International Research Journal of Environment Sciences ISSN 2319–1414
Vol. **3(10),** 12-23, October **(2014)** *Int. Res. J. Environment Sci.*

Water Quality of Rameswaram Island, Southeast Coast of India – A Statistical Assessment

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Available online at: www.isca.in, www.isca.me
Received 14th July 2014, revised 20th September 2014, accepted 16th October 2014

Abstract

Rameswaram Island, located on the southeast coast of India in Tamil Nadu, is the main pilgrimage site influenced by anthropogenic intercessions. Assessment of physicochemical characteristics of nearshore water quality was carried out during April 2011 – March 2012 to explicate its quality variations. Principal component analysis was applied to the whole data to be factorized from which the total variability extraction and existing set of different physicochemical parameters linear relationships were obtained. In PCA, high loadings were obtained for pH, temperature, SPM, salinity, DO, BOD, nutrient species of nitrogen, phosphorus and chlorophyll-a. Seasonal variations of the physicochemical parameters are observed with high deterioration of the water quality during summer.

Keywords: Rameswaram Island, Nearshore water, physicochemical, seasonal variation, principal component analysis.

Introduction

Regular monitoring of coastal water quality is the mandatory in developing countries like India, because of urbanization and industrial developments are moving towards coastal area. The inshore areas usually get disturbed with more critical water pollution problems than offshore[1]. At present, nearshore waters are in various stages of degradation as they are increasingly exploited by human for food, recreation, transport and other needs[2,3]. Considerable attentions have been paid in the recent years to study the physico-chemical parameters of the coastal waters around India in order to ascertain the water quality and productivity[4]. In tropical countries, the cyclic phenomenon of the rainfall pattern brings important changes in hydrographical characteristics of the marine ecosystem. Monitoring activities of coastal ecosystems have acquired great importance for better understanding of the past process, present patterns, and future trajectories in aquatic health[5,6]. To understand about the external driving forces as well as internal coastal processes, it is required to analyze the patterns and relationships among the water quality parameters. To detect the spatial and temporal variations of complicated data sets, multivariable statistical methods such as, principal component analysis (PCA), correlation matrix and box plots etc.,[7-9] were applied for better understanding of water quality variations and the factors linked to seasonality. To reduce the dimensionality of multivariate attributes into two or three; PCA is applied to display graphically with minimal loss of information[10]. PCA summarizes the variation in a correlated multiattribute to a set of uncorrelated components that is principal components (PCs), each of which is particular linear combination of the original variables and is estimated from the Eigen values of the covariance or correlation matrix of the original values[3]. The use of PCA to water quality assessment has increased in recent years, mainly due to the need to obtain appreciable data reduction for analysis and decision[11, 12].

In the coastal environment, the supply of nutrients is mainly influenced by the amount of fresh water inflow, rate of the rainfall, invasion of tidal pattern and also biological activities. The rainfall in India is largely influenced by two monsoons viz., southwest(SW) monsoon on the west coast, northern and northeastern India and by the northeast(NE) monsoon on the southeast coast[13,14]. Rameswaram Island, located in southeast coast of Tamil Nadu in India, surrounded by Palk Bay (PB) and Gulf of Mannar (GoM) acting as a physical barrier with limiting of water and sediment exchange, which is unique in nature and subjected to reversible monsoon activities during SW and NE monsoons. During southwest monsoon (June to September), the direction of current is clockwise in PB and the reverse in northeast monsoon (October to December), induced littoral currents in PB and GoM, which is buffered by the moving sandbar in Adams Bridge[15]. Transported by water flow, the distribution of water quality constituents are greatly influenced by the advection and diffusion processes of water movement[16]. Limited observations have been studied about the pollution aspects of Rameswaram Island. The objective of the present study is to evaluate the seasonal variation of nearshore water quality of the Rameswaram Island through statistical approach.

Material and Methods

Study area: Rameswaram Island is bounded between the longitudes 79°12’30” E to 79°21’30” E and the latitudes 9°8’55” N to 9°19’25” N with PB on its north and GoM on its south (figure-1). The length of the island is about 28 km in the east-west direction. The extreme southeastern part of Rameswaram Island, known as Dhanushkodi Foreland, a long sand spit of about 4 km length is formed up to Arichamunai (tip) from Dhanushkodi and it tends to grow longer and wider and also it is well-known in Hindu mythology and is of religious importance. The Rameswaram Island, submerged chains of Islands in the Palk strait and Mannar Island act as physical barriers between

GoM and PB[7]. As a result, the hydrography of the PB is influenced by the Bay of Bengal (BoB) waters significantly and the GoM is influenced by the Arabian Sea (AS) waters[7,17]. Rameswaram Island comprising a holy pilgrimage site and comes under the sensitive EEZ of Indian coastal water is surrounded by coral patches and National Marine Biosphere Reserve Park. The revenue for this area is mainly from fishing and tourism. There are no industrial activities in this area. The fishermen settlements are temporary shifting all along this coast for fishing. During summer, the Island gets inflow of tourists because of the pilgrimage and scenic beauty of the area. The climatology of this area has been treated into four seasons in a year i.e. (i) summer (April–May), (ii) southwest monsoon (June–September), (iii) northeast monsoon (October–December) and (iv) post-monsoon (January - March). Figure 2 shows the annual climatology variations based on JMA data[18]. The air temperature ranges from 26.9 to 30.9 °C. The peak rainfall 286.8 mm is recorded during NE monsoon. Anthropogenic influences from pilgrimage activities, tourism, organic contamination from fishing and its processing units and domestic discharges affect the coastal environment considerably. Dilution of pollution load around the Island is mainly dominated by tidal influence.

Sample collection and preservation: Surface water samples around the Rameswaram Island were collected monthly at 10 prefixed locations (figure 1 and table 1) with the help of (Global Positioning System GPS) from April 2011 to March 2012 during spring tide from the average water depths at 4-6 m within 500 m from the coast. Samples were collected in separate polythene bottles for nutrients, chlorophyll- a, suspended particulate matter (SPM), and in glass stopper bottles for the estimation of DO and BOD respectively and stored at 4°C for physicochemical analysis.

