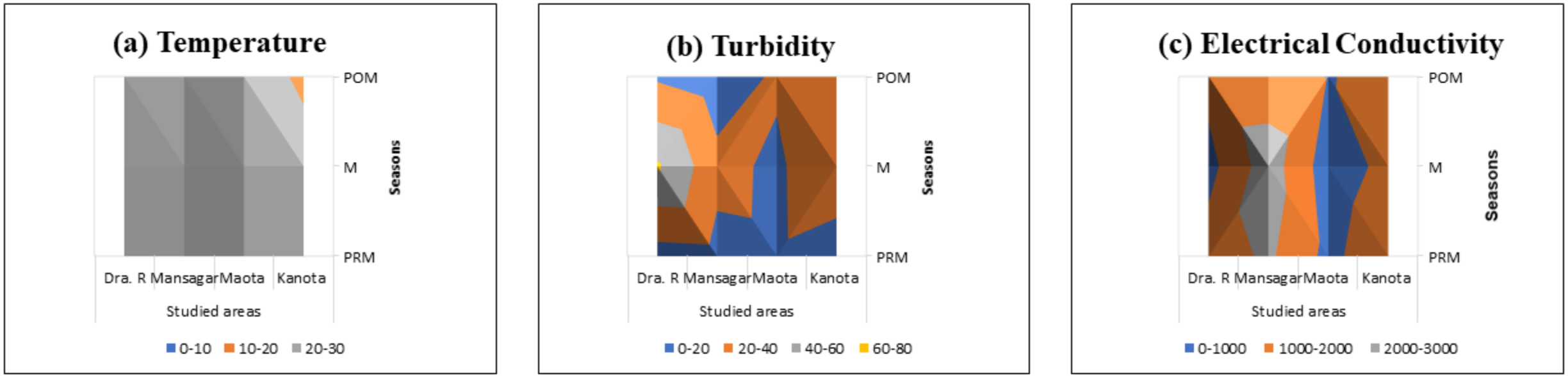


Fig. 1. Spatial contour maps illustrating seasonal variation in (a) Temperature, (b) Turbidity and (c) Electrical Conductivity across the studied surface water bodies- Dravyavati river, Mansagar lake, Maota lake and Kanota dam, during pre-monsoon, monsoon and post-monsoon seasons.

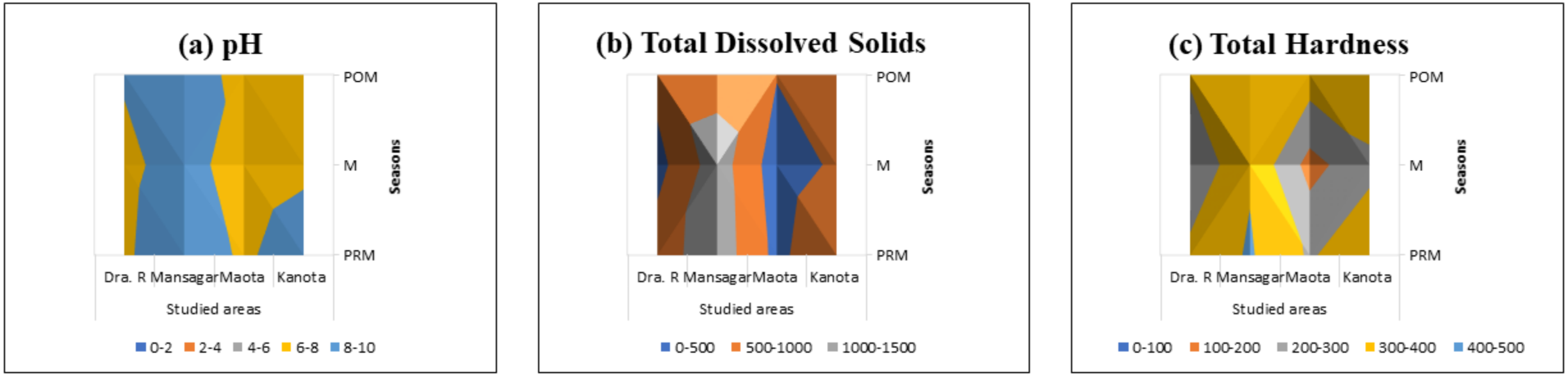


Fig. 2. Spatial contour maps illustrating seasonal variation in (a) pH, (b) Total Dissolved Solids and (c) Total Hardness across the studied surface water bodies- Dravyavati river, Mansagar lake, Maota lake and Kanota dam, during pre-monsoon, monsoon and post-monsoon seasons.

