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ASSESSMENT OF SEASONAL VARIATION IN WATER QUALITY AT ESTUARINE AND RIVERINE ZONES OF SABARMATI RIVER GUJARAT, INDIA

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ABSTRACT:
The present study was conducted at various estuarine and riverine sites of Sabarmati River which is one of the major rivers of Gujarat, India. A total of nine physico-chemical parameters of collected water samples were analyzed during March 2017 to February 2018 in order to know the seasonal and spatial variation among the studied sites. The results of different parameters are noted as: pH (6.00 to 7.10), Water Temperature (20.09°C to 39.30°C), Turbidity (2.30 NTU to 802.00 NTU), Electrical Conductivity (1.04 mS/cm to 51.89 mS/cm), Total Dissolved Solids (0.18 ppt to 25.91 ppt), Dissolved Oxygen (0.43 mg/l to 7.52 mg/l), Salinity (2.00 ppt to 34.00 ppt), Alkalinity (60.00 mg/l to 440.00 mg/l), and Total Hardness (380.00 mg/l to 6030.00 mg/l) . The results of ANOVA showed that parameters such as Water temperature and Total Hardness showed significant spatial variation whereas Water temperature, Dissolved Oxygen and Total Hardness showed significant seasonal variation. The results also revealed that, the water quality at selected sites of Sabarmati gets deteriorated by various anthropogenic activities and discharge of industrial effluents.
Keywords: *ANOVA, Estuarine Zone, Physico-Chemical parameters, Riverine Zone, Seasonal sampling, Sabarmati, Water quality*

INTRODUCTION

An estuary is a partially enclosed body of water, and its surrounding coastal habitats, where saltwater from the ocean mixes with fresh water from rivers or streams (Cameron and Pritchard, 1963, Prajapati, 2005). In fresh water the concentration of salts, or salinity, is nearly zero. The salinity of water in the ocean averages about 35 parts per thousand (ppt). The mixture of seawater and fresh water in estuaries is called brackish water and its salinity can range from 0.5 to 35 ppt. The Sabarmati River starts its journey in the Aravalli Range of Udaipur district in the state of Rajasthan in India. In the beginning of the course, it is also known as Wakal River. The majority course of the river flows in the state of Gujarat, India. Sabarmati is one of the major and important rivers of Gujarat that flows through Gandhinagar and Ahmedabad cities and finally drains into Gulf of Khambhat. Moreover, partially treated and untreated industrial effluent from various large and small scale industrial units such as pharmaceutical, petrochemical, textile, automotive, energy,

chemical, and other industries gets released in this river. Gujarat is one of the highly industrialized states of India with a strong web of pharmaceutical, petrochemical, textile, automotive, energy, chemical, and other industries (Haldar, 2014). This river discharges a large amount of sediments, as suspended load into the Gulf of Khambhat which leads to changes in the water quality of estuaries (Deshkar et al., 2012). However, the estuaries all over the world, are suffering several adverse effects from anthropogenic activities including (a) sedimentation from soil erosion owing to deforestation, poor farming practices and grazing (b) pollution from industries, agriculture and domestic sectors (c) overfishing (d) degradation of habitat of estuarine flora-fauna and (e) construction of dams in the upstream areas (Sriyanie, 2008). Hence, the present study had been carried out to know the water quality of selected estuarine and riverine sites of Sabarmati.

Study area:

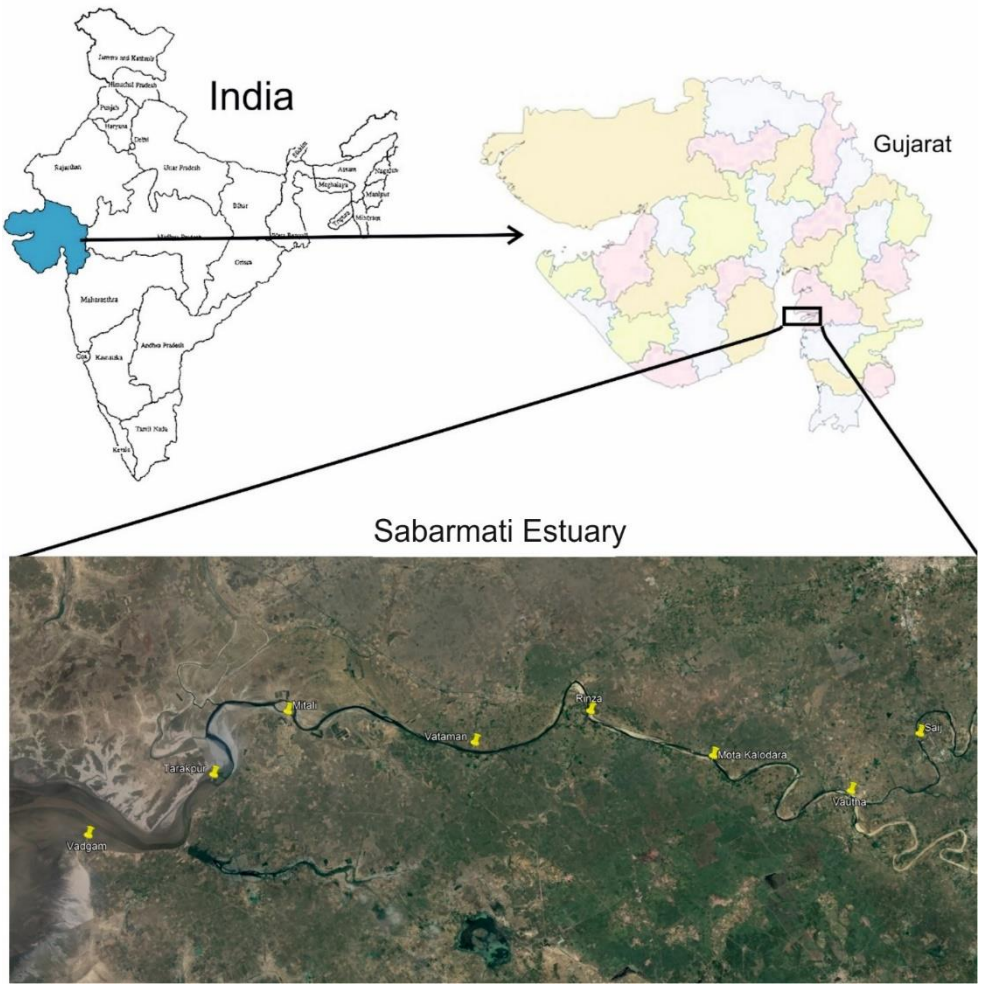

Fig.1: Sampling sites covering estuarine and riverine zone of the Sabarmati, Gujarat

River Sabarmati rises from the southwest part of Aravalli hills in Rajasthan at an elevation of about 762 m height and travels through Sabarkantha, Mahesana, Gandhinagar, Ahmedabad and Kheda districts of Gujarat before it merges into the Gulf of Khambhat. It has total length of about 381.59 km. This region is a hot, semi-arid region where the rainfall pattern is uneven and erratic. Some 95% of the average rain fall occurs during the monsoon months of July- October. The Sabarmati basin extends over states of Rajasthan and Gujarat having an area of 21,674 Sq.km with maximum length and width of 300 km and 150 km. It lies between 70°58' to 73°51' east longitudes and 22°15' to 24°47' north latitudes. From lat. 23° N to Lat. 22° 3' N Southwards the Sabarmati river enters the estuarine zone near Rinja, which is nearly about 35 km away from mouth of Sabarrnati river (Gulf of Cambay) (Prajapati, 2005).

Methodology

A total of eight sites were selected for the collection of samples, the GPS location of which are given in Table 1. Out of these eight sites, four sites were selected near the mouth of estuary having high tidal influence whereas the remaining four sites were selected in riverine zone having higher influence of freshwater. The water samples for physical and chemical parameters determination were collected from the selected sites for two seasons i.e. summer and winter from March 2017 to February 2018 during high tide and low tide. Two riverine sites i.e. Saij and Vautha do not have tidal influence and therefore, only one sample per season was collected. The samples were collected in polyethylene bottles and brought to the laboratory for ex-situ analysis of water parameters. In the field itself; pH, Temperature, Electrical Conductivity, TDS, Salinity, Turbidity and Dissolved Oxygen were analyzed by using multi-parameter kit (Made: Oakton). The chemical parameters that were performed at laboratory included Alkalinity and Total Hardness.

In order to know, whether there is significant variation in water quality among different sites and during two seasons and tides, Two-way Analysis of Variance (Two-way ANOVA) was carried out.

The total investigation period of eight months was divided into two seasons i.e. Summer (March 2017 to Mid-June 2017) and Winter (November 2017 to February 2018) for seasonal comparison. In order to know, whether there is significant variation in water quality among different sites and during two seasons and tides, Two-way Analysis of Variance (Two-way ANOVA) was carried out on data obtained in this study by using data package available in MS-Office excel 2010.

Results and Discussion:

The spatial and temporal variation in water quality has been depicted in graphical form whereas the average values of water parameters in two seasons along with standard deviation are given in table 2.

