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Water Quality Assessment of Maithon Multi-Purpose Reservoir System along its Longitudinal Gradient using multivariate Statistical Methods and WQI

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Abstract
The reservoir water quality of Maithon reservoir was analyzed by using the method of Multivariate-statistical-techniques. Water samples were collected on bi-monthly basis from four different sampling stations along the longitudinal gradient of the reservoir by considering a time frame of 1.5 years. The output results were compared with the international and national water quality criteria. Study demonstrates the application of various statistical techniques like Principal Component Analysis (PCA)/ Factor Analysis (FA), Pearson Correlation Index (PCI) and Cluster Analysis (CA). PCA/FA identified five principal components (factors)in the entire dataset explaining 86.443% variance in the dataset for the Riverine-Zone (RZ), 85.589% variance for the Transition-Zone (TZ), 80.859% variance for the Lacustrine-Zone (LZ) and83.391% variance for Down-Stream(D/S) zone. The Water Quality Index (WQI)was also computed to know the overall quality of the reservoir water for various purposes (domestic purpose, industrial purpose, irrigation purpose etc.). The value of overall WQI computed was 40.22 which reveal that the reservoir water falls under good category. This study suggests the applicability and necessity of multivariate-statistical-techniques for analyzing and interpreting vast and complicated data sets, with an eye on improving the water quality and creation of monitoring networks for the efficient management of water resources.

Keywords: Water quality, Water quality indices, Longitudinal gradient, Physico-chemical, Principal Component analysis, Factor analysis

1. Introduction

From time immemorial water is the driver of all civilizations throughout the human history. It is a fundamental human need and a valuable commodity without which no socio-economic development will continue. Water is most valuable, essential and priceless renewable resource (Sarkar and Abbasi; 2006).Because of plethora of water on earth, quantity of water was not a big concern till 1960s. In the backdrop of rapidly increasing population as well as socio-economic developments, the demand for water was paramount. Along with this, during last three decades concern for water quality came into play as access to safe water and sanitation are universal requirement and fundamental human rights (International Meteorological Congress, Lecture Series, May 2003). With the passage of time quality and quantity of water both became a matter of concern for the society.

Contemplating and assessing the surface water quality is unarguably a vital task as they are of indispensable significance for all the living beings with a special focus on humans (Boyd 2015; Wang et al., 2018; Ustaoglu and Tepe, 2018). Singh et al., 2016 performed a study to assess the seasonal variations in physicochemical parameters of Kanke dam, Ranchi. Results of this study indicated that most of the parameters were within the permissible limit whereas some of the water quality parameters were found beyond permissible limit which inferred the unsuitability of water for various purposes. Atique and An, 2018 monitored the chemical health status of Chungju reservoir in South Korea, using the technique of Water Pollution Index (WPI) and multivariate technique by taking a long term historical data from 1992 to 2016.The prime focus of this study was to identify the nutrient contributing factors to the reservoir water and establishing a trend analysis pattern amongvarious physicochemical parameters. Monsoon rainfall event was found to be the most persuasive factor in water quality fluctuation during this study. Ustaoglu and Tepe, 2018 monitored the sediment metal contamination and spatio-temporal variations in surface water quality of Pazarsuyu stream water by using the multivariate-statistical technique and pollution indicators for 1 year time period. Results showed the suitability of stream water for irrigation purpose and with some extensive treatment could be used for domestic purpose. Gakiiand Jepkoech, 2019 analyzed water quality data from different countries in Kenya using decision tree classifier namely random forest, J48, LMT, hoeffding tree and decision stump using the WEKA software package.Pramanik et al., 2020analyzed the seasonal variations in water quality parameter trends of Tilaiya dam by considering a 4-year long-term dataset (2013-2017). A prevalent effect on reservoir water quality was observed during and after the monsoon season in this study. WQI (Water Quality Index), PI (Pollution Index), CPI (Comprehensive Pollution Index) analysis revealed that the reservoir water quality health fallsunder the good category.

In several past decades extensive research as well as studies by various research communities has been carried out in the field of water quality analysis and monitoring andmost of the studies inferred the variations in physicochemical parameters only. No inclusive information is available in literaturesto analyze the water quality (hydro-chemistry) trend of Maithon reservoir along its longitudinal gradient. Therefore, the prime focus of the present studyis on analyzing the spatial variations in water quality (hydrochemistry) trend of Maithon reservoir along its longitudinal gradientand also finding out the suitability of reservoir water quality for various purposes.

2. Material and methods

2.1 Baseline scenario of the study area

Present study focused on analyzing the variations in water quality(hydrochemistry) of Maithon multi-purpose reservoir system along its longitudinal gradient. Maithon dam was built up by Damodar Valley Corporation (DVC) between 1951 and 1957 on the River Barakar,a significant tributary of the Damodar River.Maithon dam across Barakar River encompasses a catchment area of about 6294 square-kilometer.Figure 1 shows the location map of Maithon reservoir and the sampling stations from which water samples have been collected.

2.2 Sampling, monitoring and physicochemical analysis

From every sampling station chosen, along the longitudinal gradient of the reservoir (starting from riverine zone to the down-stream site of the dam) water samples were collected in triplicate on bi-monthly (twice in every month at an interval of 15 days) basis to analyze and interpret a large data set obtained during a monitoring phase of 18(January 2020 to June 2021) months. 5-liter polyethylene sampling bottles were used for collecting and quantifying the hydro-chemical properties of the water samples collected at a depth of approximately 20-40 cm and was immediately taken to the laboratory for testing. Water samples were collected and transported to laboratories in accordance with standard procedures (APHA/AWWA/WEF,2012).Along the longitudinal gradient of the reservoir first, second third and fourth sampling station was located at Riverine-Zone (RZ), Transition-Zone (TZ), Lacustrine-Zone (LZ) and Down-Stream (D/S) respectively.The water quality parameters, analytical units, analytical methods and the various National and International standards followed during the analysis of the water samples has been summarized in Table 1.

