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Full Length Research Paper

Study of seasonal and spatial variation in surface water quality of Cauvery river stretch in Karnataka

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In this study, multivariate statistical techniques, such as discriminant, factor /principal component and cluster analyses were applied to water quality data set monitored in pre- and post- monsoon for twenty five locations during three years to investigate seasonal and spatial variations in river water quality. The variables were mainly divided into two categories viz., nonconservative – DO, BOD, COD, nitrates and phosphates and conservative parameters – TDS, conductivity, alkalinity, hardness, calcium, magnesium, sodium, potassium and sulfates. Trivial elevated values of all non conservative Characteristics in pre-monsoon and some conservative parameters (SO4, Cl) in post-monsoon period reflected contribution on temporal effect on surface water. Results of principal component analysis evinced that all the parameters equally and significantly contribute to water quality variations in the river basin for both the seasons. Factor 1 and factor 2 analysis revealed the inverse relation of DO, indicating the control of dissolved oxygen on organic load and nutrients in different seasons. Hierarchical cluster analysis grouped twenty five stations into three clusters in pre-monsoon and six clusters in post- monsoon with similar water quality features. Third clustered group of former and sixth of latter consisted one station (St.25), exhibiting significant spatial variation in physico-chemical composition.

Key words: Multivariate analysis, cauvery, cluster, conservative parameters, temporal and spatial variations.

INTRODUCTION

The Cauvery River and its tributaries such as Harangi, Hemavathi, Lakshmanateerta, Lokapavani, Kabini, Suvarnavathi, Shimsa, Arkavathi, Noyyal, Bhavani, and Amaravathi are the major source of water for drinking, agricultural, and industrial desires in Karnataka and Tamilnadu states of India. The river covers a drainage area of nearly 87,000 km^2 in the southern part of the Indian subcontinent and it flows through densely populated areas from Coorg (Karnataka) in the Western Ghats to Bay of Bengal (Govindraj et al., 2009).

Multivariate analysis is a statistical technique for simultaneous analysis of two or more variables observed from one or more sample objects. The main objective of this analysis is to estimate the extent or amount of relationship among the variables along with the study of mean, deviation, variance and some other characteristics.

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Principal component analysis, factor analysis, cluster analysis and discriminant analysis are the main components of the interdependent multivariate analysis and are also called data reduction techniques (Buyan, 2005).

Multivariate statistical techniques help in the interpretation of complex data matrices to better understand the water quality and ecological status of the studied systems and allows for identification of the possible factors that are responsible for the variations in water quality and, offer valuable tool for developing appropriate strategies for effective management of the water resources (Lee et al., 2001; Regunath et al., 2002; Singh et al., 2006; Hayal and Hiilya, 2009; Pejman et al., 2009). The objective of the study is to analyze the 19 parameters of water along 25 locations of river Cauvery for 2 seasons (premonsoon and post monsoon during2006 - 2009). The obtained water quality data was subjected to multivariate statistical techniques to evaluate homogeneity and heterogeneity between sampling stations and to, differentiate water quality variables for temporal variations in the Cauvery