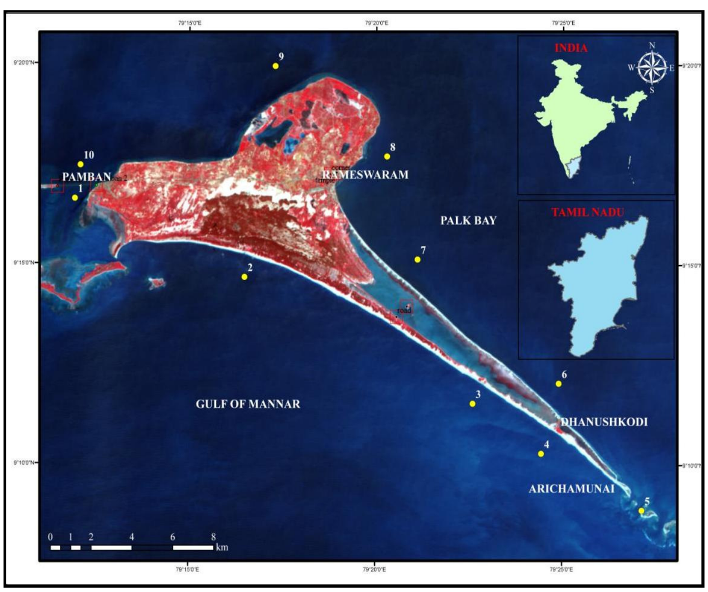

Figure-1
Study area with sampling stations

Table-1
Sampling stations of Rameswaram Island

Station No.	Name of the stations	Water depth (m)
	Gulf of Mannar	
1	Pamban South	6.0
2	Kunthukal	5.2
3	Muuntharaiyar Chathiram	5.1
4	Dhanushkodi	5.3
5	Arichamunai tip	1.3
	Palk Bay	
6	Palam	3.4
7	Kodhandaramar Kovil	3.8
8	Agneetheertham	4.1
9	Villoonditheertham	3.6
10	Pamban North	5.8

Physicochemical analysis: Water samples were analyzed for various physical, chemical and biological parameters based on the procedures described by Grasshoff K. et.al.[19] and Srtickland J.D.H. et.al.[20]. *Insitu* observation of temperature, pH and salinity were measured using digital thermometer, pH meter (WTW 330i probe, Germany with 0.01 resolution) and salinity meter (WTW 330i probe with accuracy of ±1 digit and 0.1 mS resolution) respectively and turbidity was measured using nephelometer (Cyber Scan IR TB 100 having 0.01 NTU resolution). DO and BOD concentrations were determined using Winkler's titrimetric methods[19]. For SPM, 500 ml of the sample was filtered through 0.45 µm filter paper and the paper was dried at 105°C up to a constant weight[19]. The samples were filtered using 0.45 µm filter paper for nutrients and Glass Fiber filter paper for chlorophyll–a (Chl- a) in the Millipore Filter Unit. Dissolved nutrients (nitrate, nitrite, ammonia, total nitrogen and total phosphorus) and Chl-a were estimated by standard colorimetry methods[19]. A double beam UV Visible Spectrophotometer (Systronics Visiscan 167) was used for the colorimetry analysis.

Principal component analysis: Principal component analysis assisted to recognize the factors or origin responsible for seasonal water quality variations[21]. PCA was carried out with factors having Eigen vectors higher than one (Kaiser Criterion). The Principal Components (PCs) were extracted in decreasing order of importance, so that the first PC accounts for as much of variation as possible and each successive component account less. As the first PC accounts for the co variation shared by all attributes, this may be a better estimate than simple or weighted averages of the original variables[6]. PCs actually take the cloud of data points and rotate it such a way that maximum variability is visible[22]. The most significant variables in the components represented by high loadings (correlation coefficient > 0.7) taken into consideration for evaluating the components[23]. STATISTICA software was used to carry out all the statistical analyses, including PCA.

Results and Discussion

The descriptive statistics of the physicochemical parameters of Rameswaram Island are shown in table-2 and the seasonal fluctuation of mean values of water quality parameters are illustrated in box plot (figures 3 - 10). The box plot is composed of a box around the midpoint (i.e., mean or median) representing of the selected range (i.e., standard error, standard deviation, min-max, or constant) with whiskers outside of the box representing a selected range. Significant seasonal spatial and temporal variations of the all water quality parameters are revealed. pH remains alkaline throughout the study period at all stations registering a maximum during SW monsoon, which could be attributed to the high salinity of water[24]. Fluctuations in pH during different seasons is attributed to factors such as removal of CO_2 photosynthesis through bicarbonate degradation, dilution of seawater by freshwater influx, low primary productivity, reduction of salinity and temperature besides decomposition of organic materials[25]. The analogous trend in pH in the coastal waters was reported from Point Calimere[26] and from Parangipettai and Cuddalore[27]. The surface water temperature is higher during summer, because of longer photoperiod, clear sunshine and parched wind during summer and is lower in post monsoon, due to obscure sky and heavy rainfall. Similar observations have been recorded[12, 26, 28, 29]. A significant seasonal fluctuation of Salinity shows with high values in SW and low during NE. This can be due to the high degree of evaporation in SW as well as freshwater input due to precipitation during NE. Similar trend in the salinity values is also observed from various parts in southeast coast of India[4, 13,24, 26, 30-32]. Higher SPM is recorded during NE monsoon, because of the turbulence experienced in the shallow nearshore waters onset of NE monsoon. DO vary between 5.55 and 7.57 mgL^{-1} and 4.16–5.55 mgL^{-1} during post monsoon and NE monsoon respectively. This could be attributed to the solubility of DO saturated with minimum temperature during post monsoon[13,24,26,27&28] and increased organic inputs from the urban areas during NE monsoon. BOD varies extensively higher in summer (1.50–9.30 mgL^{-1}) and lowers in NE (0.88–1.90 mgL^{-1}). High BOD is recorded at Agnitheertham where the main pilgrimage activities as well as the discharge of dissolved organic matter added from land-based resources, such as domestic wastewater from the township[33, 34].

During NE and SW monsoon seasons, nutrient species of nitrogen (N) and phosphorus (P) show higher values than other seasons. Nitrite-N (NO_2-N) is the least during NE while nitrate-N (NO_3-N) has more than triple the concentration during SW. Similarly, ammonia-N (NH_3-N) and total nitrogen (TN) also recorded high values during NE monsoon compared to the other seasons. The maximum values of nitrogen compounds are recorded at Agnitheertham. Total phosphorus (TP) is high during SW. One of the key factors that enrich the phosphate concentration is the exchange of phosphorous between water and sediment through interstitial water as well as the regenerative property of the sediment is known to play an indispensable role on the distribution of the nutrient[6,35,36]. High Chlorophyll-a values are noticed during summer season and it is low during NE monsoon. High nitrogen content associated with low chlorophyll concentrations during NE monsoon indicates that the nitrogen concentration is regulated by phytoplanktonic growth. The Chl-a in the upper layer of tropical oceans is limited by the availability of nutrients. Therefore, oceanic processes that can bring nutrients into the euphotic zone are of prime importance[37, 38].