2.3 Water quality indices computation

The present study not only focuses on determination and quantification of variations in individual water quality parameters but also on quality assurance of the water in terms of water quality indices. Water quality index/indices (WQI) express the overall water quality of any water sample under investigation and also help in assuring its suitability for various purposes like drinking, domestic, agricultural, industrial, fisheries etc. The main objective of WQI is to turn the complex water quality data into information which is easily understandable by any person or the general public.

Weighted Arithmetic Water Quality Index Method (WAWQI), National Sanitation Foundation Water Quality Index (NSFWQI), British Columbia Water Quality Index (BCWQI), Canadian Council of Ministers of the Environment Water Quality Index (CCMEWQI), Smith's Index, Oregon Water Quality Index (OWQI), Overall Index of Pollution (of surface water) (OWQI), Florida Stream Water Quality Index (FWQI) etc. are some of the water quality indices that have been formulated and very frequently used in public domain for the assessment and monitoring of water quality (Pramanik et al., 2020;Zandagba et al., 2017;Imneisi& Aydin, 2016; Hasan et al., 2015; Tirkey et al., 2015; Javid et al., 2014; Kumari & Rani, 2014; Patki et al., 2013; Muntasir et al., 2012; Bharti & Katyal, 2011; Jindal & Sharma, 2011; Singh et al., 2011; Alobaidy et al., 2010; Asadi et al., 2007; Moscuzza et al., 2007; Debels et al., 2005; Sarkar and Abbasi, 2006; Sharifi, 1990). WQI summarizes and simplifies all the raw analytical data by merging them into a single value or data. These single values obtained after the WQI calculation will fall under one of the WQI category (i.e., either Excellent/Good/Fair/Poor etc.) of the method adopted.

Weighted Arithmetic Index Method (Pramanik et al.,2020; Hasan et al., 2015; Javid et al., 2014; Kumari & Rani, 2014; Bharti & Katyal, 2011) has been used for calculating the Water Quality Index (WQI) of all the respective zones (R-zone, T-zone, and L-zone) along the longitudinal gradient of the reservoir including the down-stream site.

Overall [WQI] = $\sum_{i=1}^{n} W_n * Q_n \,/\, \sum_{i=1}^{n} W_n$ (1)

Where, W_n is the unit weight corresponding to the n^{th} water quality parameter, Q_n is the sub-index value (quality rating value) of the n^{th} water quality parameter. The sub-index value (Q_n) was calculated using the following mathematical relation:

$$Q_n = \frac{[(V_n - V_o)]}{[(S_n - V_o)]} * 100 \quad (2)$$

Where, V_n is the observed mean concentration of the n^{th} parameter of a given sample of water, $S_n$is the standard permissible value of the n^{th}parameter of the given sample of water and V_oIndicates the ideal value of the n^{th} parameter in pure water (generally$V =_o 0$, for most parameters except for pH)

$$Q_{PH} = \frac{[(V_{PH} - 7)]}{[(8.5 - 7)]} * 100 \quad (3)$$

An inverse relation is existing between the unit weight (W_n) factor and standard permissible value (S_n) of the corresponding parameter. Mathematically the relation can be formulated as follows:

$$W_n = \frac{K}{S_n} \quad (4)$$

Where, $K = \frac{1}{\sum_{i=1}^{n} \frac{1}{S_n}}$(5)

On summation of unit weight factors (Wn) of all the selected parameters, the value will be equal to unity i.e., 1. Ranges of Water Quality Index (WQI), and corresponding water quality grading, status and their possible uses (Pramanik et al., 2020; Hasan et al., 2015; Tirkey et al., 2015) has been summarized in Table 2.

2.4 Statistical analysis

The annual means of the water quality parameters are chosen, and their standard deviations, maximum and minimum values were analyzed using One-way ANOVA (Analysis of Variance) test to determine whether there is any statisticallysignificant difference ($p < 0.05$)or not. Pearson correlation Index (PCI) was used to measure the statistical relationship between the parameters and Hierarchical Cluster Analysis (HCA) was performed for finding out the similarity among the sampling stations. Principle Component Analysis (PCA) were used to reduce data set into correlated factors called as principle components/factors. Weighted Arithmetic Index method was used for WQI calculation. SPSS (Version 16) software was used to perform all the statistical analysis.

3. Results and Discussion

Water Quality Index (WQI) of the reservoir water along its longitudinal gradient was found to be 42.34 for RZ, 36.82for TZ,41.51for LZ and 45.92forD/S, while cumulative WQI of the reservoir water was measured to be 40.22 during a time frame of 1.5 year (Table 3). The value of WQI of the reservoir water obtained in this study infers that the water sample falls under the category of Good quality (26<WQI<50) and could be considered suitable for various sectors like household (domestic), industrial and irrigation purposes.