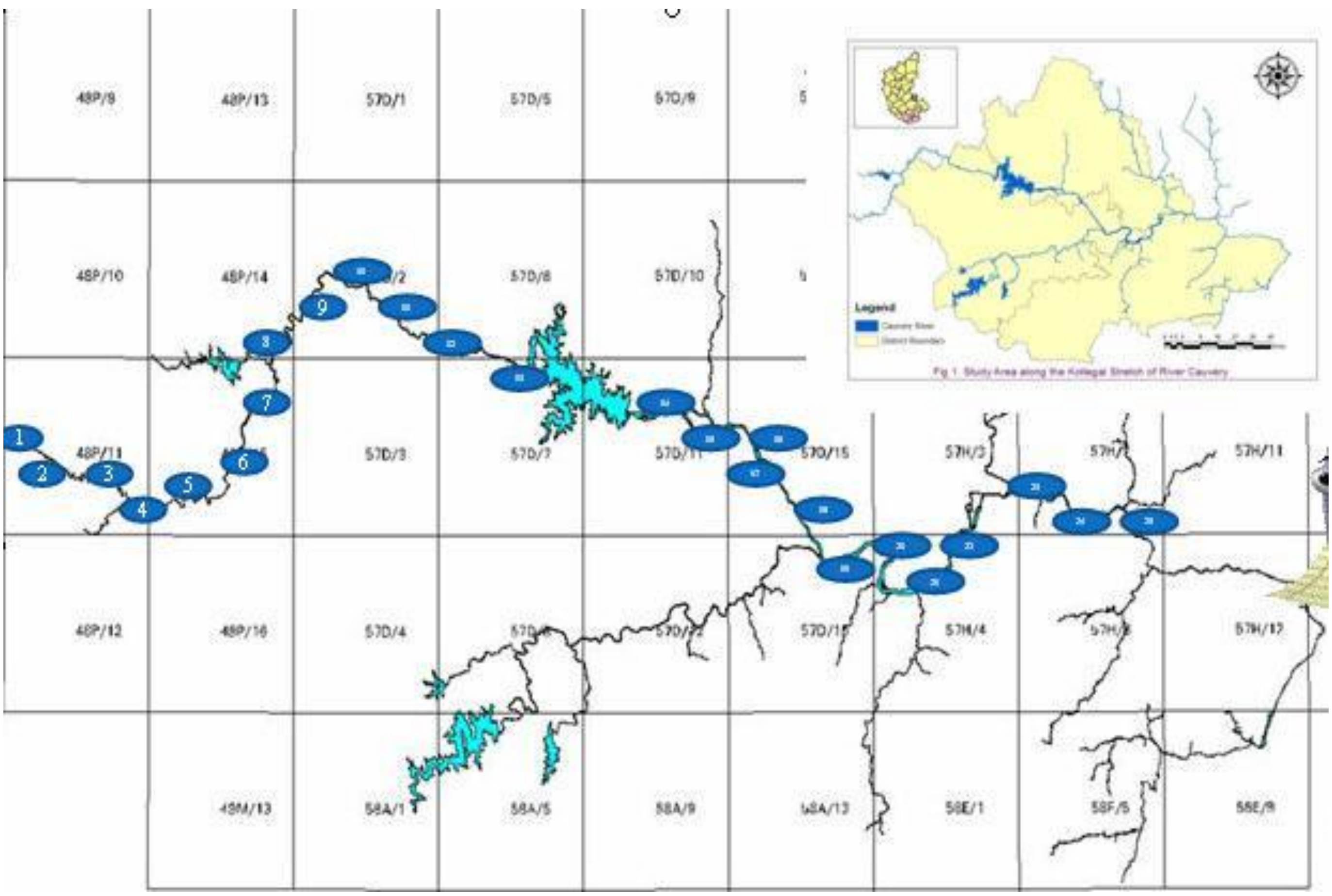

Figure 1. Map showing study area.

river basin.

MATERIAL AND METHODS

Cauvery River from its origin point Talacauvery to Arkavathi Sangama near Kanakpura in Karnataka spread over 300 km in length was chosen as study area. Twenty five locations were selected based on domestic, agricultural and industrial activities in the vicinity of river basin, recreation and ritual practices with the river body and also river - tributaries confluence point (Figure 1). Geographical details of the sampling locations and possible sources of contamination are given in Table 1.

Surface water samples were collected from 25 stations for pre and post monsoon seasons, three each during 2006 to 2009. The collected samples were kept in 2L polythene plastic bottles cleaned with metal free soap water, rinsed many times with distilled water and finally soaked in 10% nitric acid for 24 h, and rinsed with ultrapure water in the end. All the water samples were stored in insulated cooler containing ice and delivered on the same day to laboratory and maintained at 4°C until processing and analysis as suggested in Kazi et al. (2009).

Water samples were analysed for pH, electrical conductivity (EC), total dissolved solids (TDS), dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), chlorides (Cl), sulfates (SO_4), nitrates (NO_3), phosphates (PO_4), total hardness (TH), bicarbonates (HCO3), sodium (Na), potassium (K), total alkalinity (TA), calcium hardness (Ca.H) and magnesium hardness (Mg.H) using standard methods (APHA 2005). Results obtained were subjected to multivariate statistical analysis using Statistical Package for Social Scientists (SPSS) 15th version.

RESULTS AND DISCUSSION

Descriptive characteristics (minimum, maximum, mean and standard deviation) of each data set of general, conservative and nonconservative parameters is given in Table 2 and error bar plots are depicted in Figures 2 - 11.

Seasonal analysis

Mean values were taken into consideration as characteristic values to see the differences during two different seasons (Table 2) . The average values of pH and TDS recorded highest in pre-monsoon compare to post monsoon, which could be due to acidification of water by elevated microbial degradation of organic debris and concentrated dissolved solids in warmer period. As a momentous role of DO amount in water quality of river,

Table 1. Geographical details of the sampling location and possible sources of contamination.