Physical parameters

Water temperature

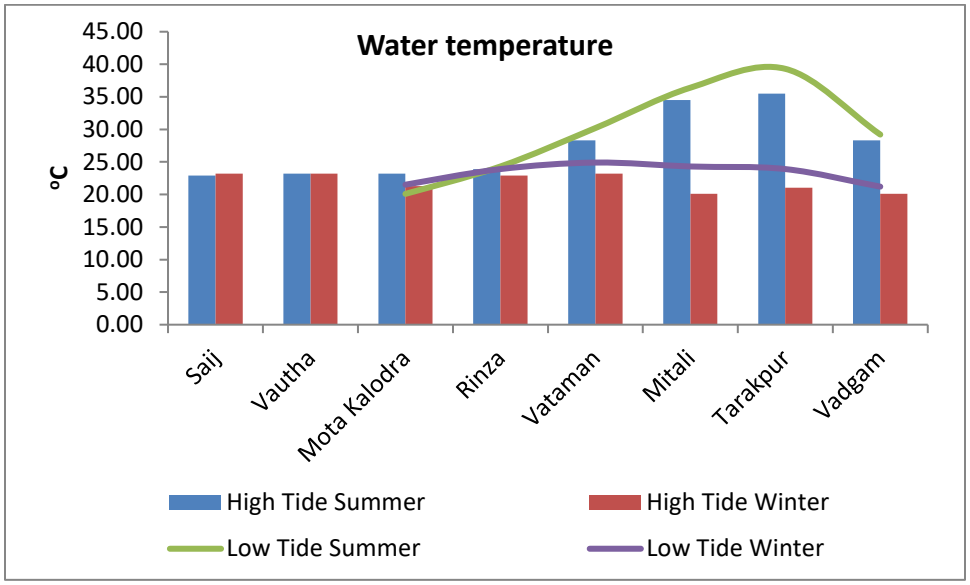

Fig. 2 Seasonal variation in water temperature at selected sites of Sabarmati river estuary

Water temperature is an important parameter which influences the chemical process such as dissolution-precipitation, adsorption-desorption, oxidation-reduction and physiology of biotic community in an aquatic habitat **(**van Aken, 2008**).** In present study, the values of water temperature fluctuated from 20.09°C to 39.30°C. The highest water temperature i.e. 39.30°C was recorded at Tarakpur during low tide in summer and the lowest value i.e. 20.09.°C was recorded at Mitali winter during high tide and Mota kalodra summer during low tide (Fig.2). The average value of water temperature for summer and winter seasons along with the standard deviation are 29.92^{o}C±6 and 22.48^{o}C±1.6, respectively (Table 2). The water temperature in rivers get affected by certain factors such as heat exchange on the earth surface under controlled radiation in and out, ground water movement and chemical and thermonuclear processes occurring in an aquifer (Drever, 1997). Singh et al. (2010), also observed fluctuation in water temperature from 16°C to 28°C showing minimum and maximum values in winter and summer seasons, respectively at four

rivers of Manipur. The variations in temperature across the different stations and over the three different seasons were highly significant (Table 3).

Turbidity

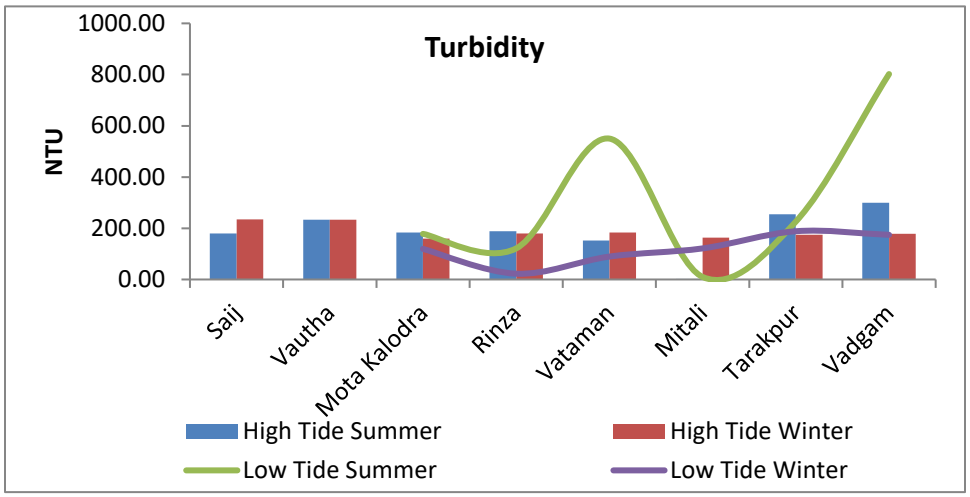

Fig. 3 Seasonal variation in turbidity at selected sites of Sabarmati river estuary

Turbidity is often used as a general term to describe the lack of transparency or "cloudiness" of water due 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). Turbidity at various sites varied from 2.30 NTU to 802.00 NTU. The highest turbidity (i.e. 802.00 NTU) was recorded at Vadgam during low tide in summer. On the other hand, lowest turbidity (i.e. 2.30 NTU) was recorded at Mitali in summer during high tide, respectively (Fig.3). The average values of turbidity during summer and winter seasons were recorded as 241.42±208 NTU and 158.61±55.8 NTU, respectively (Table 2). Haldar et al., 2014 observed turbidity ranging from 22.40 NTU to 234.30 NTU in waters of Sabarmati River. Results of two-way ANOVA showed statistically insignificant values for variation in turbidity among different sites and seasons (Table 3).

