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Research article

WATER AND SEDIMENT QUALITY CHARACTERISTICS NEAR AN INDUSTRIAL VICINITY, VADINAR, GULF OF KACHCHH, GUJARAT, INDIA

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ABSTRACT: The present study was carried out for a period of 1 year to investigate two important biotopes along the coastal waters of Vadinar, near Jamnagar, Gujarat which is marked by oil handling ports, Single Buoy Moorings (SBMs), wastewater outlets of oil industries and significant vessel movement. Qualitative and quantitative data on coastal water quality and sediment quality were collected in order to ascertain the health of this coastal waters and to find out whether the ongoing industrial activities in this coast has any impact on these biotopes in terms of important physio-chemical characteristics. Analysis of coastal water health through examination of 9 crucial water quality parameters indicated that all the parameters are well within the prescribed limits and no gross contamination could be discerned, showing that the coastal water in and around the industrial is clean and unpolluted. Significant parameters like dissolved oxygen (5.14 mg/l), BOD (1.84 mg/l) COD (7.64 mg/l), PHc (6.59 µg/l) and Phenol (12.67 µg/l) are either comparable with the other unpolluted coastal waters or are within the prescribed limits which do not pose threat to the marine biota. Levels of three analysed sediment quality parameters namely texture (grain size analysis), Total Organic Carbon (TOC) and Petroleum Hydrocarbon (PHc) were comparable with other unpolluted coastal sediments. Petroleum Hydrocarbons (wet weight) in the sediment showed a mean value of 1.88±2.74 µg/g. In spite of pronounced coastal and port related activities, near normal levels recorded are attributable to the significant carrying capacity, direction of water current and turn-over time of water mass in the Gulf environment.

Key words: Water quality, Sediment, Petroleum hydrocarbon, GoK, Oil refinery

INTRODUCTION

Physico-chemical and Biological characteristics are good indicators of water quality[1]. Nearly 40% of the total open ocean area and 30% of the total area of the world's continental shelves lie within the tropics[2]. The quality of surface water in the coastal regions is influenced by both natural processes and anthropogenic activities[3]. Good quality of water resources depends on a large number of physicochemical parameters, the magnitude and source of any pollution load; to assess that, monitoring of these parameters is essential[4]. Marine water quality has become a matter of serious concern because of its effects on human health and aquatic ecosystem including marine life[5]. Coastal area is such a productive ecosystems and water quality of such environment is considered to be significant with regard to the health of humans and animals. The hydrobiology of marine ecosystem plays an important role in predicting and tracking the changes happening in any coastal water body. Water quality parameters which significantly affects the water environment includes pH, temperature, Salinity, nutrients, suspended matters and toxic substances. Several recent studies have summarized the potential nature and consequences of global change on coastal areas and marine resources (Boesch *et al.*, 2000). Many times natural factors (geology, hydrology) and anthropogenic factors also play a major role in influencing the quality of coastal waters. In general, Oil pollution is found to be one of the major factor which causes deleterious effects on water environment especially ecosystems like coastal regions known to be the major regions.

Southern coastal stretch of Gulf of Kachchh, of late is witnessing a significant change in terms of increased human activities through aggressive industrial development. An assortment of industries like oil refineries, thermal power plants, ports and jetties, mining, cement and fertilizer & chemical industries have come up in this coastal belt in the last few decades. Vadinar-Salaya coastal belt, in a stretch of 20 km is a site of intensive maritime activity marked by three Single Buoy Moorings (SBMs), three oil handling jetties, one thermal power station and one oil refinery in addition to many point source effluent outlets originating from the nearby industries. In the light of this development, it became imperative to document the present status of coastal water quality in Vadinar coastal stretch which will both serve as a benchmark and a tool for coastal management. In view of this importance, the present study investigated nine crucial water quality and sediment quality parameters in the six study sites namely JSW, JBW, SSW, SBW, NJW and PCW and two sediment abiotic parameters namely sediment texture, Total Organic Carbon (TOC) in four station JSW, SSW, NJW and PCW off the Vadinar coast for 12 months (Nov 2010-Oct 2011).
This paper presents consolidated outcome of the water quality and sediment quality parameters carried out in the coastal waters in and around and Vadinar coast in order to monitor the coastal water quality and its health & status.