The Pearson-correlation analysis has been performed to establish the relation among different water quality parameters and the same has been summarized in table 3. This relation has been defined as; positively strong strength of correlation for r = 0.5 to 1,positively moderate for r = 0.3 to 0.5and positively weak for r=0.1 to0.3. The negative value signifies the inverse relation among the different water quality parameters. For example, a strong negative correlation can be seen in-between Total Hardness and Temperature ($r = -.652$; $p < 0.01$) and also a moderate negative correlation can be seen in-between pH and Temperature ($r = -.463$; $p < 0.01$). On the other hand, a strong positive correlation has been observed in-between Turbidity and Temperature ($r = .534$; $p < 0.01$).

Further, strong positive correlation can be seen in-between TH and EC ($r = .755; p < 0.01$), TH and pH ($r = .650; p < 0.01$), TDS and EC ($r = .725; p < 0.01$), Cu and EC ($r = .725; p < 0.01$), Cu and TDS ($r = .740; p < 0.01$), Ca^{2+} and EC ($r = .843; p < 0.01$), Ca^{2+} and TH ($r = .775; p < 0.01$), Ca^{2+} and Cu ($r = .559; p < 0.01$), Mg^{2+} and EC ($r = .716; p < 0.01$), Mg^{2+} and pH ($r = .823; p < 0.01$), Mg^{2+} and TH ($r = .691; p < 0.01$), Mg^{2+} and TDS ($r = .641; p < 0.01$), Cl and pH ($r = .638; p < 0.01$), Alkalinity and EC ($r = .619; p < 0.01$), alkalinity and pH ($r = .673; p < 0.01$), Alkalinity and TDS ($r = .768; p < 0.01$), Alkalinity and Cu ($r = .567; p < 0.01$), Alkalinity and Mg^{2+} ($r = .821; p < 0.01$), DO and Cu ($r = .639; p < 0.01$), DO and Mg ($r = .509; p < 0.01$) &DO and Alkalinity ($r = .687; p < 0.01$).

A very strong correlation of TH with Ca^{2+} ($r = .775;p < 0.01$) and with Mg^{2+} ($r = .691; p < 0.01$) gives an inference that, the catchment area contributing to the reservoir water must have deposition of limestone up to a larger or some extent, over and through which when water surpasses, it leads to detection of Ca^{2+} content in the water. On the other hand, the passage of water over or through dolomite or some other magnesium bearing formations may results into presence of Mg^{2+} in water. TH and Cl^- ($r = .389; p < 0.01$), SO_4 ($r = .360; p < 0.01$), alkalinity ($r = .386; p < 0.01$) shows a moderate strength of correlation among each other.TDS shows a moderate strength of correlation with Ca^{2+}, Cl^-, and DO($r = .456$, $r = .417$, $r = .446$ and $r = .35$ respectively). Table 4 shows the Pearson correlation analysis summarized sheet showing the relation among different water quality parameters.

In this study the Hierarchical Cluster Analysis (HCA) technique has been used for the clustering of water quality parameters with similar characteristics in all the four zones of Maithon dam. HCA is one of the most widely used methods for determining the intuitive similarity relations between any variable and the complete dataset, and it displays the results in the form of a tree diagram (dendrogram) that depicts the impendency of variables to one another by reducing dimensionality. Clustering of all the 18 physicochemical WQ parameters have been done using Ward's technique with squared Euclidean distance similarity measures. Analysis revealed that the WQ parameters were found to be grouped in 3-different cluster which is shown in Figure 2.

Principle Component Analysis (PCA) is a method of creating new variables, known as Principal Components, which are linear composites of the original variables. PCA uses algorithms to reduce data into correlated factors that provide a conceptual and mathematical understanding of the construct of interest.In order to find out the suitability of dataset to perform PCA, the Kaiser-Meyer-Olkin (KMO) test and Barlett-test were performed. If the value obtained in KMO-Test is greater than or equal to 0.7 ($KMO_{Test} \geq 0.7$), the dataset is considered to be very good to perform PCA. If the KMO_{Test} value comes under the range of 0.5 to 0.7, the data set is considered as sufficient to perform PCA and if its value falls below 0.5 the dataset is not acceptable to perform PCA. In the present study the KMO_{Test} value is found to be 0.64. The value of P (Sig.)

in Barlett-test was found to be P<0.05, which indicates the suitability of dataset to perform PCA. Analysis of 18 WQ parameters inferred that the PCA yielded 5-factors (components) having Eigen-value greater than 1.

The principle components were used to categorize the water quality factor loadings as high, moderate, or weak, based on their absolute loading strengths of >0.75, 0.75-0.51, and 0.50-0.30, respectively (Atique and An 2019).In Riverine zone (RZ), five principlecomponentsaccounted for 86.443% of total variance (Table 5). Strongco-relation was found in between pH, Cl^- with PC-1; Ca^{2+}, EC, TH with PC-2; PO_4, Alkalinity with PC-3 and Na with PC-5. Moderate co-relation was found in between K, TH, Mgwith PC-1; Mg with PC-2; K, TDS with PC-3 and DO with PC-4. Weak co-relation was found between SO_4 with PC-1;K, SO_4 with PC-2; K, Alkalinity with PC-4 and DO with PC-5.In Table 5 shows the variable and factor loading after varimax rotation for riverine zone.

In Transition zone (TZ), theyielded 5 principlecomponents accounted for 85.589% of total variance (Table 5). On analyzing, Strongco-relation was found in between EC, Ca, TH with PC-1; pH, Cl, with PC-2; PO_4, Alkalinity with PC-3; Fe with PC-4 and Na with PC-5. Moderate co-relation was found in between K, Mg with PC-1; TH with PC-2 and Turbidity, SO_4 with PC-4. Further, weak co-relation was observed in between NO_3, Mg, SO_4 with PC-2; K, Cu, TDS with PC-3 and DO with PC-5. The variable and factor loading after varimax rotation for transition zone has been shown in Table 5.

