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GIS approach in assessing the status of neritic water quality and petroleum hydrocarbons in Bay of Bengal (From Chennai to Nagapattinam, Tamilnadu), India

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ABSTRACT

Neritic coastal water samples, collected onboard in Ocean Research Vessel (Sagar Purvi, NIOT) at a depth of 15m from the shore in August, 2010 at 15 coastal stations (opposite to the river mouths, fish landing centres and nuclear power station) stretching from Chennai to Nagapattinam, Bay of Bengal, Tamilnadu, were analysed for water quality parameters to find the impact of anthropogenic activities/sea based activities on the coastal water. Significant contribution from the present study reveals that the dissolved oxygen content in the neritic waters ranged from 1mg/l to 5.2mg/l which shows a decreasing trend from north to south direction. Kaliveli coastal water is highly polluted with petroleum hydrocarbon (1772.50ug/l) followed by Ponnaiyar river region, Cooum river region and Puducherry coastal area and the wind direction was found to be mostly towards Southwest and West. The higher concentration of petroleum hydrocarbons at Kaliveli coastal area gives a great concern because it is an important bird area, an important point for winter migrants like Storks (*Ciconia ciconia*) and crested pochards. There is a lack of awareness about ecological importance and protection of such wetlands among local people. The present study necessitates continuous monitoring and modeling of petroleum hydrocarbons along with prevailing hydrodynamic conditions in the coastal water which will be useful in improving the health status of marine environment, nearby wetland and associated biota.

Keywords: GIS, coastal water quality, petroleum hydrocarbons, wind direction, wetland importance.

1. Introduction

In Tamilnadu, India, the coastal area is blessed with back waters and estuaries. The biodiversity in the coastal water are significantly high. The coastal area is undergoing a rapid development stage of having new harbour, expansion of harbours, industrialization (small scale and large scale industries, power plant, oil exploration, tourism related activities etc) and other commercial activities in the coastal zone which not only degrade the quality of coastal water but also pose a serious health hazard to marine biota (Tran *et al*, 2002; Beiras *et al*, 2003). There is an urge to preserve, conserve and protect the coastal habitats and marine environment from all manmade activities. Marine pollution occurs mainly through marine operations (ship movements, fishing operations, boating activities, ship breaking activities, dredging etc); land based discharges from urban runoff and industrial activities etc. (GESAMP, 1993). The basic requirement in controlling the pollution is the generation of data on pollutant levels in the environment.

The petroleum hydrocarbons, Polycyclic Aromatic Hydrocarbons (PAHs) are organic pollutants and have a widespread distribution in the environment. When the PAH enter the marine environment, considerable portion of PAH gets distributed in the surface water before get accumulated in sediment and transferred to biota. Concentrations of about 16 PAHs, classified as priority pollutants by the US Environmental Protection Agency (USEPA) and the European Union are being investigated in sediments, soils, air particulates and organisms due to their mutagenic and carcinogenic properties (Norena-Barroso, *et al*., 1999). The pollutant may get dispersed; diluted or deposited owing to the dynamicity of coastal water and the level of pollution may vary from very low to very highly polluted nature. Hence it is imperative to have systematic monitoring program in the concerned area to have a clear insight into the pollution level; to find out the impact of human activities on the environment and the ways and means to combat the pollution. The present study is aimed at to find out spatial distribution of petroleum hydrocarbons and the status of neritic coastal water of Bay of Bengal, at a depth of 15m stretching from Chennai to Nagapattinam coast, Tamilnadu, India using GIS approach.

2. Materials and method

Coastal surface water samples at 15 coastal stations (opposite to the river mouths, fish landing centres and nuclear power station) from Chennai to Nagapattinam were collected onboard in Ocean Research Vessel (Sagar Purvi, National Institute of Ocean Technology [NIOT], Govt. of India) at a depth of 15m in August, 2010 (Fig.1 and Table 1). They were analyzed for water quality parameters like pH, temperature, dissolved oxygen, ammonia, nitrite, phosphate as per APHA (1995) and petroleum hydrocarbons to find out the impact of anthropogenic activities/sea based activities on the coastal water. The atmospheric temperature ranges from 27ºC to 30ºC and the rainfall is 900mm/year.

