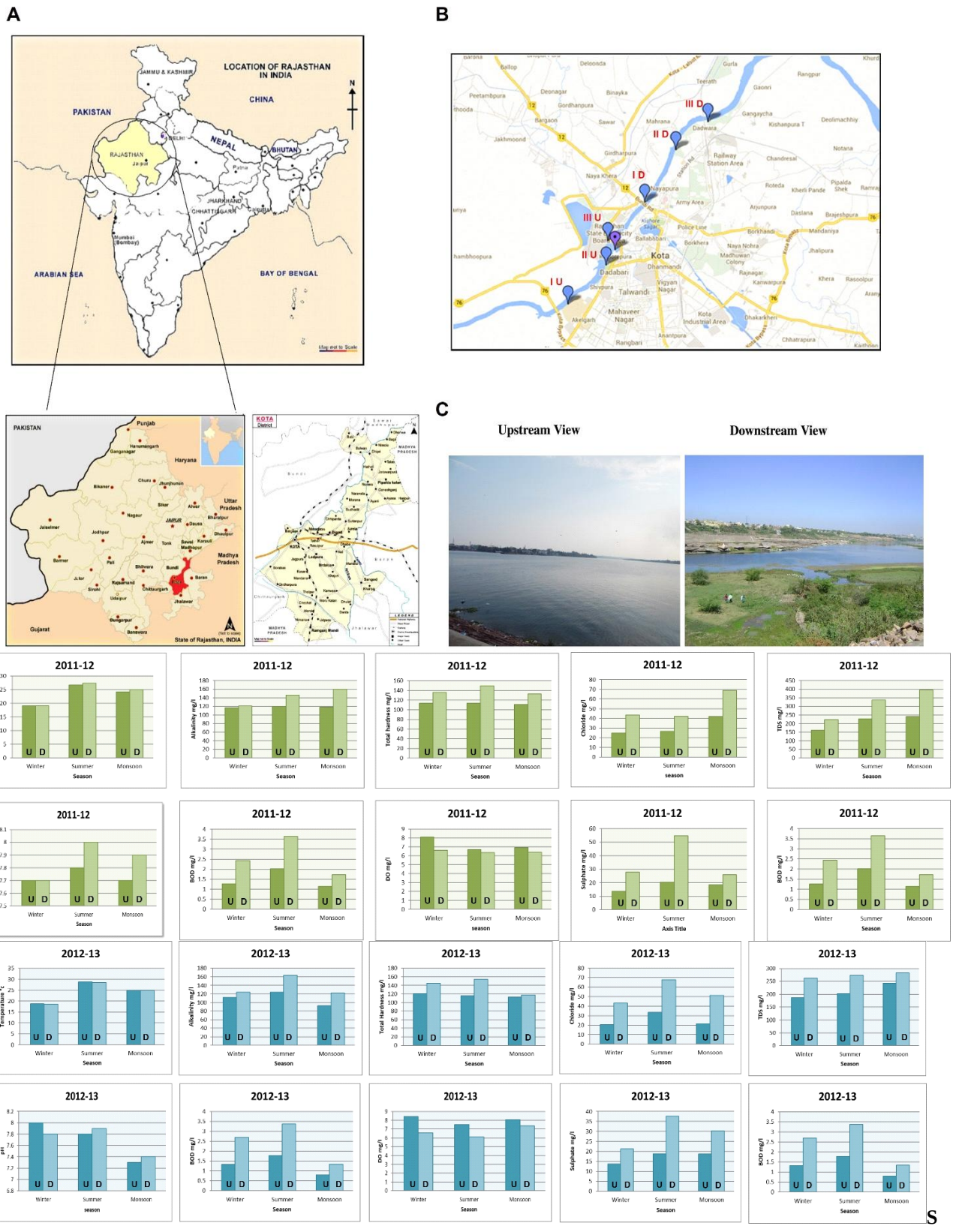
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Upstream View
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Seasonal variations in physico-chemical parameters of Kota barrage, Kota Rajasthan