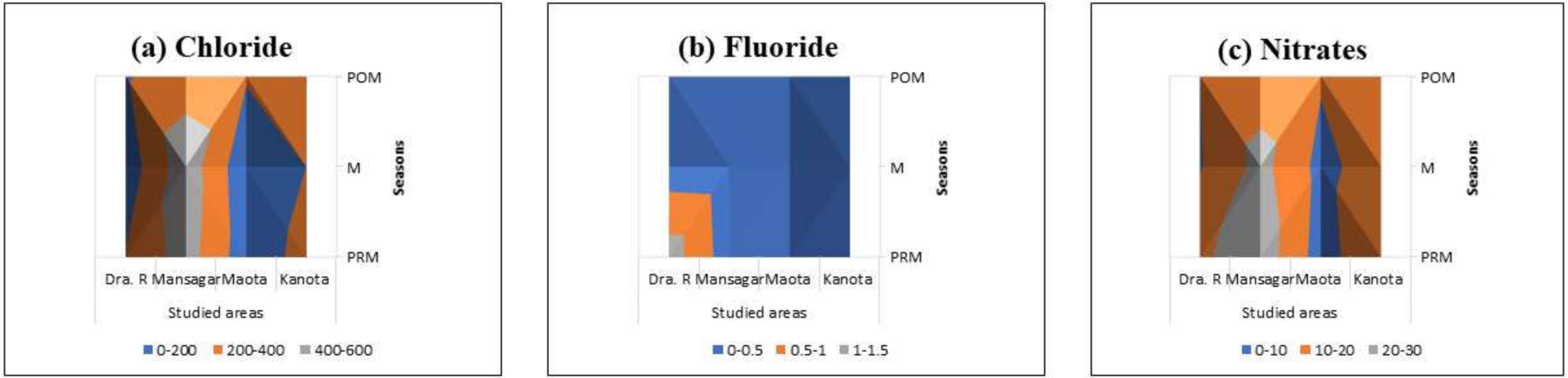


Fig. 3. Spatial contour maps illustrating seasonal variation in (a) Chloride, (b) Fluoride and (c) Nitrates across the studied surface water bodies- Dravyavati river, Mansagar lake, Maota lake and Kanota dam, during pre-monsoon, monsoon and post-monsoon seasons.

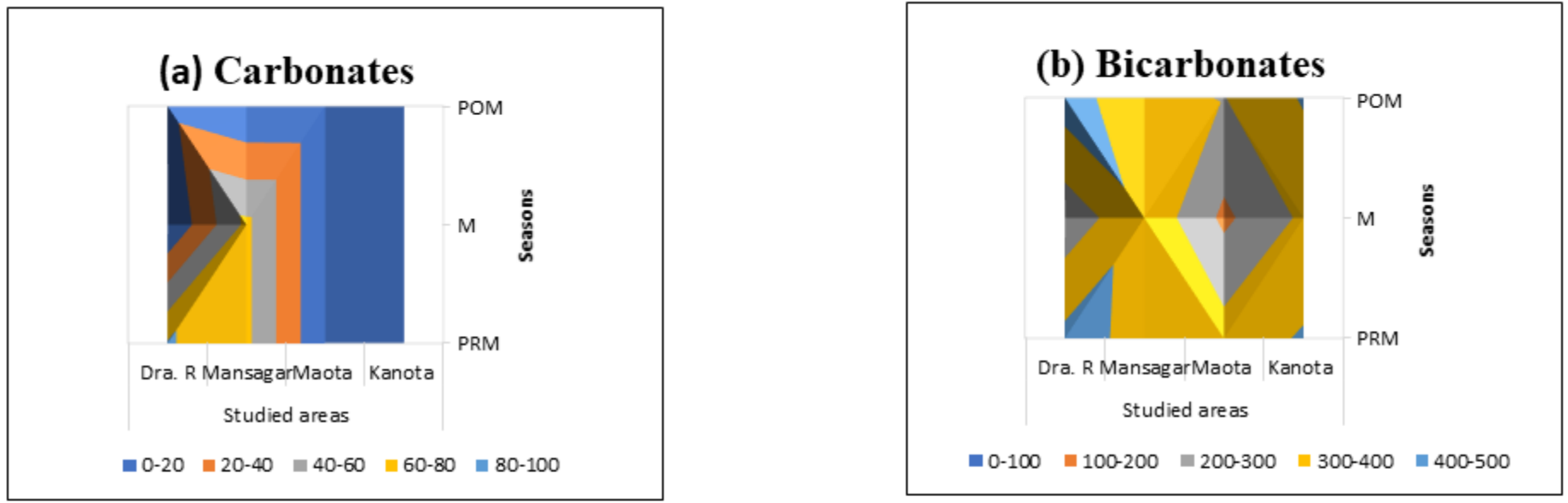


Fig. 4. Spatial contour maps illustrating seasonal variation in (a) Carbonates and (b) Bicarbonates across the studied surface water bodies- Dravyavati river, Mansagar lake, Maota lake and Kanota dam, during pre-monsoon, monsoon and post-monsoon seasons.