Similarly, 80.859% of total variance has been accounted by the yielded 5 principle components in Lacustrine Zone (LZ). This has been shown in Table 5. Strong co-relation was observed in between Ca, TH, EC with PC-1; pH, Cl with PC-2; TDS, Alkalinity with PC-3; Cu with PC-4 and SO_4 with PC-5. Adding to this, Moderate co-relation was found in between K, Mg with PC-1; Mg with PC-2 andFe with PC-4. On the other hand, Weak co-relation was observed in between Alkalinity with PC-1; TH with PC-2; Temperature with PC-3; DO with PC-4 and EC, Turbidity with PC-5.

Similarly, 83.391% of total variance has been accounted by 5 principle components in Downstream Zone (DZ). This has been shown in Table 5. Strong co-relation was observed in between Ca, TH, EC with PC-1; Cl with PC-2; Cu, TDS with PC-3; SO_4 with PC-4 and DO, Na with PC-5. Moderate co-relation was observed in between Mg with PC-1; Mg, pH with PC-2 and Alkalinity with PC-3. Weak co-relation was observed in between pH, PO_4 with PC-1; Mg, Temperature with PC-3 and Turbidity, Fe with PC-4.

Water temperature is a significant parameter in water quality analysis as it affects the aquatic life and distribution of aquatic ecosystems by controlling the rate of chemical and biological processes. During the study period (18 months), the temperature variation was in between16.5^{o}Cto 31.8^{o}C with overall average of 24.9^{o}C.No sign of thermal pollution was detected as the temperature in all the four sampling sites was found to be within the range of WHO and BIS norms and with minimal variation among the samples collected from the four sites along the longitudinal gradient of the reservoir.The purer the water the lower is the electrical conductivity (EC). In this study, EC recorded as 164.8 to 235.59µs/cm with an average EC of 197.75µs/cm. The EC recorded during this period is within the limit and does not exceed the WHO & BIS norms. EC is one of the important parameters for measuring water quality. Though EC showed clear and strong increasing trend during the study period.EC may rise as a result of sewage or effluent mixing, erosion of certain geological minerals such as gypsum and halite, evaporation and consequent salt concentration increases, or decline as a result of dilution effects from freshwater inputs through rainfall (Pramanik et al. 2020)

In this study, pH shows very less variation from 6.641 to 7.699 only with annual average pH value of 7.267 which can be expressed as good for domestic, industrial and irrigation. Adding to this, TH also shows low variation from 54.90 to 79.19 mg/L with annual average TH value of 67.26 mg/L and can be classified as soft water (<75mg/l ; WHO, 2011).The turbidity ranged from 1.56 to 6.98 NTU with an annual average of 3.74 NTU. Highest turbidity is observed during monsoon (June – October) which indicates the possible mixing of run-off water carrying soil and mud.Natural sources like sewage wastes, industrial wastewater and surface rainwater (WHO, 2017) contribute to TDS in water. TDS, in this study, ranged from 104.71 to 155.36 mg/L with overall average of 129.84 mg/L. Maximum average TDS of 143.81mg/L is recorded in Riverine zone followed by TDS of 135.22 mg/L in downstream. Further, average TDS of 124.5 mg/L is recorded in Transition zone and least TDS of 115.79mg/L is recorded in lacustrine zone. Alkalinity shows variation range from 50.26 to 89.91 mg/L with an annual average value of 72.56 mg/L. For determining water quality, Alkalinity is an important measure as it is having the ability to neutralize acids and has the property of wastewater treatment making it suitable for drinking purpose. DO level was measured between 5.2 to 7.88 mg/L with annual average DO level of 6.52 mg/L which is very good for aquatic life. Dissolved Oxygen level in water determines Ecological health of aquatic ecosystem. Aquatic life is put under stress if dissolved oxygen level is <5.0 mg/l in water. The value of mean, maximum, minimum, overall and standard deviation of all the physicochemical parameters from all the four sampling stations are summarized in Table 6as Mean ± SD.

Fe, Cu, Ca^{2+}, Mg^{2+}, Cl^-, SO_4, PO_4, K, Na and NO_3 did not show any specific spatial trend. Annual average values of the mentioned minerals are 0.05 mg/L, 0.06 mg/L, 16.87 mg/L, 6.07 mg/L, 12.04 mg/L, 5.81 mg/L, 0.2 mg/L, 1.42 mg/L, 1.82 mg/L and 0.31 mg/L respectively. Rest of the parameters (Temp, EC, PH, TH, Turbidity, TDS, Alkalinity, DO) showing clear trend are shown inFigure 3.

4. Conclusion

For the sustainabilityof water bodies and its neighboring ecosystem a comprehensive study as well asunderstanding of both short as well as long term water quality trend is necessary. In this study the multivariate-statistical-technique has been used for the assessment of spatial variations in surface water quality of Maithon reservoir along its longitudinal gradient.Study demonstrates the application of Pearson correlation analysis for the establishment of relationship among various water quality parameters. Hierarchical cluster analysis clustered the 18 water quality parameters and 4 sampling stations into 3 clustersof same water quality characteristics. The PCA resulted 5 factors having Eigen value greater than 1 which accounts for 82.493 % of the cumulative variance.After performing this study the following inferences were concluded: (i) The permitted thresholds of WHO and BIS criteria for drinking water were not exceeded by any of the selected water quality parameter in all the four selected sampling sites along the longitudinal gradient of the reservoir; (ii) Computed WQI (Water Quality Index) rated the reservoir water as "Good" and can be considered as suitable for various sectors like household (domestic), irrigational or industrial purposes.The study demonstrates the significance of multivariate-statistical-analysis in handling data sets with high-dimensions.The findings of this study could be significant in maintaining future reservoir water quality and will provide a theoretical foundation for reservoir water quality managers to make better decisions.