Sl. No	Sampling location	Latitude E	Longitude N	Alt(MSL)	Possible sources of contamination
1	Nagateertha	75°, 29’, 17.4”	12°,23’,17.7”	1010	No human interference.
2	Bhagamandala	75°, 32’, 4.4”	12°,23’,4.7”	856	Ash dropping and other ritual activities.
3	Kodeyetturu	75°,40’,13.4	12°,19’,53.6”	805	Domestic activities.
4	Balamuri	75°,43’,31.8”	12°,17’,46.8”	761	Domestic and ritual activities.
5	Kondengeri	75°,47’,54.4”	12°,17’,50.6”	755	Domestic activities.
6	Dubhare	75°,54’,44.5”	12°,23’,20.8”	742	Recreational, abstraction of water for irrigation.
7	Kushalnagar	75°,58’,7.07”	12°,26’,55.72”	730	Domestic activities and small scale industrial effluents.
8	Ramanathkanive	75°,57’,43.8”	12°,30’,30.09”	726	Washing cloths, bathing and ritual activities.
9	Basavanatti	76°,01’,8.49”	12°,34’,23.32”	715	Irrigational and domestic and sand dredging activities.
10	Ramnathapura	76°,05’,21.18”	12°,36,23.07”	705	Washing cloths, bathing and ritual activities.
11	Basavapatna	76°,07’,22.38”	12°,36’,24.58”	677	Domestic and abstraction of water for drinking and irrigation.
12	Belluru	76°,14’,28.44”	12°,31’,17.72”	705	Domestic and abstraction of water for drinking and irrigation.
13	Hampapura	76°,23’,54.15”	12°,28’,7.62”	661	Irrigational activities.
14	Krishnaraja sagar	76°,35’,3.94”	12,25’,28.62”	623	Irrigational activities.
15	Srirangapatna	76°,43’,26.26”	12°,24’,12.26”	578	Ash Dropping and recreation.
16	Mahadevapura	76°,46’,43.92”	12°,23’,5.63”	570	Irrigation, Sand dredging, Abstraction of water, and Domestic activities.
17	Bannuru	76°,50’,23.97”	12°,19’,16.24”	549	Ash Dropping, Irrigation, Abstraction of water, and Recreation.
18	Somanathapura	76°,52’,21.29”	12°,16’,40.77”	548	Irrigation, Recreation and Sand dredging.
19	T.Narasipura	76°,54’,53.06”	12°,12’,5.19”	540	Ash Dropping, Irrigation, Recreation and Sand dredging.
20	Mudukutore	77°,02’,10.11”	12°,13’,32.07”	567	Recreation, Bathing, Washing cloths and other domestic activities.
21	Dasanapura	77° 06’ 0.7”	12° 11’ 15.7”	554	Irrigation, sand dredging, and domestic activities.
22	Satyagala	77°,09’,20.9”	12°,17’,9.2”	549	Irrigation, sand dredging and domestic activities.
23	Bheemeshwari	77°,15’,55.2”	12°,18’,54”	304	Recreation.
24	Muttati	77°,18’,39.2”	12°,18’,12”	285	Recreation and ritual activities.
25	Kanakapura Sangama	77°,26’,4.4”	12°,17’,2.8”	278	Recreation and ritual activities.

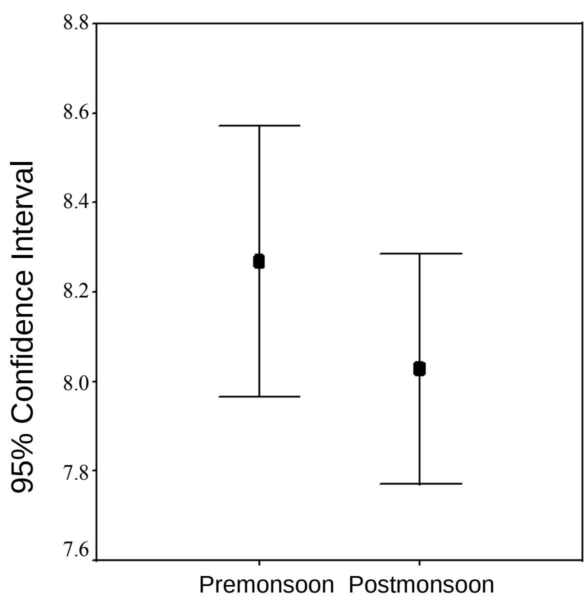

Figure 2. Error plot for pH

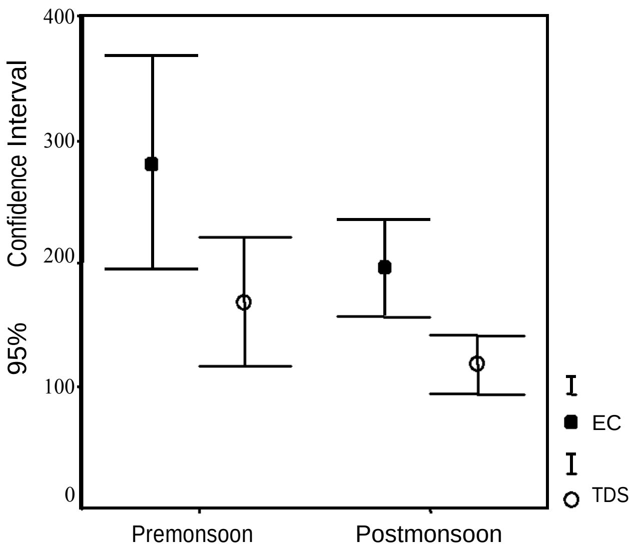

Figure 3. Error plot for EC and TDS.