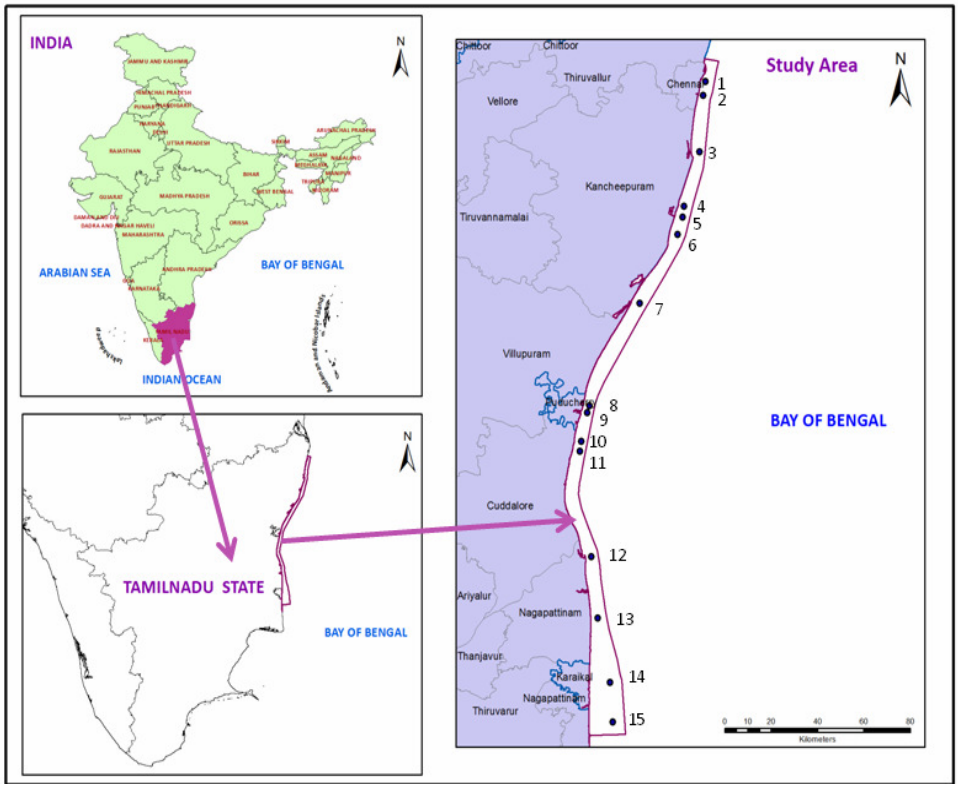

Figure 1: Sampling stations location (From Chennai to Nagapattinam)

Table 1: Details of sampling stations

Station name in the sea (opposite to)	Latitude	Longitude	Time of sampling (hrs)	Wind speed (m/hr)	Wind Direction
Cooum river	13'03"45	80'18"18	07.45	6.8	SW
Adyar river	13'00"50	80'17"65	08.45	6.0	W
Muttukadu	12'48"38	80'16"76	10.55	16.5	W
Mahabalipuram	12'36"76	80'13"23	13.15	Rain	SW
Kalpakkam port	12'34"33	80'12"91	13.55	Rain	SW
Kalpakkam town	12'30"65	80'11"75	14.50	Rain	SW
Kaliveli	12'15"86	80'02"86	18.30	8.2	SW
Puducherry	11'53"89	79'51"25	06.30	13.1	NW
Varahanadi river	11'52"37	79'50"67	07.20	6.7	W
Ponnaiyar river	11'46"25	79'49"25	08.30	Rain	W
Gadilam river	11'44"11	79'48"95	09.05	17.5	SW
Coleroon river	11'21"50	79'51"62	13.30	10.4	SW
Cauvery river	11'08"35	79'53"07	16.30	13.9	W
Nagapattinam	10'46"03	79'56"60	07.35	23.6	NW
Karaikkal	10'54"56	79'55"97	10.10	Rain	SW

The petroleum hydrocarbons were extracted from the coastal water by n-hexane. The fluorescence of the samples was measured in Fluorescence Spectrophotometer (F-2000 HITACHI) at 360nm as emission wavelength with 310nm as excitation wavelength (IOC, UNESCO, 1984). The Chrysene (Merck) was used as the standard reference. The data were integrated in ARCGIS spatial analyst/Inverse Distance Weighted (IDW) platform and the outputs are shown in the Figures 2-5.

3. Results and discussions

The general coastal water quality standards (swimming and aquatic life) for several parameters are specified in the Table 2 (Shanmugam *et.al*, 2006) and the results of the quality of the surface neritic coastal water in August, 2010 are shown in Tables 3,4 and in Figures 2-5.