Meera Bhatnagar, Nilima Bharadwaj

Govt PG College, Kota, Rajasthan, India

ABSTRACT: Assessment of the physico-chemical parameters of a water body plays a vital role in understanding the water environment, ecology, and ecosystem. We studied the seasonal variation of physicochemical parameters of water of Chambal river at Kota barrage, Kota. Water samples were collected monthly spanning three distinct seasons to study temperature, pH, dissolved oxygen (DO) concentration, 5-day biochemical oxygen demand (BOD), chloride ion concentration, orthophosphate concentration, water hardness, nitrate concentration, alkalinity, total dissolved solids (TDS) concentration using standard methods. The temperature variation was not significant between upstream and downstream. pH ranged from 7.1 to 8.6 showing alkaline nature of water body and is in the safe range. In general, pH increased during summer and got diluted in monsoon increasing again in winter. Total dissolved solids and alkalinity appeared in higher amount at downstream as compared to upstream. Total hardness was found to be high during summer indicating water quality to be of hard category. Dissolved oxygen concentration always remained lower at downstream stations irrespective of season. Nutrients like sulphate, nitrate and chlorides showed maximum values in summer while phosphate content was found maximum during monsoon. Comparatively lower values of chloride at upstream indicated negligible anthropogenic activity while same trend was observed for BOD at upstream showing that the water body is free from organic pollution. In conclusion, summer is the season at which parameters like DO, BOD reached to the limits of standard (oligotrophic to eutrophic) at downstream stations while in monsoon periods total dissolved solids, chloride and nitrates reveal highest fluctuations across the different stations in the barrage.

KEYWORDS: physico-chemical parameters, Kota, Chambal river, water pollution

I. INTRODUCTION

Water supports life on earth. The quality and quantity of water at a place determines the health, wealth, and prosperity of that region. Water is one of the most important and precious natural resources and is vital for all life activities. Aquatic ecosystems harbors a variety of communities which constitute the characteristics and functioning of the ecosystem in terms of maintaining production and food chain. The nature and health of the aquatic communities is a direct expression of the quality of water. Water pollution due to increase in anthropogenic activities and hydrological cycle alterations due to Earth's changing climate has changed the behavior of water bodies and needs to be closely studied. A way to measure water quality of a water body is to examine its different physical and chemical attributes. **Kant and Vohra (1989)** have suggested that the management of any aquatic ecosystem includes conservation of habitat particularly with an aim to maintain physico-chemical quality of water. Unlike marine environment which is known for its constancy, the fresh water reservoir is subjected to variation in the environmental factors such as temperature, dissolved gasses, pH, hardness, alkalinity, salinity, BOD, COD, free CO_2, phosphates and nitrates. Seasonal variation in physicochemical properties of water is an important aspect of water quality assessment and management. Understanding the seasonal variation of these parameters can shed light on the overall degradation of water quality and help us address these issues for the sustainable development of humans. A number of studies including **Behbahaninia (2005)** rhave reported a relationship between altered physico-chemical parameters of waters and pollution in those waters. **Prasad and Saxena (1980)** were of the view that pollution has a direct relationship with dissolved solids. **Awasthi and Tiwari (2004)** studied the seasonal trends of abiotic factors in Govindgarh lake at Rewa (M.P.) and found that the lake is gradually stepping towards pollution. **Jafari and Gunale (2006)** observed that industrialization and urbanization around Mutha river near Pune is leading to eutrophication of the river because of increasing organic enrichment. Water quality and pollution status of Chambal River studied by **Saksena et al. (2008)** points towards the oligosaprobic nature of the stretch of river in Madhya Pradesh.

In this work, we studied the water quality of Chambal river at Kota barrage in Kota, Rajasthan. Chambal River is the only perennial river flowing through Kota city. Kota Barrage is constructed on the Chambal River. There are a number of water bodies in and around Kota namely Abhera pond, Alnia dam, Kishore sagar, Jawahar sagar dam and several tributaries of Chambal. Water of the barrage is utilized to generate power and to irrigate fields and for municipal supply. Apart from plankton this barrage is influenced by various other anthropogenic activities such as

agriculture, bathing, washing, discharge of animal excreta and industrial wastes. Thus, the study of this barrage will help in better management of this water body to overcome the harmful effects of abiotic influences.

