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Quality Characterization of Coastal Water in Gujarat Coast, India

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***Abstract**: Statistical analysis such as principal component analysis was employed to evaluate the status of water quality for nine monitoring regions. The present study was carried out to determine the physicochemical parameters of water of different coastal region of Gujarat India during pre monsoon time. Seasonal variations of different parameters investigated were as follows: temperature (25-36 ^{0}C), pH (5.4-9.16), electric conductivity (3.39-62.8 m/s), salinity (1.8-42.5 ppt), dissolved oxygen (3.05-7.70 mg/L), sulphate (0.37-1.01 mg/L), total nitrogen (1.825-4.54 mg/L), phosphate (0.009-0.143 mg/L) and total organic carbon (3.66-43.45 mg/L). pH, salinity, and temperature indicated a correlation at P<0.01. PCA identified the temporal and spatial characteristics of trophic and showed that the water quality was moderated in all the coastal regions stations. The result of above parameters also indicates that most of the nutrients and chemical parameters were influenced by the increase in the salinity and anthropogenic activity. Therefore, results provide baseline information on the environmental conditions and anthropogenic impact along the coastal region of Gujarat.*

***Keywords**: Environment, anthropogenic, principal component analysis and coastal region.*

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I. Introduction

Coastal areas are complex, dynamic and productive ecosystem and are also foci of human settlements, industry and tourism (Morris *et al.* 1993). With the growth of human population and industrialization, marine water has received large amounts of pollution from recreation, fish culture and discharge of polluted effluents. In India, Gujarat has longest coastline (1,663 km) and bound by Arabian Sea on the west and south-west area (Gujarat SAPCC 2014). The Gujarat coast has been broadly classified into five regions Rann of Kachchh, Saurashtra coast, Gulf of Kutch, Gulf of Khambhat and south Gujarat coast based on the variation in the climate, substrate constituent and topography (SAC 1992). Sea water resource constitutes one of the major natural water resources that are under the threat of over exploitation and pollution caused by anthropogenic activities (Bhadja *et al.* 2012). Sea water quality changes with time and space because of its effect on human and aquatic ecosystem particularly marine life (Gupta *et al.* 2009). Therefore, sea water quality monitoring and assessments are necessary for effective water quality management (Udoinyang *et al.* 2015). Physico-chemical characterizations are indeed a vital tool of predicting and tracking the changes happening in any costal water body. Water quality parameters such as pH, salinity, micro and macro nutrients, dissolved oxygen and temperature significantly affect the water environment. Several recent studies have reported the potential nature and consequences of global changes on costal environment (Karthikeyan *et al*. 2014; Boesch *et al.* 2000). The distributions of flora fauna in marine system are mainly controlled by the physical and chemical characteristics of the water body. Coastal regions between Okha to Bhavnagar and Surat is hub for mega industries like textile, cement, chemicals, soda power plant, fertilizer and other supportive industries. This coastline is also known for its rich biodiversity (Bhadja *et al.* 2012). Therefore, it is important to monitor the various physico-chemical parameters as a preliminary step for the assessment of pollutants and their impact on the sea water quality. In this context, the present study was carried out to monitor and compare physicochemical parameters of the coastal region such as Navsari, Dumas beach, Ghogha, Narara, Sikka, Salaya, Dwarka, Bet Dwaraka, Okha coasts in Gujarat, India. The parameters were further analysed using principal component analysis (PCA) tool to evaluate the trophic status of water quality of Gujarat coast of India.

II. Material And Methods

Study site description:

The water sampling were done from different locations of Gujarat coast, India, Okha (69° 4′ 0″ E, 22° 28′ 0″), Dwarka (69° 8′ 12″ E & 21° 28′ 0″ N), Bet Dwarka (69° 7′ 1″ E 22° & 26′ 58″ N), Narara (69° 42′ 0″ E & 22° 13′ 0″ N), Sikka (69° 50′ 0″ E & 22 26′ 0″ N), Salaya (69° 36′ 0″ E & 22° 19′ 0″ N), Dandi (72° 47′ 48″ E

& 20° 53′ 13″ N), Dumas (72° 16′ 0″ E & 19° 30′ 0″ N), Ghogha (72° 16′ 48″ E & 21° 40′ 48″ N) in the month of April and May, 2014. The sampling locations are shown in Fig 1. The study area located in the Saurashtra coast, some part of Gulf of Khambhat and south Gujarat is mostly muddy interspersed with rocky and sandy intertidal belts, surrounded by mangroves, corals and many small Island ecosystems. Water samplings and preservations were carried out according to the methods prescribed by APHA *et al.* (1989).