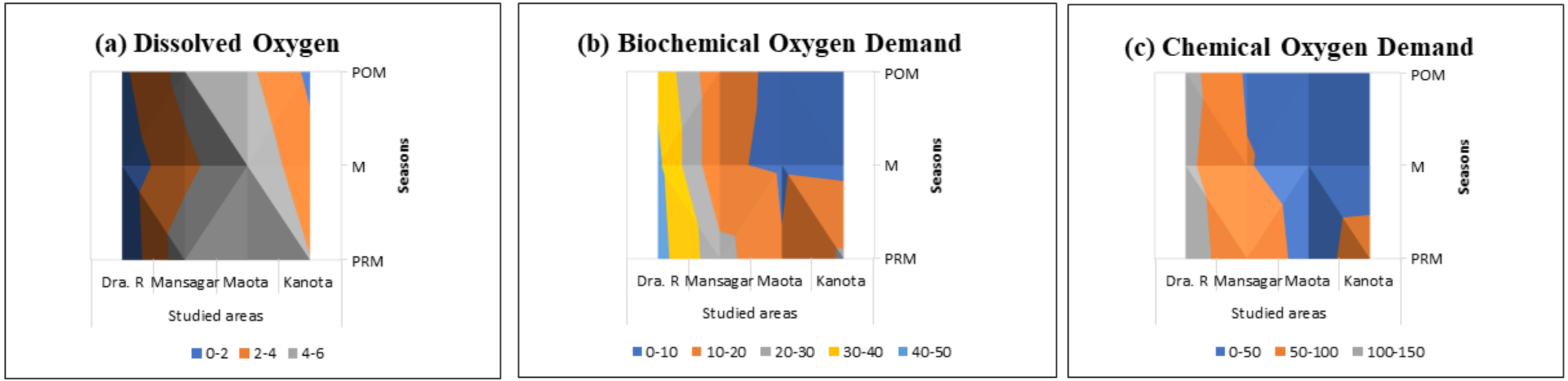


Fig. 5. Spatial contour maps illustrating seasonal variation in (a) Dissolved Oxygen (b) Biochemical Oxygen Demand and (c) Chemical Oxygen demand across the studied surface water bodies- Dravyavati river, Mansagar lake, Maota lake and Kanota dam, during pre-monsoon, monsoon and post-monsoon seasons.

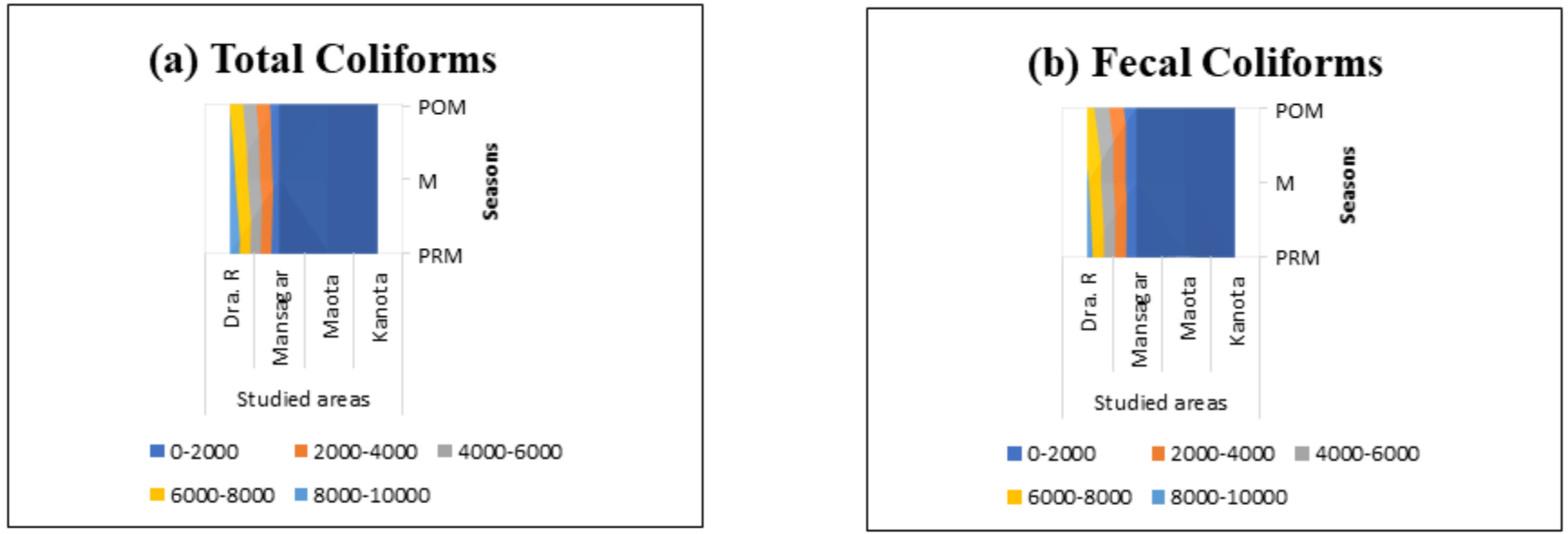


Fig. 6. Spatial contour maps illustrating seasonal variation in (a) Total Coliforms and (b) Fecal Coliforms across the studied surface water bodies- Dravyavati river, Mansagar lake, Maota lake and Kanota dam, during pre-monsoon, monsoon and post-monsoon seasons.

Table 1

Multivariate Analysis of Variance (MANOVA) showing the effects of area and season on the combined set of water quality parameters.

