

Assessment of spatial variations in physico-chemical quality of water of Gujarat Coast

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ABSTRACT

The objective of present study is to reveal spatial variations at 16 intertidal locations of Gujarat coast, India. The monitoring of coastal water quality was done on bi-monthly basis for during March-2016 to September 2017. Surface water samples were collected from the selected sampling sites and analysed to provide information regarding spatial variation observed in different water quality parameters. The range of parameters were recorded as follow: [pH (7.10 – 8.7); Water temperature (21- 34.8 °C); Turbidity (0.8 NTU – 670 NTU); Conductivity (14.8 mS/cm – 96.41 mS/cm); Total Dissolved Solids (7.29 ppt – 80.0 ppt); Dissolved Oxygen (2.50 mg/l – 9.40 mg/l); Alkalinity (60 mg/l- 680 mg/l); Acidity (20 mg/l to 165 mg/l); Total Hardness (500 mg/l – 23700 mg/l); Salinity (13.14 ppt – 82.61ppt); Nitrate (0.02 mg/l to 10.30 mg/l); Nitrite (0.01 mg/l – 0.36 mg/l) and Phosphate (0.05 mg/l – 7.60 mg/l)]. The study revealed that, overall quality of water of Gujarat coast is in a good state suitable for flora and fauna, however, certain areas are under anthropogenic pressure and need continuous monitoring to know its effect on water quality and dependent biotic communities.

Keywords: coastal water, correlation, Gulf of Kachchh, Gulf of Khambhat, water quality.

Journal of Economic Literature (JEL) Classification Number: Q25, Q53

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1. INTRODUCTION

Coastal zone in India are important because of high productivity of its ecosystems, concentration of population, exploitation of natural resources, discharge of waste effluent and municipal sewage, development of various industries, increasing load on harbors, spurt in recreational activities and above all petroleum exploration activities (ISRO & CWC, 2014).

Coastal water quality is influenced by natural, geological and oceanographic processes, and by human activities. The human impacts on coastal water quality come from land, shoreline, and marine activities (Soomai et al., 2011). Oceans in vicinity of urban areas (also called 'urban oceans') act as the final repositories of pollutants from a variety of point and nonpoint sources of human waste. This mainly includes surface water runoff, discharge of treated sewage through submarine outfalls,

deposition of airborne pollutants, and submarine discharge of contaminated groundwater. These pollutants carry with them nutrients, pathogens, pesticides, and heavy metals that contaminate the coastal water near urban areas (Ahn et al., 2005).

Knowledge on coastal water quality is important from the view point of coastal resource usage and management (Mishra et al., 2015; Kudale and Sankar, 2008; Melloul and Collin, 2007). Significant variations in physico-chemical characteristics affect the water quality which is important for the survival of the aquatic and mangrove ecosystems in the coast-land environments (Pejman et al., 2009).

The coastal region of Gujarat is mainly important as it has diversified composition of flora and fauna in its extended intertidal and sub tidal zones. It is also important from the view point of industrialization which includes industries like refineries, power plants, soda ash, chemicals and fertilizers manufacturing etc. Moreover, it provides ground to fisherman and therefore, many fish landing centers are located throughout the Gujarat coast. The present study was carried out to assess the water quality of intertidal areas of Gujarat coast from March 2016 to September 2017.

2. MATERIALS AND METHODS

2.1. Study area

Gujarat, on the west coast of India has the longest coastline (~1600 km) among all the maritime states of India. Gujarat coast provides a wide variety of coastal features due to its varied physiographic, geomorphology and coastal processes. Saurashtra coast is less indented and moderately straight. From Gopnath point to Diu towards the west numerous cliffs, mudflats, beaches, estuaries and embayment are seen. The coastline of Gujarat is mainly divided into four segments including two Gulfs;

I. Gulf of Kachchh (GoK): It lies between 22°15' to 23°40'N latitude and 68°20' to 70°40'E longitude. The gulf is an east-west oriented indentation between Saurashtra and Kachchh peninsulas. The GoK is bordered by Kachchh district in north and Jamnagar district in south with Rajkot district covering a little portion of the gulf in its eastern side. Coral reef ecosystem, Marine National Park and Sanctuary, Great and Little ran of Kachchh, Mangrove ecosystem, Sea grass beds and algal communities are the major characteristics of Gulf of Kachchh (ICMAM, 2002).

II. Saurashtra coast: Encircled by the open sea, the Saurashtra coast is situated between two Gulfs (Latitude 22°15' to 20°50'N and Longitude 68°58' to 71°30' E). It is further divisible into two segments namely the south-western coast of Dwarka- Diu facing the Arabian Sea and the south eastern coast of Diu-Bhavanagar. The Dwarka-Diu segment comprised of smooth and straight sandy beaches whereas the other segment i.e. Diu-Bhavanagar shows a transition from open sea to gulf environment between Diu and Talaja (Stanley, 2013).

III. Gulf of Khambhat: The Gulf of Khambhat is south to north penetration of the Arabian Sea on the western shelf of India between the Saurashtra peninsula and mainland Gujarat. It is located approximately between 20°30' – 22°20' north latitude and 71°45'-72°53' E longitude. The gulf is intercepted by several inlets of major rivers such as Narmada, Tapi, Mahi, Sabarmati, Shetrunji, Purna and other minor rivers. Extensive mudflats, estuaries and creeks with high regime, large quantities of sediment transport characterize the Gulf of Khambhat (ICMAM, 2002).

IV. South Gujarat Coast: South Gujarat coastline is situated around 20°30' and 20°07' N – 72°50' E. This region of Gujarat coast has smaller stretch of coastline passing through only Surat, Navsari and Valsad districts and is characterized by high tidal amplitude of 8 to 10 meters (Stanley, 2013).

The present study was carried out at 16 locations of Gujarat coast. Table 1 illustrates the GPS locations of sampling sites (n=16) and Fig. 1 depicts the map of sites selected for collection of samples.