In the present study, the pH of the surface coastal water varied from 9.5 to 10.2. The minimum and maximum coastal water temperature was found to be 27.3ºC and 28.8ºC respectively which may be due to the different times of sampling during the day. The lowest salinity value of 34psu was noted against the river regions (Adyar, Coleroon and Cauvery) and the highest salinity value of 37psu was at Kaliveli and Puducherry regions. The dissolved oxygen (DO) content in the coastal water ranged from 1mg/l to 5.2mg/l. The lowest DO (1.0mg/l) was in the Cooum river region showing the anthropogenic impacts on the coastal water and the highest concentration of DO (5.2mg/l) was at Kalpakkam port region. However, the Kalpakkam town had only 4.7mg/l of DO in the coastal water. To the south, still the DO concentration shows a decreasing trend and varied between 3.4 to 3.2mg/l (from

Puducherry up to Gadilam river region). Still down south, the region between Coleroon, Cauvery and Nagapattinam, the DO concentration fluctuated from 2.2 to 2.5mg/l showing the anthropogenic impact through the rivers on the coastal water.

Table 2: General coastal water quality standards (swimming and aquatic life)

Parameters	Standards
PH	7.8–8.3
Temperature (°C)	30
Odour	Unobjectionable
Turbidity (NTU)	10 NTU or less
Total Suspended Sediments (TSS)	25 mg L^{-1} or less
Dissolved Oxygen (DO)	4 mg L^{-1} or more
Biochemical Oxygen Demand (BOD_5)	30 mg L^{-1} or less
Chemical Oxygen Demand COD	250 mg L^{-1} or less
Total Coliform Bacteria	200 MPN / 100ml or less
Nitrate	10 mg L^{-1} or less
Nitrite	10 mg L^{-1} or less
Total Nitrogen	1 mg L^{-1} or less
Phosphorus as Phosphate PO_4^{-3}	0.1 mg L^{-1} or less
Chlorophyll-*a*	15 mg L^{-1} or less
Trace/toxic metals (Maximum Limit)	
Cadmium	0.01 mg L^{-1}
Lead	0.1 mg L^{-1}
Copper	0.02 mg L^{-1}
Nickel	0.01 mg L^{-1}
Zinc	0.1 mg L^{-1}
Iron	0.1 mg L^{-1}
Manganese	0.1 mg L^{-1}
Chromium	0.1 mg L^{-1}
Cobalt	0.005 mg L^{-1}

Table 3: Coastal water quality analysis (Chennai to Nagapattinam, August,2010)

Station Name	pH	Temp (ºC)	Salinity (psu)	DO (mg/l)
Cooum	9.6	28.3	36	1.0
Adyar	10.1	28.8	34	3.4
Muttukadu	9.8	28.7	35	4.9
Mahabalipuram	9.7	28.7	35	4.4
Kalpakkam port	9.9	28.2	36	5.2
Kalpakkam town	9.5	27.7	36	4.7
Kaliveli	9.5	28.2	37	4.3
Puducherry	9.6	27.3	37	3.4
Varahanadi	9.7	27.8	36	3.4
Ponnaiyar	9.6	27.8	36	3.4
Gadilam	9.7	27.9	36	3.2
Coleroon	9.7	28.2	34	2.3
Cauvery	9.9	28.5	34	2.5
Nagapattinam	10.2	27.8	35	2.3
Karaikkal	10.2	27.8	36	2.2
Minimum	9.5	27.3	34	1.0
Maximum	10.2	28.8	37	5.2

Table 4: Coastal water quality analysis (Chennai to Nagapattinam, August,2010)

Station Name	NH_3 (mg/l)	NO_2 (mg/l)	PO_4 (mg/l)	PHC (ug/l)
Cooum	3.0	0.25	0.20	64.00
Adyar	4.0	0.25	0.30	-31.80
Muttukadu	2.0	0.25	0.20	-68.88
Mahabalipuram	0.2	0.30	1.00	-56.10
Kalpakkam port	0.1	0.25	0.30	-58.22
Kalpakkam town	0.2	0.20	0.25	-43.10
Kaliveli	0.1	0.10	0.10	1772.50
Puducherry	2.0	0.25	0.15	14.00
Varahanadi	3.0	0.30	0.10	-56.00
Ponnaiyar	2.0	0.10	0.10	93.50
Gadilam	3.0	0.10	0.10	-14.60
Coleroon	0.2	0.25	0.10	-65.31
Cauvery	2.0	0.25	0.10	-39.10
Nagapattinam	0.1	0.25	0.10	-42.50
Karaikkal	0.2	0.25	0.10	-65.23
Minimum	0.1	0.10	0.10	14.00
Maximum	4.0	0.30	1.00	1772.50