Effect		Value	F	Hypothesis df	Error df	Sig.
Intercept	Pillai's Trace	1.000	4164.330[b]	16.000	15.000	.000
	Wilks' Lambda	.000	4164.330[b]	16.000	15.000	.000
	Hotelling's Trace	4441.952	4164.330[b]	16.000	15.000	.000
	Roy's Largest Root	4441.952	4164.330[b]	16.000	15.000	.000
Season	Pillai's Trace	1.897	18.478	32.000	32.000	.000
	Wilks' Lambda	.002	20.309[b]	32.000	30.000	.000
	Hotelling's Trace	50.737	22.197	32.000	28.000	.000
	Roy's Largest Root	38.848	38.848[c]	16.000	16.000	.000
Area	Pillai's Trace	2.791	14.159	48.000	51.000	.000
	Wilks' Lambda	.000	36.834	48.000	45.408	.000
	Hotelling's Trace	541.329	154.128	48.000	41.000	.000
	Roy's Largest Root	520.270	552.787[c]	16.000	17.000	.000

a. Design: Intercept + Season + Area

b. Exact statistic

c. The statistic is an upper bound on F that yields a lower bound on the significance level.

Table 2

Tests of between-subjects effects from MANOVA showing the influence of independent variables (areas and seasons) on dependent variables (water quality parameters). Significant values (p<0.05) indicate that individual parameters vary significantly across study locations and seasonal conditions.

Source	Dependent Variable	Type II Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	pH	7.676[a]	5	1.535	15.114	.000
	Temp	445.323[b]	5	89.065	28.967	.000
	EC	8871517.389[c]	5	1774303.478	13.380	.000
	TDS	3114911.472[d]	5	622982.294	19.126	.000
	TH	154797.028[e]	5	30959.406	12.842	.000
	Turbidity	4908.977[f]	5	981.795	7.131	.000
	Chloride	584579.359[g]	5	116915.872	18.581	.000
	Nitrate	1060.340[h]	5	212.068	15.007	.000
	Fluoride	1.884[i]	5	.377	5.056	.002
	Carbonate	19666.987[j]	5	3933.397	8.730	.000
	Bicarbonate	149367.278[k]	5	29873.456	10.935	.000
	TC	463910468.278[l]	5	92782093.656	535.516	.000
	FC	420859707.278[m]	5	84171941.456	508.372	.000
	BOD	6233.726[n]	5	1246.745	104.287	.000
	COD	38198.456[o]	5	7639.691	48.759	.000
	DO	86.204[p]	5	17.241	13.581	.000
Intercept	pH	2340.947	1	2340.947	23046.697	.000
	Temp	25016.694	1	25016.694	8136.196	.000
	EC	63904036.000	1	63904036.000	481.896	.000
	TDS	18294154.694	1	18294154.694	561.648	.000
	TH	3757782.250	1	3757782.250	1558.777	.000
	Turbidity	18200.708	1	18200.708	132.190	.000
	Chloride	2026418.681	1	2026418.681	322.056	.000
	Nitrate	7450.567	1	7450.567	527.234	.000
	Fluoride	3.318	1	3.318	44.523	.000
	Carbonate	12634.135	1	12634.135	28.041	.000
	Bicarbonate	4316698.778	1	4316698.778	1580.052	.000
	TC	259113409.000	1	259113409.000	1495.541	.000
	FC	168515015.111	1	168515015.111	1017.778	.000
	BOD	13808.208	1	13808.208	1155.022	.000
	COD	140725.018	1	140725.018	898.156	.000
	DO	381.551	1	381.551	300.552	.000
Season	pH	1.764	2	.882	8.683	.001
	Temperature	373.722	2	186.861	60.773	.000
	EC	687429.167	2	343714.583	2.592	.092

	TDS	397416.056	2	198708.028	6.101	.006
	Total Hardness	72751.167	2	36375.583	15.089	.000
	Turbidity	3691.540	2	1845.770	13.406	.000
	Chloride	13973.331	2	6986.666	1.110	.343
	Nitrate	161.817	2	80.909	5.725	.008
	Fluoride	.336	2	.168	2.254	.122
	Carbonate	6689.795	2	3344.898	7.424	.002
	Bicarbonate	83329.389	2	41664.694	15.251	.000
	TC	1082980.167	2	541490.083	3.125	.058
	FC	1553626.389	2	776813.194	4.692	.017
	BOD	512.748	2	256.374	21.445	.000
	COD	2428.169	2	1214.084	7.749	.002
	DO	1.317	2	.659	.519	.600
Area	pH	5.912	3	1.971	19.401	.000
	Temperature	71.601	3	23.867	7.762	.001
	EC	8184088.222	3	2728029.407	20.572	.000
	TDS	2717495.417	3	905831.806	27.810	.000
	Total Hardness	82045.861	3	27348.620	11.345	.000
	Turbidity	1217.437	3	405.812	2.947	.049
	Chloride	570606.028	3	190202.009	30.229	.000
	Nitrate	898.523	3	299.508	21.194	.000
	Fluoride	1.548	3	.516	6.924	.001
	Carbonate	12977.191	3	4325.730	9.601	.000
	Bicarbonate	66037.889	3	22012.630	8.057	.000
	TC	462827488.111	3	154275829.370	890.444	.000
	FC	419306080.889	3	139768693.630	844.159	.000
	BOD	5720.979	3	1906.993	159.515	.000
	COD	35770.287	3	11923.429	76.099	.000
	DO	84.887	3	28.296	22.289	.000