Fig. 1 Map showing selected sampling sites for water and soil along the Gujarat Coast
(Source: Google map)

Table 1 Sample collection sites for water of intertidal areas along the Gujarat Coast

Site No.	District	Taluka	Site	
			Name	GPS location
1	Kachchh	Lakhpat	Koteshwar	23° 41' 532"N; 68° 31' 564" E
2	Kachchh	Mundra	Bhadreshwar	22° 52' 597"N; 69° 53' 942" E
3	Kachchh	Bhachau	Surajbari	23° 11' 411" N;70° 43' 006" E
4	Jamnagar	Jamnagar	Khijadiya	22° 31' 205" N;70° 07' 599" E
5	Jamnagar	Jamnagar	Narara	22° 29' 001" N;69° 42' 580" E
6	Jamnagar	Okhamandal	Poshitra	22° 24' 086" N;69° 12' 215" E
7	Devbhumi Dwarka	Bhanvad	Harsiddh	21° 50' 054" N;69° 21' 423" E
8	Gir-Somnath	Maliya	Mangrol	21° 05' 493" N;70° 06' 436" E
9	Porbandar	Porbandar	Mul Dwarka	20° 45' 245" N;70° 39' 342" E
10	Amreli	Jafrabad	Jafrabad	20° 51' 263" N;71° 23' 015" E
11	Bhavnagar	Ghogha	Ghogha	21° 40' 195" N;72° 17' 132" E
12	Anand	Khambhat	Vadgam	22° 16' 716"N;72° 27' 199" E
13	Bharuch	Hansot	Katpore	21° 31' 564" N;72° 44' 312" E
14	Surat	Choryasi	Dumas	21° 04' 766" N;72° 42' 419" E
15	Navsari	Jalalpore	Borsi	20° 55' 758" N;72° 46' 188" E
16	Valsad	Umargam	Udwada	20° 28' 006" N;72° 51' 299" E

2.2. Methodology

Water sample collection: Surface water samples for analysis of physical and chemical parameters were collected on bi-monthly basis from the selected sampling point into a clean plastic container (2 liters). The samples were collected during the high tide period from the intertidal region of the Gujarat coast during March 2016 to September 2017. The collected samples were labeled properly, preserved in icebox and transported to the laboratory for *ex-situ* analysis at field stations as well as central lab. Table 2 describes the methodologies followed for analyzing water parameters.

Table 2 Methodology followed for analysis of water samples

SN	Parameters	Instruments & Methods	
		Instruments	Methods
	<i>In-situ</i>		
1	pH	pH meter	Electrometric
2	Temperature	Digital Thermometer	Electrometric
3	Conductivity	Conductivity Meter	Electrometric
4	Total dissolved solids	TDS meter	Electrometric
5	Turbidity	Turbidity Meter	Electrometric/Nephelometric
6	Dissolved Oxygen (DO)	-	Winkler's Method
	<i>Ex-situ</i>		
8	Acidity	-	Titrimetric
9	Alkalinity	-	Titrimetric
10	Total Hardness	-	Titrimetric
11	Ca Hardness	-	Titrimetric
12	Mg Hardness	-	Titrimetric
13	Chloride	-	Argentometric titration
14	Salinity	-	Argentometric titration
15	Nitrite	Hanna multi-parameter kit	Colorimetric Method
16	Phosphate	Hanna multi-parameter kit	Colorimetric Method

3. RESULTS AND DISCUSSION

In the present study, the physicochemical characterization of water and soil of 16 sampling sites were carried out. The results of site-wise variation in selected parameters are illustrated in graphical form as minimum, maximum and average values for the entire study period.

1) pH:

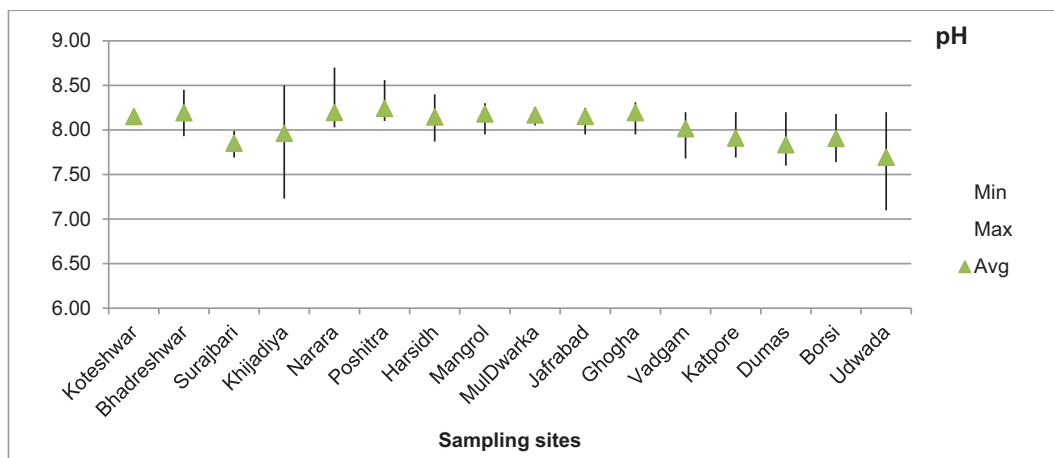


Fig. 2.2 Variation in sea water pH at selected sites of Gujarat Coast

pH is known as the most important water parameter as many properties, processes and reaction are dependent on pH. Changes in temperature, salinity and biological activity are caused due to change in the pH concentration along with time. Most of the natural seawaters are generally alkaline due to the presence of sufficient quantities of carbonate (Govindasamy et al., 2012). The above graph shows pH range of 16 sites in which the maximum pH was observed at Narara (8.7) in the month of January'17 and the minimum pH was observed at Udwada (7.10) in the month of July'16. The obtained pH values are within the range of SW-I sea water quality criteria defined by Central Pollution Control Board (CPCB, 1971). According to Chetana & Somashekhar (1997), the winter maxima are due to decreased decomposition rate, owing to reduced microbial activity and increased algal productivity.

Sea water pH is typically limited to a range between 7.5 and 8.4 (Chester, 1990). The principal system that regulates pH in the sea water is carbonate system consisting of CO_2 , H_2CO_3 , HCO_3^- , salt content and alkalinity due to borates (Lower, 1999).

2) Temperature:

The temperature variation is one of the factors in the coastal and estuarine systems, which influences the physicochemical characteristics and also influence the distribution and abundance of flora and fauna (Soundarapandian et al., 2009). In present study the temperature varied from 21°C to 34.80°C. The maximum value at Vadgam was recorded in the month of May'16 and the minimum value was recorded during January'17 at Harsidh.