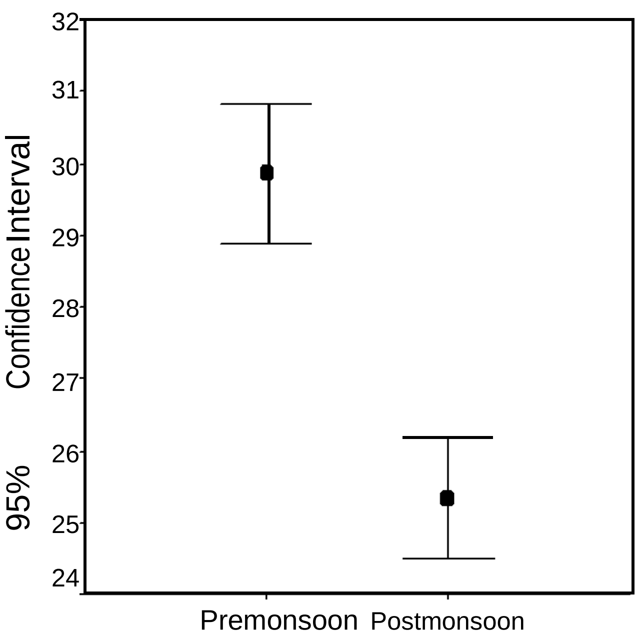

Figure 4. Error plot for temperature.

the average concentration of DO was highest in pre-monsoon and lowest in post-monsoon and is directly proportional to temperature, BOD and COD. It might be due to copious growth of phytoplankton with less water flow, disturbance and uprooting leading to increased generation of O_2 by photosynthetic activities.

TH, HCO_3 and Na were recorded comparatively highest in pre-monsoon and lowest in post- monsoon. The carbonate alkalinity is absent /negligible in most of the stations through out the study. Hence the TA is mostly due to the presence of bicarbonates.

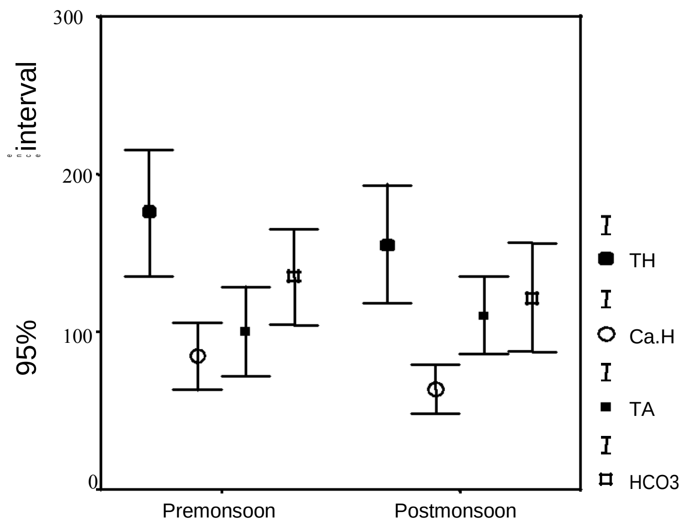

Figure 5. Error plot for TH, Ca.H, TA and HCO_3.

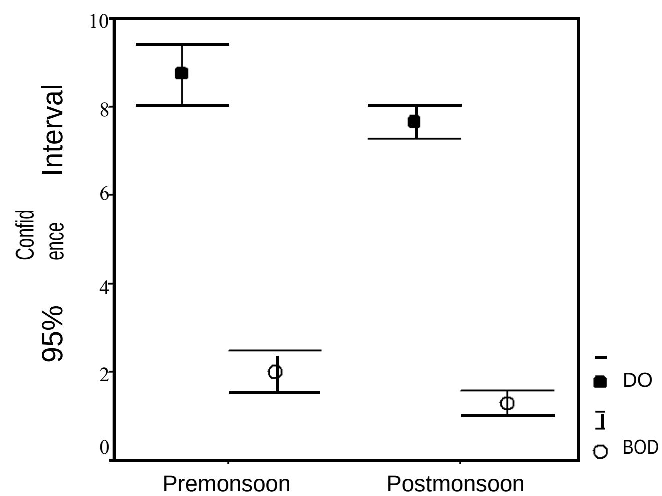

Figure 6. Error plot for DO and BOD.

Inorganic constituents like SO_4, Cl, exhibited higher values in post-monsoon and lowest in pre-monsoon, while PO_4, NO_3 and K recorded vice-versa. Application of chemical fertilizers, run off from agricultural field, leaching of phosphorous rich bed rock, domestic and sewage inflow and other anthropogenic sources (Girija et al., 2007; Govindraj, 2009) are the possible point and non point sources of surface water.

Factor analysis

Principal component analysis/factor analysis was performed on 15 variables for the 25 different sampling stations in two seasons of three years duration, in order to identify imperative seasonal water quality parameters. The principal component analysis results along with

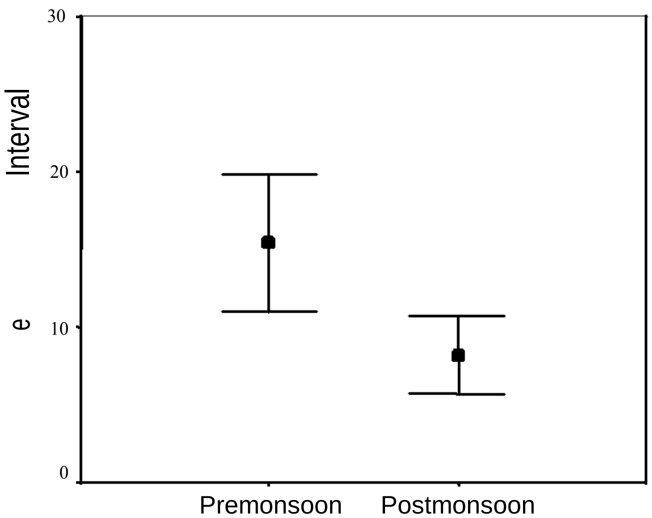

Figure 7. Error plot for COD.