a. R Squared = .716 (Adjusted R Squared = .668) b. R Squared = .828 (Adjusted R Squared = .800)

c. R Squared = .690 (Adjusted R Squared = .639) d. R Squared = .761 (Adjusted R Squared = .721)

e. R Squared = .682 (Adjusted R Squared = .628) f. R Squared = .543 (Adjusted R Squared = .467)

g. R Squared = .756 (Adjusted R Squared = .715) h. R Squared = .714 (Adjusted R Squared = .667)

i. R Squared = .457 (Adjusted R Squared = .367) j. R Squared = .593 (Adjusted R Squared = .525)

k. R Squared = .646 (Adjusted R Squared = .587) l. R Squared = .989 (Adjusted R Squared = .987)

m. R Squared = .988 (Adjusted R Squared = .986) n. R Squared = .946 (Adjusted R Squared = .937)

o. R Squared = .890 (Adjusted R Squared = .872) p. R Squared = .694 (Adjusted R Squared = .643)

Table 3
Multiple comparison through post-hoc test of surface water samples on the basis of seasons.

Multiple Comparisons

Tukey HSD

Dependent Variable	(I) Season	(J) Season	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
pH	0	1	.54*	.130	.001	.22	.86
		2	.29	.130	.080	-.03	.61
	1	0	-.54*	.130	.001	-.86	-.22
		2	-.25	.130	.150	-.57	.07
	2	0	-.29	.130	.080	-.61	.03
		1	.25	.130	.150	-.07	.57
Temperature	0	1	5.17*	.716	.000	3.40	6.93
		2	7.75*	.716	.000	5.99	9.51
	1	0	-5.17*	.716	.000	-6.93	-3.40
		2	2.58*	.716	.003	.82	4.35
	2	0	-7.75*	.716	.000	-9.51	-5.99
		1	-2.58*	.716	.003	-4.35	-.82
Electrical Conductivity	0	1	291.67	148.666	.139	-74.84	658.17
		2	294.58	148.666	.134	-71.92	661.09
	1	0	-291.67	148.666	.139	-658.17	74.84
		2	2.92	148.666	1.000	-363.59	369.42
	2	0	-294.58	148.666	.134	-661.09	71.92
		1	-2.92	148.666	1.000	-369.42	363.59
TDS	0	1	251.25*	73.680	.005	69.61	432.89
		2	173.92	73.680	.063	-7.72	355.56
	1	0	-251.25*	73.680	.005	-432.89	-69.61
		2	-77.33	73.680	.552	-258.97	104.31
	2	0	-173.92	73.680	.063	-355.56	7.72
		1	77.33	73.680	.552	-104.31	258.97
Total Hardness	0	1	92.58*	20.045	.000	43.17	142.00
		2	-5.33	20.045	.962	-54.75	44.08
	1	0	-92.58*	20.045	.000	-142.00	-43.17
		2	-97.92*	20.045	.000	-147.33	-48.50
	2	0	5.33	20.045	.962	-44.08	54.75
		1	97.92*	20.045	.000	48.50	147.33
Turbidity	0	1	-24.32*	4.790	.000	-36.13	-12.51
		2	-7.95	4.790	.237	-19.76	3.86
	1	0	24.32*	4.790	.000	12.51	36.13

		2	16.37*	4.790	.005	4.56	28.18
	2	0	7.95	4.790	.237	-3.86	19.76
		1	-16.37*	4.790	.005	-28.18	-4.56
Chloride	0	1	47.93	32.383	.315	-31.91	127.76
		2	28.84	32.383	.650	-50.99	108.68
	1	0	-47.93	32.383	.315	-127.76	31.91
		2	-19.08	32.383	.827	-98.92	60.75
	2	0	-28.84	32.383	.650	-108.68	50.99
		1	19.08	32.383	.827	-60.75	98.92
Nitrate	0	1	3.49	1.535	.075	-.29	7.28
		2	5.08*	1.535	.007	1.29	8.86
	1	0	-3.49	1.535	.075	-7.28	.29
		2	1.58	1.535	.563	-2.20	5.37
	2	0	-5.08*	1.535	.007	-8.86	-1.29
		1	-1.58	1.535	.563	-5.37	2.20
Fluoride	0	1	.21	.111	.156	-.06	.49
		2	.20	.111	.196	-.08	.47
	1	0	-.21	.111	.156	-.49	.06
		2	-.01	.111	.991	-.29	.26
	2	0	-.20	.111	.196	-.47	.08
		1	.01	.111	.991	-.26	.29
Carbonate	0	1	20.50	8.666	.062	-.87	41.86
		2	33.08*	8.666	.002	11.71	54.44
	1	0	-20.50	8.666	.062	-41.86	.87
		2	12.58	8.666	.328	-8.78	33.94
	2	0	-33.08*	8.666	.002	-54.44	-11.71
		1	-12.58	8.666	.328	-33.94	8.78
Bicarbonate	0	1	110.67*	21.339	.000	58.06	163.27
		2	20.25	21.339	.614	-32.36	72.86
	1	0	-110.67*	21.339	.000	-163.27	-58.06
		2	-90.42*	21.339	.001	-143.02	-37.81
	2	0	-20.25	21.339	.614	-72.86	32.36
		1	90.42*	21.339	.001	37.81	143.02
Total Coliform	0	1	144.08	169.930	.677	-274.84	563.01
		2	418.17	169.930	.050	-.76	837.09
	1	0	-144.08	169.930	.677	-563.01	274.84
		2	274.08	169.930	.256	-144.84	693.01
	2	0	-418.17	169.930	.050	-837.09	.76
		1	-274.08	169.930	.256	-693.01	144.84
Fecal Coliform	0	1	189.58	166.118	.497	-219.94	599.11
		2	503.75*	166.118	.013	94.22	913.28