The water quality trend is inferred by correlation matrix and PCA. The seasonal correlation matrix of 12 variables is given in table 3. During summer and SW monsoon, pH is positively correlated with temperature, while pH is negatively correlated with SPM, ammonia and TN during summer. A negative correlation of temperature with SPM, salinity, nitrite and TN is observed in all seasons. A positive correlation of salinity with SPM, DO and TN during SW monsoon and chlorophyll-a in post monsoon is observed. SPM is positively correlated with TN in all seasons except NE monsoon and it is negatively correlated with nitrite during summer. DO is negatively correlated with BOD in all seasons except in post monsoon. A negative correlation is observed between BOD and DO during summer. A positive correlation of nitrite with nitrate and TN is observed during NE and ammonia with TN during summer. A negative correlation of TP with DO is observed during NE monsoon. Negative correlation of chlorophyll-a, with nitrate in summer and positive correlation with salinity in post monsoon is observed. It is found that a strong linear relationship exists between some of the variables from the correlation matrix. Thus, PCA was conducted to characterize the linear correlations and the loadings of 12 variables for each of the PCs were obtained. The first PC is influenced by each original variable. For each season three factors were obtained through the factor analysis performed on the PCs. Results of varimax rotated components matrix of FA including factor loadings, eigenvalues, percentage of total variance and cumulative variance values are presented in table 4. Figure 11-14 represents the results obtained for the first and second factors in different seasons. Classification of factor loading is ‘strong’, ‘moderate’ and ‘weak’ corresponding to absolute loading values of >0.75, 0.75 – 0.50, and 0.50 -0.30 respectively[21, 39].

It is observed that the factor 1 is dominant in all seasons and together accounted for 34.01% in summer, 32.21% in SW, 35.24% in NE and 26.17% in post monsoon of the total variance. During NE monsoon the maximum eigen values of 4.23 is observed due to the nutrients associated with strong loadings of TN, TP and ammonia (0.80, 0.81 and 0.75), and strong negative loadings of SPM and DO (-0.75). Due to the monsoon impacts, the nutrient enrichment induces the domination factor1. Factors 2 and 3 are accounted for 23.68% and 17.57% in summer, 27.94% and 14.37% in SW, 20.13% and 16.46% in NE and 22.91% and 19.30% in post monsoon of the total variance. Factor 2 and 3 are dominant during SW monsoon and post monsoon respectively. During SW monsoon, factor 2 records an Eigen values of 3.35, because of the nutrients associated with strong and moderate positive loadings of nitrate and chlorophyll (0.76 and 0.74) respectively, and strong negative loadings of DO (-0.82). The maximum Eigen values of 2.32 for factor 3 during post monsoon may be attributed to the nutrients associated with moderate negative loadings of nitrate and TN (-0.74) correlate significantly with each other, suggesting a common source. Factor 2 portrays a strong positive loading with BOD and a strong negative loading with DO and salinity during summer. This is because of the organic loadings which indicates that the increased the concentration of pollution. In PCA outputs, the positive loadings of nutrients along with negative loadings of DO, pH and temperature indicates that nutrients contribution related with pollution sources and also it might be due to the consumption of large amounts of oxygen by the organic matter[3, 6, 14, 40]. The major source of ammonia from the sewage which is the indicative of pollution and the presence of nitrate is mainly due to processes such as nitrification[42]. PCA supported these observations in all seasons.

Conclusion

Nearshore water quality around Rameswaram Island, show the maximum enrichment of nutrients during NE monsoon compared with other seasons because of the precipitation. At Agnitheertham, high BOD with low DO is observed during summer, due to pilgrimage and tourism in addition to the domestic pollution. The major anthropogenic impacts on the coastal waters of the study area are due to the intensification of tourism, fishing and urbanization by discharging sewage from hotels and settlements directly into the sea. These discharges lead to degradation of coastal water quality causing significant negative impacts on marine ecosystem in water quality, aquatic organisms and coral reefs in particular[8,14,41]. High salinity and high DO are observed during SW monsoon in Mukuntharaiyar Chathiram and during post monsoon at Pamban south respectively. The minimum concentration of nutrients, temperature and salinity are found during post monsoon period and DO, SPM are low during summer monsoon around the Rameswaram Island. The pragmatic values of physicochemical parameters of water mass around Rameswaram do not show much of spatial variations, but temporal changes in nutrients separates the water quality of PB and GoM regions, because of monsoonal behavior such as precipitation and reversible current patterns prevailing in this study area.

Acknowledgement

Authors are thankful to the Ministry of Earth Sciences (MoES), Govt. of India for financial assistance; Principal Chief Conservator of Forests and Chief Wildlife Warden, Tamil Nadu Forest Department and Wildlife Warden, Gulf of Mannar Marine National Park for research permission.

Table-2
Descriptive Statistics for Surface Waters of the Sampling Stations in Rameswaram Island

Parameter	Summer		SW Monsoon		NE Monsoon		Post Monsoon	
	Range	Mean± SD	Range	Mean± SD	Range	Mean± SD	Range	Mean± SD
pH	8.08–8.32	8.22±0.07	8.12-8.29	8.24±0.06	8.03-8.25	8.16±0.06	7.92-8.10	8.01±0.06
Temperature (^{o} C)	29.00-30.65	30.25±0.48	28.95-30.03	29.53±0.43	27.87-30.80	28.98±0.85	27.47-29.53	28.58±0.72
Salinity (psu)	29.40-30.50	29.94±0.41	31.00-32.50	31.55±0.47	27.81-31.05	28.89±1.04	28.87-29.90	29.28±0.33
SPM (mg/L)	31.60-57.10	45.01±8.48	44.00-64.20	52.95±7.35	48.40-73.73	63.69±8.69	36.67-53.33	42.36±4.42
DO (mg/L)	4.15-6.65	5.45±0.68	4.43-6.30	5.25±0.71	4.16-5.55	4.86±0.49	5.55-7.57	6.58±0.68
BOD (mg/L)	1.50-9.30	3.48±2.25	1.58-5.39	2.60±1.09	0.88-1.90	1.29±0.30	0.69-2.67	1.60±0.59
Nitrite (µmol/L)	0.18-0.64	0.35±0.12	0.12-0.27	0.21±0.04	0.26-0.71	0.42±0.12	0.06-0.35	0.18±0.10
Nitrate (µmol/L)	0.35-2.08	1.27±0.59	0.72-2.06	1.44-0.43	0.94-1.92	1.36±0.33	0.19-1.50	0.67±0.39
Ammonia (µmol/L)	1.35-7.04	4.19±1.84	0.85-4.62	1.98±1.26	3.03-7.12	5.31±1.53	0.62-4.77	2.31±1.18
Total Nitrogen (µmol/L)	9.58-30.42	19.67±5.99	20.00-26.67	23.75±2.69	34.72-51.65	41.29±4.69	22.22-40.00	29.22±5.99
Total Phosphorus (µmol/L)	0.78-2.05	1.50±0.78	1.49-6.46	3.46±1.38	0.49-1.63	1.16-0.44	0.42-1.19	0.90±0.21
Chlorophyll – a (mg/m^3)	0.27-3.50	1.65±0.27	0.12-2.55	1.34±0.68	0.45-1.45	0.82±0.41	0.42-2.15	0.86±0.49