Chemical parameters

pH

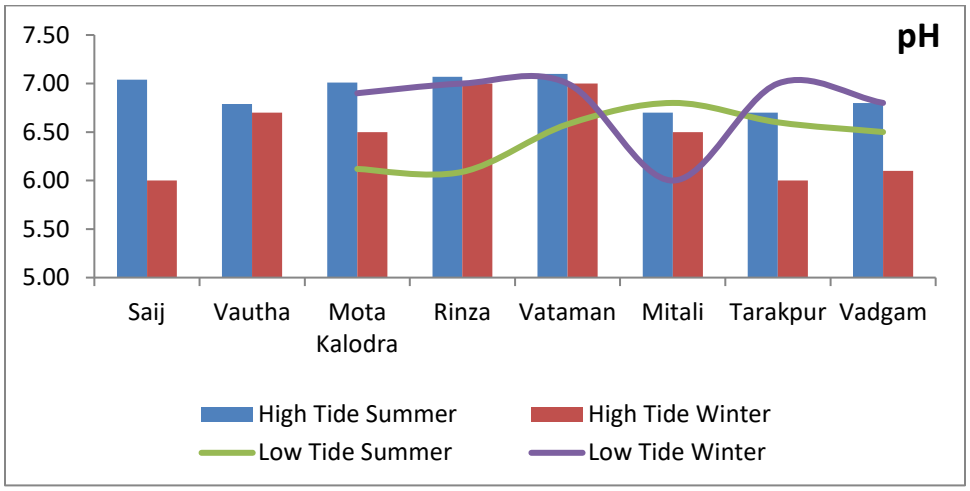

Fig. 4 Seasonal variation in pH at selected sites of Sabarmati river estuary

The pH is the scale of intensity of acidity and alkalinity of water and measures the concentration of hydrogen ions. pH is most important in determining the corrosive nature of water (Gupta *et al.*, 2009). It also affects other chemical reactions such as solubility and metal solubility (Fakayode, 2005). The pH at all the sampling sites varied from 6.00 to 7.10 (Fig.4). Waters at all the sites showed acidic to near neutral condition of water. The highest pH (i.e. 7.10) was observed at Vataman during high tide. On the other hand, lowest pH (i.e. 6.00) was observed at Saij and Tarakpur during high tide and at Mitali at low tide. The values of seasonal average of pH for summer and winter are 6.71±0.32 and 6.61±0.42, accordingly (Table 2). The acidic pH at selected sites might have attributed to the confluence of sewage water and highly acidic industrial waste water from surrounding industrial estate (Hiremath & Shetty, 1988**).** Statistical analysis by two-way ANOVA on pH of water as a function of variation among sites and seasons are statistically insignificant (Table 3).

Electrical Conductivity

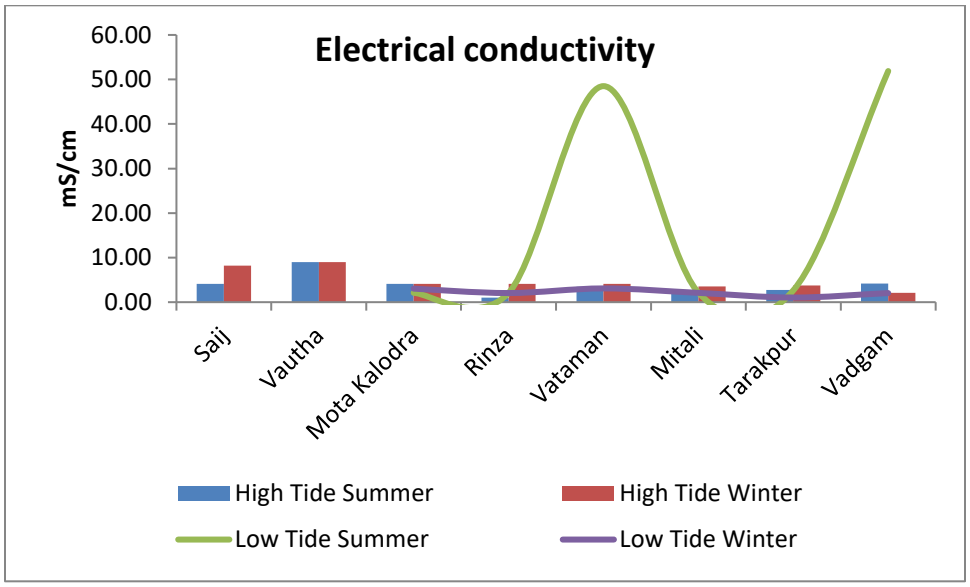

Fig. 5 Seasonal variation in Electrical conductivity at selected sites of Sabarmati river estuary

