Research Article

Surface Water Quality Index of Ujjani Reservoir and its Assessment, Solapur District, INDIA

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Abstract

This study was aimed at evaluating surface water parameters of Ujjani reservoir to identify major pollutant sources using multivariate statistics. Hydrochemistry of surface water in Ujjani reservoir was used to assess the quality of surface water for determining its suitability for drinking purposes**.** In two consecutive years along 20 stations of Ujjani reservoir, water parameters such as Temperature, pH, Turbidity, Electrical conductivity (EC), Total Dissolved Solids (TDS), Total Hardness (TH), Total Alkalinity (TA), Ca^{++}, Mg^{++}, Na^{+}, K^{+}, Cl^{-}, HCO_3^{-}, CO_3^{--}, SO_4^{--}, NO_3^{-}, SAR, PO_4^{3-}, DO, BOD and COD were determined in two seasons i.e. pre-monsoon and post- monsoon. Based on the Piper trilinear diagram it was confirmed all the water samples are alkali type excepting three samples which are away from the dam wall which are alkaline earth. In both seasons i.e. pre and post-monsoon, there is a good correlation between the electrical conductivity and elements Ca^{++}, Mg^{++}, K^{+}, Cl^{-}, SO_4^{--}, HCO_3^{-} and BOD. Total Hardness and elements Ca^{++}, Mg^{++}, HCO_3^{-} and TA. The range of values for WQI from different sampling stations showed variations from 44.90 to 189.53. It was inferred that the water quality of Ujjani dam varied from moderately to severely polluted (WQI method). Our findings highlighted the deterioration of water quality in the dam due to industrialization, urbanization and modern agricultural practices.
Keywords: Ujjani reservoir, Piper trilinear diagram, Water quality index, Correlation coefficient. Industrialization, Urbanization.

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INTRODUCTION

The tremendous development of industry and agriculture in recent years has perceptibly altered the aquatic ecosystem in several respects and as such, they are exposed to all local disturbances regardless of where they occur (Venkatesan, 2007). Surface water quality is a very sensitive issue, which transcends national boundaries. It is influenced by many factors, including atmospheric chemistry, the underlying geology, the vegetation (or organic matter decay), and anthropogenic agents (Ammar *et al*., 2011). The health of reservoirs and their biological diversity are directly related to the health of almost every component of the ecosystem (Ramesh *et al*., 2007). In view of this, the monitoring of water quality is the first step that can lead to management and conservation of aquatic ecosystems (Garg *et al*., 2010).). In the wake up increasing urbanization and industrialization, the pollution potential of Ujjani dam deserves critical assessment and hence, the need of the present study. The Ujjani dam has been built at a distance of approximately 150 km from Pune across the river Bhima. It has a storage capacity of 1517GL and total length of 160 kms (Including its meanderings bends). Its maximum width is 7-8 kms. The areal distance of a dam to its most upstream point and backwater at Daund is approximately 73 kms. The Mula- Mutha Rivers flow through the cities of Pimpri, Chinchwad and Pune, only to carry a huge load of sediments, chemicals and discharge into river Bhima near Pargaon. It is, therefore, decided to monitor the pollution level of Ujjani dam by collecting and analyzing the water samples from different places with a view to study the

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physical and chemical characteristics and to investigate the factors responsible for causing pollution.

The Study Area

The Ujjani dam (Topo sheet No. 47 N/4; Latitude 18^0 04' 24" N and Longitude 75^0 07' 15" E is located in the district of Solapur (Taluka-Madha). Its catchment is spread over 14856 sq. kms while 9766 sq. kms are free area of the dam. The Ujjani reservoir is not situated in the hilly tracts of the Western Ghats but in the midst of plains and hence, its depth is comparatively less, resulting in a huge spread of its water surface. A number of streams such as Karanja nala, Dalaj nala, Palasdev nala and Bhigwan nala flow into the reservoir mainly during the rainy seasons. Keeping in view, the locations of these incoming nalas, as well as, of industrial and agricultural regions, the probable point and non-point sources of water pollution have been identified (**Fig.1**).