Table-3
Seasonal Variations of the Water Quality Parameters of Rameswaram Island

SUM MON	**PH**	**TEMP**	**SAL**	**SPM**	**DO**	**BOD**	**NO2**	**NO3**	**NH4**	**TN**	**TP**	**CHL**
PH	1.00											
TEMP	**0.62**	1.00										
SAL	0.11	0.32	1.00									
SPM	**-0.68**	**-0.62**	-0.33	1.00								
DO	-0.02	0.41	**0.58**	-0.17	1.00							
BOD	0.25	0.15	-0.46	-0.07	**-0.60**	1.00						
NO2	0.08	0.10	0.41	**-0.66**	0.30	-0.40	1.00					
NO3	-0.12	0.30	0.27	-0.40	0.18	0.28	0.48	1.00				
NH4	**-0.73**	-0.41	-0.14	**0.64**	0.16	-0.12	-0.04	0.18	1.00			
TN	**-0.80**	-0.41	-0.34	**0.80**	-0.02	-0.24	-0.30	-0.17	**0.77**	1.00		
TP	-0.39	-0.06	0.50	0.13	0.22	-0.36	0.24	0.05	0.20	0.25	1.00	
CHL	-0.04	-0.55	0.17	0.29	-0.08	-0.45	-0.03	**-0.72**	-0.04	-0.02	0.33	1.00
SW MONS	**PH**	**TEMP**	**SAL**	**SPM**	**DO**	**BOD**	**NO2**	**NO3**	**NH4**	**TN**	**TP**	**CHL**
PH	1.00											
TEMP	**0.71**	1.00										
SAL	-0.23	**-0.60**	1.00									
SPM	-0.38	**-0.82**	**0.73**	1.00								
DO	0.14	-0.30	**0.63**	0.57	1.00							
BOD	0.18	-0.18	-0.13	-0.05	-0.18	1.00						
NO2	0.14	0.15	0.11	-0.18	-0.06	0.09	1.00					
NO3	-0.58	-0.37	-0.04	0.06	**-0.68**	0.31	-0.06	1.00				
NH4	-0.46	-0.57	-0.10	0.19	-0.09	0.55	-0.52	0.46	1.00			
TN	-0.22	**-0.67**	**0.65**	**0.71**	0.44	0.31	0.47	0.06	0.01	1.00		
TP	-0.54	-0.31	0.00	0.10	-0.43	0.21	0.11	0.57	0.12	0.31	1.00	
CHL	-0.01	0.01	-0.22	-0.10	-0.38	0.52	-0.40	0.55	0.44	-0.14	0.39	1.00
NE MONS	**PH**	**TEMP**	**SAL**	**SPM**	**DO**	**BOD**	**NO2**	**NO3**	**NH4**	**TN**	**TP**	**CHL**
PH	1.00											
TEMP	0.42	1.00										
SAL	0.20	-0.42	1.00									
SPM	-0.59	-0.04	0.03	1.00								
DO	-0.45	0.05	-0.09	0.52	1.00							
BOD	0.04	0.09	0.27	-0.21	0.16	1.00						
NO2	-0.15	-0.35	0.10	-0.29	-0.37	0.56	1.00					
NO3	0.15	-0.28	0.49	-0.20	-0.53	0.52	**0.82**	1.00				
NH4	-0.26	-0.07	0.13	-0.23	0.33	0.17	-0.19	-0.30	1.00			
TN	0.24	-0.11	0.18	**-0.77**	-0.32	0.49	**0.65**	0.51	0.36	1.00		
TP	0.56	0.26	0.07	-0.50	**-0.91**	0.04	0.38	0.56	-0.33	0.39	1.00	
CHL	-0.29	-0.40	0.11	0.55	0.31	-0.05	-0.09	-0.04	-0.30	-0.56	-0.43	1.00
POST MON	**PH**	**TEMP**	**SAL**	**SPM**	**DO**	**BOD**	**NO2**	**NO3**	**NH4**	**TN**	**TP**	**CHL**
PH	1.00											
TEMP	0.26	1.00										
SAL	-0.57	**-0.66**	1.00									
SPM	-0.41	0.26	-0.07	1.00								
DO	-0.25	0.16	0.16	0.43	1.00							
BOD	0.02	0.22	0.06	0.14	**0.77**	1.00						
NO2	-0.03	**-0.73**	0.49	-0.04	0.28	0.34	1.00					
NO3	-0.17	-0.30	-0.08	0.20	-0.41	-0.32	-0.05	1.00				
NH4	0.36	-0.31	-0.22	-0.38	-0.46	-0.39	0.19	0.02	1.00			
TN	-0.34	0.08	-0.36	**0.69**	-0.08	-0.24	-0.12	**0.63**	-0.01	1.00		
TP	-0.06	0.01	-0.01	0.13	0.44	0.13	0.20	-0.18	-0.07	0.13	1.00	

CHL	-0.13	-0.44	**0.75**	-0.23	-0.01	0.01	0.40	-0.11	-0.10	-0.45	0.31	1.00

Table-4
Seasonal Factor Loadings from a Principle Component Factor Analysis (rotated) for Rameswaram Coastal Waters