II.STUDY AREA

Kota is located on a high sloping table land forming part of Malwa Plateau at 23° 45´ to 25° 53´ North latitudes and 75° 9´ to 77° 27´ east longitudes southeast to north east of the town. Kota is spread over an area of 5217 sq. km where urban area covers 310.05 sq km and 4906 sq. km is covered by rural areas. The 960 km long Chambal River, a principal tributary of river Yamuna originates from Singar Chowri peak in Vindhyan ranges of Mhow in Indore district of Madhya Pradesh State. The river flows for about 320 km in a northern direction before entering a deep gorge in Rajasthan at Chourasigarh about 96 km upstream of Kota. The river approaches Kota city near Akelgarh water filter plant and leaves the city near Rangpur/Keshoraipatan.

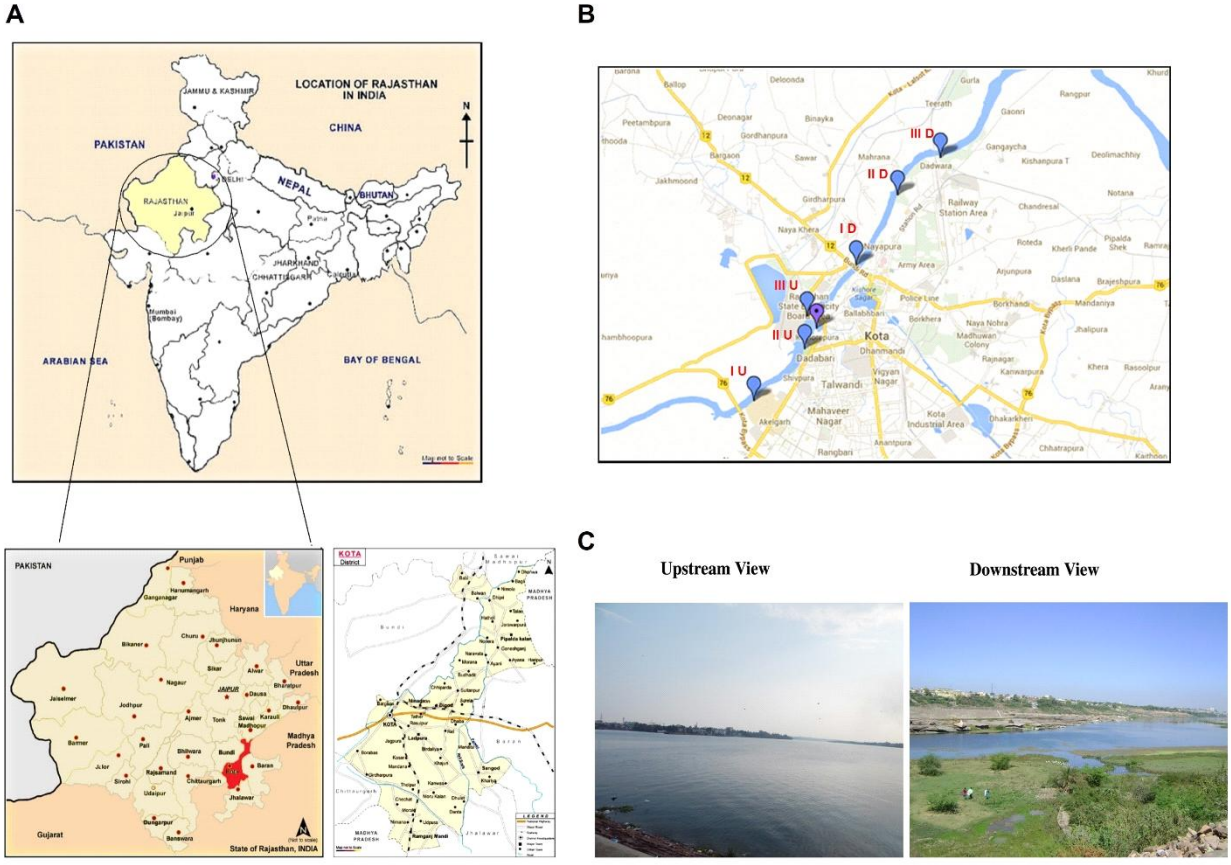

Figure 1. Study area. A.) Map of India showing the state of Rajasthan and Kota district area B.) Selected upstream and downstream sampling stations along the Chambal River. C.) Photographs of Upstream and Downstream view.