The Electrical Conductivity (EC) of water is proportional to the quality of dissolved ions and indicates the changes in composition of materials and overall concentrations of ions in water (El Morhit, and Mouhir 2014). The EC and concentration of salts in water are in direct proportion to each other (Westbrook et al., 2006). In the present study, Electrical Conductivity at various sites was found ranging from 1.04 mS to 51.89 mS. The highest EC (i.e. 51.89 mS) recorded at Vadgam during low tide in summer. On the other hand, lowest EC (i.e. 1.04 mS) was recorded at Rinza in summer during high tide (Fig.5). The season wise average value of EC was recorded as 10.04±17.00 mS and 3.73±0.8 mS during summer and winter seasons, respectively (Table 2). Similar values of conductivity (i.e. 0.593 ms/cm – 54.700 ms/cm) was recorded for Loukkos river estuary (El Morhit, and Mouhir, 2014). Another study by Behera et al. (2014) also reported EC values ranging from 5.160 ms/cm to 17.33 ms/cm for Mahanadi river delta of Odisha. The results

of two-way ANOVA suggested that the variation in EC between sites and seasons are statistically insignificant (Table 3).

Total Dissolved solids (TDS)

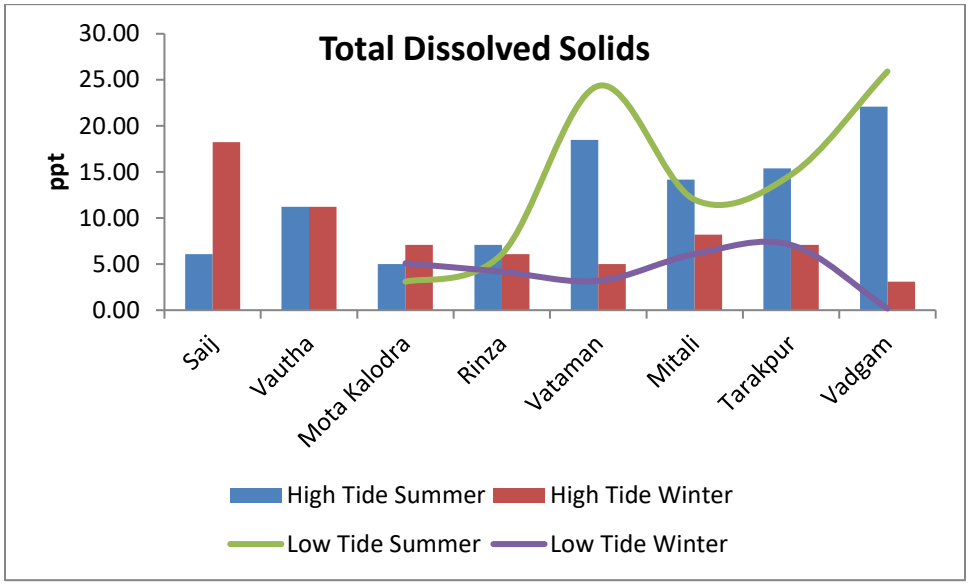

Fig. 6 Seasonal variation in TDS at selected sites of Sabarmati river estuary

The total dissolved solids (TDS) mainly indicate the presence of various kinds of minerals like ammonia, nitrite, nitrate, phosphate, alkalis, some acids, sulphates and metallic ions etc which are comprised of both colloidal and dissolved solids in water. It is also an important chemical parameter of water (Kabir et al, 2002). In present study, Total Dissolved Solids at various sites was found ranging from 0.18 ppt to 25.91 ppt. The highest TDS (i.e. 25.91 ppt) recorded at Vadgam during low tide in summer. On the other hand, lowest TDS (i.e. 0.18 ppt) was recorded at Vadgam in summer during low tide (Fig.6). The average values along with standard deviation for summer and winter season are 13.26±7.41 ppt and 6.56±4.26 ppt, correspondingly (Table 2). High values of total dissolved solids during summer season may be attributed to increased evaporation due to high temperature and, decrease in water volume (Kumbhar et al, 2009). Kataria

et al. (1996) reported that increase in value of TDS indicated pollution by extraneous sources. Statistical analysis of data also suggests insignificant variation in TDS values among sites and between seasons (Table 3).