Variable (Sum)	**Factor 1**	**Factor 2**	**Factor 3**	**Variable (SW)**	**Factor 1**	**Factor 2**	**Factor 3**
pH	**-0.81**	0.32	0.36	pH	-0.69	-0.28	-0.05
Temperature	**-0.75**	-0.04	-0.24	Temperature	**-0.97**	0.04	0.12
Salinity	-0.39	**-0.76**	0.13	Salinity	0.65	-0.58	0.04
SPM	**0.94**	0.10	0.01	SPM	**0.83**	-0.39	-0.18
DO	-0.21	**-0.73**	-0.11	DO	0.28	**-0.82**	-0.35
BOD	-0.17	**0.78**	-0.36	BOD	0.23	0.46	0.08
Nitrite	-0.44	-0.59	-0.12	Nitrite	-0.09	-0.29	**0.88**
Nitrate	-0.38	-0.21	-0.42	Nitrate	0.44	**0.76**	0.23
Ammonia	**0.71**	-0.27	-0.49	Ammonia	0.50	0.55	-0.51
Total Nitrogen	**0.87**	-0.13	-0.30	Total Nitrogen	**0.74**	-0.37	0.42
Total Phosphate	0.21	-0.68	0.08	Total Phosphate	0.44	0.51	0.50
Chlorophyll	0.34	-0.23	**0.86**	Chlorophyll	0.12	**0.74**	-0.17
Eigen value	4.08	2.84	2.11	Eigen value	3.87	3.35	1.72
% Total Variance	34.01	23.68	17.57	% Total Variance	32.21	27.94	14.37
Cumulative %	34.01	57.69	75.26	Cumulative%	32.21	60.15	74.52
Variables (NE)	Factor 1	Factor 2	Factor 3	Variables (PM)	Factor 1	Factor 2	Factor 3
pH	0.52	0.55	-0.16	pH	-0.30	0.34	0.67
Temperature	0.01	**0.73**	0.11	Temperature	-0.62	-0.52	0.47
Salinity	0.25	-0.48	-0.06	Salinity	**0.87**	0.10	-0.30
SPM	**-0.75**	-0.30	-0.36	SPM	-0.19	**-0.71**	-0.51
DO	**-0.75**	-0.24	0.45	DO	0.40	**-0.83**	0.18
BOD	0.42	-0.47	0.36	BOD	0.36	-0.64	0.38
Nitrite	0.68	-0.58	-0.05	Nitrite	**0.72**	0.10	-0.14
Nitrate	**0.75**	-0.52	-0.30	Nitrate	-0.30	0.21	**-0.74**
Ammonia	-0.09	-0.07	**0.88**	Ammonia	-0.15	0.68	0.07
Total Nitrogen	**0.80**	-0.15	0.51	Total Nitrogen	-0.51	-0.28	**-0.74**
Total Phosphate	**0.81**	0.34	-0.36	Total Phosphate	0.28	-0.34	0.01
Chlorophyll	-0.51	-0.48	-0.47	Chlorophyll	**0.78**	0.22	-0.04
Eigen value	4.23	2.42	1.98	Eigen value	3.14	2.75	2.32
% Total Variance	35.24	20.13	16.46	% Total Variance	26.17	22.91	19.30
Cumulative %	35.24	55.37	71.84	Cumulative %	26.17	49.08	68.39