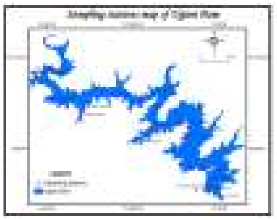


Figure 1

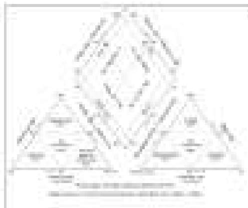
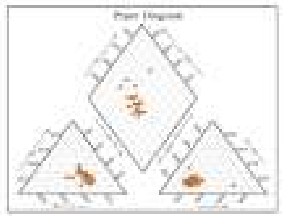


Figure 2



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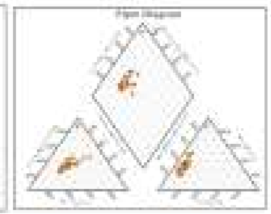

Figure 4

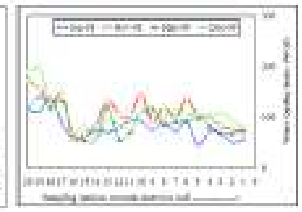

Figure 5

METHODOLOGY

Sampling for the physico-chemical parameters were done on each station for pre-monsoon (June-2008 and May-2009) and post-monsoon (Nov.2008 and Dec-2009) seasons. As per the norms of the APHA, the water samples were collected in plastic bottles and partially tested in the field, as well as, in the laboratories. During the course of present study 10 physico-chemical parameters were determined for each sample. The measurements of pH, total dissolved solids (TDS) and dissolved oxygen (DO) were made in the field, immediately after the collection of samples, using a portable water quality analyzer. Dissolved oxygen was again determined in laboratory. Parameters like total hardness, total alkalinity, biological oxygen demand (BOD), chloride, calcium and magnesium were analyzed by titrimetry. Sulphate was determined by "Shimadzu" double beam UV spectrophotometer (Model 160A) with 10mm path length quartz cuvette. Values for total dissolved solids (TDS) were obtained initially for some samples. Subsequently, these were also obtained by multiplying observed electrical conductance with the Hem's factor 0.65 (Hem, 1970). The methods used for chemical analysis were standardized according to the procedure given in 'Standard Methods for the Examination of Water and Waste Water by APHA-AWWA-WPCF (1998).

RESULTS AND DISCUSSIONS

Piper Trilinear Diagram of surface water

The chemical classification of the water is very important and plays a significant role in determining the utility for various purposes. Chemistry of the surface water alters from the point of its entry or exit due to various parameters like geology, soil, weathering, sewage disposal and environmental conditions and hence for proper interpretations, it is essential to note the chemical changes taking place in the water system. The geochemical characteristic of surface water can be understood by the graphical representation of the major cations and anions contains with the help of tri-linear diagram to hydro chemical evolution. A trilinear diagram to describe water chemistry using only major ions was first attempted by Hill, (1940) which was further refined by Piper, (1944). The Piper diagram has been widely used to distinguish the similarities and differences in the composition of waters and to classify them into certain types demonstrated by the Piper diagram (Karanth, 1989). This diagram consists of two lower triangles that show the percentage distribution, on the milliequivalent basis, of the major cations (Ca^{++} , Mg^{++}, Na^{+} & K^{+}) and the major anions ($SO_4{}^{2-}$, Cl- , $CO_3{}^{2-}$ and $HCO_3{}^{-}$) and a diamond shaped part above that summarizes the dominant cations and anions to indicate the final water type. Overall characteristics of water are represented in the diamond shaped field by projecting the position of triangular field (Karanth, 1995). In the present study, the classification of surface water based on its geochemical facies has been done with the help of Piper, (1953) diagrams using Rock-ware 2000 software that gives different facies in the area. In the Piper diagram the alkaline earth elements (Ca^{++} and Mg^{++}), alkali metals (Na^{+} and K^{+}), weak anions (HCO_3^{-}) and strong anions (Cl^{-} and SO_4^{--}) are considered for defining the primary character of the water samples. During pre-monsoon, in general the surface water types are predominantly strong acid type away from the dam wall which gradually bears weak acids. Simiaraly all the water samples are predominantly of alkali type (Na + K exceeding Ca+ Mg) except two water samples extremally away from the dam wall which are alkaline earth type. During post-monsoon, all the surface water samples strong acids. All the water samples are alkali type excepting three samples which are away from the dam wall which are alkaline earth. Thus there could variation in the dominance of the cations and anions concentrations during pre and post-monsoon seasons.