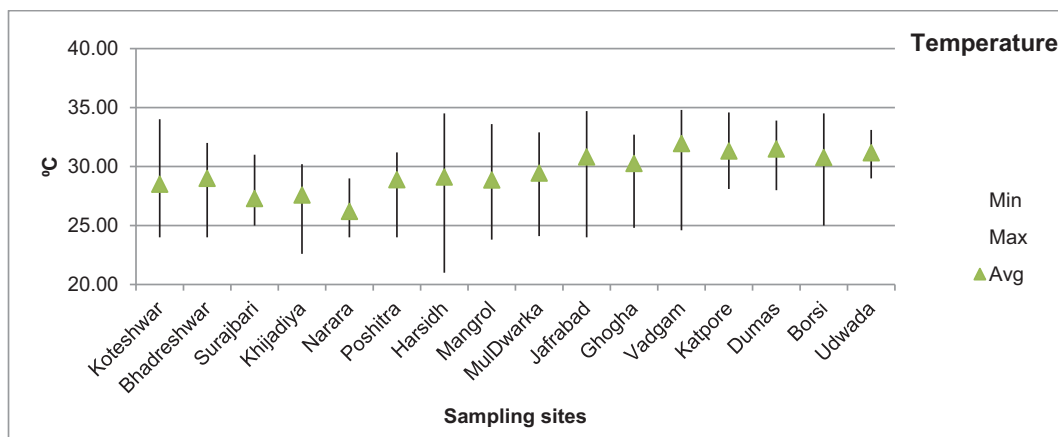


Fig. 2.3 Variation in sea surface temperature (°C) at selected sites of Gujarat Coast

During the present study, it was observed that temperature varied according to the seasonal fluctuations of atmospheric temperature; with maximum during summer and minimum during winter at selected sites.

3) Dissolved Oxygen (DO):

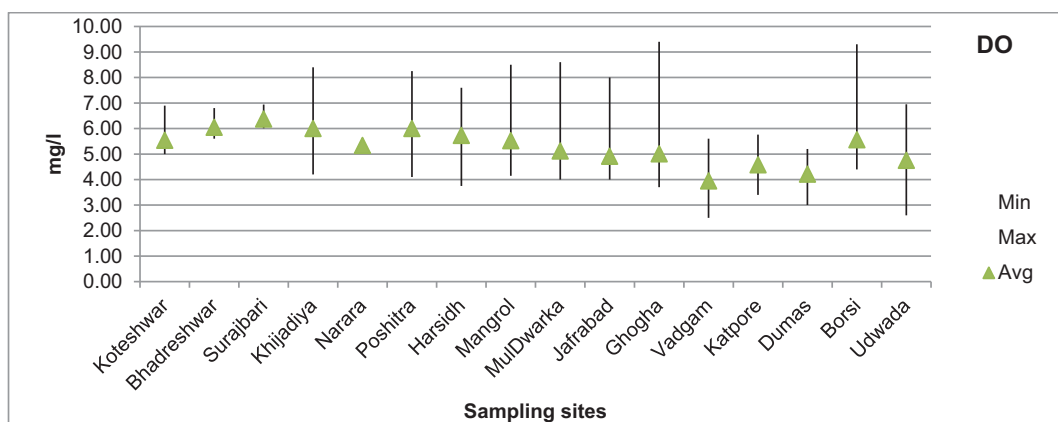


Fig. 2.4 Variation in Dissolved Oxygen (mg/l) at selected sites of Gujarat Coast

Dissolved Oxygen is an important constituent of water, and its concentration in water is an indicator of prevailing water quality and ability of water body to support a well-balanced aquatic life. However, in a dynamic coastal environment the impact is considerably lowered because of tidal action and turbulence (Pena, 2010).

During present study, variation in dissolved oxygen content was from 2.50 to 9.40 mg/l. Dissolution of oxygen in water is affected by the temperature and salinity (Vijayakumar et al., 2000). The minimum value was observed at Vadgam (2.50 mg/l) during May'16 and maximum value was observed at Gogha (9.40 mg/l) during January'17, which might be due to the cumulative effect of higher wind velocity (Das et al., 1997). The average values of DO falls well within the SW-I and SW-II sea water quality criteria given by CPCB. Reid (1961) stated that the solubility of oxygen in water increased by lowering the temperature i.e. solubility of oxygen in water is known to be affected inversely by the rise in temperature (Kumar and Oomen, 2011, Hutchinson 1957, and Nedumaran et al.2001).Due to

biological activity in the ocean, the oxygen content is controlled not only by the exchange of oxygen through the air-sea interface and the mixing of water, but also by photosynthesis, respiration and oxidation of organic matter (Miyake & Saruhashi, 1956).

4) Turbidity:

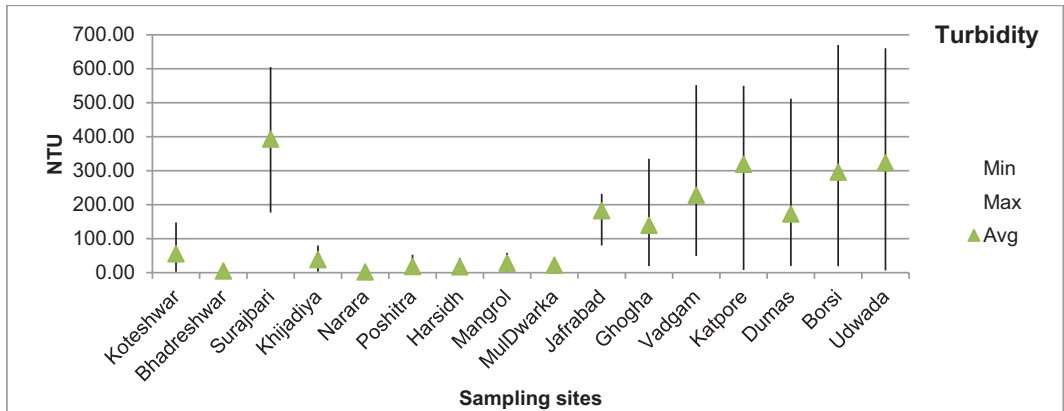


Fig. 2.5 Variation in turbidity (NTU) at selected sites of Gujarat Coast

Turbidity is generally used to express the lack of transparency and clarity of water owing to the presence of suspended and colloidal materials such as clay, silt, finely divided organic and inorganic matter and plankton or other microscopic organisms (Wilson, 2010; Lawler, 2004). Turbidity is affected by the dissolved and suspended matter concentration of the marine water.