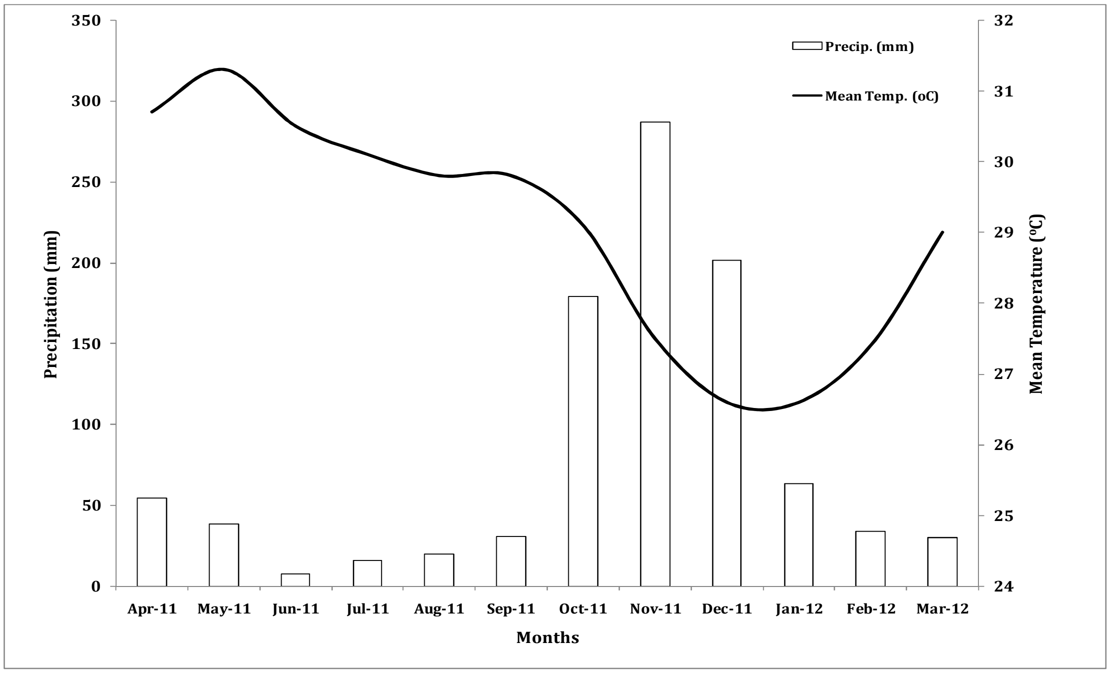

Figure-2
Annual Precipitation and Mean Air Temperature of Rameswaram Island

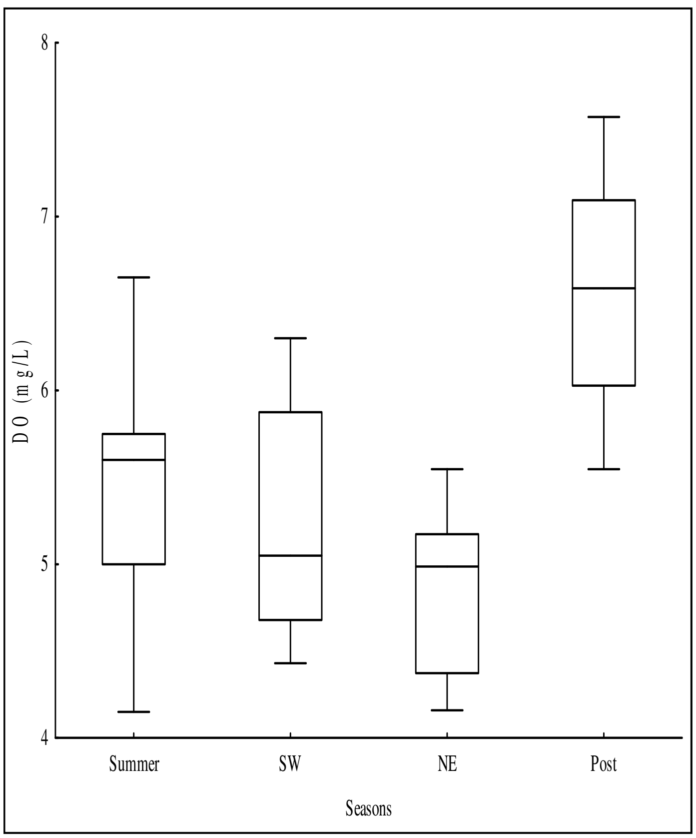

Figure-3
Seasonal Variations of DO around Rameswaram Island

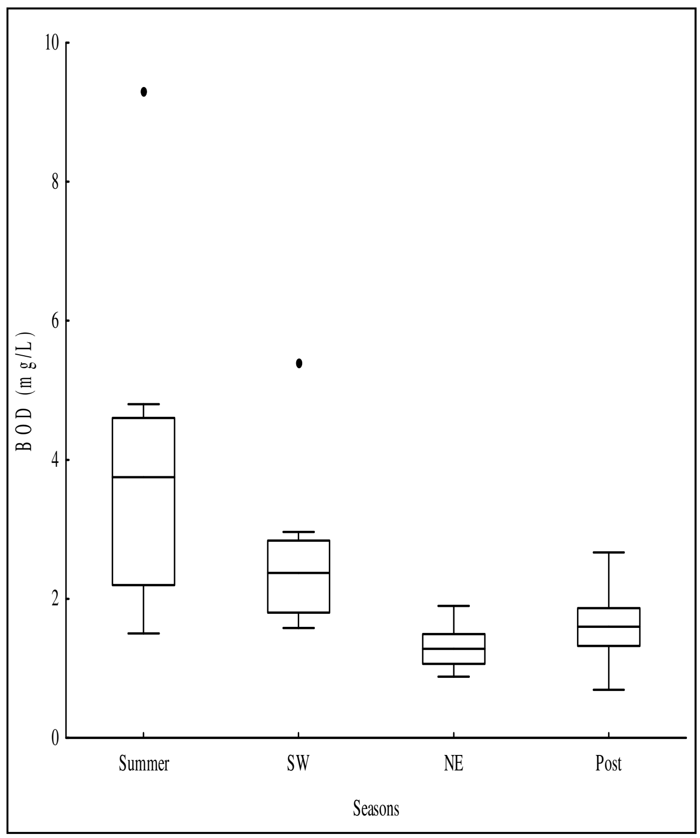

Figure-4
Seasonal Variations of BOD around Rameswaram Island

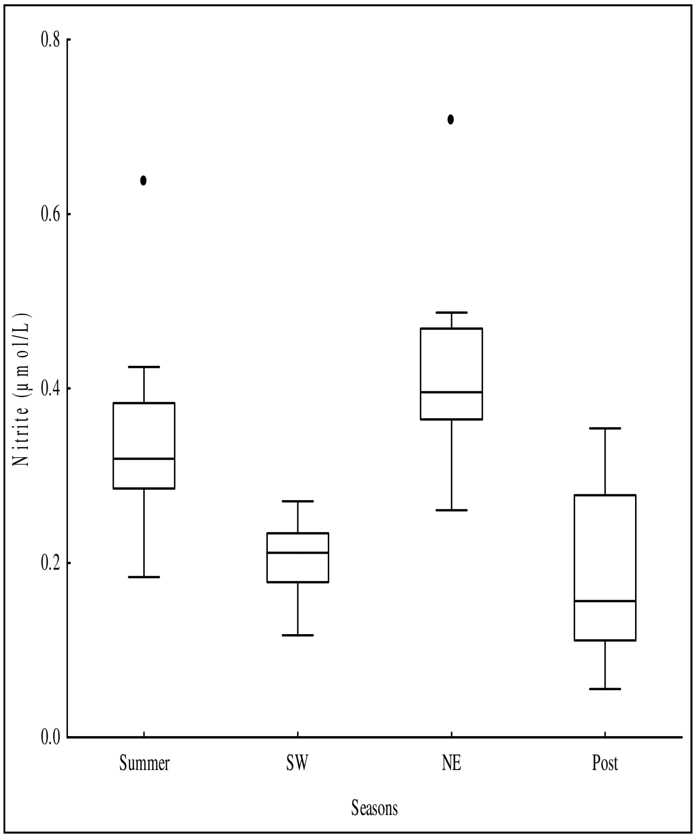

Figure-5
Seasonal Variations of No$_2$-N around Rameswaram Island

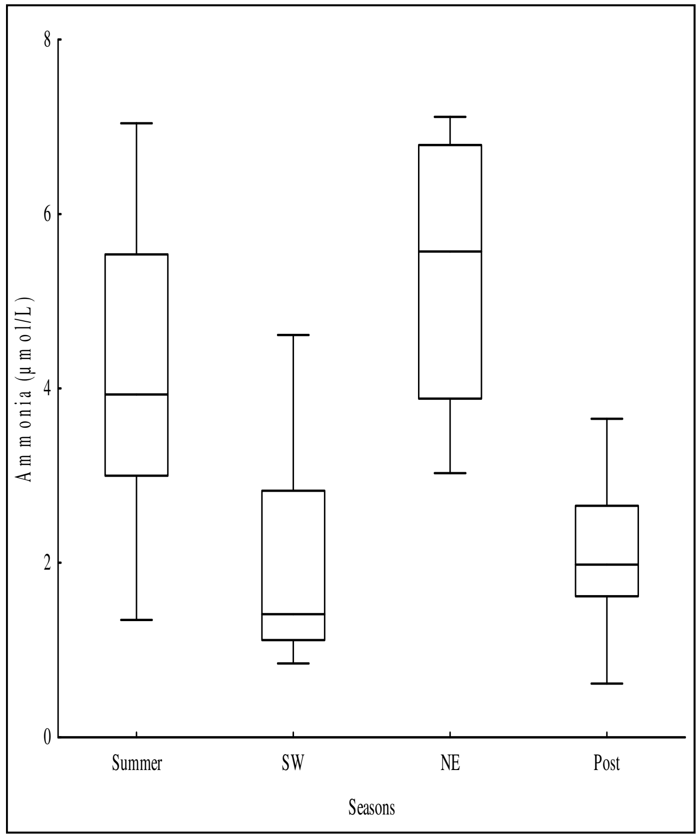

Figure-7
Seasonal Variations of NH$_3$-N around Rameswaram Island

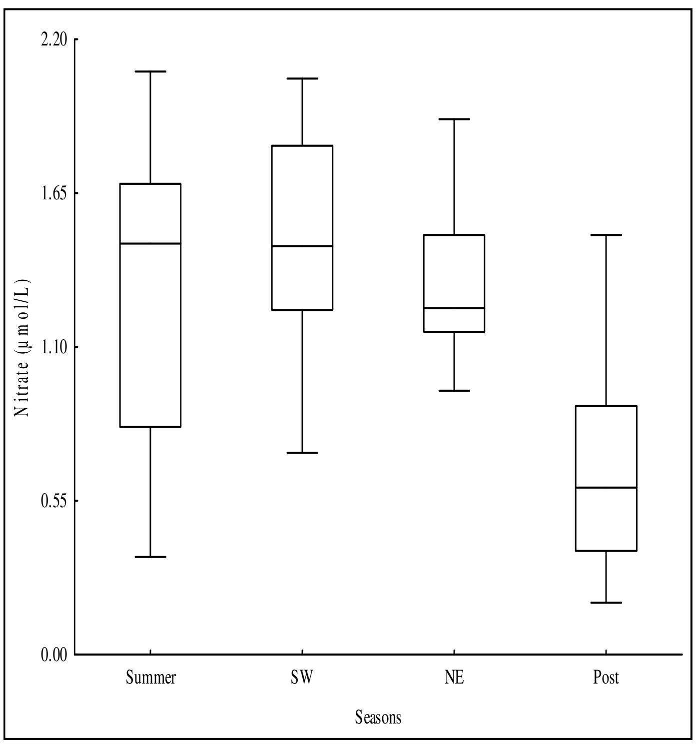