There are four major dams built on the Chambal River: Gandhi Sagar dam and Rana Pratap Sagar Dam located in Madhya Pradesh while Jawahar Sagar Dam and Kota Barrage located in Rajasthan. Kota Barrage is the fourth in the series of Chambal valley projects located about 0.8 km upstream of Kota city in Rajasthan. Water released after power generation at Gandhi Sagar Dam, Rana Pratap Sagar Dam and Jawahar Sagar Dam is ultimately diverted by Kota Barrage for irrigation in Rajasthan and Madhya Pradesh through canals on the left and the right sides of the river. To study the physicochemical characteristics of Kota Barrage, the study area was divided into six sampling stations within a 15 km stretch of the river. Kota Barrage was taken as a reference point and three study stations each were marked on either side of the Barrage and categorized as Upstream (I U, II U, and III U) and Downstream (I U, II D, and III D) stations as shown in figure 1.

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III.METHODS

Testing physical parameters of water

Temperature of air and water were measured by a standard grade thermometer calibrated to measure 0.1 °C increments. While observing air temperature, the mercury bulb was prevented from direct exposure to sunlight. Surface water temperature was noted by dipping the bulb of the thermometer in water. Colour of water was visually observed against the colour of distilled water. Odour and frothing were noted by shaking the water sample for five minutes in a reagent bottle. Generally, water may have fishy moldy, chlorinous or earthy aromatic odour. The foaming of water indicates the presence of detergents of surface-active substances.

Testing chemical parameters of water

pH of surface water was measured using a pen pH meter (pHep, HANNA instruments) at sampling stations and confirmed by measurement using a calibrated digital pH meter after samples were transported to the lab.

Total Dissolved solids were measured using a pen digital TDS meter (HM make) at sampling stations..

Total alkalinity was measured by standardized acid titration method and calculated using the following formula:

TA as $CaCO_3$ ppm =

where B = ml of HCl used with phenolphthalein and methyl orange as color indicators

Dissolved Oxygen was measured by Modified Winkler's Method using the following formula:

Dissolved Oxygen (DO) mg/L = () v

where N = Normality of the titrant, V = Volume of Sample (ml), v = volume of titrant used (ml)

Chloride was estimated by the Silver Nitrate method **(APHA, 1998)**.

Chloride in mg/L =

Where N = normality of titrant.

To estimate total hardness of water, samples were titrated against EDTA solution using eriochrome black-T indicator, Hardness was calculated using the formula:

Hardness (mg/L $CaCO_3$) =

Nitrates were estimated by phenoldisulphonic acid method **(APHA, 1992)**. Sample was analyzed using a Spectrophotometer at 410 nm. The nitrate value was calculated using the standard Calibration Curve.

Analysis of phosphate in the water sample was done by Molybdate method **(Murphy and Relay, 1962)**.

BOD was calculated from the values of dissolved oxygen estimated from the fresh and incubated samples for five days **(APHA, 1998)**. BOD was calculated using the formula:

BOD_5 (mg/ml) = $D_1 - D_2$

Where D_1 = Initial Dissolved oxygen in sample (mg/L), D_2 = Dissolved oxygen after 5 days of incubation (mg/L)

The correlation between different parameters was calculated in Microsoft Excel 2007.