Physico-chemical analysis

All the chemicals were purchased from Sigma Aldrich, USA. Physical parameters of sea water like temperature, pH, salinity, turbidity and conductivity were measured directly in the field using multi parameter analyzer (Horiba U52, Kyoto, Japan). Total solids (TD) and total suspended solid (TSS) were determined gravimetrically as prescribed by APHA. Water samples were fixed for dissolved oxygen (DO) and analysed using titrimetrically by Winkler's method. The nutrient parameters (phosphate, nitrate, nitrite, ammonia, total nitrogen and sulphate) were analysed using standard methods (APHA 1992). Total organic carbon (TOC) was measured using TOC analyzer. All the experiment was carried out in triplicate and data quality was ensured through standardization.

Statistical analysis:

Principal Component Analysis:

Statistical analysis was carried out using XLSTAT 15.1. Before PCA, all the variables were transformed by dividing them with standard deviation (n-1) and normalization was carried out. The results obtained were subjected to multivariate statistical analysis such as principal component analysis (PCA) for the interrelation between different physico-chemical parameters and the study area. All the graphs have been made using Microsoft Office Excel.

III. Result And Discussion:

The physiochemical parameter in coastal region mainly affected by water circulation, tidal cycles, morphology and fresh water inputs (Arhonditsis *et al.* 2000). Temperature is one of the important parameter influencing physicochemical characteristics of sea water and biological behavior of coastal ecosystem (Sundarananickam et al. 2008). The water temperature showed a variation from 25-36 ^{o}C. The maximum temperature was recorded from Okha 35.5 ^{o}C and minimum temperature from Gogha 25.11^{o}C and Bet Dwarka 25.41 ^{o}C (Fig. 2a). Temperature was affected by various factors such as removal of shading stream bank vegetation, weathering and storm water. In a balanced ecosystem pH is maintained within the range of 5.5 to 8.5 (Chandrasekhar *et al.* 2003). A variation in pH values from 5.74-9.16 with a maximum pH value of 9.16 from Dwarka and minimum pH value of 5.74 in the Naraya region of jammnagar was reported in this study. The pH value changes from acidic to alkaline when colloidal particles mix with seawater and become coagulated (Anila Kumary *et al.* 2007). Moreover, Kaul and Handoo (1980) reported that increase in pH is due to increased metabolic activities of autotrophs, because they utilize more carbon dioxide and liberate oxygen thus reducing H^+ ion concentration. Dwarka, Bet Dwarka and okha shows slight alkaline pH values (Fig. 2b) which may be due high anthropogenic activities by pilgrims in these regions.

The electrical conductivity (EC) values varied from 3.53 to 62.9 ms/cm (Fig. 2c). Conductivity of sea water is highly influenced by the change in the concentration of sulphate and chlorides. The presence of higher conductivity in Dwarka region (62.9 ms/cm) reflects that sea water accumulates high salt content which indicates high dissolved solid. The high conductivity was also due to their uneven rocky substratum, rough tidal activity which increases the solid levels and is responsible for the variations in the conductivity. The fluctuation in total EC was due to fluctuation in total dissolved solids and salinity (Boyd *et al.* 1981). Therefore, conductivity measurements can be used to predict the water quality. Table 1 depicts the correlation matrix between the different physicochemical parameters of sea water. The positive correlation obtained between EC and pH indicates EC is largely influenced by the pH.

Salinity of different coastal regions ranged from 1.8 to 42.5 ppt (Fig. 2d). The salinity of Salaya 1.8 ppt was found to be very low compared to other studied regions possibly due to the mixing of incoming freshwater with sea water near the sampling sites. The salinity act as limiting factor in the distribution of living organism and changes due to evaporation and dilution in the coastal ecosystem (Paramasivan Kannan 2005). Thus, change in salinity of sea water is due to influx of freshwater from land run off, caused by the monsoon or by tidal variations (Saravanakumar *et al.* 2008). The significant strong positive correlation was obtained with EC (r^2 = 0.999; $p < 0.05$) and TSS (r^2 = 0.976) whereas negative correlation with nitrite (r^2 = 0.776) and phosphate (r^2 = 0.827). This clearly indicates that the salinity mostly influences physical as well as nutrients presents in the sea water and has direct relation.