Figure-6
Seasonal Variations of NO$_3$-N around Rameswaram Island

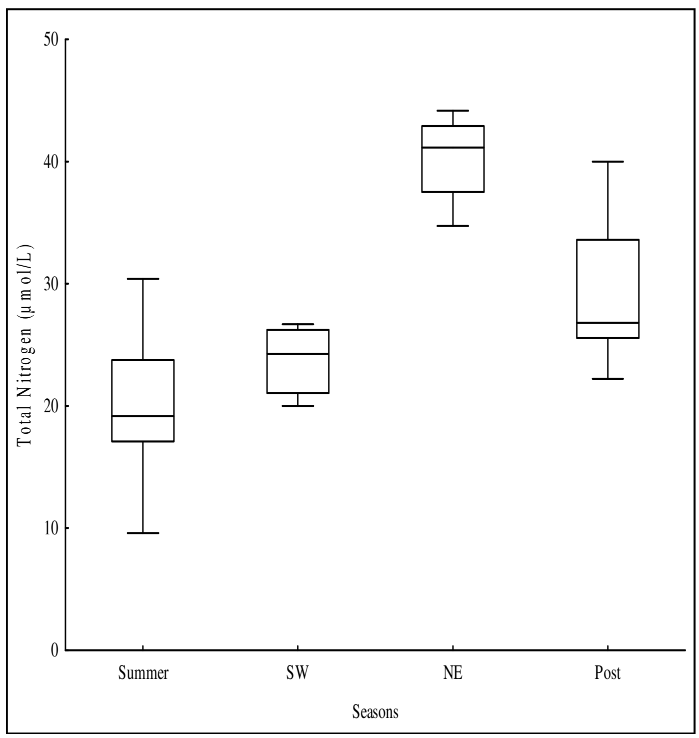

Figure-8
Seasonal Variations of Total Nitrogen Rameswaram Island

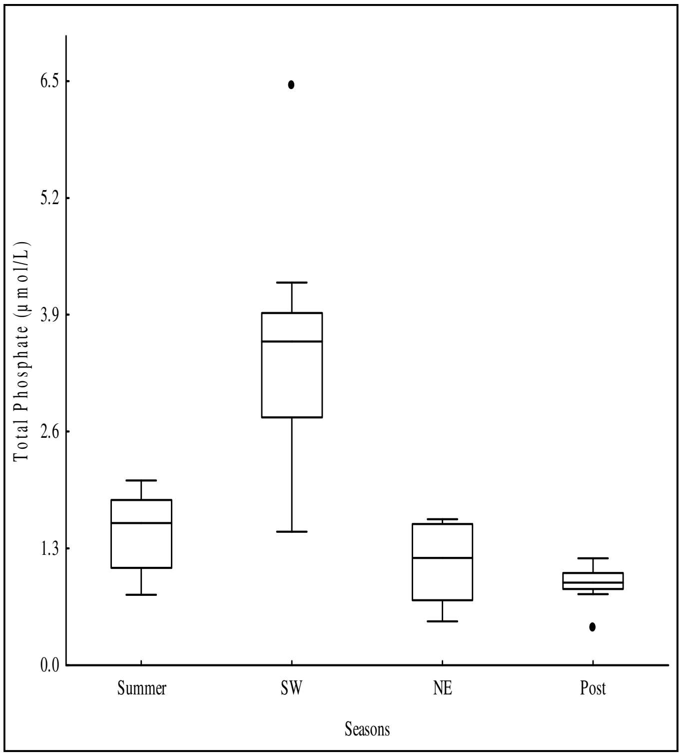

Figure-9
Seasonal Variations of Total Phosphorous Rameswaram Island

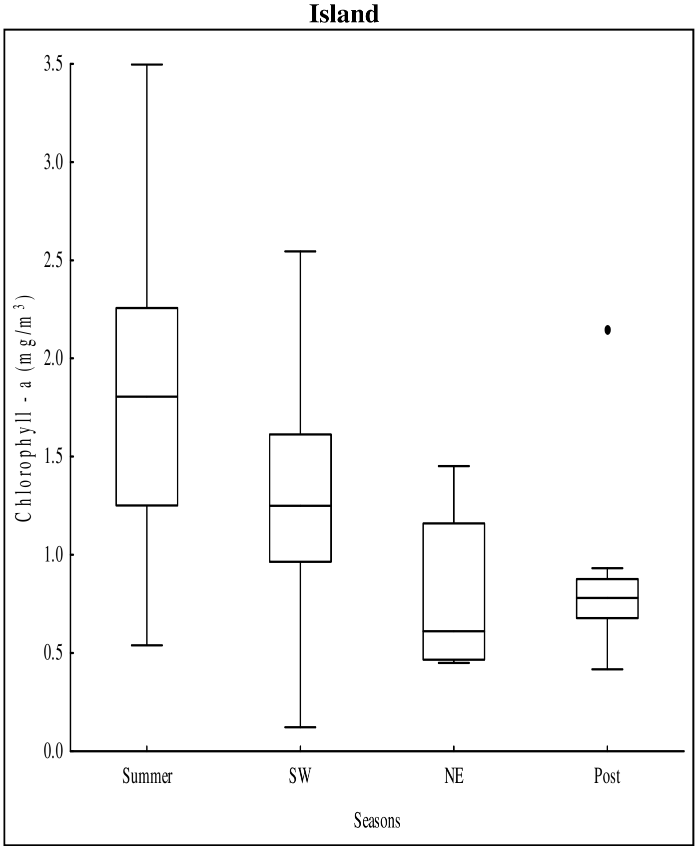

Figure-10
Seasonal Variations of Chl-a around Rameswaram Island

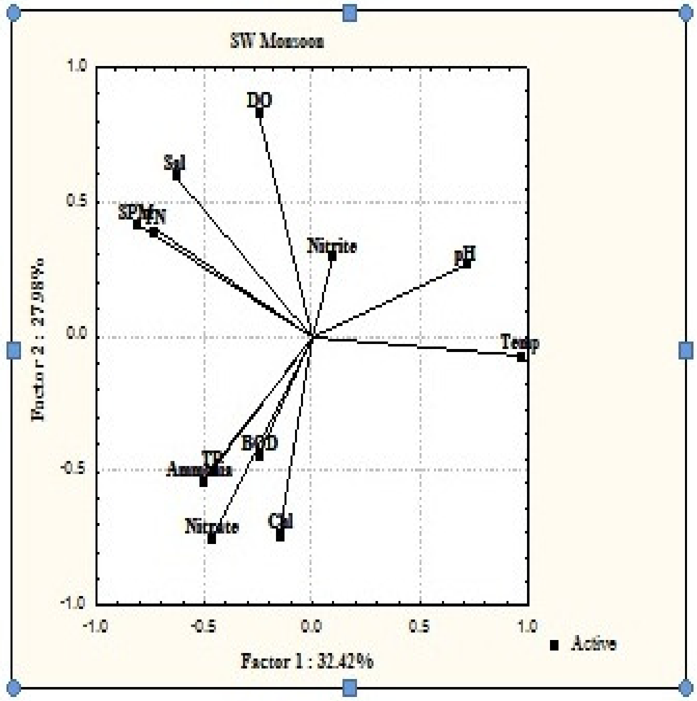

Figure-11
Seasonal Variations of Two-dimensional Plot of Water Quality from Two Principal Components of the PCA during summer