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Tables:

Table 1 Water quality parameters and associated analytical methods

SL. NO.	Parameters	Method Name	Unit	Analytical Method
1	Temperature	IS:3025 (P-9)1984, RA 2013	°C	Calibrated Thermometer - GH ZEAL Ltd.
2	EC	IS 3025 (Part 14)-2013	µS/cm	Electro-Chemistry - Conductivity Meter - OAKTON PC 510
3	pH	IS 3025 (Part 11)-1984 Reaffirmed :2012		Electro-Chemistry - pH Meter - OAKTON pH 700
4	TH	IS 3025 (Part 21)-2013	ppm as $CaCO_3$	Titrimetry-Standardized 0.02 (N) EDTA Solution

5	Turbidity	IS 3025 (Part 10)-1984 Rffm: 2012	NTU	Turbiditimetry-Nephelo Turbidity Meter - HF SCIENTIFIC INC.
6	TDS	APHA 2540–C, 23rd Edition, 2017	ppm	Sample evaporated to dryness in Hot Air Oven (KEMI)
7	Fe	IS 3025 (Part 53)-1988 Rffmd 2014	ppm as Fe	Colorimetry-Test Kit - 1.14403.0001 (MERCK)
8	Cu	IS 3025 (Part 42)-1992 Rffmd 2014	ppm as Cu	Colorimetry-Test Kit - 1.14414.0001 (MERCK)
9	Ca^{2+}	IS 3025 (Part 21)-2013	ppm as $CaCO_3$	Titrimetry-Standardized 0.02 (N) EDTA Solution
10	Mg^{2+}	IS 3025 (Part 21)-2013	ppm as $CaCO_3$	Titrimetry-Standardized 0.02 (N) EDTA Solution
11	Cl^-	IS 3025 (Part 32)- 1988 Rffmd 2014	ppm as Cl^-	Ion Chromatography
12	SO_4^{2-}	IS 3025 (Part 24) - 1986 Rffmd 2014	ppm as SO_4^{2-}	Spectrophotometry-HACH DR 2800
13	F^-	IS 3025 (Part 60)- 2008 Rffm: 2013	ppm as F^-	Ion Chromatography
14	Alkalinity	IS 3025 (Part 23)- 1986 Rffm: 2009	ppm as $CaCO_3$	Titrimetry-Standardized 0.02 (N) Nitric Acid Solution
15	D.O	APHA 23rd Edn-4500-O	ppm	Probe Method - DO Meter - HACH Orbisphere 3100
16	F R C	APHA 23rd Edn-4500-CL G	ppm	Colorimetry-Chemical Reagent - TestChlor (MERCK)
17	PO_4^{3-}	APHA 23rd Edn-4500-P	ppm as PO_4^{3-}	Spectrophotometry-HACH DR 2800
18	K	IS 3025 (Part 45)-1993 Rffm: 2009	ppm as K	Ion Chromatography
19	Na	IS 3025 (Part 45) - 1993 Rffmd 2014	ppm as Na	Ion Chromatography
20	HCO_3^-	IS 3025 (Part 51)-2001; Rffm:2012	ppm as $CaCO_3$	Titrimetry-Standardized 0.02 (N) Sulphuric Acid Solution
21	NO_3^-	IS 3025 (Part 34)- 1988; Rffm: 2014	ppm as NO_3^-	Spectrophotometry-HACH DR 2800

Table 2 Ranges of WQI and corresponding water quality grading

WQI	Grading	Water Quality Status	Possible Uses
0 – 25	A	Excellent	Drinking, Industrial and Irrigation
26 – 50	B	Good	Domestic, Industrial and Irrigation
51 – 75	C	Fair	Industrial and Irrigation
76 -100	D	Poor	Irrigation
101-150	E	Very Poor	Restricted use for Irrigation
>150	F	Unfit for consumption	Proper treatment required prior to use

Table 3 Zone wise WQI of the reservoir water along its longitudinal gradient

Zone	WQI	Water Quality Category
RZ	42.34	Good
TZ	36.82	Good
LZ	41.51	Good
DZ	45.92	Good
Overall	40.22	Good

Table 4 Pearson Correlation Analysis summarized sheet showing the relation among different water quality parameters.