Dissolved oxygen

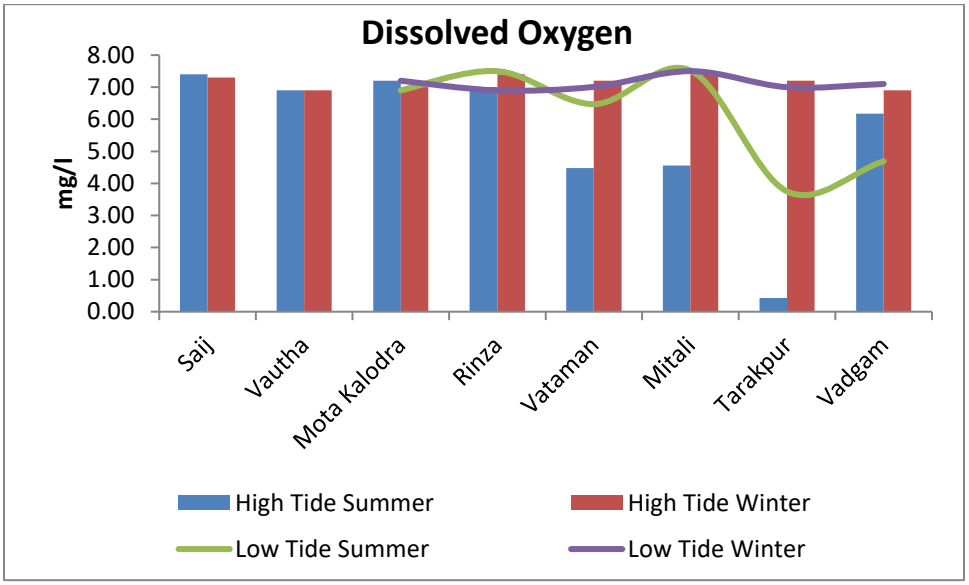

Fig. 7 Seasonal variation in Dissolved at selected sites of Sabarmati river estuary

Dissolved oxygen is an important parameter which is used for assessing the water quality and helps to understand anthropogenic impacts and natural self-purification capability of the river (Kannel et al. 2007). However, in a dynamic coastal and estuarine environment the impact is considerably lowered because of tidal action and turbulence (Pena, 2010). In present study, Dissolved Oxygen at various sites varied from 0.43 mg/l to 7.52 mg/l. The highest DO (i.e. 7.52 mg/l) recorded at Mitali during low tide in summer. On the other hand, lowest DO (i.e. 0.43 mg/l) was recorded at Tarakpur in summer during high tide (Fig.7). The average value of DO during summer and winter seasons are 5.78±2.0 mg/l and 7.14±0.2 mg/l, respectively (Table 2). When temperature increases, solubility of gas in water decreases and microbial activity increases; both these changes can reduce DO in water. In summer with the increase in water temperature, there

was reduction in DO, whereas in winter months due to decrease in temperature, the level of DO increased. These results were in conformity with Masood & Krishnamurthy, 1990 and Srivastava *et al.*, 2003. The variation in DO between selected sites is statistically insignificant though seasonal variations showed significant variation (Table 3).

Salinity

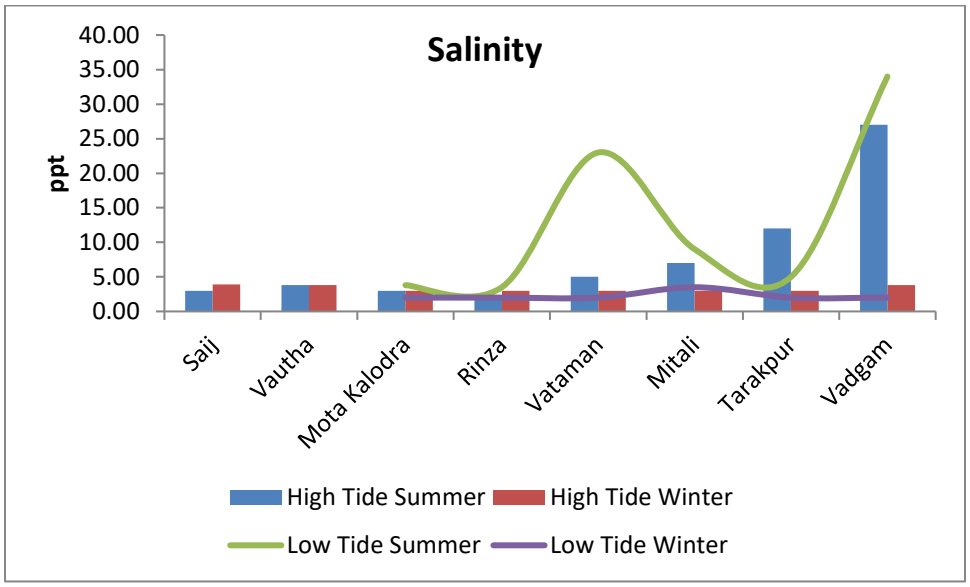

Fig. 8 Seasonal variation in Salinity at selected sites of Sabarmati river estuary

Salinity explains the percentage of chloride in water. Chlorides exist in all waters due to percolation of sewage through dirty areas, infiltration of seawater into groundwater aqyuifers and industrial effluents containing soda and potash (El Morhit, and Mouhir 2014). Shiel et al. (2006) stated that biotic communities present in estuarine regions are acclimatized for certain range of salinity where they thrive. During present study, salinity at various sites varied from 2.00 ppt to 34.00 ppt. The highest salinity (i.e. 34.00 ppt) recorded at Vadgam during low tide in summer. On the other hand, lowest chlorinity (i.e. 2.00 ppt) was recorded at Rinza in summer during high tide, at Mota Kalodara in winter during low tide, at rinza in winter during low tide, at vataman in winter

during low tide, at Tarakpur in winter during low tide, and at vadgam in winter during low tide (Fig.8). The average value of Salinity 10.08±10.3 ppt and 2.86±0.74 ppt during summer and winter seasons, respectively (Table 2). Similar results have been reported by Martin et al. (2008) from Cochin estuaries wherein the values of salinity ranged from 0 ppt during monsoon to 30 ppt in pre-monsoon which found to be corroborated with present results. Statistical analysis suggests insignificant variation in salinity among sites whereas variation between seasons is found to be significant (Table 3).