Turbidity values ranges from 0.8 NTU to 670.0 NTU in the present study, the maximum value was recorded at Borsi in the month of September'16 whereas the minimum value at Bhadreshwar during March'17. Abnormal values of turbidity are usually due to discharge of water and due to floating sediments carried by the river from catchment areas (Muduli & Panda, 2010). The sites present in Gulf of Khambhat revealed higher turbidity values due to heavy discharge of sediments and waste water from the major rivers like Narmada, Tapi, Mahi, Sabarmati etc. High turbidity and associated suspended solid concentrations have important ecological impacts, because of light suppression effects.

5) Conductivity:

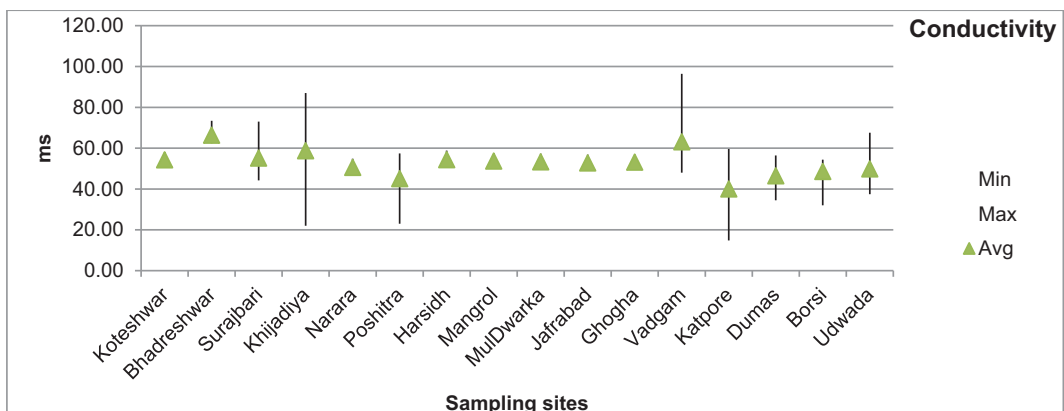


Fig. 2.6 Variation in conductivity (mS) at selected sites of Gujarat Coast

Electrical conductivity (EC) estimates the amount of total dissolved salts or the total amount of dissolved ions in the water. Suspended objects and the dissolved solids play a crucial role in the sea water conductivity. Electrical Conductivity is in Positive correlation with Total Dissolved solids, the more total dissolved solids in water, particularly salts, the greater is its electrical conductivity (Westbrook et al. 2005). Conductivity (electrical conductance), is strongly influenced by the concentration of dissolved constituents (Maiti, 2003).

Fig. 2.6 depicts the values of conductivity recorded at different sites of Gujarat coast during entire study period. The values ranged from 14.8 mS/cm (Katpor) to 96.41 mS/cm (Vadgam) in the month of January'17 and May'16 respectively. Sampling sites which are adjoined to the open sea shows the minimum fluctuation in the conductivity values.

Conductivity of the water is also related to the Total Dissolved Solids, Turbidity & Suspended solids; which more or less remain constant in the open sea water and varies greatly at the creeks and other isolated region, which explains the wider fluctuation in conductivity at Vadgam, Katpore, Khijadiya, and Surajbari. The values of Conductivity and TDS are directly proportional to each other and therefore, the sites with high TDS values revealed higher values of conductivity.

6) Total Dissolved Solids (TDS):

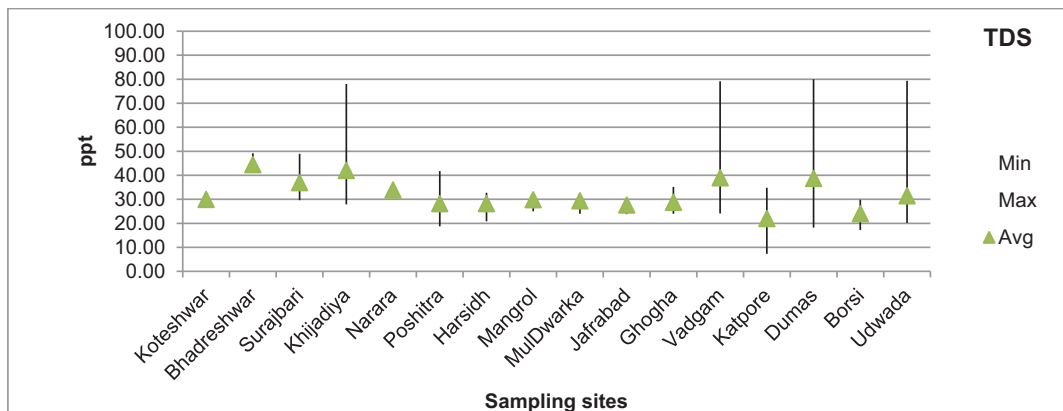


Fig. 2.7 Variation in Total Dissolved Solids (ppt) at selected sites of Gujarat Coast

Total Dissolved Solids (TDS) refers to the amount of dissolved ions, minerals, salts, metals and other chemicals in water. TDS is generally associated with inorganic salt and there is a close parallelism between TDS and conductivity. Total Dissolved solids have been found to be dependent on a variety of factors including: substrate type, tidal height, water velocity and depth of water mixing (Chagas and Suzuki, 2005). Dissolved Solids are also important to aquatic life by keeping cell density balanced; it can affect an organism's ability to move in a water column, causing it to float or sink beyond its normal range (Hilario et al., 2017).

TDS of surface water in Gujarat coastal area varied from 7.29 ppt to 80.0 ppt. As shown in the graph the highest concentration of TDS was found at Dumas in May'17 whereas the minimum value was observed at Katpor in January'17. High values of total dissolved solids during summer season might be attributed to increased evaporation due to high temperature and, decrease in water volume (Kumbhar et al, 2009). The present study results corroborates with the findings of Behera et al.(2014),

the author has also reported peak values during Summer months for the samples collected from Mangrove ecosystem of Odisha.