III.RESULTS AND DISCUSSION

Temperature is one of the important physical parameters of any water reservoir which regulates the natural processes in the environment. During the current study period, maximum temperature was recorded at station II D (34 °C) in summer while the minimum water temperature was observed at station III U (16.8 °C) in winter. Temperature followed an increasing trend from winter to monsoon to summer. The pH values ranged between 7.1 and 8.6 indicating alkaline nature of waters at Kota barrage. These findings were consistent with **Saksena et al. (2008)** where alkaline water in Chambal River in Madhya Pradesh was reported. Additionally, the maximum pH was observed during summer whereas minimum during the monsoon, which concurs with the observations made by **Hujre (2008)** and **Kadam (2010).** The levels of different parameters studied were plotted and are presented in Figure 1 and 2 for study year 2011-12 and 2012-13 respectively. Correlation between parameters at upstream and downstream stations in both study periods was also calculated. As seen in Tables 1-4, Correlation analysis exhibited positive correlation of pH with dissolved oxygen, BOD, and Phosphates, and negative correlation with TDS and alkalinity at upstream. However, downstream pH was positively correlated with BOD and negatively correlated with DO and alkalinity.

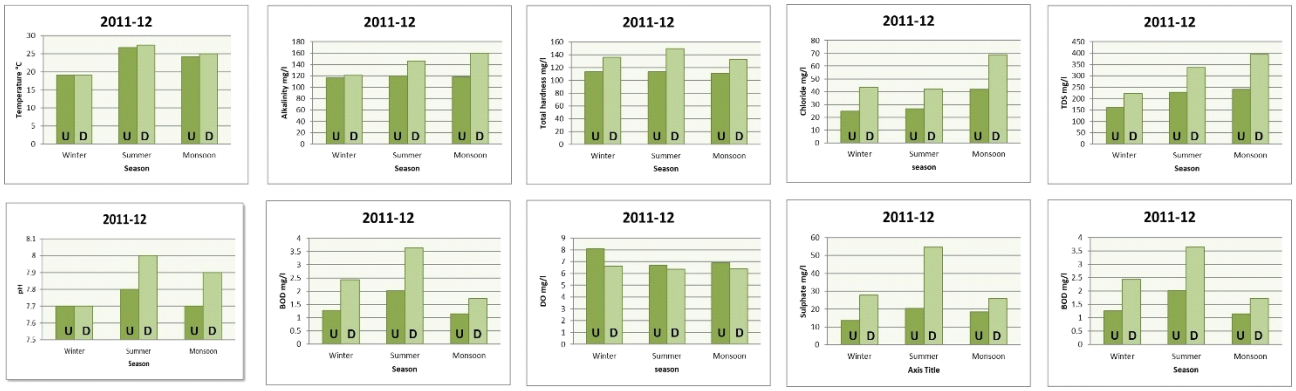

Figure 1. Levels of various physico-chemical parameters measured at 3 upstream and 3 downstream stations at Kota barrage, Kota during study period 2011-12. U=upstream, D=downstream.

The total dissolved solids indicate the general nature of water quality **(Venkataramaiah 2011)**. In the present investigation, seasonal analysis showed higher values of total dissolved solids at downstream stations as compared to upstream stations in all seasons. The maximum level of total dissolved solids during monsoon season might be due to a large amount of sediment load being transported from the catchment area of river. Total dissolved solids value ranged from 145 mg/L to 572 mg/L in different seasons. In present study, total hardness at all the stations was found to be maximum in summer largely due to reduced inflow and evaporation as observed by **Kaur et al. (1996)**. **Garg (2002)** also observed seasonal difference in hardness in river Mandakini at Chitrakoot. According to **Kannan (1991)**, water with total hardness of 0-60 mg/L is considered soft; 60-120 mg/L is considered as medium and above 120 mg/L is considered very hard. At upstream stations, total mean hardness ranged between 111 mg/L and 117 mg/L and thus, the water can be regarded as moderately hard as compared to downstream where mean total hardness was found to be 135 mg/L and 145 mg/L during the entire study period.