The dissolved oxygen (DO) concentration ranged from 3.56 to 7.70 mg/L, the higher value was recorded from Salaya 7.70 mg/L and lower for Dwarka 3.56 mg/L (Fig. 2e). Relatively lower value for DO was

mainly due to high organic production, reduced agitation and turbulence of the coastal and estuarine. The inverse relationship between temperatures and DO is natural processes because increase in temperature leads to the saturation of oxygen in water and thus can hold less DO (Satheeshkumar et al 2011). Moreover, Das *et al.* (1997) observed seasonal variation of dissolved oxygen was mainly due to freshwater influx and ferruginous impact of sediments.

The total suspended solids (TSS) and turbidity ranged from 13 to 37.7 mg/L and 21 to 113 NTU respectively (Fig. 3). The high TSS was recorded from Dwarka 37.7 mg/L and lowest was recorded from Salaya 15 mg/L. The highest value of TSS was due to the organic and inorganic matter produced by living organism. The increased suspended particles decreases DO content. Venkatesharaju *et al.* (2010) also reported that DO had negative correlation with turbidity. The present study also showed that TSS strongly and positively correlated salinity, EC and turbidity (r^2 = 0.976, 0.964 and 0.732; $p < 0.05$) respectively. This indicates that weathering and riverine transport increases the load of suspended solids.

The nutrients are one of the most important parameters which influence growth, metabolic activities of biotic components and reproduction. The distribution of nutrients mainly depends upon tidal conditions, season and fresh water influx from land (Sarvanakumar *et al*. 2008). The maximum concentration of inorganic phosphate was recorded for Salaya 0.249 mg/L and minimum was for Naraya 0.009 mg/L (Fig. 4a). The high concentration of phosphate was due to the diffusion and migration of phosphorus from the sediment pore water to the overlying water (Faragallah *et al.* 2009). Mishra *et al.* (1993) also reported increased concentration of phosphate during monsoon season. Phosphate shows negative correlation with salinity, EC and TDS whereas positively correlation with nitrite. Sanders *et al.* (1997) reported role of total suspended solids for removal of phosphate. Also re-suspension of sediments and water movement relatively increases high content of phosphorous and nitrogen content. The results in Fig. 4b showed the spatial variation of sulphate at the investigated sampling sites. The highest concentration of sulphate was recorded from the sampling site Dandi 1.03 mg/L and lowest was recorded from Salaya 0.37 mg/L. The highest content of sulphate was due to decomposition of organic matter which liberates hydrogen sulphate and by photochemical degradation the sulphate liberated. The positive correlation was obtained with EC and ammonia (r^2= 0.671 and 0.853) respectively.

The nitrite and nitrate content in all coastal sites ranged from 0.19 to 2.60 mg/L and 0.18 to 3.8 mg/L respectively (Fig 5a). The low value of nitrite content in Dwarka coast (0.19 mg/L) was attributed to low river discharge into sea and also by the use of nitrite by phytoplankton. Higher value of nitrite is through the oxidation of ammonia from nitrogen to nitrite and then consequently to nitrate. Further, high value of nitrite was due to the various reasons which include reduction of nitrate, recycling of nitrogen and bacterial decomposition, phytoplankton excretion and due to denitrification and air sea interaction exchange of chemicals (Saravankumar *et al.* 2008; Mathew and pillai 1990). The total nitrogen concentration ranged from 1.82 to 4.54 mg/L. The high concentration of total nitrogen was recorded at Salaya (4. 54 mg/L) and low in Okha 1.82 mg/L. The lower value of total nitrogen in Okha coast was due to the low concentration of organic matter.

Ammonia concentration varied from 0.07 mg/L to 0.75 mg/L (Fig 5a). Minimum ammonia concentration was recorded near Salaya coastal region and maximum was recorded on Dandi coast. The high concentration of ammonia mainly depends upon the surface runsoff wastes, maximum algal growth and excretion of ammonia by phytoplankton organisms (Kawabata *et al* 1993). The total organic carbon varied from 3.66 to 43.45 mg/L (Fig. 5b). Reddy and Hariharan (1986) reported the distribution of total organic carbon depends upon the type of sediments i.e sediments with decrease in clay content decreases the total organic carbon content. In this study the total organic carbon was high in some of the sampling site i.e Gogha (43.45 mg/l), Naraya (42.25 mg/L) and Dwarka (37.12 mg/L) respectively. The statistical analysis also revealed strong correlation between inorganic carbon organic carbon and total organic carbon. The high content of organic carbon at these sampling sites was due to the rich source of overlying waters in mangrove ecosystem. Furthermore, high organic carbon in the mangrove coastal region possibly due to the mangrove and terrestrial detritus present in the suspended matter (Jagtap 1987).