The minimum and maximum concentration of ammonia in the coastal water was 0.1mg/l and 4.0mg/l. The highest concentration of ammonia was noticed in Adyar river region. Besides, the Cooum, Varahanadi and Gadilam river regions had a concentration of 3mg/l of ammonia in the water. The nitrite concentration varied from 0.1mg/l to 0.3mg/l. The Mahabalipuram showed a highest concentration of nitrite in the coastal water besides Varahanadi region. The concentration of phosphate fluctuated between 0.1mg/l and 1mg/l. The highest level of phosphate was again noticed at Mahabalipuram site which is a world renowned heritage, recreation and tourism site.

3.1 Petroleum hydrocarbons (PHC)

Oil was the first of the recognized "marine pollutants" which is to be controlled and regulated (GESAMP, 2007). Petroleum compounds have an adverse impact on the environment. The near shore areas are subjected to excessive contaminations not only by the anthropogenic inputs but also by the sea based activities (transportation, oil exploration and production etc). Vessels have a significant contribution by transporting these compounds in the marine environment (Anyakora *et al.*, 2005). Besides wind also plays an important role in dispersion of oil in the marine environment. In the present study, the wind speed varied between 6-23.6m/hr (light breeze to gentle, moderate and fresh breeze based on Beaufort's scale). The highest and lowest wind speed was noticed at Nagapattinam and Adyar river region respectively.

The petroleum hydrocarbons range in sediments in polluted coastal regions was found to be l00-12000ug/g while in unpolluted coastal basins was around 70ug/g (NAS, 1975). Nair *et.al* (1995) noted a high concentration of petroleum hydrocarbons in Cochin estuarine sediments that ranged from 249ug/g to 570ug/g. A high concentration of 39.2ug/l of PHC was noted in the coastal waters off Bassein-Mumbai (Chouksey *et.al*, 2004). However, the concentration

of petroleum hydrocarbons in the present study reveals a minimum of 14ug/l at Puducherry and a maximum of 1772.50ug/l at Kaliveli in the coastal water (Fig.6). Out of the fifteen stations sampled, only these stations i.e 1) the Coum river region, 2) Kaliveli region, 3) Puducherry region, 4) Ponnaiyar river region showed positive result for petroleum hydrocarbons. The wind direction was mostly towards shore i.e. Southwest (SW) and West (W). Wind generated surface waves are the principal source of energy input which might be reason for the higher concentration of petroleum hydrocarbon at Kaliveli region from nearby Ponnaiyar river region and Puducherry region.