Temp	1																	
EC	-0.110	1																
PH	-.463**	.548**	1															
TH	-.652**	.755**	.650**	1														
Turbidity	.534**	-0.105	-.203*	-.527**	1													
TDS	.311**	.725**	.454**	.281**	0.150	1												
Fe	0.124	-0.043	-0.160	-0.150	.230**	-0.006	1											
Cu	.287**	.725**	.263**	.246**	.382**	.740**	0.082	1										
Ca	-.305**	.843**	.335**	.775**	-.296**	.456**	0.008	.559**	1									
Mg	-.298**	.716**	.823**	.691**	-.224**	.641**	-0.161	.438**	.472**	1								
Cl	-.332**	.402**	.638**	.389**	0.001	.417**	0.063	.254**	.364**	.478**	1							
SO4	-0.139	.461**	0.059	.360**	0.083	.210*	.203*	.304**	.652**	0.065	.511**	1						
Alkalinity	0.092	.619**	.673**	.386**	-0.035	.768**	-.200*	.567**	.270**	.821**	.280**	-.201*	1					
DO	.188*	.418**	.313**	0.152	.228**	.446**	-0.074	.639**	0.129	.509**	0.038	-.235**	.687**	1				
PO4	-0.060	.181*	.278**	.202*	-.357**	.270**	-0.090	-.181*	0.120	0.161	.326**	0.082	.204*	-.275**	1			
K	-.466**	0.052	-0.098	.337**	-.308**	-.371**	-0.054	-0.080	.313**	-0.129	-.213*	0.025	-.219**	-0.104	-0.086	1		
Na	0.125	-0.039	-0.114	-0.064	.285**	-.193*	-0.018	0.155	-0.062	-0.081	-.235**	-.268**	0.077	.402**	-.392**	.223**	1	
NO3	.234**	-0.056	0.161	-.345**	.664**	.260**	0.059	.464**	-.204*	0.008	.260**	-0.052	.240**	.314**	-.258**	-.225**	0.138	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 5 Variable and factor loading after varimax rotation for Riverine zone (RZ), Transition Zone (TZ), Lacustrine Zone (LZ) and Downstream (D/S).Extraction method: PCA. Rotation method: Varimax with Kaiser Normalization.

Variable / Sampling Station	Factor 1				Factor 2				Factor 3				Factor 4				Factor 5			
	RZ	TZ	LZ	D/S	RZ	TZ	LZ	D/S	RZ	TZ	LZ	D/S	RZ	TZ	LZ	D/S	RZ	TZ	LZ	D/S
PH	0.92	0.94	0.93	0.95	0.15	0.01	0.16	0.24	0.07	0.22	0.15	0.01	0.16	0.07	-0.19	-0.05	-0.14	-0.05	0.13	-0.10
Cl^-	0.86	0.92	-0.93	-0.93	-0.24	0.20	0.19	0.25	-0.03	0.18	-0.14	0.05	-0.05	-0.02	-0.08	-0.02	0.19	-0.08	0.00	-0.11
Temp.	-0.85	-0.87	0.90	0.92	-0.39	0.32	0.33	0.20	0.12	0.21	-0.07	-0.24	-0.09	0.00	-0.17	-0.05	-0.05	-0.10	0.16	-0.10
Cu	-0.78	0.78	0.85	0.91	-0.26	0.56	0.04	0.00	0.22	0.09	0.16	-0.02	0.14	-0.15	-0.24	-0.05	-0.26	-0.03	0.37	-0.12
DO	-0.62	0.75	-0.78	-0.78	0.05	0.22	-0.24	-0.23	0.02	0.31	-0.11	-0.13	0.51	-0.27	0.12	0.39	0.45	0.30	0.38	0.07
K	0.56	0.67	0.73	0.68	0.47	0.45	0.11	0.55	0.51	0.23	-0.22	0.30	0.30	-0.04	-0.37	0.06	0.23	-0.27	-0.09	-0.08
NO_3	0.08	0.18	0.68	-0.25	-0.93	0.94	0.56	0.88	0.17	0.20	0.14	-0.09	0.00	0.00	0.15	0.13	-0.21	0.07	0.22	0.06
Ca^{2+}	0.20	-0.21	0.30	0.42	0.90	0.90	0.84	0.72	0.21	-0.05	0.21	-0.12	0.25	0.03	-0.04	-0.16	-0.09	0.10	0.11	-0.16
EC	-0.52	-0.38	-0.19	-0.47	0.89	-0.83	0.78	-0.67	0.21	-0.03	-0.35	0.45	-0.25	0.20	0.15	0.12	-0.11	0.05	0.12	0.10
Turbidity	-0.36	-0.50	-0.54	-0.40	-0.76	-0.69	-0.69	-0.61	-0.12	0.31	0.38	-0.23	-0.40	-0.04	0.19	0.50	-0.03	0.10	-0.08	0.04
TH	0.63	0.03	-0.08	-0.29	0.76	-0.59	-0.13	-0.10	0.05	0.48	0.94	0.82	0.05	-0.05	0.12	0.14	-0.02	-0.52	0.07	0.02
Mg	0.58	0.21	0.37	0.13	0.65	0.12	0.02	-0.14	0.06	0.80	0.82	0.76	0.15	0.06	-0.10	0.06	-0.18	0.24	-0.23	-0.33
PO_4	-0.06	0.22	0.06	0.30	0.16	-0.05	0.01	0.22	0.81	0.79	0.28	0.70	0.00	-0.28	0.83	-0.53	0.20	-0.07	-0.10	0.07
Alkalinity	-0.01	-0.14	0.24	0.20	0.13	-0.44	0.05	0.07	0.79	-0.13	0.25	-0.38	0.48	0.80	-0.78	0.83	-0.01	0.22	-0.06	-0.03
TDS	-0.54	-0.65	-0.22	0.33	-0.20	-0.15	0.09	-0.15	0.54	-0.09	0.01	-0.25	-0.18	0.67	0.54	-0.68	-0.45	0.20	0.01	-0.09
Fe	-0.06	0.23	0.11	0.01	-0.08	0.34	0.06	0.16	-0.14	-0.46	-0.26	-0.20	-0.93	0.64	0.06	-0.61	0.10	-0.02	0.86	-0.10
Na	0.18	0.00	0.09	-0.20	-0.02	-0.42	-0.12	0.20	0.17	-0.37	-0.34	-0.08	-0.07	-0.54	0.44	0.17	0.87	0.40	-0.71	0.89
SO_4	0.35	-0.04	-0.17	0.04	0.40	0.05	-0.38	-0.37	-0.43	0.17	0.03	-0.10	0.14	0.11	-0.09	-0.02	-0.43	0.84	-0.51	0.86
Eigenvalue	7.20	6.82	6.56	6.57	3.31	3.41	2.87	2.74	2.18	2.14	2.00	2.37	1.54	1.61	1.87	1.80	1.34	1.43	1.25	1.53