	1	0	-189.58	166.118	.497	-599.11	219.94
		2	314.17	166.118	.159	-95.36	723.69
	2	0	-503.75*	166.118	.013	-913.28	-94.22
		1	-314.17	166.118	.159	-723.69	95.36
BOD	0	1	7.55*	1.412	.000	4.07	11.03
		2	8.39*	1.412	.000	4.91	11.87
	1	0	-7.55*	1.412	.000	-11.03	-4.07
		2	.84	1.412	.825	-2.64	4.32
	2	0	-8.39*	1.412	.000	-11.87	-4.91
		1	-.84	1.412	.825	-4.32	2.64
COD	0	1	18.17*	5.110	.004	5.57	30.76
		2	16.57*	5.110	.008	3.97	29.16
	1	0	-18.17*	5.110	.004	-30.76	-5.57
		2	-1.60	5.110	.947	-14.20	11.00
	2	0	-16.57*	5.110	.008	-29.16	-3.97
		1	1.60	5.110	.947	-11.00	14.20
DO	0	1	.38	.460	.686	-.75	1.52
		2	.43	.460	.630	-.71	1.56
	1	0	-.38	.460	.686	-1.52	.75
		2	.04	.460	.995	-1.09	1.18
	2	0	-.43	.460	.630	-1.56	.71
		1	-.04	.460	.995	-1.18	1.09

Based on observed means.

The error term is Mean Square(Error) = 1.270.

*. The mean difference is significant at the .05 level.

Table 4
Multiple comparison through post-hoc test of surface water samples on the basis of areas.

Multiple Comparisons

Tukey HSD

Dependent Variable	(I) Area	(J) Area	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
pH	0	1	-.81*	.150	.000	-1.22	-.40
		2	.29	.150	.240	-.12	.70
		3	-.27	.150	.305	-.68	.14
	1	0	.81*	.150	.000	.40	1.22
		2	1.10*	.150	.000	.69	1.51
		3	.54*	.150	.006	.14	.95
	2	0	-.29	.150	.240	-.70	.12
		1	-1.10*	.150	.000	-1.51	-.69
		3	-.56*	.150	.005	-.96	-.15
	3	0	.27	.150	.305	-.14	.68
		1	-.54*	.150	.006	-.95	-.14
		2	.56*	.150	.005	.15	.96
Temp	0	1	1.61	.827	.230	-.64	3.86
		2	-.52	.827	.921	-2.77	1.73
		3	3.07*	.827	.004	.82	5.31
	1	0	-1.61	.827	.230	-3.86	.64
		2	-2.13	.827	.068	-4.38	.11
		3	1.46	.827	.311	-.79	3.70
	2	0	.52	.827	.921	-1.73	2.77
		1	2.13	.827	.068	-.11	4.38
		3	3.59*	.827	.001	1.34	5.84
	3	0	-3.07*	.827	.004	-5.31	-.82
		1	-1.46	.827	.311	-3.70	.79
		2	-3.59*	.827	.001	-5.84	-1.34
EC	0	1	-885.11*	171.665	.000	-1351.89	-418.34
		2	432.33	171.665	.077	-34.44	899.11
		3	-249.89	171.665	.476	-716.66	216.89
	1	0	885.11*	171.665	.000	418.34	1351.89
		2	1317.44*	171.665	.000	850.67	1784.22
		3	635.22*	171.665	.005	168.45	1102.00
	2	0	-432.33	171.665	.077	-899.11	34.44
		1	-1317.44*	171.665	.000	-1784.22	-850.67
		3	-682.22*	171.665	.002	-1149.00	-215.45
	3	0	249.89	171.665	.476	-216.89	716.66