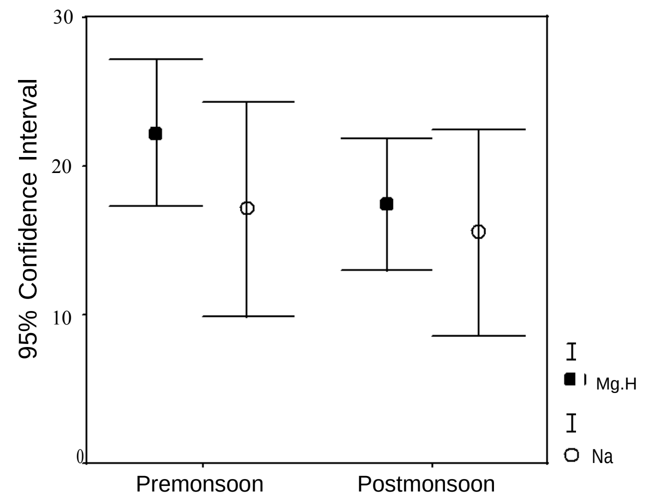

Figure 9. Error plot for Mg.H and Na.

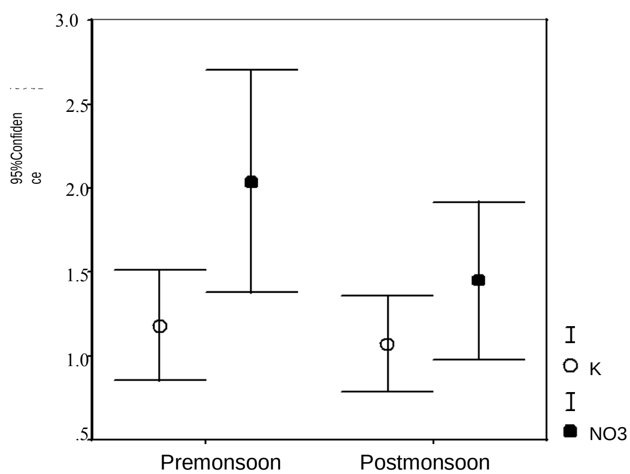

Figure 8. Error plot for K and NO3.

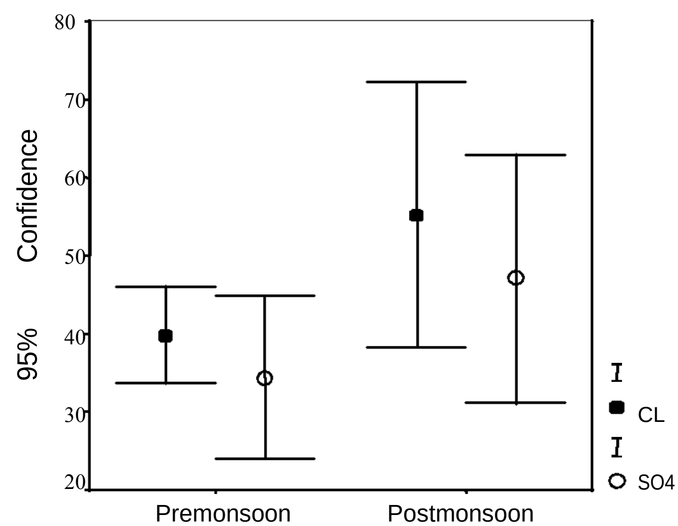

Figure 10. Error plot for Cl and SO4.

factor loading values and percentage of variance for all stations are presented in Table 3.

An eigen value gives a measure of the significance of the factor: the factor with highest eigen values are the most significant. Eigen values of 1.0 or greater are considered significant (Shreshta and Kazama, 2007; Pejman et al., 2009) . Factor loading is classified as strong, moderate and weak corresponding to absolute loading values of >0.75, 0.75 - 0.50 and 0.50 - 0.30 respectively (Liu et al., 2003). Two factors or PCs explained 88.9 and 86.9% of the total variance for pre-monsoon and post-monsoon respectively, which was adequate to give a good initiative of the data structure. Factor 1 of the pre-monsoon accounted for 77.5% of the total variance, which was positively and strongly (>0.75) loaded with Eigen values of almost all the parameters except weak loading (<0.5) of DO. Whereas in the case of post-monsoon factor 1 exhibited moderate (0.75 - 0.5) and positive factor loading of all the parameters except DO with 74.6% of the total variance was observed. Of the second factor in both the seasons only DO was exhibiting more than 0.8, indicating strong and positive association. In this study each water quality parameter with a strong eigen value (>75%) was considered to be a significant parameter contributing to temporal variations of the water quality in Cauvery river. Both organic and inorganic parameters equally contributing and strong factor loadings in water quality variations for two seasons.