Study Area

Vadinar-Narara coast, where the present study locations SSW (22°29'54.88",69°39'40.99"), JSW (22°27'5.93",69°40'3.15") NJW (22°27'11.44"69°40'28.47") and PCW (22°28'37.98"69°42'58.17") are situated is highly broken, surrounded by sensitive ecosystems like mangroves, corals, mudflats and many small Island ecosystems (Plate 1). Several minor and major tidal incursions, forming network of creek systems add further landscape diversity to this coastal belt. The study area located in the southern coastline of the Gulf of Kachchh is mostly muddy interspersed with rocky and sandy intertidal belts, experiencing tidal conditions of Arabian Sea. Dense mangrove stands and patches of dead and live coral formations in the vicinity are some special features of this coastal belt. Kalubhar Island which is close to the study location is the biggest Island in the Gulf system with highly broken shore and many mangrove lined creek systems with coral formations.

MATERIALS AND METHODOLOGY

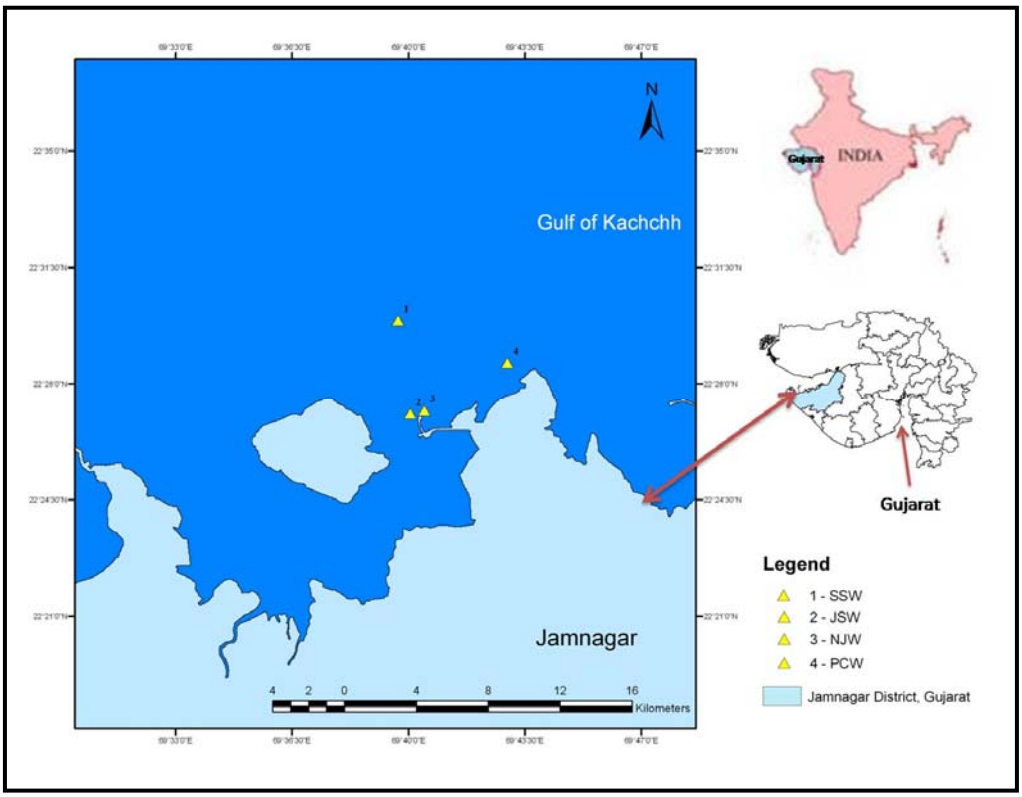
The surface water samples for all the parameters were collected using a clean bucket. Niskin sub sampler (Partex model-2.5 litre capacity) with self closing mechanism was used for collecting the bottom water samples. Surface and bottom water samples for salinity, total dissolved solids were collected and stored in PVC bottles. The samples for and Petroleum Hydrocarbons and phenolic compounds were collected in glass bottles of 2.5 lit (amber glass) and 0.5 lit respectively and analysis were performed employing Standard procedures. Surface water temperatures were measured using standard mercury filled centigrade thermometer immediately at site. Hydrogen ion concentration of the samples were measured using a pre-calibrated pH probe immediately after collection. Salinity was estimated by Argentrometric method and total dissolved solids (TDS) by gravimetric method. Estimation of Dissolved oxygen and Biological Oxygen Demand (DO&BOD) was carried out following Winkler's method and estimation of COD by open reflux method[9]. Samples for Petroleum hydrocarbons (PHc) were extracted with HPLC grade N-hexane. The organic layer was separated and dried over anhydrous sodium sulfate. The fluorescence of the extract was measured using Shimadzu RF-Spectrofluorometer with calibration using Saudi Arabian Crude Oil. Analytical grade chemicals were used throughout the study. All the reagents and calibration standards required for this study was prepared using deionized water.