7) Acidity:

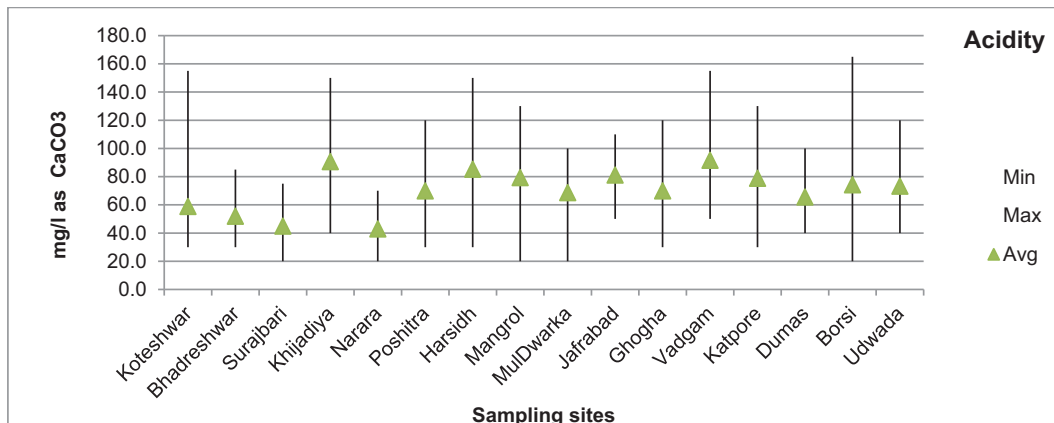


Fig. 2.8 Variation in Acidity (mg/l as CaCO₃) at selected sites of Gujarat Coast

In oceanography, the carbonate system is one of the most important components of the Chemical Perspective as it controls the acidity of seawater and governs the carbon cycle. Within the mix of acids and bases in the Earth-surface environment, the carbonate system is the primary buffer for the acidity of water, which determines the reactivity of most chemical compounds and solids (Emerson and Hedges, 2008). As shown in the Fig. 2.8, the Acidity values ranges from 20.00 mg/l to 165.00 mg/l in the month of November'16 and March'16, respectively. The highest value was reported at Borsi whereas lower values recorded at Mangrol, Mul Dwarka and Narara i.e. 20 mg/l.

Salts of carbonates, bicarbonates and hydrogen ions play an important role in maintaining the acidity of marine water. Likewise, the gradual degradation of litter and organic matter generated from the mangroves raise the acidity of the ocean water. Sites that are comprised of dense mangrove patches has higher values of acidity as it provides large quantity of litter and their degradation results in high values of acidity.

8) Alkalinity:

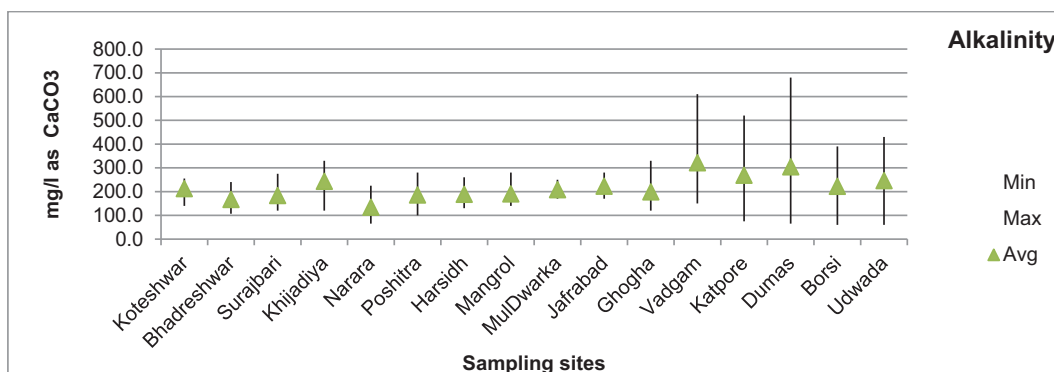


Fig. 2.9 Variation in Alkalinity (mg/l as CaCO₃) at selected sites of Gujarat Coast

Alkalinity is more significant than pH as it takes into account the principal constituents that influence water's ability to regulate pH, and acts as buffering system of the medium (Smitha et al., 2007).

The Alkalinity results ranges from 60.00 mg/L (Udwada and Borsi) to 680 mg/L (Dumas). The average values of alkalinity were found to be more at sites of Gulf of Khambhat and South Gujarat coast. Alkalinity determines the buffering capacity of water and is significant for aquatic life in a water system because it equilibrates the pH changes that occur naturally as a result of photosynthetic activity of phytoplankton (Kaushik and Saksena, 1989). Higher values of Alkalinity are also attributed to higher values of TDS in water (Thompson, 2006).

9) Salinity:

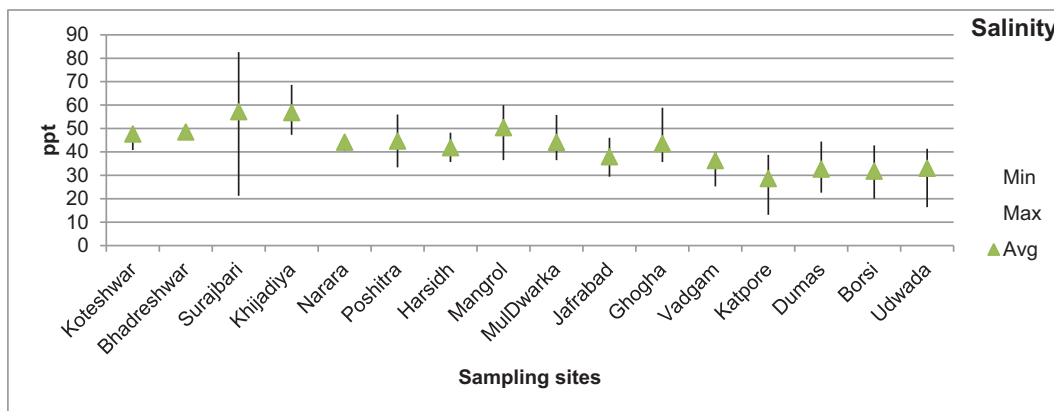


Fig. 2.10 Variation in Acidity (mg/l as CaCO_3) at selected sites of Gujarat Coast

Salinity is the indicator of freshwater incursion in the near shore coastal water as well as extrusion of tidal water in inland water bodies. Salinity influences several processes such as dissolution, dispersion, dilution in seawater due to high dissolved salt content and higher density. Salinity acts as a limiting factor in the distribution of living organisms, and its variation caused by dilution and evaporation is most likely to influence the fauna in the intertidal zone (Gibson, 1982).