Principal Component analysis (PCA)

PCA was carried out to investigate the compositional pattern between sea water quality parameters at the different sampling sites. PCA with eigenvalue greater than 1 were used as a cut – off value to determine the number of factors. The first 4 principal components with eigenvalue > 1 represent 89.28 % of the cumulative percentage used to assess the behavior of sea water quality at the different sampling sites (Table. 2). Factor 1 explained 43.55 % of the total variance showing a strong positive loading for phosphate (0.947), nitrite (0.841) and total nitrogen (0.754) but a strong negative loading for electrical conductivity (-0.911), salinity (-0.909), total dissolve solid (-0.853) and sulphate (-0.780) these differences may be due to tidal effects (Table 1). Factor 2 accounts for 21.10 % variance with strong positive loading for inorganic carbon (0.908), organic carbon (0.864) and total organic carbon (0.930) attributes a lot of land changes in the land development that also depends on the different coastal environment in studied area. Factor 3 explained 13.60 % variance showing

moderate positive loading of turbidity (0.528) and nitrate (0.738). These results may be due to intrusion of anthropogenic activities. Finally, factor 4 formed strong positive loading of pH (0.820) and moderate negative loading of dissolved oxygen (-0.649) with 11.02 % total variance these attributed discharge of river stream into the sea water. Table 1 demonstrated the factor loading values after PCA for different sampling sites.

The variability for F1 and F2 are 43.55 % and F2 21.10 % and are explained in Fig 6. Biplot graph was analysed to evaluate the relationship of sources apportioned from the factor loading value and different sampling sites. Sampling sites Sikha and Dumas dominated due to the tidal variation and influx of freshwater from land run off towards sea water were correspond to the factor 1 of PCA analysis. Sampling site Naraya, Bet Dwarka and Gogha was highly correlated to the factor 2 which consistent with variation in the sediments as these sampling sites are rich in the mangrove ecosystem. Dandi and Okha were weekly correlated to the studied variables.

IV. Conclusion

In this study Principal component Analysis (PCA) was successfully applied to evaluate variation in the sea water quality parameters of the different coastal regions of Gujarat. PCA identified spatial and temporal variations in the analyzed water quality and strong correlation between parameters. The water quality of all the coastal regions was almost near to the standard water quality parameters possibly due to less anthropogenic impact on the coast. PCA also confirmed that salinity, pH, phosphate, DO and TOC serve as critical parameters of water quality throughout the studied coastal regions. Thus, the present study illustrated the usefulness of principal component analysis a statistical tool for the analysis and interpretation of complex data set and water assessment.