Correlation – Coefficient

The statistical regression analysis has been found to be a highly useful tool for correlating different parameters. Correlation analysis measures the closeness of the relationship between chosen independent and dependent variables. It is the mutual relationship between two variables. Direct correlation exists when increase or decrease in the value of one parameter is associated with a corresponding increase or decrease in the value of the other (Karunakaran *et al*., 2009). The correlation coefficients approach reduces data into a small set without losing the key information from the original data (Sajil Kumar *et al*., 2011). The systematic calculation of correlation coefficients between water quality variables and regression analyses provide an indirect means for rapid monitoring of water quality. The correlation is said to be positive when increase in one parameter causes the increase in the other parameter and it is negative when increase in one parameter causes the decrease in the other parameter. The correlation coefficient (r) has a value between +1 and -1. The correlation between the parameters is characterized as strong, when it is in the range of +0.8 to 1.0 and -0.8 to -1.0, moderate when it is having value in the range of +0.5 to 0.8 and -0.5 to -0.8, weak when it is in the range of +0.0 to 0.5 and -0.0 to -0.513. Conductivity shows significant correlation with twenty water quality parameters namely pH, EC, Temperature, turbidity, total dissolved solids, total hardness, total alkalinity, Na^+, Ca^{2+}, Mg^{2+}, HCO_3^- , Cl^-, SO_4^{2-}, NO_3^-, PO_4^{3-}, DO, BOD, COD and SAR concentration of water with value of regression coefficient.This correlation coefficient measures the degree of association or correlation that exists between two variables, one taken as dependent variable. The greater the value of regression coefficient, the better is the fit and more useful the regression variables (Navneet Kumar and Sinha, 2010). The correlation coefficient is given as

$$r_{x,y} = \frac{\sum(x - x_m)(y - y_m)}{\sqrt{[\sum(x - x_m)]^2[\sum(y - y_m)]^2}}$$

To study the correlation between various water quality parameters, the regression analysis was carried out using computer software SPSS, version–7.5.The correlation matrix for different surface water quality variables for different water sources in Ujjani reservoir are shown in tables- Table 7.3.1 and 7.3.2. The surface water samples during pre-monsoon disclosed a strong correlation between EC and TDS (r = 0.92) which further indicated that variation in EC concentration is controlled by TH, Ca^{2+}, Cl^- and SO_4^{2-} concentration. Another strong correlation also observed between turbidity and TH,TA, Na^+, Ca^{2+}, Mg^{2+}, HCO_3^- , Cl^-, SO_4^{2-}, NO_3^- (r = between 0.79 and 0.88) confirm a common primary source which is both domestic effluent/sewage and/or fertilizer application. Perfect positive correlation coefficient was observed between TA and HCO_3^- (r =1.0) in both pre and post monsoon seasons. Whereas high positive correlation was observed between TDS and Ca^{2+} (r = 0.96). High positive correlation coefficient was observed between TDS and Cl^- (r = 0.94); Ca^{2+} (r = 0.96); HCO_3^- (r = 0.89); TH and Ca^{2+} (r = 0.98); TA (r =0.86); SO_4^{2-} and TDS (r = 0.92); Ca^{2+} and Mg^{2+} (r = 0.89); Na^+ and HCO_3^- (r = 0.81);Ca^{2+} and SO_4^{2-} (r = 0.94); Mg^{2+} and HCO_3^- (r = 0.95); HCO_3^- and SO_4^{2-} (r = 0.94); TH and HCO_3^- (r = 0.94); TH and Mg^{2+} (r= 0.96); TA and SO_4^{2-} (r = 0.94); K^+ and SO_4^{2-} (r= 0.83); Ca^{2+} and SO_4^{2-} (r = 0.94). While low to moderate negative correlation coefficients are seen among pH and EC (r= -0.26), TDS and DO (r = - 0.73); TA and DO (r = -0.68); SO_4^{2-} and DO (r = - 0.77); temperature and DO (r = - 0.45); EC and SAR (r = -0.29).