		1	-635.22*	171.665	.005	-1102.00	-168.45
		2	682.22*	171.665	.002	215.45	1149.00
TDS	0	1	-539.00*	85.078	.000	-770.34	-307.66
		2	210.67	85.078	.084	-20.67	442.00
		3	-172.44	85.078	.201	-403.78	58.89
	1	0	539.00*	85.078	.000	307.66	770.34
		2	749.67*	85.078	.000	518.33	981.00
		3	366.56*	85.078	.001	135.22	597.89
	2	0	-210.67	85.078	.084	-442.00	20.67
		1	-749.67*	85.078	.000	-981.00	-518.33
		3	-383.11*	85.078	.001	-614.45	-151.77
	3	0	172.44	85.078	.201	-58.89	403.78
		1	-366.56*	85.078	.001	-597.89	-135.22
		2	383.11*	85.078	.001	151.77	614.45
TH	0	1	-101.00*	23.146	.001	-163.94	-38.06
		2	16.78	23.146	.886	-46.16	79.71
		3	-64.56*	23.146	.043	-127.49	-1.62
	1	0	101.00*	23.146	.001	38.06	163.94
		2	117.78*	23.146	.000	54.84	180.71
		3	36.44	23.146	.408	-26.49	99.38
	2	0	-16.78	23.146	.886	-79.71	46.16
		1	-117.78*	23.146	.000	-180.71	-54.84
		3	-81.33*	23.146	.007	-144.27	-18.40
	3	0	64.56*	23.146	.043	1.62	127.49
		1	-36.44	23.146	.408	-99.38	26.49
		2	81.33*	23.146	.007	18.40	144.27
Turbidity	0	1	14.69	5.531	.058	-.35	29.73
		2	12.36	5.531	.137	-2.68	27.40
		3	5.24	5.531	.779	-9.80	20.28
	1	0	-14.69	5.531	.058	-29.73	.35
		2	-2.33	5.531	.974	-17.37	12.71
		3	-9.44	5.531	.338	-24.48	5.60
	2	0	-12.36	5.531	.137	-27.40	2.68
		1	2.33	5.531	.974	-12.71	17.37
		3	-7.11	5.531	.579	-22.15	7.93
	3	0	-5.24	5.531	.779	-20.28	9.80
		1	9.44	5.531	.338	-5.60	24.48
		2	7.11	5.531	.579	-7.93	22.15
Chloride	0	1	-287.67*	37.393	.000	-389.34	-185.99
		2	37.76	37.393	.745	-63.91	139.44
		3	-76.00	37.393	.199	-177.68	25.68
	1	0	287.67*	37.393	.000	185.99	389.34

		2	325.43*	37.393	.000	223.75	427.11
		3	211.67*	37.393	.000	109.99	313.34
	2	0	-37.76	37.393	.745	-139.44	63.91
		1	-325.43*	37.393	.000	-427.11	-223.75
		3	-113.76*	37.393	.024	-215.44	-12.09
	3	0	76.00	37.393	.199	-25.68	177.68
		1	-211.67*	37.393	.000	-313.34	-109.99
		2	113.76*	37.393	.024	12.09	215.44
Nitrate	0	1	-9.11*	1.772	.000	-13.93	-4.29
		2	4.68	1.772	.060	-.14	9.50
		3	-2.89	1.772	.378	-7.71	1.93
	1	0	9.11*	1.772	.000	4.29	13.93
		2	13.79*	1.772	.000	8.97	18.61
		3	6.22*	1.772	.007	1.40	11.04
	2	0	-4.68	1.772	.060	-9.50	.14
		1	-13.79*	1.772	.000	-18.61	-8.97
		3	-7.57*	1.772	.001	-12.39	-2.75
	3	0	2.89	1.772	.378	-1.93	7.71
		1	-6.22*	1.772	.007	-11.04	-1.40
		2	7.57*	1.772	.001	2.75	12.39
Fluoride	0	1	.41*	.129	.015	.06	.76
		2	.55*	.129	.001	.20	.90
		3	.23	.129	.295	-.12	.58
	1	0	-.41*	.129	.015	-.76	-.06
		2	.14	.129	.705	-.21	.49
		3	-.18	.129	.494	-.53	.17
	2	0	-.55*	.129	.001	-.90	-.20
		1	-.14	.129	.705	-.49	.21
		3	-.32	.129	.080	-.67	.03
	3	0	-.23	.129	.295	-.58	.12
		1	.18	.129	.494	-.17	.53
		2	.32	.129	.080	-.03	.67
Carbonate	0	1	-11.44	10.006	.666	-38.65	15.76
		2	31.54*	10.006	.018	4.33	58.75
		3	31.21*	10.006	.020	4.01	58.42
	1	0	11.44	10.006	.666	-15.76	38.65
		2	42.99*	10.006	.001	15.78	70.19
		3	42.66*	10.006	.001	15.45	69.87
	2	0	-31.54*	10.006	.018	-58.75	-4.33
		1	-42.99*	10.006	.001	-70.19	-15.78
		3	-.33	10.006	1.000	-27.54	26.88
	3	0	-31.21*	10.006	.020	-58.42	-4.01