Alkalinity

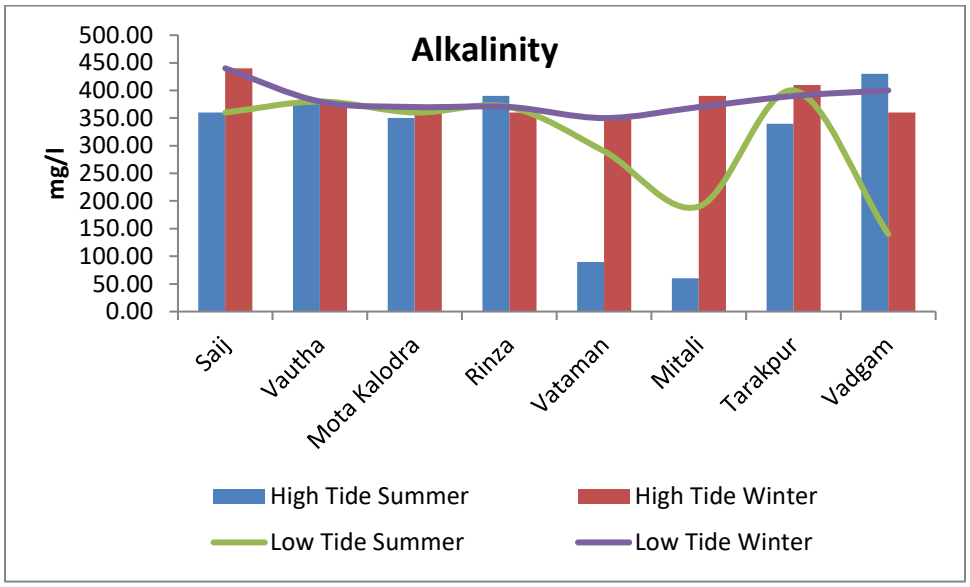

Fig. 9 Seasonal variation in Alkalinity at selected sites of Sabarmati river estuary

Alkalinity of water is a measure of weak acid present in it and of the cations balanced against them (Sverdrup *et al.*, 1942). 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). Measuring alkalinity is important in determining the estuary's ability to neutralize acidic pollution from rainfall or wastewater. Alkalinity at various sites varied

from 60.00 mg/l as $CaCO_3$ to 440.00 mg/l as $CaCO_3$ during entire study period. The highest alkalinity (i.e. 440.00 mg/l as $CaCO_3$) recorded at Saij during high tide in winter. On the other hand, lowest alkalinity (i.e. 60 mg/l as $CaCO_3$) was recorded at Mitali in summer during high tide, respectively (Fig.9). The seasonal average values along with SD of alkalinity were found to be 296.43±123.00 mg/l and 378.57±24.5 mg/l during summer and winter seasons, correspondingly (Table 2). Jamson (1993) observed high carbonates during summer period in certain polluted rivers of Gujarat which is also observed during the present investigation. The ANOVA depicted insignificant variation in alkalinity among sites and between (Table 3).

Total Hardness

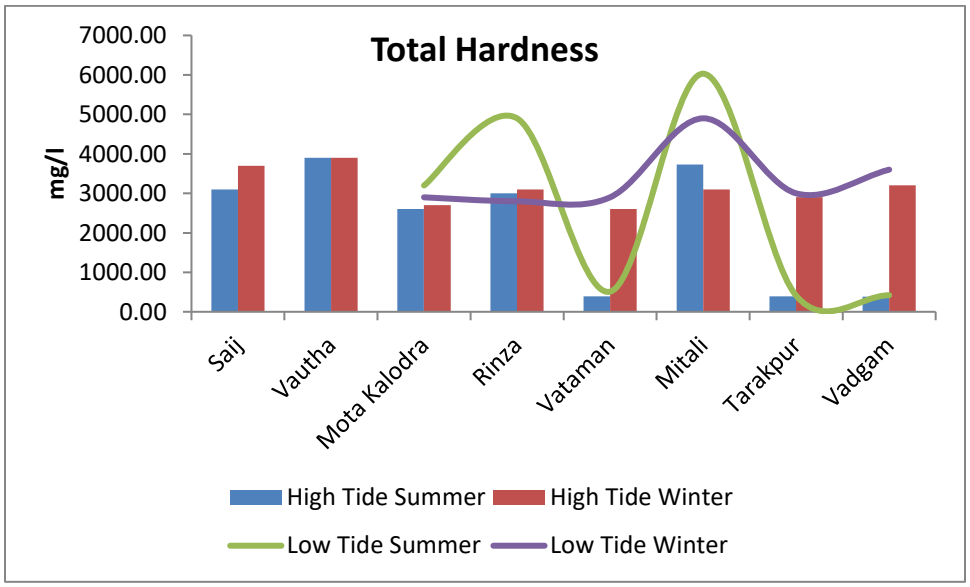

Fig. 10 Seasonal variation in Total Hardness at selected sites of Sabarmati river estuary