Cluster analysis

The affiliation among the stations were obtained through cluster analysis using word's method (linkage between

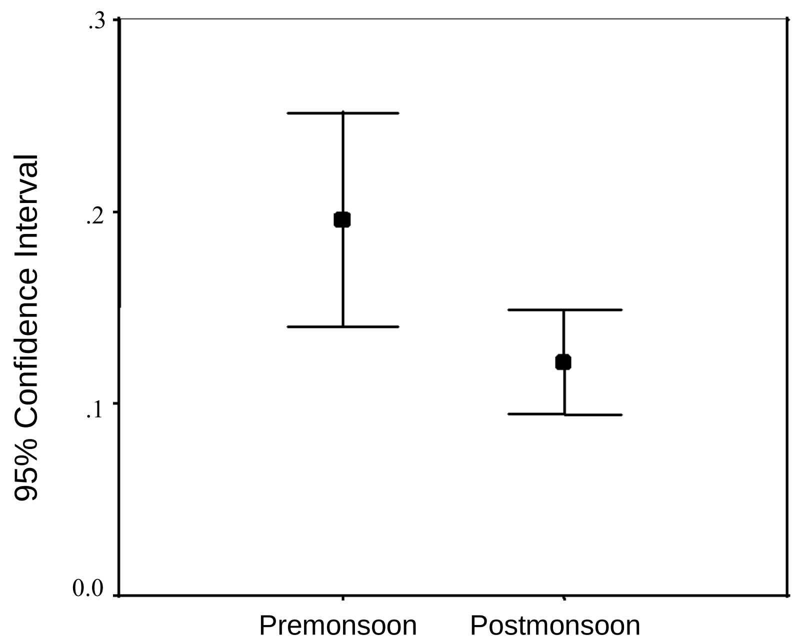

Figure 11. Error plot for PO_4.

Table 2. Descriptive statistics of General, Conservative and Non-conservative variables.

		Pre-monsoon				Post-monsoon			
		Minimum	**Maximum**	**Mean**	**Standard Deviation**	**Minimum**	**Maximum**	**Mean**	**Standard Deviation**
General parameters	PH	6.69	9.39	8.27	0.74	6.68	8.99	8.03	0.63
	EC	56.90	1035.00	280.67	209.88	45.60	406.00	195.29	92.66
	TEMP	22.50	34.60	29.85	2.34	21.00	28.30	25.34	2.05
Conservative parameters	TDS	34.14	621.00	168.40	125.93	27.36	243.60	117.18	55.60
	TH	40.00	375.00	175.60	97.46	30.00	305.00	155.60	90.36
	Ca.H	18.00	180.00	84.64	50.17	15.00	145.00	63.47	37.64
	Mg.H	5.37	47.58	22.19	11.82	2.87	39.04	17.42	10.59
	TA	19.00	227.90	99.70	68.68	20.00	280.33	110.40	60.00
	Cl	20.00	90.00	39.84	14.84	15.00	235.00	55.24	41.15
	NA	2.50	91.47	17.08	17.57	2.20	86.80	15.55	16.84
	K	0.20	4.60	1.18	0.80	0.10	2.90	1.07	0.70
	SO4	14.70	141.20	34.39	25.12	10.50	215.00	47.02	38.55
	HCO3	24.40	342.00	134.69	73.19	23.18	278.00	121.64	83.79
Non-conservative parameters	DO	6.36	12.87	8.74	1.71	6.17	10.10	7.68	0.93
	BOD	0.40	4.70	2.00	1.18	0.20	3.20	1.29	0.72
	COD	2.10	37.95	15.48	10.76	1.40	23.60	8.16	6.10
	PO4	0.04	0.74	0.20	0.14	0.04	0.33	0.12	0.07
	NO3	0.50	6.84	2.04	1.61	0.30	4.70	1.45	1.13

Units: All values are expressed in mgL^{-1} except pH, EC and temperature.

groups), with euclidian distance as a similarity measure and were amalgamated into dendrogram plots (Figures 12 and 13). The physico-chemical Characteristics like pH, Temperature, EC, TDS, TH, Ca.H, Mg.H, TA, HCO_3, Cl, SO_4, NO_3, PO_4, DO, BOD and COD were used as variables to show the spatial heterogeneity among the stations as a result of sequence in their relationship and the degree of contamination.

There were three major groups obtained from the pre-monsoon season while post-monsoon season yielded

Table 3. The factor loading values and the explained variance of water quality parameters in two seasons.

Pre-monsoon			Post-monsoon		
Parameters	**Factor 1**	**Factor 2**	**Parameters**	**Factor 1**	**Factor 2**
pH	0.7055	0.1452	pH	0.8743	0.3219
EC	0.9504	-0.1524	EC	0.7775	0.1562
TDS	0.9504	-0.1523	TDS	0.7775	0.1562
TH	0.9297	0.3001	TH	0.9527	0.2031
TA	0.9080	0.3579	TA	0.9824	-0.0213
Cl	0.9466	-0.1095	Cl	0.8377	-0.4963
Na	0.9159	-0.3170	Na	0.8415	-0.5130
K	0.7597	-0.5426	K	0.9528	-0.0634
SO4	0.8962	-0.3280	SO4	0.8313	-0.4889
HCO3	0.9745	0.1022	HCO3	0.9408	0.1518
DO	0.3845	0.8107	DO	0.3635	0.8371
BOD	0.9309	0.2307	BOD	0.9608	-0.0269
COD	0.9191	0.3038	COD	0.9456	0.0192
PO4	0.9171	-0.3069	PO4	0.9360	-0.1533
NO3	0.9314	0.0641	NO3	0.7901	0.4068
Variance (%)	77.5043	11.4111	Variance (%)	74.5988	12.4041
Cumulative (%)	77.5043	88.9154	Cumulative (%)	74.5988	87.0028