Acknowledgments

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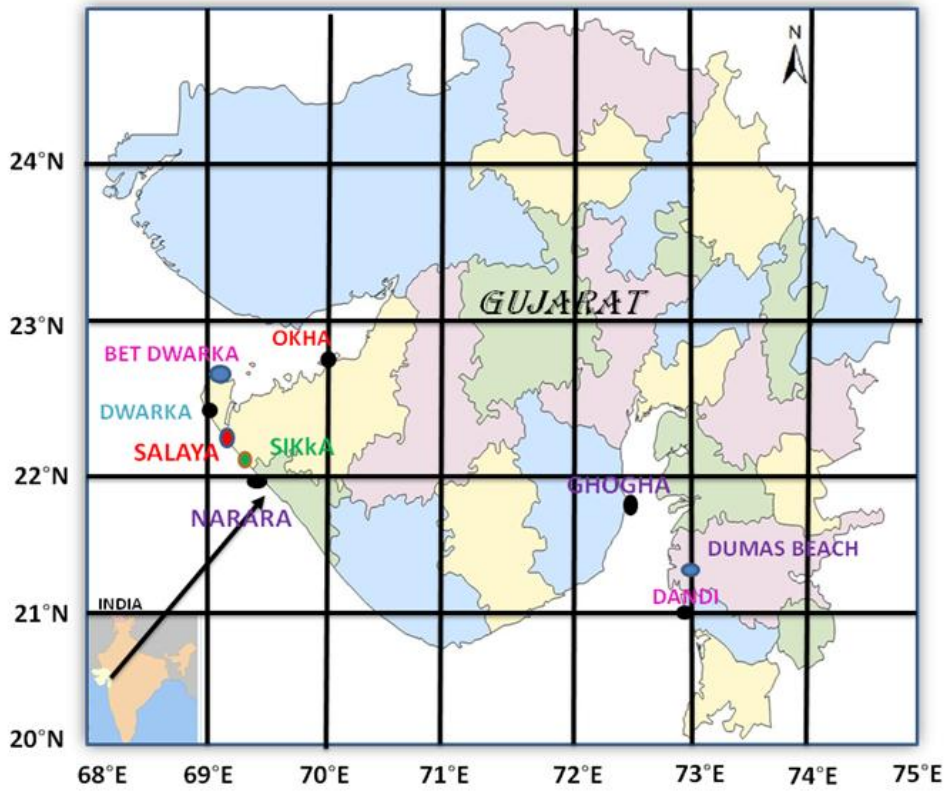
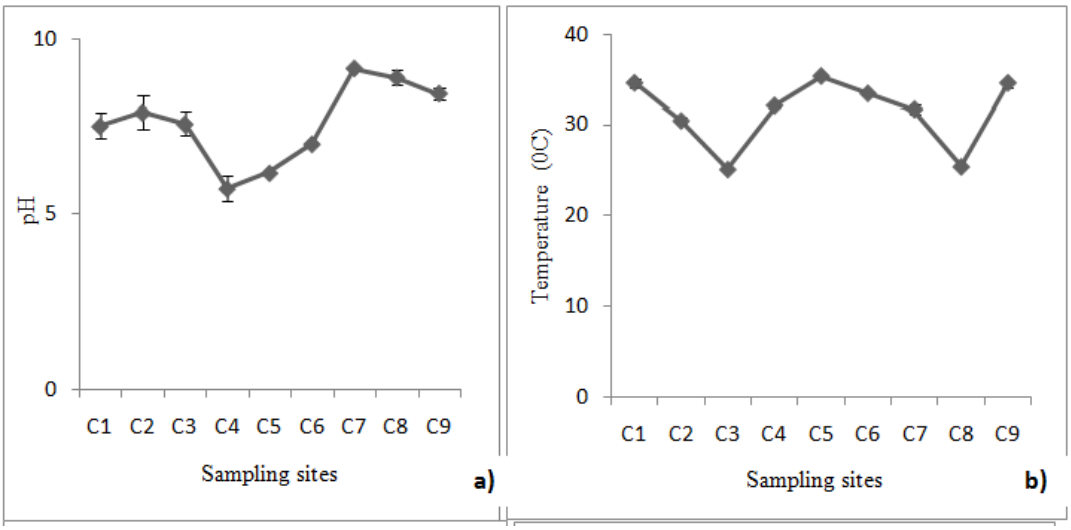


Figure 1: Locations of sampling sites



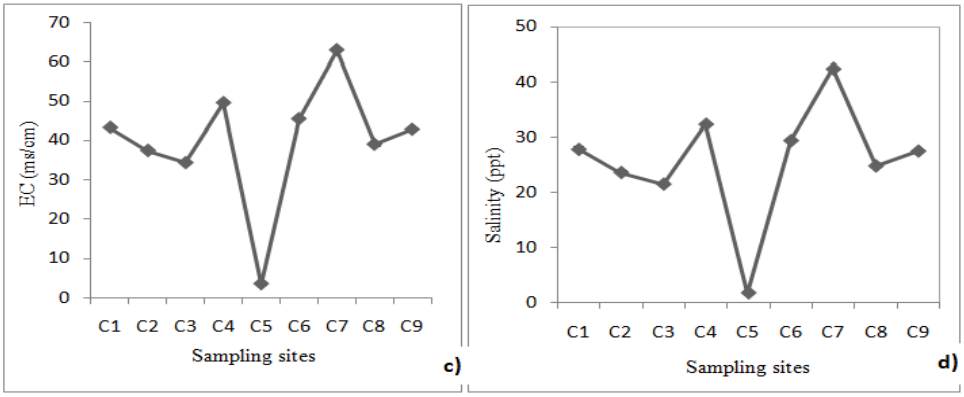


Figure 2: Variation of physical –chemical parameters of different coasts of Gujarat: a) pH b) Temperature (^{o}C) c) Electrical conductivity (EC) (ms/cm) d) Salinity (ppt) (C1: Dandi; C2:Dumas; C3 Ghogha; C4 Naraya; C5 Salaya; C6 Sikha; C7 Dwarka; C8 Bet Dwarka; C9 Okha)