		1	-42.66*	10.006	.001	-69.87	-15.45
		2	.33	10.006	1.000	-26.88	27.54
Bicarbonate	0	1	11.00	24.640	.970	-56.00	78.00
		2	98.78*	24.640	.002	31.78	165.78
		3	-7.78	24.640	.989	-74.78	59.22
	1	0	-11.00	24.640	.970	-78.00	56.00
		2	87.78*	24.640	.007	20.78	154.78
		3	-18.78	24.640	.871	-85.78	48.22
	2	0	-98.78*	24.640	.002	-165.78	-31.78
		1	-87.78*	24.640	.007	-154.78	-20.78
		3	-106.56*	24.640	.001	-173.55	-39.56
	3	0	7.78	24.640	.989	-59.22	74.78
		1	18.78	24.640	.871	-48.22	85.78
		2	106.56*	24.640	.001	39.56	173.55
TC	0	1	8215.00*	196.218	.000	7681.46	8748.54
		2	8335.56*	196.218	.000	7802.02	8869.09
		3	8289.22*	196.218	.000	7755.68	8822.76
	1	0	-8215.00*	196.218	.000	-8748.54	-7681.46
		2	120.56	196.218	.927	-412.98	654.09
		3	74.22	196.218	.981	-459.32	607.76
	2	0	-8335.56*	196.218	.000	-8869.09	-7802.02
		1	-120.56	196.218	.927	-654.09	412.98
		3	-46.33	196.218	.995	-579.87	487.21
	3	0	-8289.22*	196.218	.000	-8822.76	-7755.68
		1	-74.22	196.218	.981	-607.76	459.32
		2	46.33	196.218	.995	-487.21	579.87
FC	0	1	7825.56*	191.817	.000	7303.98	8347.13
		2	8038.00*	191.817	.000	7516.43	8559.57
		3	7771.11*	191.817	.000	7249.54	8292.68
	1	0	-7825.56*	191.817	.000	-8347.13	-7303.98
		2	212.44	191.817	.688	-309.13	734.02
		3	-54.44	191.817	.992	-576.02	467.13
	2	0	-8038.00*	191.817	.000	-8559.57	-7516.43
		1	-212.44	191.817	.688	-734.02	309.13
		3	-266.89	191.817	.514	-788.46	254.68
	3	0	-7771.11*	191.817	.000	-8292.68	-7249.54
		1	54.44	191.817	.992	-467.13	576.02
		2	266.89	191.817	.514	-254.68	788.46
BOD	0	1	25.82*	1.630	.000	21.38	30.25
		2	31.57*	1.630	.000	27.13	36.00
		3	28.81*	1.630	.000	24.38	33.24
	1	0	-25.82*	1.630	.000	-30.25	-21.38

		2	5.75*	1.630	.007	1.32	10.18
		3	2.99	1.630	.276	-1.44	7.43
	2	0	-31.57*	1.630	.000	-36.00	-27.13
		1	-5.75*	1.630	.007	-10.18	-1.32
		3	-2.76	1.630	.346	-7.19	1.68
	3	0	-28.81*	1.630	.000	-33.24	-24.38
		1	-2.99	1.630	.276	-7.43	1.44
		2	2.76	1.630	.346	-1.68	7.19
COD	0	1	55.94*	5.901	.000	39.90	71.99
		2	82.33*	5.901	.000	66.29	98.38
		3	70.30*	5.901	.000	54.26	86.34
	1	0	-55.94*	5.901	.000	-71.99	-39.90
		2	26.39*	5.901	.001	10.34	42.43
		3	14.36	5.901	.092	-1.69	30.40
	2	0	-82.33*	5.901	.000	-98.38	-66.29
		1	-26.39*	5.901	.001	-42.43	-10.34
		3	-12.03	5.901	.197	-28.08	4.01
	3	0	-70.30*	5.901	.000	-86.34	-54.26
		1	-14.36	5.901	.092	-30.40	1.69
		2	12.03	5.901	.197	-4.01	28.08
DO	0	1	-3.52*	.531	.000	-4.97	-2.08
		2	-3.86*	.531	.000	-5.30	-2.41
		3	-1.82*	.531	.009	-3.27	-.38
	1	0	3.52*	.531	.000	2.08	4.97
		2	-.33	.531	.922	-1.78	1.11
		3	1.70*	.531	.016	.26	3.14
	2	0	3.86*	.531	.000	2.41	5.30
		1	.33	.531	.922	-1.11	1.78
		3	2.03*	.531	.003	.59	3.48
	3	0	1.82*	.531	.009	.38	3.27
		1	-1.70*	.531	.016	-3.14	-.26
		2	-2.03*	.531	.003	-3.48	-.59

Based on observed means.

The error term is Mean Square(Error) = 1.270.

*. The mean difference is significant at the .05 level.

Table 5
Water Quality Index of surface water bodies.

WQI Standards	
Water Quality Index	**Water Quality Status**
0-25	Excellent
26-50	Good
51-75	Poor
76-100	Very poor
>100	Unfit for consumption

Pre-Monsoon		
Locations	**WQI**	**Water quality status**
Dravyavati River	40369.36801	Unfit for consumption
Mansagar Lake	25317.65287	Unfit for consumption
Maota Lake	49426.21809	Unfit for consumption
Kanota Dam	63837.66329	Unfit for consumption

Monsoon		
Locations	**WQI**	**Class**
Dravyavati River	118432.0788	Unfit for consumption
Mansagar Lake	62762.07869	Unfit for consumption
Maota Lake	34189.36792	Unfit for consumption
Kanota Dam	80998.80399	Unfit for consumption

Post Monsoon		
Locations	**WQI**	**Class**
Dravyavati River	40094.35907	Unfit for consumption
Mansagar Lake	25372.23376	Unfit for consumption
Maota Lake	49418.83326	Unfit for consumption
Kanota Dam	64372.37969	Unfit for consumption