Seabed sediments were collected using Van-Veen type of grab whereas intertidal sediments were collected using a handheld shovel and after collection, the scooped samples were transferred to Aluminum foil (or glass container), labeled and stored under refrigerated conditions and were thawed, oven dried at 40^0C and ground to a fine powder before analyses. PHc were isolated from the sediment samples by saponifying with methonolic KOH followed by extraction with hexane. Hydrocarbons were then separated using aluminum oxide (alumina) and estimated by Spectrofluorometer (excitation – 310 nm; emission – 360nm) as per the standard protocol. Total Organic Carbon (TOC) in sediment was estimated[10].

RESULTS AND DISCUSSION

Results of the 9 water quality parameters in the four study stations are shown in Annexure 2.1 and their description is given below for different parameters.

Plate 1: Map showing the study area at Vadinar coastal stretch



Water Quality

pH

Major fluctuation in the pH of the sea water will alter the chemical and biological milieu of marine environment drastically. Hence, pH is one of the best indicators to find out the zone of pollution in the environmental study. The pH of marine waters is usually quite stable and ranges between 7.5 and 8.5[11]. Water pH during this one year study varied from 7.3 (JBW-September, 2011) to 8.8 (N2-March, 2011) (Figure 1). Almost all the pH values recorded were within the limits except during March 2011. Recorded values are within the limit and did not show any abnormality. Similar pattern in pH was earlier reported[12] and it is stated that the higher value of pH during summer may be due to the uptake of CO_2 by photosynthesizing organisms.

Temperature

Temperature variation in coastal and estuarine system may influence the physico-chemical characteristics and distribution and abundance of flora and fauna. During the present study temperature varied from 20.5°C (SBW - February, 2011) to 32.2°C (PCW-May, 2011) (Figure 1). The temperature in the PCW station was high during May 2011 due to summer effect and shallowness of the water. In the present study, it was observed that highest temperature was noticed in the months of May and the lowest temperature in the months of February. Although the central Gulf is well mixed, GoK has two dynamic thermohaline systems which have relatively cold and high saline waters in eastern region and warm and less saline region in western region[13].

Petroleum Hydrocarbons (PHc)

Petroleum hydrocarbons are organic chemicals composed of fused benzene rings formed during incomplete combustion of coal, oil, petrol and wood. Main sources of oil pollution are from oil fields, oil refineries, loading-unloading and/or shipment activities. Oil is the major pollutant to the marine environment as the fate and effects of the PHc is of great concern for general wellbeing of the aquatic ecosystem. The present study for the past one year showed variation in the PHc from 0.1 µg/l (SSW-January, 2011) to 28.1 µg/l (PCW-May, 2011) (Figure 1).