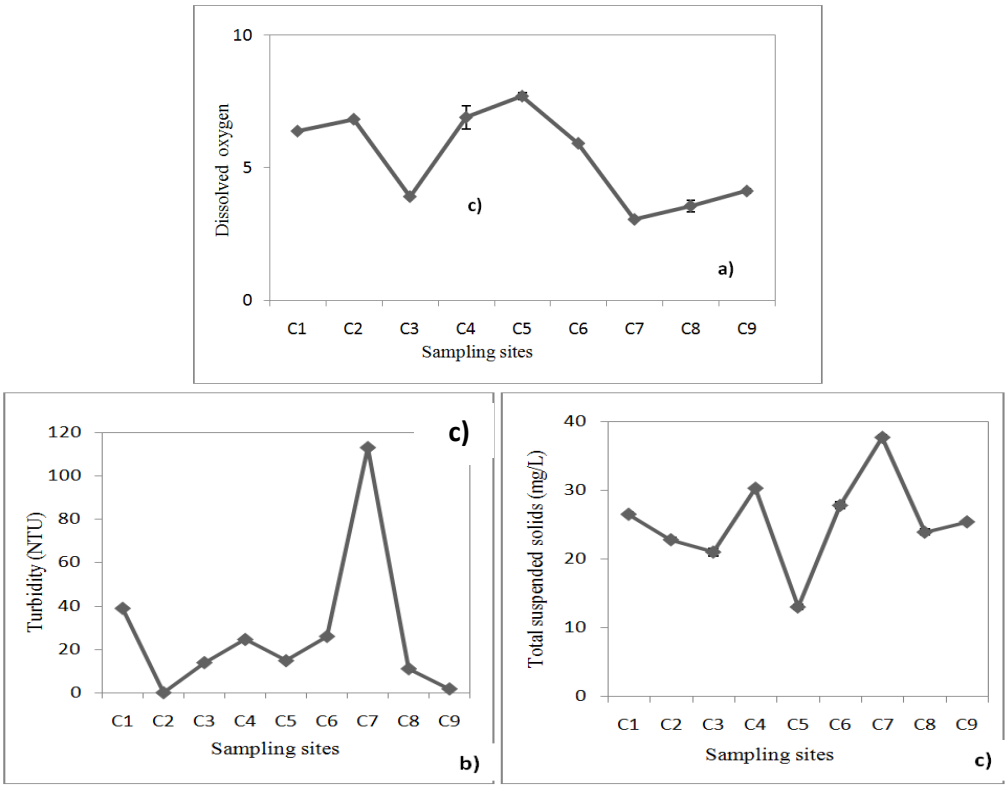


Figure 3: Variation of physical –chemical parameters of different coasts of Gujarat a) dissolved oxygen b) turbidity c) total suspended solid (C1: Dandi; C2:Dumas; C3 Ghogha; C4 Naraya; C5 Salaya; C6 Sikha; C7 Dwarka; C8 Bet Dwarka; C9 Okha)

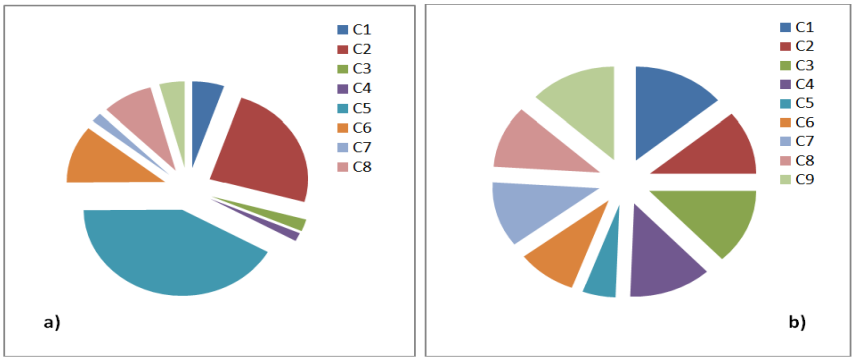


Figure 4: Variation of nutrient concentration along the different coasts of Gujarat a) phosphate b) sulphate (C1: Dandi; C2:Dumas; C3 Ghogha; C4 Naraya; C5 Salaya; C6 Sikha; C7 Dwarka; C8 Bet Dwarka; C9 Okha)