In present study, the concentration of salinity ranges from 13.14 ppt to 82.61 ppt with the maximum value at Surajbari (May'17) and the minimum value at Katpor (January'17). The average values of salinity were found to be more in Gulf of Kachchh sites. The large variation of air and water temperature and scanty rainfall, makes the GoK a high saline water body (Kunte, 2001).

The sites of Gulf of Khambhat and South Gujarat coast revealed comparatively lower values of salinity; which was presumably due to the large quantity of freshwater inflow in these major rivers of Gujarat.

10) Hardness:

The hardness of water depends upon the dissolve salts present in the water (Prasad and Patil, 2008). Cations of calcium, magnesium, iron and manganese contribute to the hardness of water (Shrivastava and Patil, 2002). In present study, total hardness value ranges from 500 mg/l to 23700 mg/l. The minimum value was observed at Katpor (January'17) and the maximum value was observed at Vadgam (May'16). Calcium and Magnesium ions are usually the only ions present in significant concentrations; therefore, hardness is generally considered to be a measure of the calcium and magnesium content of water (Maiti, 2003).

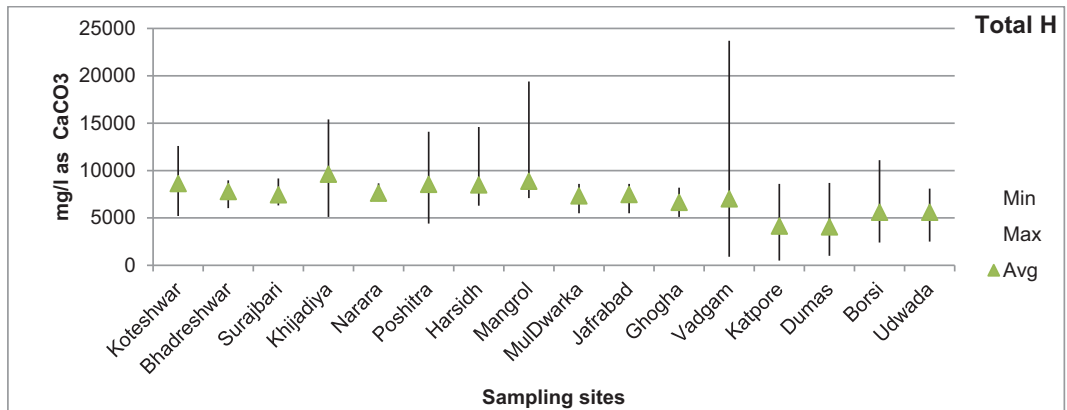


Fig. 2.11 Variation in Total Hardness (mg/l as CaCO₃) at selected sites of Gujarat Coast

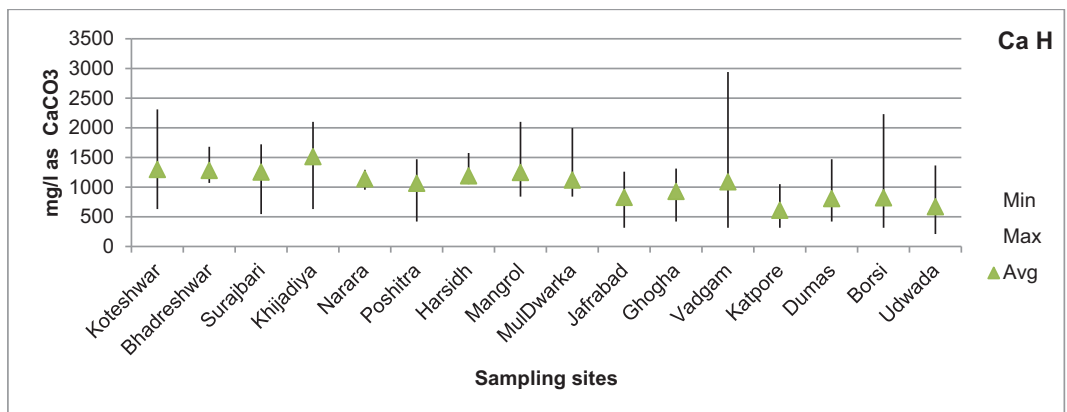


Fig. 2.12 Variation in Calcium Hardness (mg/l as CaCO₃) at selected sites of Gujarat Coast

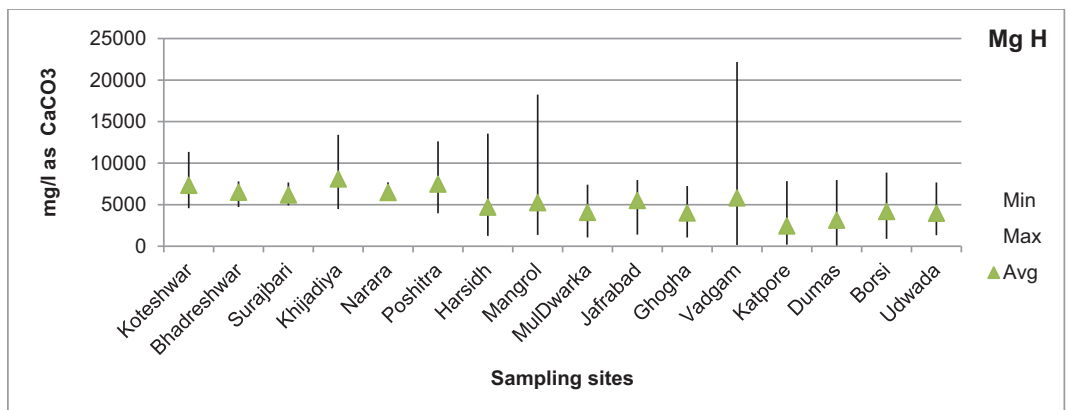


Fig. 2.13 Variation in Magnesium Hardness (mg/l as CaCO₃) at selected sites of Gujarat Coast

Calcium is an important element influencing flora of ecosystem, which plays important role in metabolism and growth (Gill, 2014). The highest calcium hardness was recorded at Vadgam during May'17 (2940 mg/l) while the least content was recorded at Udwarda in September'16 (210 mg/l). The concentration of magnesium hardness varies between 90 mg/l and 22178 mg/l with the highest and

the lowest values at Dumas and Vadgam, respectively. The increase in the values of hardness might be due to evaporation of the surface water; besides addition of Ca and Mg salts from soaps and detergents used for washing and bathing, whereas excessive dilution by rain water during monsoon can be one of the important factors responsible for lowering the hardness during monsoon and post-monsoon season (Bozniak & Kennedy, 1968).