The surface water of Ujjani reservoir during post monsoon also revealed high positive correlation coefficient between EC and Ca^{2+} (r = 0.92); TDS and TA (r = 0.90); TH and Ca^{2+} (r = 0.94); TA and Ca^{2+} (r = 0.86); Na^+ and Cl^- (r = 0.89); TDS and BOD (r = 0.80); TH and HCO_3^- (r = 0.92); TH and Mg^{2+} (r = 0.94); Similar findings made by Patil and Patil, (2010). EC and Na^+ (r = 0.82); Mg^{2+} and SO_4^{2-} (r = 0.93); Ca^{2+} and HCO_3^- (r = 0.86); turbidity and SO_4^{2-} (r = 0.80) TH and $SO4^{2-}$ (r=0.92); TDS and HCO_3^- (r = 0.90); EC and TDS (r = 0.91). Similar observation made by Gabriel and Orazulike, (2010). Strong positive correlation between EC and HCO_3^-, Cl^- SO_4^{2-} BOD (r = >83) were observed during post monsoon. While low to moderate negative correlation coefficients exist between turbidity and DO (r = - 0.40); TH and PO_4^{3-} (r = - 0.41); Mg^{2+} and PO_4^{3-} (r = - 0.45); $PO4^{3-}$ and COD (r = - 0.44); Cl and PO_4^{3-} (r = - 0.49). The relatively high positive correlation between some chemical parameters indices signifies a common origin or progressive enrichment of both the parameters. Furthermore, the relatively high negative correlations between some chemical parameters indicate evidences of groundwater mixing or pollution from anthropogenic activities.

Water Quality Index (WQI)

Water quality index (WQI) is a mechanism for presenting a cumulatively derived numerical expression defining a certain level of water quality (Bordalo *et al*., 2006). It also summarizes large amounts of water quality data into simple terms (e.g., excellent, good, bad, etc.) for reporting to management and the public in a consistent manner.WQI is one of the most effective expressions which reflect a composite influence of contributing factors on the quality of water for any water system (Sonawane and Shrivastava, 2010). To determine suitability of the water for drinking purpose and indexing system is use. Water quality indices aim at giving a single value to the water quality of a source reducing great amount of parameters into a simpler expression and enabling easy interpretation of monitoring data. In this study, various water quality indices (WQI) used for assessing surface water quality are discussed. Assessment of surface water quality can be a complex process undertaking multiple parameters capable of causing various stresses on overall water quality. To evaluate water quality from a large number of samples, each containing concentrations for many parameters is difficult. For the calculation of WQI physicochemical characteristics of surface water of Ujjani reservoir were studied. Various physicochemical parameters such as pH, total dissolved solids, total hardness, total alkalinity, calcium, magnesium, chloride, sulphate, dissolved oxygen and biochemical oxygen demands.etc have been calculated in all the samples. Water Quality Index is a form of average derived by relating a group of variables to a common scale and combining them into a single number. A WQI summarizes information by combining several sub-indices of constituents (quality variables) into a univariate expression. The group should contain the most significant parameters of the dataset, so that the index can describe the overall position and reflect change in a representative manner.

Table: Suitability of water based on (WQI)

< 50	Fit for human consumption
50-80	Moderately polluted
80-100	Excessively polluted
>100	Severely polluted

The WQI has been calculated by the following steps and for verification of the derived indices and their interpretation, the approach was identical to the one utilized by Pune Municipal Corporation (PMC).

Step 1: To calculate the quality rating (qn)

$$Quality\ rating\ q_n = 100 \times \frac{(V_n - V_i)}{(V_s - V_i)}$$

Where Vn: Actual value of a particular parameter in the water sample

Vn: The ideal value of the parameters except pH and DO which is 7.0 and 14.6 mg/L respectively.