As oxygen is directly needed by many organisms and it affects the solubility and availability of many nutrients, it is the most significant parameter affecting the productivity of aquatic systems. During the study period, DO increased with lowering of temperature. Also, the DO content was observed to be higher in the rainy and winter seasons in the present investigation. The result obtained agrees with the findings of **Suresh et al. (2011)**. The DO concentration at all the study stations of Kota barrage was above 4 mg/L throughout the study period. The DO values were always found to be lower downstream. In the summer seasons of study period, it was found that DO content was low possibly because of the decomposition of organic matter, limited flow of water and high temperature. Low concentration of DO suggests high pollution status of a station. DO was found to be positively correlated with alkalinity and phosphate at upstream whereas negatively correlated at downstream. DO was negatively correlated with sulphates and BOD at both upstream and downstream stations.

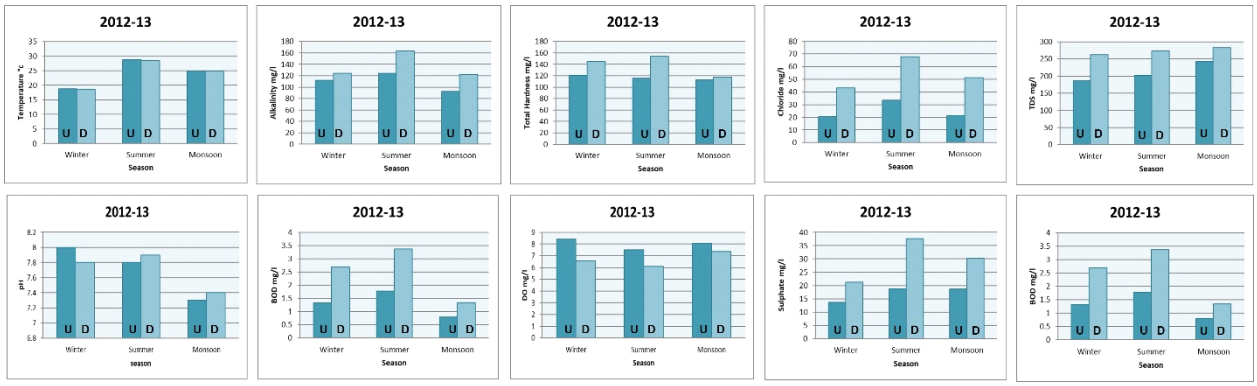

Figure 2. Levels of various physico-chemical parameters measured at 3 upstream and 3 downstream stations at Kota barrage, Kota during study period 2012-13. U=upstream, D=downstream.

Table 1. Correlation matrix between physico-chemical parameters at downstream stations (year 2011-12).

	Temp	pH	TDS	Hardness	DO	Alkalinity	SO4	NO3	O-PO4	Cl-	BOD
Temp	1.00										
pH	-0.01	1.00									
TDS	0.64	-0.31	1.00								
Hardness	0.19	0.17	0.08	1.00							
DO	-0.12	-0.05	0.17	0.04	1.00						
Alkalinity	0.50	-0.24	0.65	-0.39	-0.05	1.00					
SO4	0.48	0.51	0.14	-0.06	-0.25	0.11	1.00				
NO3	0.12	-0.12	-0.11	-0.05	-0.71	0.17	0.08	1.00			
O-PO4	0.07	-0.46	0.43	-0.31	-0.29	0.42	-0.14	0.56	1.00		
Cl-	0.30	-0.45	0.68	0.07	0.29	0.19	-0.15	-0.07	0.48	1.00	
BOD	0.39	0.58	-0.13	0.58	-0.11	0.17	0.53	-0.24	0.56	-0.42	1.00

Table 2. Correlation matrix between physico-chemical parameters at upstream stations (year 2011-12).

	Temp	pH	TDS	Hardness	DO	Alkalinity	SO4	NO3	O-PO4	Cl-	BOD
Temp	1.00										
pH	-0.38	1.00									
TDS	0.65	-0.67	1.00								
Hardness	-0.36	0.12	-0.21	1.00							
DO	-0.93	0.48	-0.66	0.45	1.00						
Alkalinity	-0.10	-0.10	0.28	0.22	0.02	1.00					
SO4	0.71	-0.40	0.64	0.18	-0.62	0.21	1.00				
NO3	-0.05	-0.54	0.35	-0.19	-0.21	0.47	-0.01	1.00			
O-PO4	-0.25	0.32	0.03	0.05	0.22	-0.04	-0.23	0.08	1.00		
Cl-	0.37	-0.41	0.34	-0.20	-0.40	-0.16	0.33	-0.23	-0.12	1.00	
BOD	0.60	0.34	0.11	0.03	-0.47	0.06	0.49	-0.23	-0.11	-0.31	1.00

Table 3. Correlation matrix between physico-chemical parameters at downstream stations (year 2012-13).