The value of magnesium was found to be higher than that of Calcium. The increased value of magnesium hardness may be due to deterioration of leaf and algae in sea water (Pawar, 2010).

11) Nitrate:

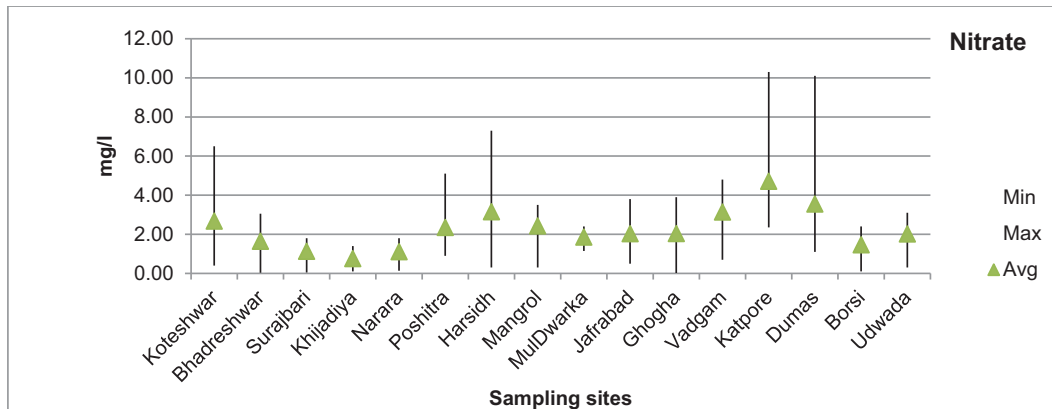


Fig. 2.14 Variation in Nitrate (mg/l) at selected sites of Gujarat Coast

Nitrate (NO_3^-) is one of the important nutrients in water body and is the common form of nitrogen in natural water. Nitrite (NO_2^-) is oxidized to nitrate after entering anaerobic regime. Similarly, plants and microorganisms reduce nitrate into nitrite but nitrite is quickly oxidized back to nitrate once it re-enters the water (Patra et al., 2011).

During present study, the Nitrate result ranges between 0.02 and 10.30 mg/L as shown in the graph. It is depicted from the graph that the highest value of nitrate was reported at Katpore (March'17) which might have attributed to high nutrient load, received through discharge of Narmada river (Kumar et al., 2012) and the lowest was recorded at Ghogha (May'17). The high content of inorganic nitrogen might be attributed to the decomposition of organic matter in the area. The wind movement is an important factor, influencing the discharge of drainage of water containing nitrogen compound (Okbah, 2005). Another possible entry of nitrate is through oxidation of ammonia form of nitrogen to nitrite and then consequently nitrates and excretion of living organism (Rajasegar, 2003).

12) Nitrite:

The concentration of Nitrite ranges from 0.01 to 0.36 mg/l. The maximum value of Nitrite was observed at Khijadiya. The sites like Koteswar, Narara, Poshitra, Surajbari, Harsidh, Mangrol, Mul Dwarka and Jafrabad has 0.01 mg/l of nitrite concentration. The concentration of nitrite was found higher among the sites of Gulf of Kachchh compare to Gulf of Khambhat as presented in above graph. Higher Nitrate value concomitant with low nitrite could have resulted from nitrification (Meera and Nandan, 2010).

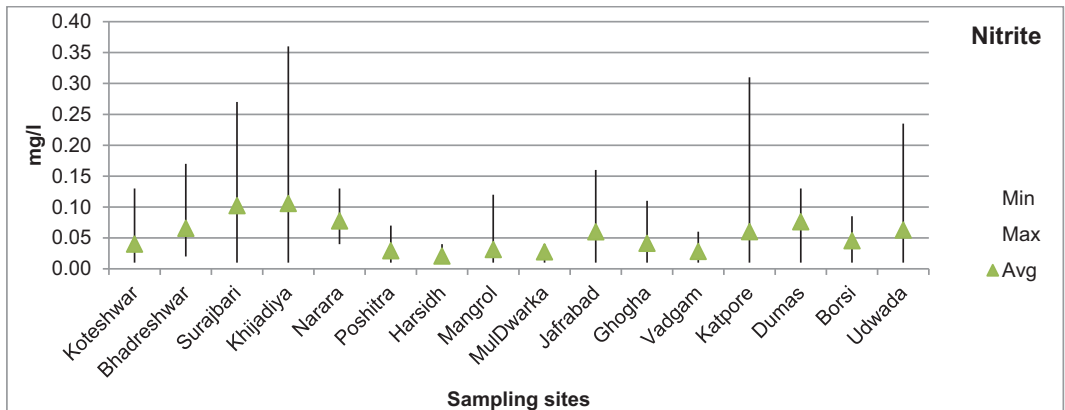


Fig. 2.15 Variation in Nitrite (mg/l) at selected sites of Gujarat Coast

The higher value of nitrite recorded in Surajbari, Khijadiya, Katpor and Udwada may be due to various reasons including variation in phytoplankton excretion, oxidation of ammonia, reduction of nitrate, recycling of nitrogen and bacterial decomposition of planktonic detritus present in the environment (Govindasamy et al., 2000; Mathew & Pillai, 1990).

13) Phosphate:

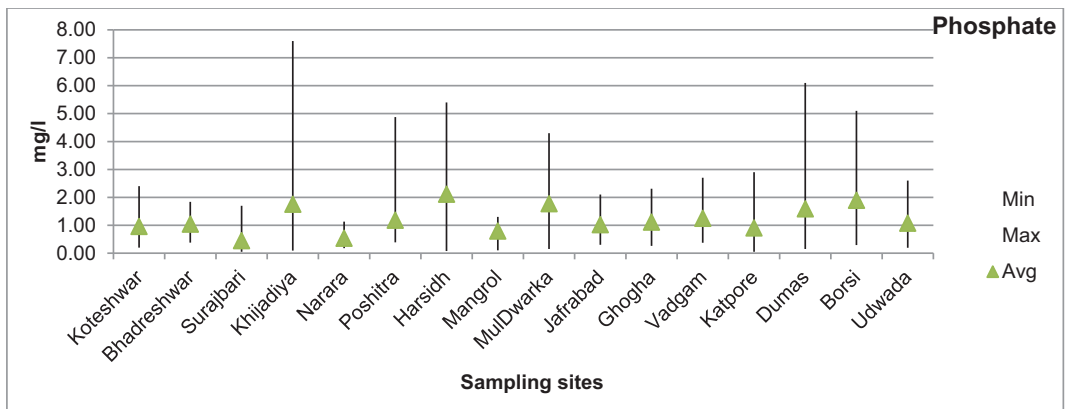


Fig. 2.16 Variation in Phosphate (mg/l) at selected sites of Gujarat Coast

Phosphate and Nitrate are the two nutrients which promote primary productivity in waterbody. Phosphate constitutes the most important inorganic nutrient that can limit the phytoplankton production in tropical coastal marine ecosystems and thereby the overall ecological processes (Cole and Sanford, 1989).