The recorded values in the 4 stations were within the limit as prescribed by CPCB which is 100 µg/L. Generally, total hydrocarbon concentration in seawater can induce harmful effect on the aquatic organisms in the range of 50 µg /l and above which was not exceeded in any of the four stations in the present study. CPCB (2002) recorded value of 116 µg/l in Vadinar waters and Chouksey *et al*[14] recorded a PHc range of 2.9 – 39.2 µg /l in the Bassein-Mumbai location. Vethamony et al. [13] after analyzing 27 years of data showed the PHc concentration in the range of 1.0 and 16 *µ*g/l which is higher than the results recorded during present study.

Phenols

Phenols are of particular interest and concern in the marine environment as they are toxic to most aquatic organisms. The entry path for the phenolic compounds into the seawater is photosynthetic plants and industrial effluents. Monthly variation in the Phenols of the sea water samples was from 0.02 µg/l (SSW-March, 2011) to 52.1 µg/l (PCW-July, 2011) (Fig. 1). These phenolic compounds are mainly biogenic in nature and the anthropogenic input from any nearby sources are not envisaged.

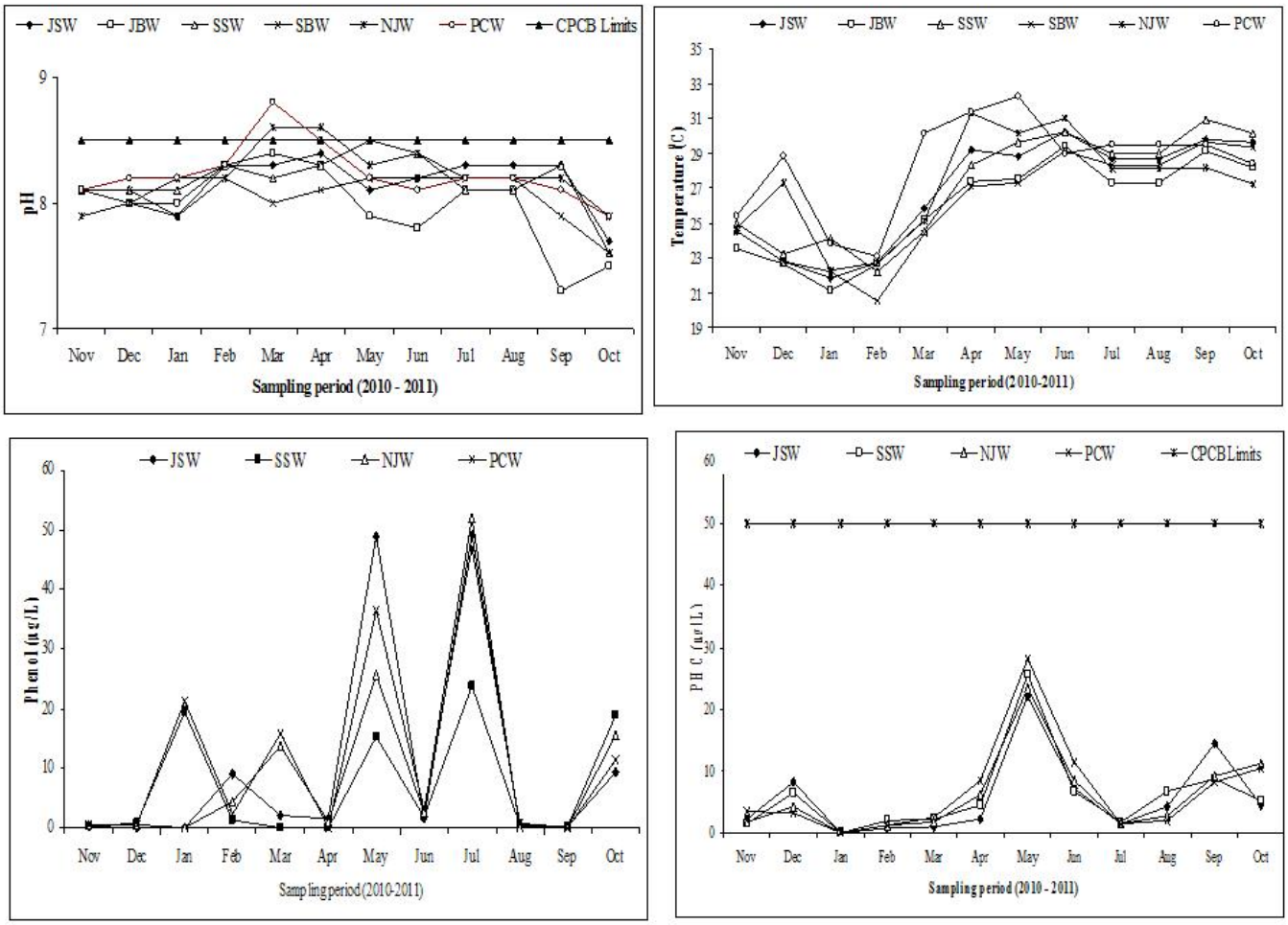


Figure 1: pH, Temperature, Phenols and Petroleum Hydrocarbon concentrations in the water samples during Nov 2010 - Oct 2011.

Dissolved Oxygen

Of all the dissolved gases in water, oxygen is the most important one for the survival of aquatic biota. Dissolved oxygen concentration varies mainly due to photosynthesis and respiration by plants and animals in water. Generally, the coastal waters are saturated with DO. This