Vs: standard value for the parameter

Step 2: To find the unit weight (Wn)

Wn for various parameters is calculated which is inversely proportional to the recommended standard for the corresponding parameter.

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

$$Where\ K = \frac{1}{\frac{1}{V_{S1}} + \frac{1}{V_{S2}} + \cdots + \frac{1}{V_{Sn}}}$$

For the present calculations the value of K is calculated to be 1.395387

Step 3: to calculate the water quality index (WQI)

WQI=Anti $\log_{10}$ (Wn $\log_{10}$ qn)

The values of WQI (table 5.1 and fig 5.7) show the spatial and temporal variations in the groundwater quality in the wells of the study area.

Table 2: WQI calculations

K = 1.395387

Parameter	Obseved value V_n	Standard value Vs	Wn=K/S_n	Quality rating (q_n)	$\log_{10}$qn	$W_n\log_{10}q_n$	WQI III
pH	8.96	8.50	0.1642	130.666667	2.12	0.35	
Ca^{++}	105.3	75.00	0.0186	140.40	2.15	0.04	
Mg^{++}	64.82	30.00	0.0465	216.07	2.33	0.11	
BOD	9.43	3.00	0.4651	314.33	2.50	1.16	
DO	4.37	5.00	0.2791	106.56	2.03	0.57	
TDS	722	300.00	0.0047	240.67	2.38	0.01	
TA	419.7	300.00	0.0047	139.90	2.15	0.01	
Cl^-	68.19	250.00	0.0056	27.28	1.44	0.01	
SO_4^{--}	260.8	200.00	0.0070	130.40	2.12	0.01	
TH	529	300.00	0.0047	176.33	2.25	0.01	
						2.28	189.53

Table 3: WQI Values (Pre and Post- monsoon)

S. No.	WQI Jun-08	WQI Nov-08	WQI May-09	WQI Dec-09
1	56.15	69.70	75.62	79.93
2	49.07	76.48	67.91	93.18
3	67.33	83.87	69.53	**109.80**
4	72.93	99.55	84.10	98.18
5	44.90	**103.51**	99.24	**108.01**
6	91.41	**135.40**	93.66	**104.88**
7	72.34	98.75	91.38	**114.33**
8	90.35	**119.05**	85.17	**100.04**
9	74.83	90.50	**116.34**	**106.96**
10	91.53	**143.66**	**110.21**	**108.38**
11	94.44	**105.10**	70.73	90.78
12	79.25	**105.17**	56.65	85.08
13	70.99	**132.71**	**119.91**	98.61
14	74.41	84.83	53.76	53.50
15	61.81	68.08	53.77	85.76
16	56.52	55.88	66.75	69.25
17	87.91	**145.38**	**133.69**	**137.81**
18	**137.27**	**125.88**	**116.92**	**126.37**
19	**111.59**	**156.59**	**140.61**	**194.79**
20	**112.97**	**171.92**	**116.76**	**189.53**

On the basis of above discussion, it may be concluded that the surface water of Ujjani reservoir at all the sites of study area is severely contaminated except few locations. From WQI results it is clear that sample from near dam wall is only less contaminated or moderately polluted. While sample from Kandalgaon (4) to Daund (20) are very poor in WQI rating and unfit for drinking as its WQI is 72 to 194.79. Estimated higher values of different parameters and calculated values of WQI suggest similar results. Assessment of water quality on the basis of WQI values is once again proved to be an effective tool. The water quality index indicates that out of 20 sampling stations almost all are polluted heavily. Therefore it is necessary to ensure that the effluent treatment plants of industries or the waste water treatment plants are working efficiently and properly.

CONCLUSIONS

The Yashawantnagar reservoir of Ujjani dam has generated a number of controversies / social issues since its construction. These include:

1. Approximately 10% of its storage is a dead storage.
2. Rise in the water borne and infectious diseases amongst the residents residing along the tributaries of the rivers merging into the Ujjani dam and
3. Mass fish mortality observed along the tributaries river Bhima.

The above mentioned social and health issues were enough to raise the eyebrows of the scientists, social activists and the victims related to these issues.