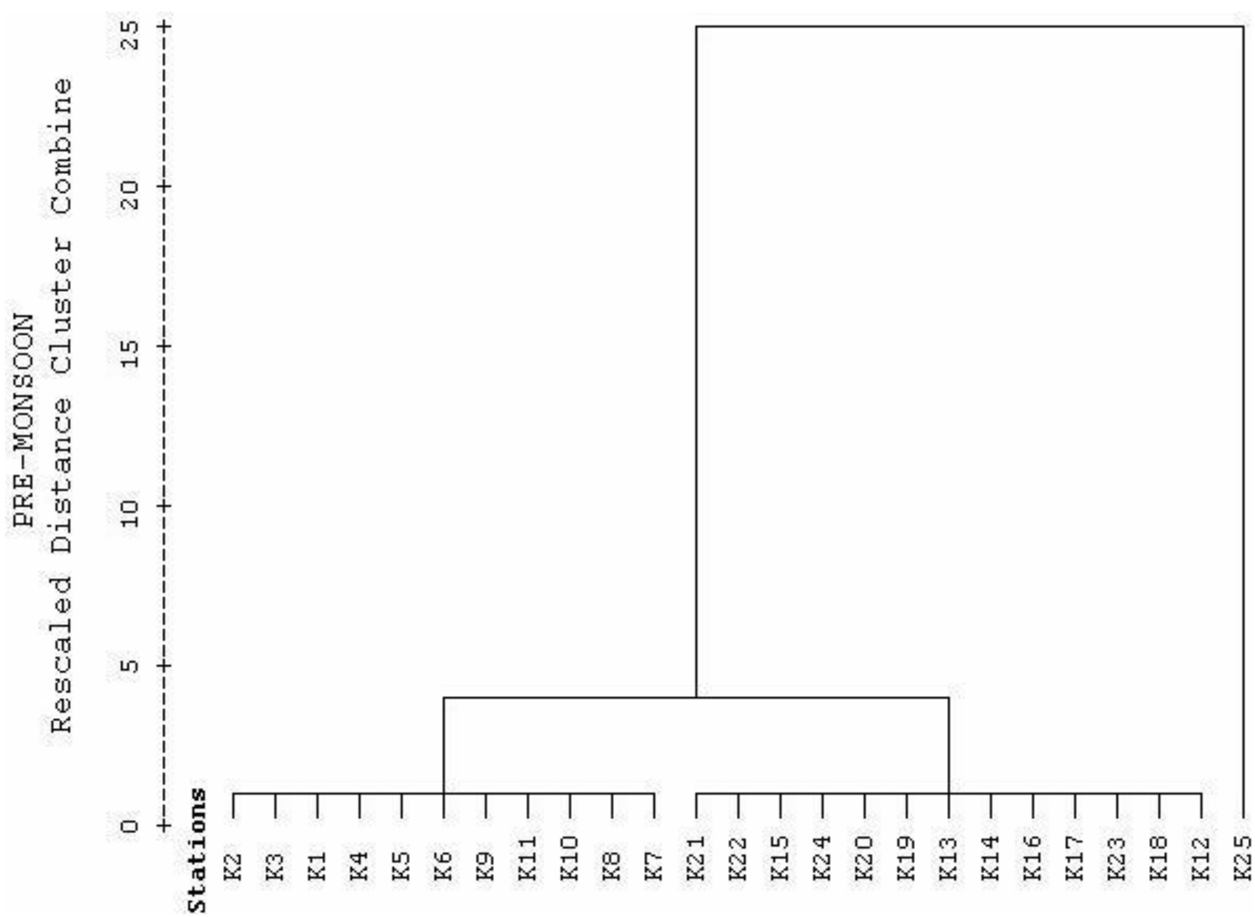

Figure 12. Dendrogram showing the relationship among the stations in Cauvery River-system during pre-monsoon.