It is observed from the above graph that the concentration of phosphate was found to be higher at Khijadiya (7.60 mg/l) and the lowest value was recorded to be 0.05 mg/l (Surajbari) during March'17 and July'16, respectively. Though the highest values of phosphate are obtained at GoK; the average values were found to be more at sites of Gulf of Khambhat and South Gujarat coast. The lowest concentration recorded in Gulf of Kachchh site i.e. Surajbari, might be due to the absence of perennial river which results into low nutrient load in GoK region; whereas, Tapi river has high phosphates levels mostly due to the high input of domestic sewage being released from Surat city (Dubey and Ujjania, 2013). Phosphates are typically present in sea water as orthophosphates. Large amount of

phosphates are brought to the sea through river run-off as in monsoon season, rate of river run-off increases which results in the increase in the values of phosphate. The river runoff during summer season is very low which might be reason of low nutrient content in the waters of Gulf of Khambhat.

2.5.1.2 Correlation matrix

Table 2.5 describes the correlation among various water quality parameters. The Dissolved Oxygen (DO) and pH of the sea water showed a positive correlation ($r = 0.73$). Both the parameters are indicators of good water quality indicating various favorable conditions for high primary and secondary productions. DO and temperature showed strong negative correlation ($r = -0.72$) with each other, which demonstrates that at high temperature the dissolution of oxygen decreases in water. A positive correlation exhibits between Salinity, TDS and Conductivity ($r = 0.46$ & $r = 0.53$). TDS is positively correlated with number of parameters like Salinity, Nitrite, Phosphate, temperature, and conductivity. Thus, a single parameter of TDS that can give reasonably good indication of a number of related parameters. Dissolved Oxygen showed a significantly negative correlation most of the parameters. Thus, DO can serves as a single useful index of water quality; as with the increasing concentration of these parameters decreases the DO concentration. The negative correlation of Salinity with nitrate and phosphate showed that, freshwater influx is considered to be the main source of nutrients in coastal waters (Kumar et al., 2009).

Table 2.5 Correlation matrix among various water quality parameters

Parameters	pH	Temp.	EC	TDS	DO	Turb.	Acidity	Alkal.	Salinity	TH	CaH	MgH	NO ₃ ⁻	NO ₂ ⁻	PO ₄ ³⁻
pH	1.00														
Temp.	-0.39	1.00													
EC	0.25	-0.38	1.00												
TDS	-0.12	0.32	0.70	1.00											
DO	0.73	-0.72	0.25	0.17	1.00										
Turb.	-0.80	0.48	-0.29	-0.17	-0.36	1.00									
Acidity	-0.10	0.58	0.00	-0.20	-0.38	0.03	1.00								
Alkal.	-0.58	0.77	-0.11	0.11	-0.76	0.47	0.59	1.00							
Salinity	0.36	-0.80	0.53	0.46	0.81	-0.42	-0.30	-0.55	1.00						
TH	0.61	-0.69	0.54	0.22	0.70	-0.66	0.04	-0.53	0.81	1.00					
CaH	0.44	-0.75	0.67	0.54	0.68	-0.60	-0.14	-0.41	0.90	0.86	1.00				
MgH	0.40	-0.64	0.51	0.45	0.64	-0.47	-0.16	-0.38	0.74	0.83	0.79	1.00			
NO ₃ ⁻	0.14	0.46	-0.13	-0.40	-0.40	0.11	0.52	0.27	-0.41	-0.11	-0.41	-0.29	1.00		
NO ₂ ⁻	-0.56	0.14	0.17	0.34	-0.25	0.55	0.08	0.44	-0.17	-0.30	-0.08	0.05	-0.18	1.00	
PO ₄ ³⁻	-0.08	0.28	0.05	0.01	-0.14	-0.22	0.58	0.36	-0.22	-0.01	0.03	-0.11	0.09	0.14	1.00

(Temp.=Temperature; EC=Electrical conductivity; TDS= Total Dissolved Solids; Alkal.=Alkalinity; TH= Total Hardness; CaH=Calcium Hardness; MgH= Magnesium Hardness; NO₃⁻= Nitrate; NO₂⁻= Nitrite; PO₄³⁻= Phosphate)

4. CONCLUSION

The coastal water was found to be alkaline and average values were recorded between 7.69 and 8.24. These values are well within the coastal water quality standards (SW-I) given by CPCB. The temperature varied almost in similar trend of air temperature i.e. highest during pre-monsoon season followed by monsoon and post-monsoon season. TDS, Conductivity and Salinity were also found to be highest during summer due to high rate of evaporation and less freshwater discharge. The average values of Dissolved Oxygen were well within the SW-II water quality standard depicting favorable condition for commercial fishing. Turbidity showed higher values at sites of Gulf of Khambhat and South Gujarat coast due to presence of estuaries of major rivers of Gujarat that carries huge load of sediments; discharging into this region. On the other hand sites of Saurashtra coast and Gulf of Kachchh have comparatively clear water that supports coral reef ecosystem. The average values of nutrients were also found to be higher in Gulf of Khambhat and South Gujarat region; this can be attributed to discharge of nutrient rich river water into the coastal and estuarine environment.

The present study revealed that the health of coastal water is in a good state for the floral and faunal community thriving in the area because of high tidal amplitude mainly in two Gulfs. Certain coastal areas experiences degrading water quality that are under the anthropogenic pressure mainly due to industrialization, development of tourism, population growth, fishing activities and oil spillage. Many large scale industries such as petro-chemicals, chemicals, cement manufacturing units, salt pans and other small scale industries have also been established on the shore of Gujarat that has major impact on coastal water quality. The deterioration of water quality may results into depletion of biodiversity.

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