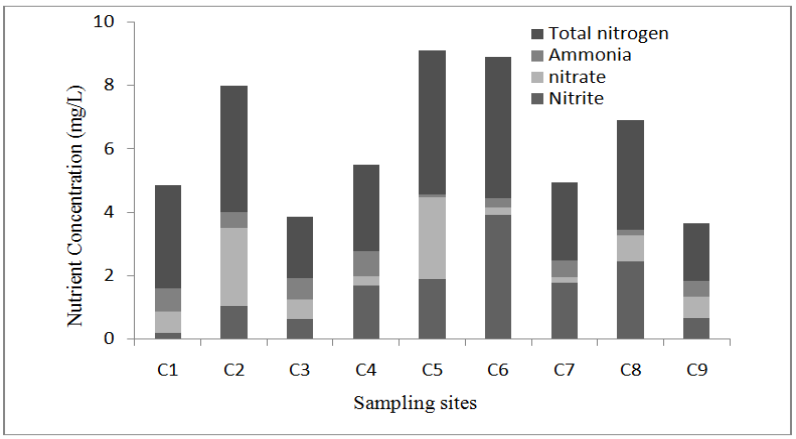


Figure 5: Variation of different source of nitrogen along the different coasts of Gujarat(C1: Dandi; C2:Dumas; C3 Ghogha; C4 Naraya; C5 Salaya; C6 Sikha; C7 Dwarka; C8 Bet Dwarka; C9 Okha)

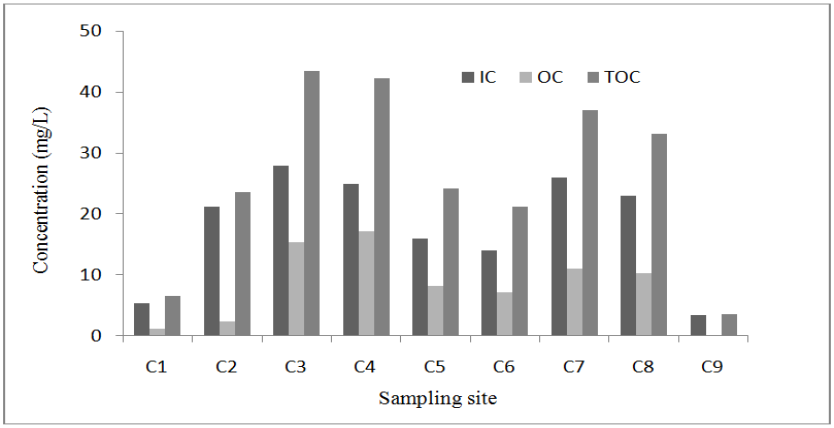


Figure 6: Variation of Inorganic carbon (IC), Organic carbon (OC) and total organic carbon (TOC) along the different coasts of Gujarat (C1: Dandi; C2:Dumas; C3 Ghogha; C4 Naraya; C5 Salaya; C6 Sikha; C7 Dwarka; C8 Bet Dwarka; C9 Okha)

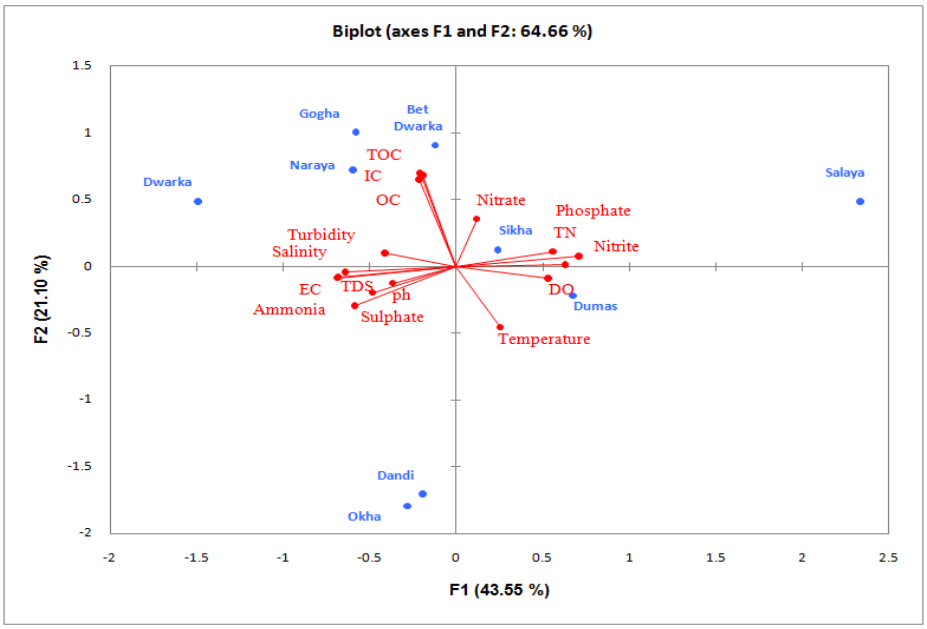


Figure 7: The biplot represents physical –chemical parameters of different coasts of Gujarat