was also evident in the present study area. The monthly variation in the DO was from 2.8 mg/L (NJW-October, 2011) to 7.7 mg/L (PCW-November, 2010) (Figure 2). PCW station recorded significant fluctuations in DO due to the shallowness of water.

Comparatively higher dissolved oxygen concentration observed during the monsoon season of September 2011 and post-monsoon month of November 2010 might be due to the cumulative effect of higher wind velocity coupled with heavy rainfall and the resultant freshwater influx. Majority of the stations showed a homogenous distribution of dissolved oxygen with the exception of a sharp decline recorded at station N2 (2.1 mg/L). Other than this, the observed DO was above 5 mg/L conforming earlier results from east and west coast of India[16, 17, 18, 19, 20].

Biological Oxygen Demand

The BOD has the capacity to alter the species diversity at a particular environment if it increases beyond a limit. Input of organic matters from terrestrial sources will increase the BOD level. In the present study of one year, BOD levels in the study area varied from 0.2 mg/L (NJW-June, 2011) to 5.9 mg/L (PCW-May, 2011) as shown in Figure 2. Perceptible inverse relationship could be discerned between DO and BOD values during the study. BOD in all the stations in the first year recorded higher values during the month of August 2011. This could be due to microbial utilization of oxygen influenced by freshwater input[21]. Very high organic load would result in greater microbial decomposition and depletion of oxygen with high BOD values and eventually form a state of anoxia[22].