The present study was, thus, undertaken to review the environmental status of this huge reservoir, considered to be the life line for the draught-prone regions of the Solapur and Pune districts.

A reservoir is a reflection of its catchment and the developments in the latter have a direct bearing on the status of the former. Such developments in the catchment include urbanization, industrialization, agricultural activities, solid and liquid waste generation and topographical alterations affecting the in-lets channels draining the catchment. Lack of proper reservoir basin management invariably leads to sewage, industrial effluents and solid waste, finally ending up into the water body. Thus eutrophication, toxification of water and siltation are direct results, in turn, leading to loss of precious water body. In the last 50 years hundreds of lakes and reservoirs have suffered huge losses all over the country. The field observations have also shown that there is sharp increase in the health problems in the township such as Bhigwan and Daund after consuming the river water. Many cases of stomach disorders, jaundice and influenza have been reported in the vicinity of the Mula–Mutha and Bhima confluence points. The incidences of fish deaths are common these days, especially during dry months of the year (April and May). This is mainly attributed due to overuse of chemical fertilizers and pesticides; and to the domestic sewage. The drainage that enters into the Ujjani dam does not have a steep gradient and hence, the velocity of the river water gets drastically reduced after reaching the backwater zone. This region has also been subjected to heavy floods, where the discharge from the streams had risen beyond the sustainable limits of the normal flow.

SUGGESTIONS

In order to prevent water pollution in the study area and also for conservation of water have been made as described below:

1) Domestic effluents from upstream region and effluents presently coming from non-point sources should be identified and collected by providing sewerage systems. The effluents should be treated adequately; pathogens should be removed and disinfected before discharging.

2) Sewage management: Decentralization of sewage management and introduction of septic tank system could reduce sewage related problems. Further, wherever possible, emphasis should be laid on recycle and reuse of sewage as a resource.

3) The sludge which is produced due to treatment of sewage should be digested, stabilized and dewatered. The dried sludge may be used as manure and soil conditioner.

4) Discharge of large volume of warm water from industries or other sources should not be allowed into this

reservoir, particularly during summer; as it adversally affects water biota life.
5) The industries situated in upstream area (Pune and Pimpri-Chinchwad) should have treatment facilities at the points of discharge to render them harmless before allowing to meet the domestic sewers.
6) Research should be encouraged to train the farmers to cultivate the crops suitable for their land.
7) Rain water harvesting could be started in these villages in order to utilize more of the highly variable rainfall. People should have the facility to receive free health care.
8) Health care programmer should be conducted to monitor the health of the affected people.

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Table 4: Correlation–Coefficient of Ujjani Reservoir water (Pre- monsoon)

	pH	*EC*	*Temp*	*Turb.*	*TDS*	*TH*	*TA*	*Na*	*K*	*Ca*	*Mg*	*HCO_3*	*Cl*	*SO_4*	*NO_3*	*PO_4*	*DO*	*BOD*	*COD*	*SAR*
pH	1.00																			
EC	-0.26	1.00																		
Temp	-0.22	0.64	1.00																	
Turb.	0.16	0.70	0.71	1.00																
TDS	-0.26	0.92	0.67	0.79	1.00															
TH	-0.08	0.85	0.72	0.88	0.96	1.00														
TA	0.13	0.75	0.63	0.88	0.86	0.94	1.00													
Na	0.05	0.50	0.65	0.82	0.65	0.75	0.81	1.00												
K	-0.30	0.74	0.66	0.62	0.84	0.84	0.75	0.54	1.00											
Ca	-0.11	0.89	0.70	0.84	0.96	0.98	0.89	0.66	0.85	1.00										
Mg	0.00	0.72	0.69	0.88	0.86	0.96	0.95	0.84	0.80	0.89	1.00									
HCO_3	0.13	0.75	0.63	0.88	0.86	0.94	1.00	0.81	0.75	0.89	0.95	1.00								
Cl	-0.23	0.83	0.70	0.80	0.94	0.95	0.86	0.74	0.78	0.94	0.88	0.86	1.00							
SO_4	-0.02	0.86	0.62	0.86	0.92	0.95	0.94	0.70	0.83	0.94	0.90	0.94	0.86	1.00						
NO_3	-0.06	0.77	0.61	0.79	0.72	0.75	0.70	0.54	0.58	0.76	0.70	0.70	0.68	0.75	1.00					
PO_4	-0.03	0.43	0.53	0.44	0.45	0.53	0.60	0.37	0.54	0.48	0.53	0.60	0.40	0.58	0.36	1.00				
DO	0.13	-0.77	-0.45	-0.48	-0.73	-0.67	-0.68	-0.46	-0.58	-0.69	-0.58	-0.68	-0.62	-0.77	-0.55	-0.43	1.00			
BOD	-0.19	0.77	0.37	0.70	0.82	0.75	0.71	0.61	0.60	0.72	0.72	0.71	0.72	0.78	0.56	0.23	-0.53	1.00		
COD	0.31	0.36	0.17	0.48	0.53	0.61	0.69	0.48	0.41	0.51	0.68	0.69	0.54	0.58	0.23	0.38	-0.38	0.50	1.00	
SAR	0.03	-0.29	0.04	0.09	-0.20	-0.16	-0.05	0.48	-0.25	-0.25	-0.02	-0.05	-0.09	-0.16	-0.08	-0.21	0.16	0.00	-0.19	1.00