The hardness of water depends upon the dissolve salts present in the water (Prasad & Patil, 2008). Cations of calcium, magnesium, iron and manganese contribute to the hardness of water (Shrivastava & Patil, 2002). Total Hardness at various sites was varied from 380.00 mg/l as CaCO3 to 6030.00 mg/l as CaCO3. The highest Total Hardness (i.e. 6030.00 mg/l as $CaCO_3$) was recorded at Mitali during low tide in summer. On the other hand, lowest Total Hardness (i.e.

380.00 mg/l as $CaCO_3$) was recorded at Vadgam in summer during high tide (Fig.10). The average ± SD value during summer and winter were 2354.29±1933 mg/l and 3232±612 mg/l, respectively (Table 2). Generally, hardness of water ranging from 50 to 150 ppm is considered moderately hard, 150 to 300 ppm is hard and above 300 ppm is very hard (Maiti, 2001). Accordingly waters in riverine and estuarine zones of Sabarmati were found to be very hard throughout the study period in all the selected sites. These observations agree with the study of Daborn (1976) and Shaji (1990). Statistical analysis by two-way ANOVA on total hardness of water as a function of variation among sites is significant whereas that of between two seasons is statistically insignificant (Table 3).

Conclusion:

The results of present study showed that some physico-chemical parameters such as Total hardness, Turbidity and Total Dissolved Solids have higher concentration at Vataman, Mitali, Tarakpur and Vadgam, than the recommended guidelines of IS 10500 – 2004 for domestic water quality. The major source of pollution at these sites includes both point and non-point sources such as local anthropogenic activities, agricultural run-off and discharge of industrial effluent. Further, this study provides better understanding about the water quality conditions of the tropical estuary and may thus help management authorities, in planning strategies for protection and conservation of Sabarmati estuarine ecosystem.

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Data obtained in this study by using data package available in MS-Office excel 2010.

Table 1– Riverine and Estuarine sites of Sabarmati River with GPS locations

SN.	Village	Latitude (N)	Longitude (S)	Type of site
1	Saij	22^0 41' 38.5"	72^0 31' 41.0"	Riverine*
2	Vautha	22^0 39' 07.7"	72^0 32' 21.6"	Riverine*
3	Mota Kalodra	22^0 36' 01.5"	72^0 29' 32.3"	Riverine*
4	Rinza	22^0 33' 25.3"	72^0 26' 38.6"	Riverine*
5	Vataman	22^0 30' 02.6"	72^0 25' 59.1"	Estuarine
6	Mitali	22^0 25' 35.6"	72^0 22' 36.5"	Estuarine
7	Tarakpur	22^0 22' 55.1"	72^0 23' 24.0"	Estuarine
8	Vadgam	22^0 18' 58.2"	72^0 23' 26.0"	Estuarine

*Note: Estuarine and Riverine sites were demarcated based on presence of tidal influence and absence of tidal influence. respectively.

Table 2: Average ± Standard deviation in water quality parameters during two seasons

SN.	Parameters	Summer (Avg.± SD)	Winter (Avg.± SD)
1.	pH	6.71 ± 0.32	6.61 ± 0.42
2.	Water Temperature	29.92 ± 6	22.48 ± 1.6
3.	Turbidity	241.42 ± 208	158.61 ± 55.8
4.	DO	5.78 ± 2	7.14 ± 0.2
5.	EC	10.04 ± 17	3.73 ± 0.8
6.	TDS	13.26 ± 7.41	6.56 ± 4.26
7.	Salinity	10.08 ± 10.03	2.86 ± 0.74
8.	TH	2354.29 ± 1933	3235 ± 612
9.	Alkalinity	296.43 ± 123	378.57 ± 24.5

Table 3: Analysis of variance (ANOVA) test for data obtained during study period

SN.	Parameter	ANOVA (Among sites)	ANOVA (Between seasons)
1.	pH	0.698	0.143
2.	Water Temperature	0.045*	0.005*
3.	Turbidity	0.147	0.203
4.	DO	0.087	0.044*
5.	EC	0.495	0.144
6.	TDS	0.540	0.191
7.	Salinity	0.075	0.056*
8.	TH	0.051*	0.458
9.	Alkalinity	0.119	0.086

* Significant at the 0.05 level

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