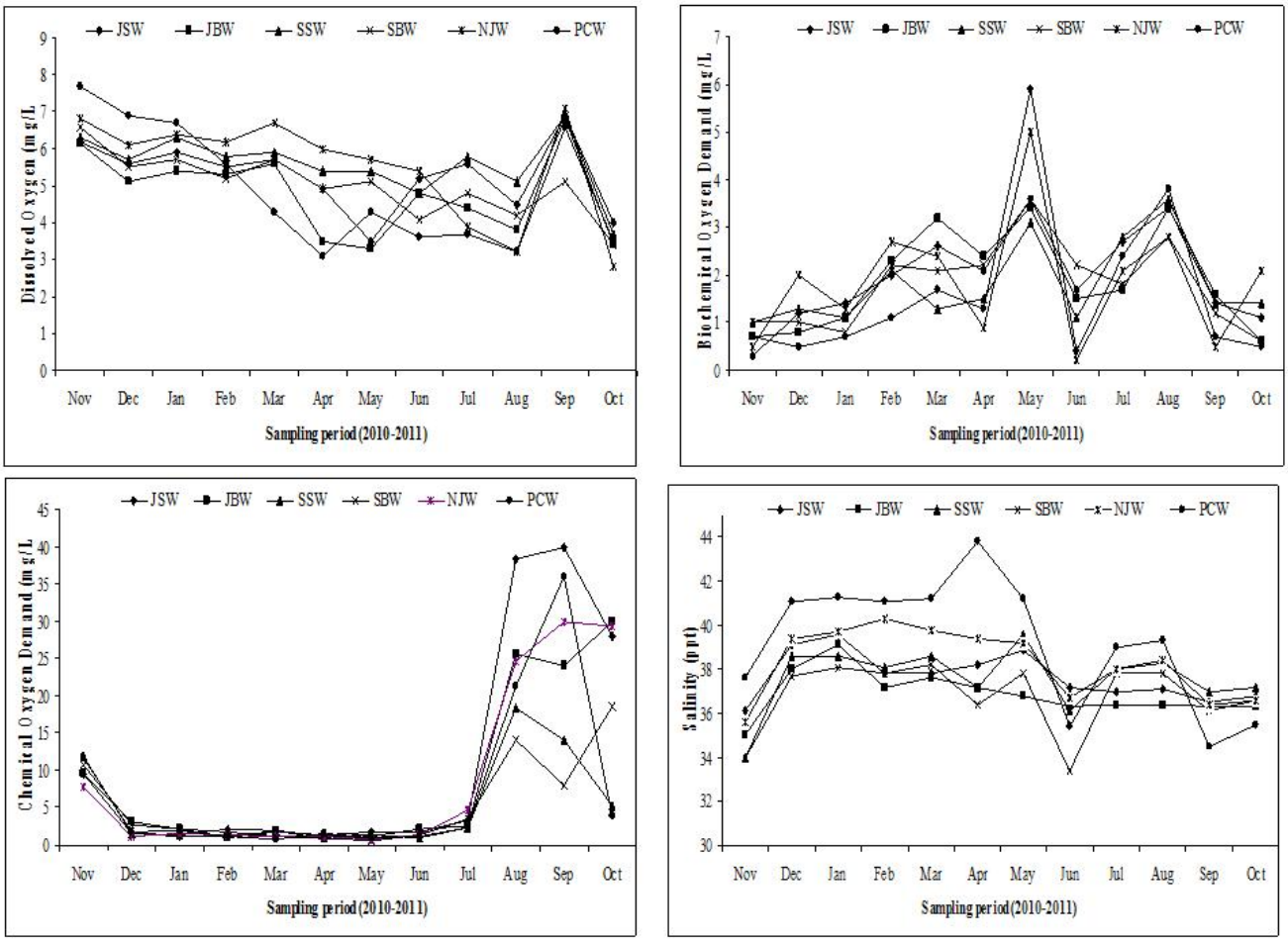


Figure 2: Dissolved Oxygen, Biochemical Oxygen Demand, Chemical Oxygen Demand and Salinity values in the water samples during Nov 2010 - Oct 2011.

Chemical Oxygen Demand (COD)

The amount of oxygen required to oxidize dissolved and particulate matter, called the Chemical Oxygen Demand (COD), is a practical measure of organic contamination. Chemical Oxygen Demand (COD) is a measure of oxygen requirement of a sample that is susceptible to oxidation by strong chemical oxidant. In the present study, the values of COD showed a maximum of 40 mg/L during September 2011 at JSW and minimum of 0.6 mg/L during May 2011 at SBW (Figure 2).