Table 5: Correlation–Coefficient of Ujjani Reservoir water (Post- monsoon

	pH	*EC*	*Temt*	*Turb.*	*TDS*	*TH*	*TA*	*Na*	*K*	*Ca*	*Mg*	*HCO_3*	*Cl*	*SO_4*	*NO_3*	*PO_4*	*DO*	*BOD*	*COD*	*SAR*
pH	1.00																			
EC	0.10	1.00																		
Temp	0.10	0.46	1.00																	
Turb.	0.21	0.71	0.49	1.00																
TDS	-0.05	0.91	0.34	0.64	1.00															
TH	-0.01	0.89	0.37	0.76	0.92	1.00														
TA	-0.19	0.87	0.34	0.67	0.90	0.92	1.00													
Na	0.00	0.82	0.54	0.67	0.83	0.90	0.88	1.00												
K	-0.30	0.59	0.20	0.42	0.61	0.73	0.75	0.76	1.00											
Ca	0.06	0.92	0.38	0.71	0.92	0.94	0.86	0.83	0.56	1.00										
Mg	-0.08	0.81	0.26	0.69	0.84	0.94	0.89	0.83	0.80	0.81	1.00									
HCO_3	-0.19	0.87	0.34	0.67	0.90	0.92	1.00	0.88	0.75	0.86	0.89	1.00								
Cl	-0.06	0.88	0.36	0.65	0.96	0.94	0.89	0.89	0.71	0.91	0.88	0.89	1.00							
SO_4	0.00	0.85	0.33	0.80	0.79	0.92	0.86	0.80	0.74	0.80	0.93	0.86	0.83	1.00						
NO_3	0.39	0.54	0.61	0.32	0.35	0.27	0.24	0.27	0.05	0.36	0.18	0.24	0.28	0.30	1.00					
PO_4	0.11	-0.29	-0.36	-0.24	-0.37	-0.41	-0.28	-0.44	-0.28	-0.35	-0.45	-0.28	-0.49	-0.33	0.06	1.00				
DO	-0.05	-0.35	-0.27	-0.40	-0.23	-0.32	-0.28	-0.33	-0.13	-0.36	-0.29	-0.28	-0.26	-0.31	0.03	0.28	1.00			
BOD	0.00	0.83	0.33	0.49	0.80	0.80	0.74	0.68	0.62	0.80	0.72	0.74	0.79	0.76	0.55	-0.16	0.07	1.00		
COD	-0.11	0.68	0.30	0.64	0.82	0.85	0.79	0.76	0.65	0.76	0.78	0.79	0.87	0.75	0.16	-0.44	-0.08	0.66	1.00	
SAR	0.01	0.47	0.55	0.29	0.40	0.43	0.42	0.69	0.39	0.39	0.35	0.42	0.49	0.38	0.21	-0.34	-0.37	0.36	0.36	1.00