% of total variance	39.98	37.90	36.46	36.51	18.36	18.95	15.96	15.21	12.08	11.90	11.11	13.19	8.58	8.92	10.38	10.01	7.45	7.93	6.94	8.48
Cumulative %	39.98	37.90	36.46	36.51	58.33	56.84	52.42	51.72	70.42	68.75	63.53	64.91	79.00	77.66	73.92	74.92	86.44	85.59	80.86	83.39

Table 6 Physicochemical Parameters of sampling stations with Mean ± Standard Deviation, Maximum and Minimum

Mean ± Standard Deviation						**Max**	**Min**
Parameters	**RZ**	**TZ**	**LZ**	**DZ**	**Overall**		
Temp	25.45 ± 4.78	25.03 ± 4.55	24.25 ± 4.55	25.12 ± 3.93	24.96 ± 4.44	31.8	16.5
EC	219.9 ± 8.64	189.89 ± 7.88	184.02 ± 8.76	197.21 ± 8.15	197.75 ± 15.97	235.59	164.81
PH	7.39 ± 0.17	7.29 ± 0.18	7.01 ± 0.11	7.37 ± 0.16	7.27 ± 0.22	7.7	6.64
TH	71.31 ± 4.97	65.83 ± 5	64.52 ± 5.17	67.39 ± 4.73	67.26 ± 5.55	79.17	54.9
Turbidity	4.41 ± 1.38	4 ± 1.31	3.54 ± 1.25	3.02 ± 1.26	3.74 ± 1.39	6.98	1.56
TDS	143.81 ± 6.77	124.53 ± 5.78	115.79 ± 5.79	135.22 ± 5.33	129.84 ± 12.16	155.36	104.71
Fe	0.06 ± 0.01	0.04 ± 0.01	0.06 ± 0.08	0.05 ± 0.01	0.05 ± 0.04	0.51	0.03
Cu	0.11 ± 0.01	0.05 ± 0.01	0.04 ± 0	0.04 ± 0.01	0.06 ± 0.03	0.13	0.02
Ca^{+2}	19.05 ± 1.13	15.31 ± 1.04	16.73 ± 1.04	16.38 ± 1.06	16.87 ± 1.73	20.31	13.08
Mg+2	6.64 ± 0.49	6.23 ± 0.38	5.07 ± 0.35	6.35 ± 0.49	6.07 ± 0.74	7.72	4.3
Cl^-	12.78 ± 0.85	11.08 ± 0.69	11.45 ± 0.74	12.83 ± 0.66	12.04 ± 1.07	13.8	9.48
$SO4^{2-}$	6.3 ± 0.34	5.07 ± 0.3	6.04 ± 0.39	5.84 ± 0.26	5.81 ± 0.56	7.26	4.45
Alkalinity	80.43 ± 4.13	76.86 ± 4.36	57.55 ± 4.02	75.41 ± 4.39	72.56 ± 9.82	89.91	49.21
DO	6.96 ± 0.35	6.87 ± 0.25	5.93 ± 0.28	6.33 ± 0.24	6.52 ± 0.51	7.88	5.2
$PO4^{3-}$	0.19 ± 0.02	0.18 ± 0.02	0.19 ± 0.02	0.24 ± 0.02	0.2 ± 0.03	0.29	0.14
K^+	1.43 ± 0.09	1.43 ± 0.09	1.51 ± 0.13	1.31 ± 0.13	1.42 ± 0.13	1.89	1.12
Na+	1.84 ± 0.07	1.88 ± 0.07	1.83 ± 0.07	1.75 ± 0.05	1.82 ± 0.08	2.06	1.62
$NO3^-$	0.39 ± 0.12	0.34 ± 0.12	0.26 ± 0.09	0.26 ± 0.09	0.32 ± 0.12	0.71	0.16

Figures:

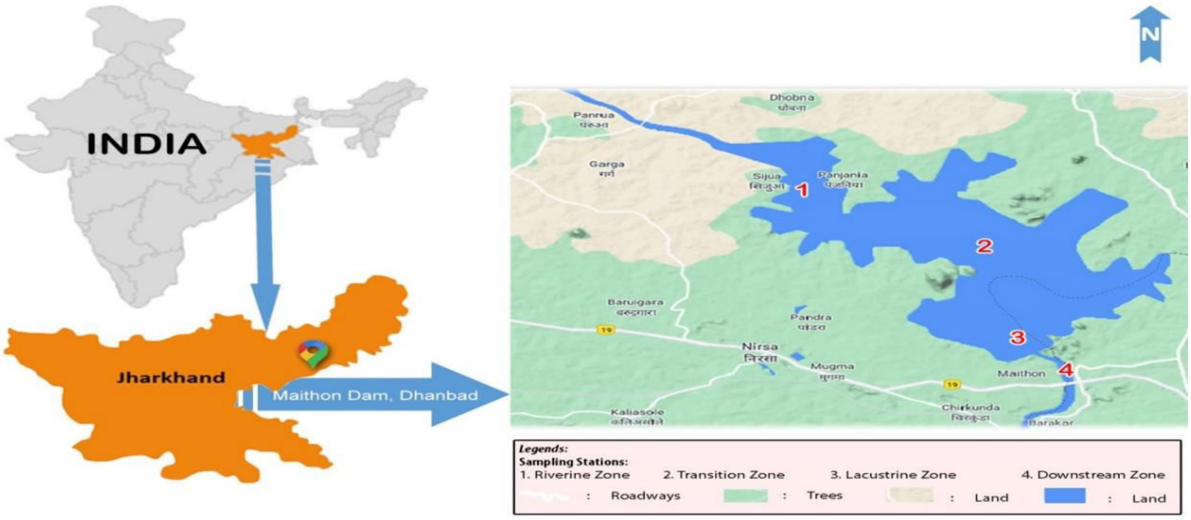

Fig. 1 Location map of Maithon reservoir and water quality sampling stations

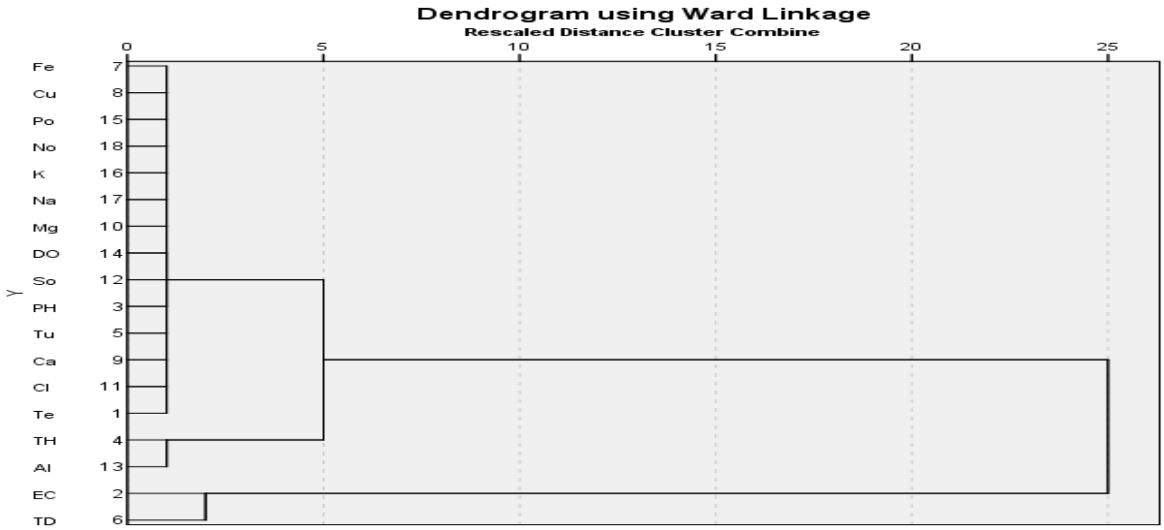

Fig. 2 Dendogram presenting the Hierarchical cluster analysis of selected water quality parameters of Maithon Reservoir.

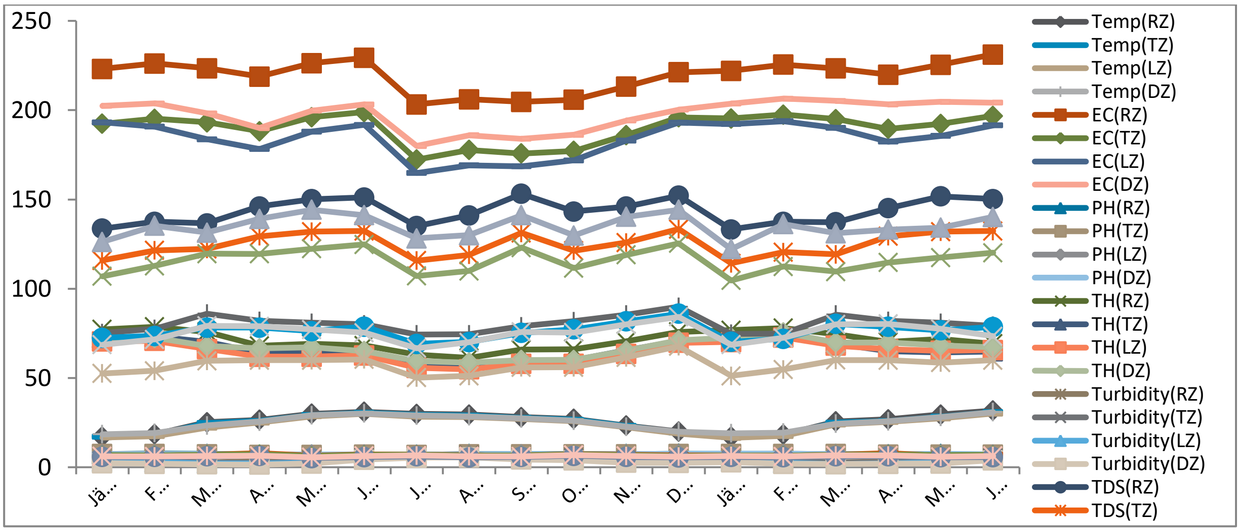

Fig. 3 Parameters variation for during the study period