COD values were comparatively higher during August, September and October of 2011. Low chemical oxygen demand was due to increased mixing of domestic waste and fresh water influx into the coast and decreased biological activity due to decreased salinity and temperature[23, 24].

Salinity

Water salinity profoundly influences the abundance and distribution of the biota in coastal, marine and estuarine environments. In the present study, values of salinity showed maximum of 43.8 ppt during April 2011 in PCW and minimum of 33.4 ppt during June 2011 at SBW (Figure 2). The recorded higher values could be attributed to shallowness of water, low rainfall and high aridity of the region along with neritic water influence[25, 26]. Poor rainfall induced aridity in the Gulf of Kutch region renders Gulf waters hypersaline round the year. In addition GoK is known to be a negative water body where evaporation exceeds precipitation[13].

Total dissolved Solids (TDS)

The total dissolved solids (TDS) in water consist of inorganic salts and dissolved materials which mostly comprises of anions and cations. Sea water has a TDS content of approximately 35.0 mg/L. In the present study a maximum TDS value of 68.2 mg/L was recorded during November 2011 in PCW (Intertidal location) and minimum of 37.8 mg/L was during March 2011 in JBW. Similar value was reported in Saurashtra coastal waters[17] (Figure 3).

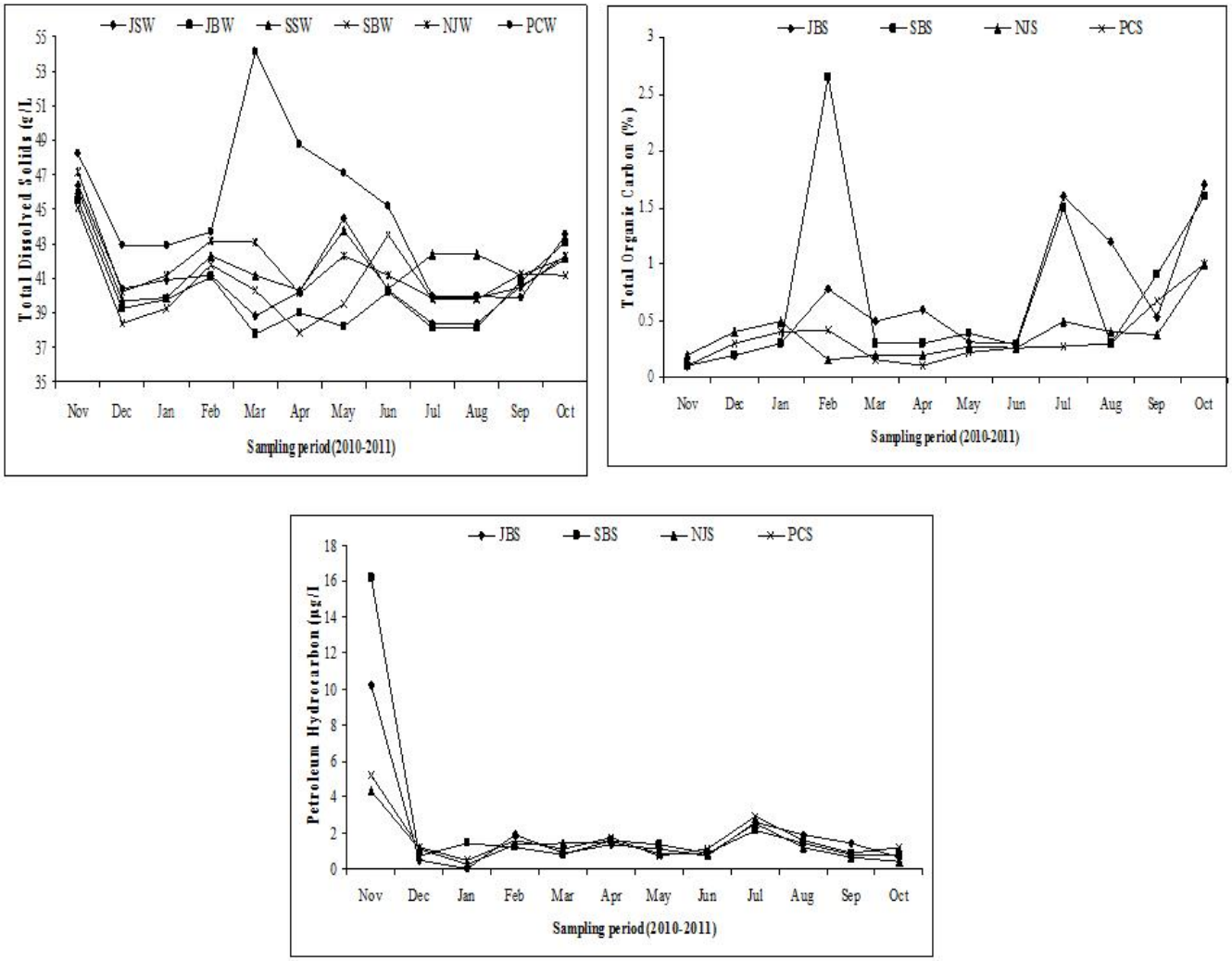


Figure 3: Total Dissolved Solids (Water), Total Organic Carbon and Petroleum hydrocarbon concentrations (Sediment) during Nov 2010 - Oct 2011.

Sediment Quality

Total organic carbon

Total organic carbon in sediment plays a major role in any aquatic system as it affects many biogeochemical processes. Total Organic Carbon (TOC) is the amount of carbon bound in an organic compound and is often used as a non-specific indicator of water quality. In the present study the values of Total Organic Carbon showed maximum of 2.65% during Feb. 2011 in SBS whereas, minimum of 0.1 % during Nov. 2011 was recorded in all the sampling points (Figure 3). Levels of TOC during July and October 2011 were also higher at SBS and JBS. Low organic content during the present study might be due to low bio-productivity, active hydrodynamics as well as granulometric composition of bottom sediments which are unable to accumulate organic carbon supplied from the water mass. Similar values observed by Saravanakumar et al[27].