	Temp	pH	TDS	Hardness	DO	Alkalinity	SO4	NO3	O-PO4	Cl-	BOD
Temp	1.00										
pH	0.19	1.00									
TDS	0.16	-0.04	1.00								
Hardness	-0.14	0.38	-0.23	1.00							
DO	-0.13	-0.39	0.36	-0.67	1.00						
Alkalinity	0.21	0.13	-0.25	0.70	-0.51	1.00					
SO4	0.37	0.19	0.31	-0.39	0.16	-0.06	1.00				
NO3	0.85	-0.10	0.42	-0.49	0.25	-0.12	0.48	1.00			
O-PO4	0.24	-0.32	0.19	-0.25	0.25	0.11	0.23	0.28	1.00		
Cl-	0.58	0.10	-0.30	-0.08	-0.30	0.10	0.37	0.55	-0.04	1.00	
BOD	0.19	0.65	-0.14	0.67	-0.78	0.38	0.02	-0.09	-0.57	0.42	1.00

Table 4. Correlation matrix between physico-chemical parameters at upstream stations (year 2012-13).

	Temp	pH	TDS	Hardness	DO	Alkalinity	SO4	NO3	O-PO4	Cl-	BOD
Temp	1.00										
pH	-0.36	1.00									
TDS	0.19	-0.60	1.00								
Hardness	-0.24	0.09	-0.34	1.00							
DO	-0.67	-0.04	0.11	0.20	1.00						
Alkalinity	0.17	0.63	-0.66	0.25	-0.28	1.00					
SO4	0.84	-0.51	0.41	-0.37	-0.62	-0.12	1.00				
NO3	0.42	-0.68	0.48	-0.25	-0.35	-0.44	0.43	1.00			
O-PO4	-0.21	0.23	0.23	-0.23	0.22	-0.05	-0.11	-0.26	1.00		
Cl-	0.57	0.21	0.02	-0.62	-0.40	0.48	0.46	0.07	0.17	1.00	
BOD	0.25	0.62	-0.64	0.33	-0.39	0.87	-0.05	-0.54	0.02	0.27	1.00

Alkalinity is a measure of buffering capacity of water and is important for aquatic life in a freshwater system because it equilibrates the pH fluctuations that occur naturally because of photosynthetic activity of phytoplankton **(Kaushik et al. 1991, Koshy and Nayar, 2000)**. In our studies comparatively higher alkalinity values in monsoon (160.2 mg/L) as compared to summer (145.9 mg/L) were observed in 2011-12. It was observed that water of station I D and II D when compared to other stations showed higher alkalinity values in all seasons during the entire period of study. At these stations sewage and anthropogenic inputs might have led to an increase in alkalinity. According to **Moyle (1946)**, natural waters containing 40 mg/L or more of total alkalinity are considered more productive which implies that this water system falls in the category of productive system. Correlation analysis indicates that alkalinity is positively correlated with sulphate, nitrate and BOD at upstream as well as at downstream stations. It showed negative correlation with phosphate and chloride at upstream. However, it showed a positive correlation with phosphate and chloride downstream stations.

In the present study, sulphate content was high in summer and low in winter at both downstream and upstream stations. Sulphate is an important mineral substance for phytoplankton growth **(Boney 1989)**. **Desai (1995)** found that, in summer the evaporation of water and rise in temperature could result in sulphate level rise which concurs well with our results. The levels of nitrates in the waters were found to be higher in summer. Similar observations were recorded by **Parikh & Mankodi (2012)** who stated that it may be due to higher plankton production, decaying macrophytes and concentration of nutrients owing to the evaporation of pond water with subsequent increase in nitrate values. Nitrate, being the highest oxidized form of nitrogen, is the most important source is biological oxidation of nitrogenous organic matter of both autochthonous and allochthonous origin in aquatic systems. Nitrate showed negative correlation with BOD and dissolved oxygen in upstream as well as downstream direction.