Table 1 Factor loading from Principal components analysis physicochemical characteristics of water of different coastal region of Gujarat (DO: dissolved oxygen: EC: electrical conductivity; TSS: total suspended solid; TN: total nitrogen; IC: inorganic carbon; OC: organic carbon; TOC: total organic carbon

	F1	F2	F3	F4	F5	F6	F7	F8
Temperature	0.339	-0.611	0.439	-0.446	0.187	-0.249	-0.150	0.004
salinity	**-0.909**	-0.104	0.323	-0.102	0.013	0.201	-0.087	-0.003
ph	-0.490	-0.167	0.132	**0.820**	0.170	0.116	0.012	-0.015
DO	0.709	-0.119	-0.011	-0.649	0.053	0.239	0.017	-0.050
Turbidity	-0.545	0.128	0.528	-0.071	0.562	-0.216	0.199	0.011
EC	**-0.911**	-0.116	0.297	-0.097	-0.018	0.226	-0.082	0.001
TSS	**-0.853**	-0.057	0.449	-0.177	0.117	0.109	-0.091	-0.049
Sulphate	**-0.780**	-0.393	-0.433	-0.074	-0.102	0.171	0.055	-0.043
Nitrate	0.158	0.473	0.738	-0.001	-0.445	0.047	-0.047	0.064
Nitrite	**0.841**	0.012	-0.196	0.165	0.374	0.261	-0.138	-0.009
Ammonia	-0.643	-0.264	-0.460	-0.508	0.110	0.133	0.075	0.105
Total Nitrogen	**0.744**	0.148	0.484	-0.100	-0.060	0.354	0.225	-0.024
Phosphorous	**0.947**	0.102	0.096	0.071	0.265	0.058	-0.064	0.027
Inorganic carbon	-0.258	**0.908**	-0.141	-0.008	0.222	0.187	-0.062	0.038
Organic Carbon	-0.282	**0.864**	-0.154	-0.303	-0.055	-0.224	-0.005	-0.068
TOC	-0.280	**0.930**	-0.153	-0.133	0.115	0.021	-0.041	-0.005

Note: Values in bold corresponds to correlation is significant at level (p =0.05).

Table 2 Correlation coefficient matrix between the physicochemical characteristics of water of different coastal region of Gujarat (DO: dissolved oxygen: EC: electrical conductivity; TSS: total suspended solid; TN: total nitrogen; IC: inorganic carbon; OC: organic carbon; TOC: total organic carbon)

Variable	Tem.	Salinity	pH	DO	Turbidity	EC	TSS	Sulphate	Nitrate	Nitrite	Ammonia	TN	Phosphate	IC	OC	TOC
Temperature	1															
Salinity	- 0.091	1														
pH	-0.370	0.446	1													
DO	0.544	-0.522	- **0.823**	1												
Turbidity	0.130	0.607	0.330	-0.381	1											
ES	-0.111	**0.999**	**0.748**	-0.521	0.571	1										
TSS	0.031	**0.976**	0.374	-0.455	0.732	**0.964**	1									
Sulphate	-0.251	0.646	0.334	-0.415	0.068	0.671	0.510	1								
Nitrate	0.002	0.053	-0.132	0.032	0.096	0.043	0.124	-0.581	1							
Nitrite	0.143	**-0.776**	-0.213	0.570	-0.446	**-0.779**	**-0.750**	-0.589	-0.154	1						
Ammonia	-0.055	0.537	-0.085	-0.056	0.160	0.552	0.462	**0.853**	-0.605	-0.473	1					
TN	0.285	-0.474	-0.373	0.656	-0.190	-0.479	-0.396	**-0.760**	0.576	0.556	-0.635	1				
Phosphate	0.314	**-0.827**	-0.373	0.637	-0.334	**-0.840**	**-0.741**	**0.847**	0.159	**0.913**	**-0.682**	**0.749**	1			
TC	-0.697	0.141	0.008	-0.231	0.255	0.132	0.156	-0.089	0.200	-0.040	0.044	-0.088	-0.092	1		
OC	-0.510	0.102	-0.309	-0.157	0.220	0.091	0.148	-0.061	0.261	-0.324	0.135	-0.202	-0.245	**0.825**	1	
TOC	-0.649	0.131	-0.126	-0.210	0.252	0.120	0.160	-0.081	0.235	-0.162	-0.084	-0.140	-0.161	**0.971**	**0.936**	1

Note: Values in bold corresponds to correlation is significant at level (p =0.05)

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