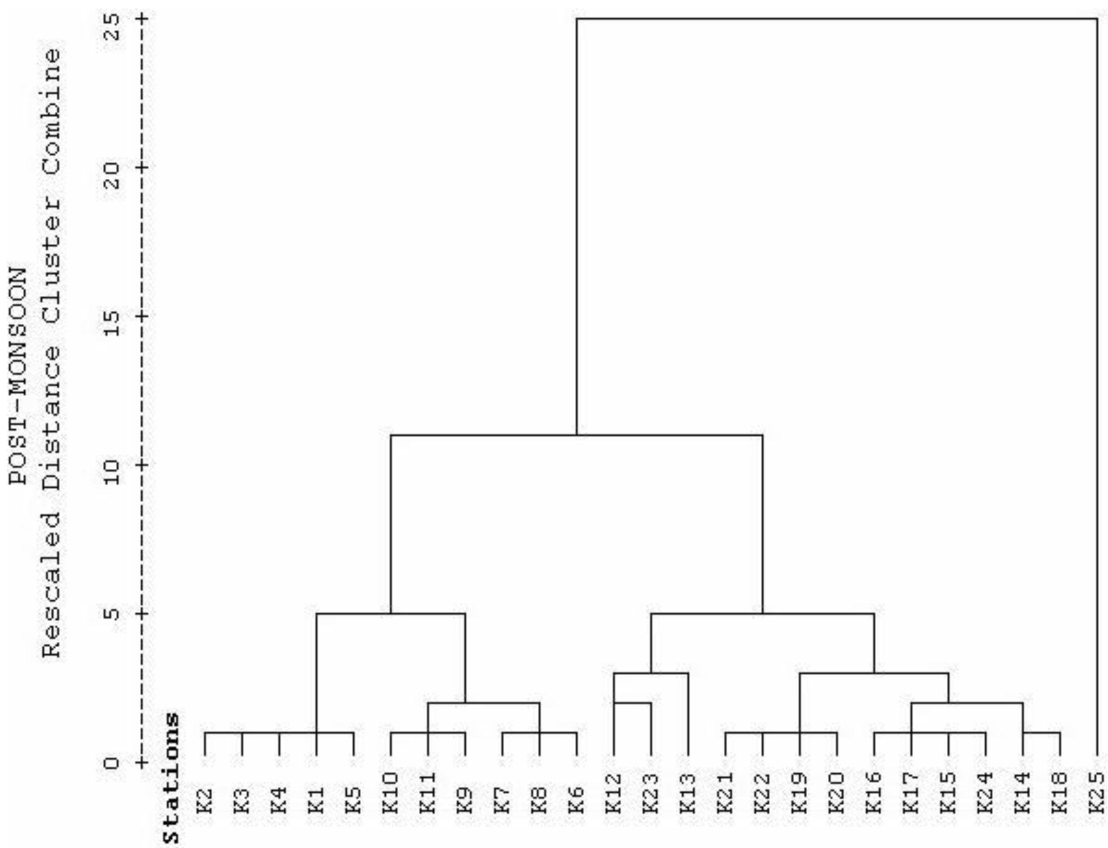

Figure 13. Dendrogram showing the relationship among the stations in Cauvery River-system during post monsoon seasons.

four groups and the likely groupings are summarized below. The third and fourth group of pre and post-monsoon consisted of one station (K25) respectively.

In the pre-monsoon season group1 and group 2 were exhibiting similar variation in comparison with group 3, providing evidence that former two groups could be categorized as less polluted and latter as highly polluted, due to agricultural and urban run-off into the river.

In the case of post-monsoon, increased number of linkages revealed spatial variation among the stations is noticeable and it could be due to inflow of contaminants from point and non-point sources through rain water and tributaries into the riverine system. The number of stations clustered to form a group is in the sequence of V>II>I>IV>III>VI. The group clustered with a large number of stations construed the spatial similarity in their physico-chemical composition amongst them, as influenced by river run-off.

Third clustered group of pre-monsoon and sixth of post-monsoon consisted of unique station (St.25), exhibiting significant spatial variation in physico-chemical composition. It related the degree of revelation to human interference and extent of pollutants received by river basin. The number of clustered groups obtained through dendrogram for pre-monsoon and post-monsoon signifying temporal impact on the river water quality too.

Conclusion

Comparing the mean values, it can be concluded that conservative variables – TDS, TH, HCO3, Ca.H, Mg.H, Na & K are slightly higher and SO4, TA, Cl are lower in the pre-monsoon period than in the Post-monsoon (Table 4). On the other hand nonconservative parameters – DO, BOD, COD, NO3 and PO4 are clearly higher in the pre-monsoon compared to post-monsoon and showed a clear cut temporal effect. Inverse relation of DO with other variables in factor 1 and strong positive association in factor 2 analysis signifies the role of dissolved oxygen in determining surface water quality of the river Cauvery. By cluster analysis, it is proved that in both the seasons Arkavathi Sangama (St.25) alone formed a group with highest euclidian distane compared to other cluster groups reflecting inflow of organic pollutants through tributary and extent of pollution in the stretch. Third cluster group in pre-monsoon and sixth cluster group in post-monsoon period as enunciated by euclidian distance indicated the noticeable spatial variation among different stations in the river stretch.

Table 4. Group of clustered stations during pre-monsoon and post-monsoon seasons.

Groups	Pre-monsoon	Post-monsoon
I	K2-K3-K1-K4-K5- K6-K9-K11-K10-K5-K7	K2-K3-K4-K1-K5
II	K21-K22-K15-K24-K20-K19-K13- K14-K16-K17-K23-K18-K12	(K10-K11-K9)- (K7-K8-K6)
III	K25	K12-K23-(K13)
IV	-	K21-K22-K19-K20
V	-	(K16-K17-K15-K24)-(K14-K18)
VII	-	K25

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