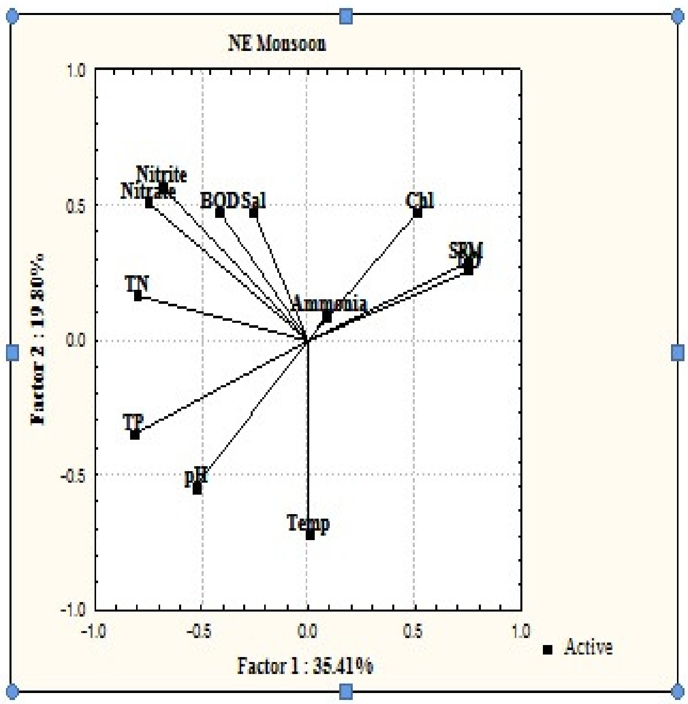

Figure-12
Seasonal Variations of Two-dimensional Plot of Water Quality from Two Principal Components of the PCA during SW monsoon

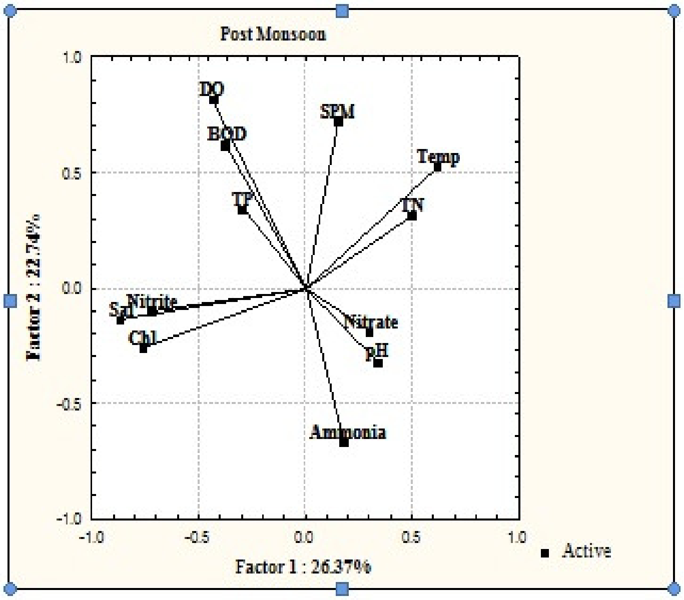

Figure-13
Seasonal Variations of Two-dimensional Plot of Water Quality from Two Principal Components of the PCA during NE monsoon

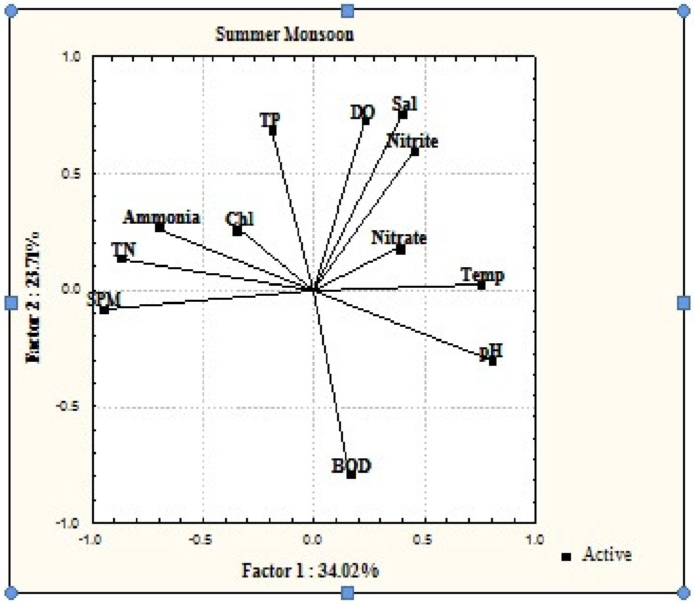

Figure-14
Seasonal Variations of Two-dimensional Plot of Water Quality from Two Principal Components of the PCA during Post monsoon

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