Petroleum hydrocarbons

Petroleum hydrocarbons (PHc) in the marine environment originate from crude oils and other terrestrial sources. Petroleum hydrocarbon products are complex mixtures of chemicals. In the present study, values of PHc in sediment showed maximum of 16.2 µg/g (wet weight) during Nov. 2010 at SBS, whereas minimum of 0.2 µg/g during Jan. 2011 was recorded at NJS (Figure 3). Petroleum Hydrocarbons in estuarine and coastal system in and around Mumbai was reported to vary broadly from 0.9 to 107.7 ppm[14] which is far higher than the values recorded during the present study and the role of good flushing system of GoK, which is attributed to the strong directional tidal currents, in dispersing PHc contaminants has been observed by Vethamony et al.[13].

CONCLUSION

Monthly analysis of coastal water health through examination of 9 crucial water quality parameters for one year in Vadinar waters indicated that all the parameters were with in the normal values with few exceptions being pH (8.8). Important parameters like DO, BOD, COD, Phenols and PHc were either comparable with the other coastal waters or were well within the prescribed limits. Higher levels of salinity observed presently is apparently due to the aridity of the intertidal zone resulting in the high evapo-transpiration rates prevailing in Gulf of Kachchh waters. Similarly, values of PHc and phenol also indicated that the studied coastal waters are normal without any negative influence of ongoing industrial activities. Present values of sediment PHc represent only background levels and no gross sediment contamination in the study area is evident. As a whole, the present study results indicate no gross changes in water and sediment quality components due to operations of nearby industrial activities.

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