At downstream stations, higher phosphate content was observed compared to upstream stations during the entire study period, with the maximum orthophosphate content in monsoon season which may be due to the washing, domestic waste, agricultural runoff containing fertilizers and release of sediments due to strong wind action during this season. Similar reports have been made by **Sinha et al. 1998, Gill 2004 and Sridhar et al. 2006, Parikh and Mankodi 2012.** Orthophosphate showed positive correlation with TDS and nitrate at all stations. Temperature and BOD negatively correlated with orthophosphate at upstream stations while they showed positive correlation with orthophosphate at downstream stations. Dissolved oxygen was positively correlated with orthophosphate at upstream stations and negatively at downstream stations.

The amount of chloride content of any water body gives an idea about the nature and extent of pollution. Chloride occurs naturally in all types of water. Most important source of chloride in the natural freshwater is the discharge of domestic sewage and its concentration serves as an indicator of sewage pollution **(Trivedy and Goel 1986)**. The upstream stations were observed to have lesser chloride values as compared to downstream stations suggesting that downstream stations were more affected by anthropogenic interference. In the year 2012-2013, maximum concentration of chloride was observed in summer. This may be due to continuous evaporation of water. Such an increase in chloride is in conformity with the earlier observations of **Harshey et al. (1982)**.

BOD is a measure of the oxygen in water that is required by aquatic aerobic organisms. During the present study, BOD fluctuated from 0.4 mg/L to 5.1 mg/L. Seasonal analysis showed higher BOD range (1.8 mg/L to 3.6 mg/L) in summer and lower BOD range (0.8 mg/L to 1.7 mg/L) in monsoon (Figure 20) Similar trend was observed by **Varghese et al. (1992)**, **Devaraju et al. (2005)**, **Yadav and Shrivastava (2011)**. The correlation study showed that

BOD was positively correlated with temperature, pH, alkalinity, Sulphate and Phosphate, while it showed a negative correlation with TDS, DO and Chloride at downstream. At upstream, BOD has been positively correlated with temperature, pH, TDS, hardness, alkalinity and Phosphates, and has shown negative correlation with DO.

IV.CONCLUDING REMARKS AND OPINION

Analysis of physico-chemical parameters of Kota barrage during the study period (2011-12 and 2012-13) is presented in this paper. We found that the temperature variation was insignificant between upstream and downstream stations while the pH was slightly alkaline (7.1-8.6). pH was seen to increase during summer, lowering in monsoon and increasing again in winter months. Total dissolved solids and alkalinity appeared in higher amount at downstream as compared to upstream stations. Total hardness was high during summer which put the water in the hard water category. Regardless of the season, dissolved oxygen concentration always remained lower at downstream stations. Nutrients like sulphate, nitrate and chlorides reached maximum values in the summer whereas phosphate content peaked during monsoon. Relatively lower chloride values of chloride at upstream suggested insignificant anthropogenic activity. Trends in BOD also suggested that the water body is essentially free from organic pollution. Overall, summer was the season at which parameters like DO and BOD reached the limits of standard (oligotrophic to eutrophic) at station I D and II D downstream stations (I D) while in monsoon periods total dissolved solids, chloride and nitrates reveal highest fluctuations across the different stations in the barrage.

The present work investigating the physico-chemical water quality parameters led us to conclude that summer is the season when certain parameters reach their maximum limits, pointing towards eutrophication of the water body. Moreover, it can be inferred that water quality is gradually deteriorating from upstream to downstream in Chambal River at Kota barrage. Identification of contamination sources, like sewage inputs, industrial effluents and other anthropogenic activities in the river water is essential so that mitigation efforts can be put in pace and further deterioration of water can be prevented.

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