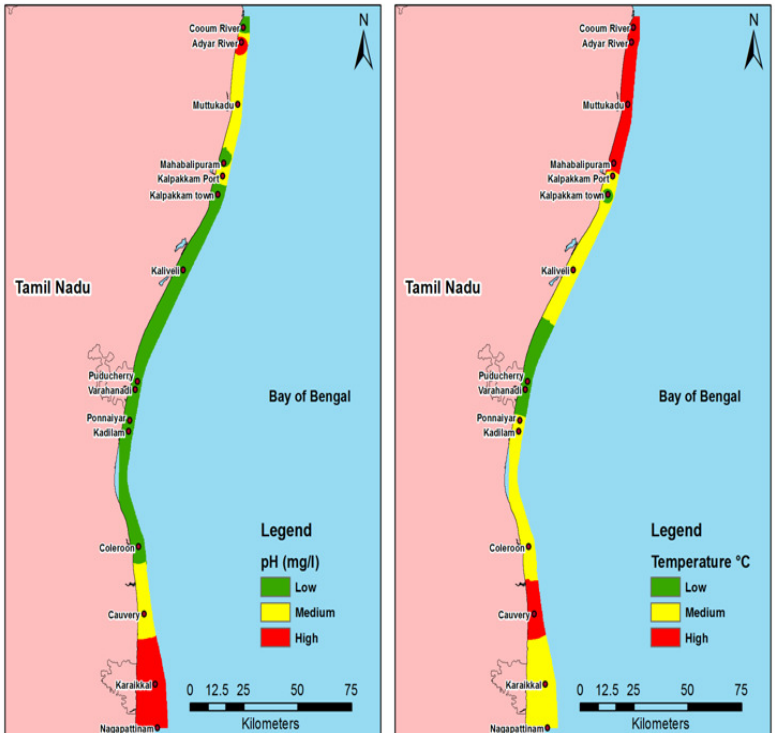

Figure 2: pH and Temperature of coastal water, August, 2010

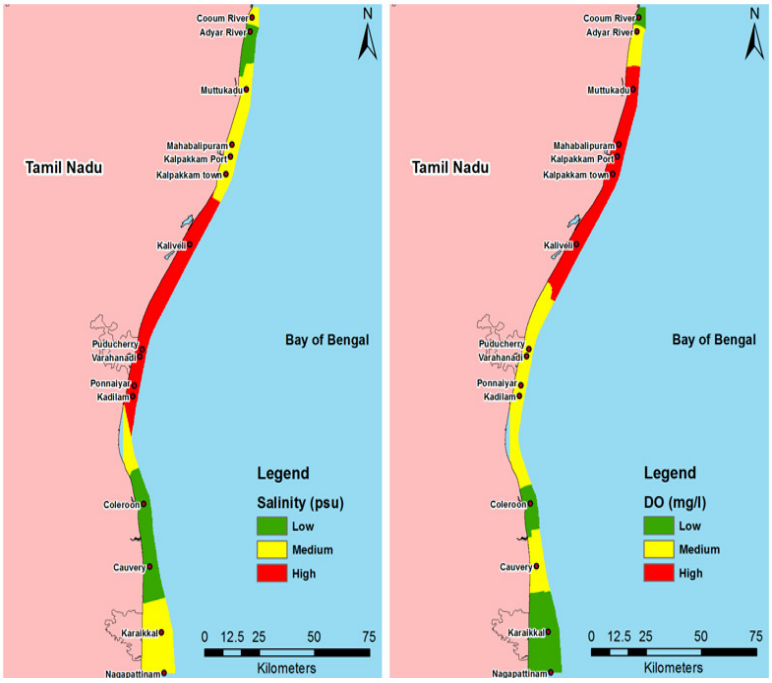

Figure 3: Salinity and DO of coastal water, August 2010

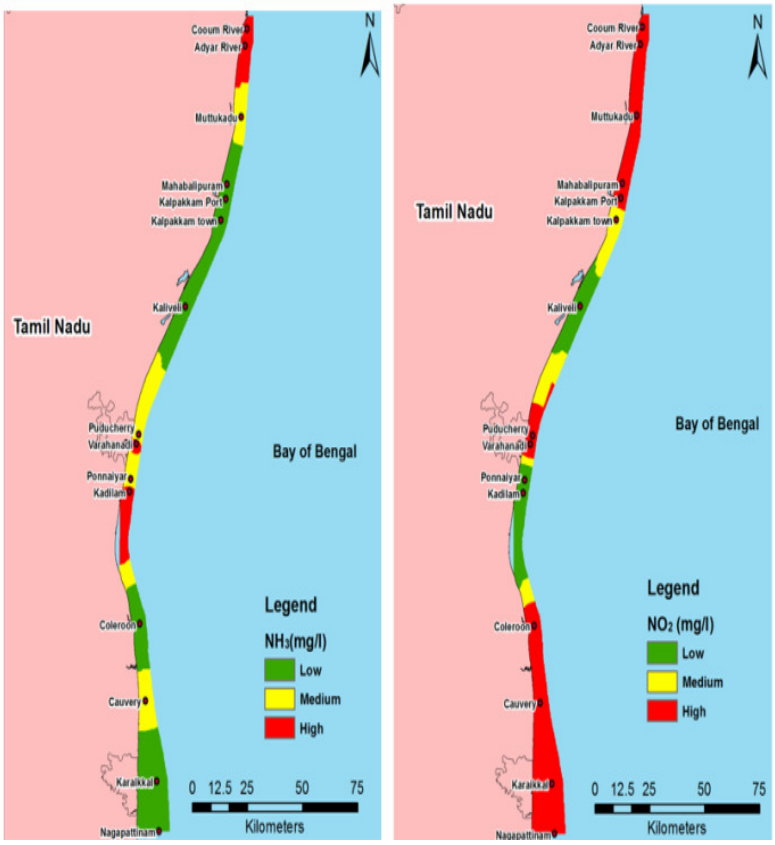

Figure 4: Ammonia and Nitrite in the coastal water, August 2010

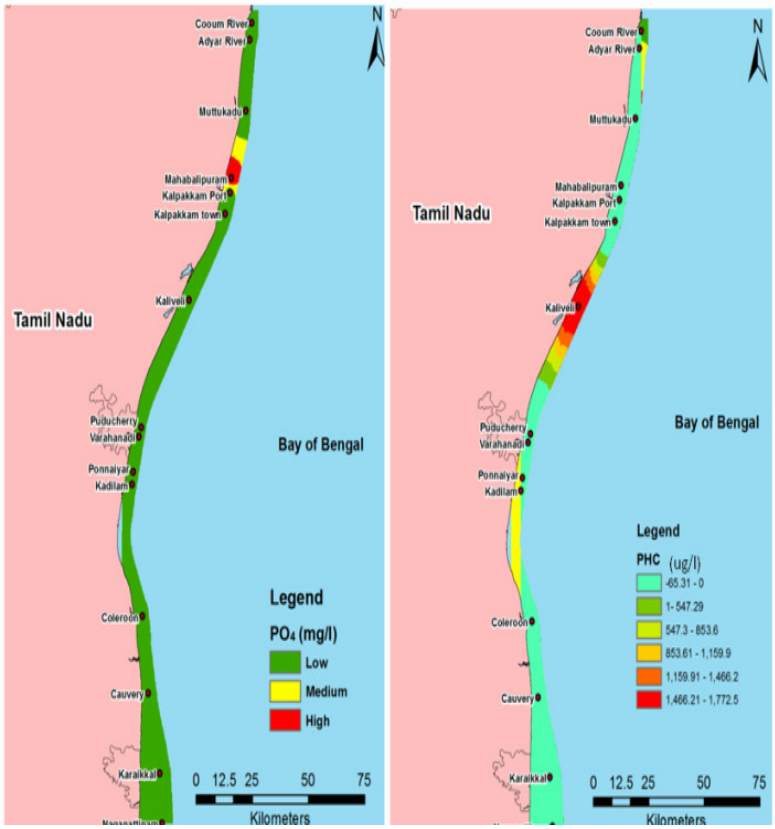

Figure 5: Phosphate and PHC in the coastal water, August 2010

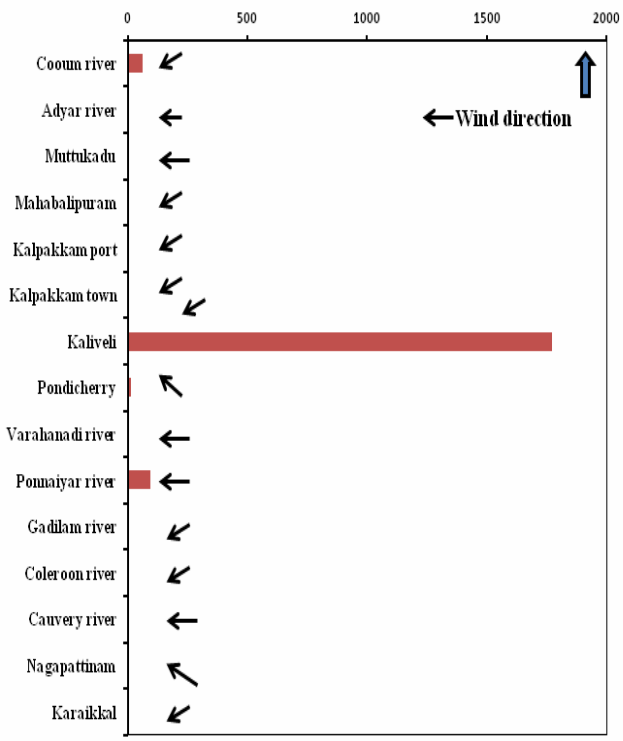

Figure 6: PHC concentration in neritic coastal water, Bay of Bengal (µg/l)

The petroleum hydrocarbons increase the risks to the surface and bottom dwellers through contamination (Nikolaou *et.al*, 2009, Veerasingam *et.al*, 2011a, Veerasingam *et.al*, 2011b). The hydrocarbon content of the Indian seafood ranges from 0.6 to 3.0 mg/kg of wet.wt. (Ramamurthy,1991) whereas, the PHC residues in the fish caught off Bassein-Mumbai showed a maximum concentration of 10.8ppm wet wt. (Chouksey *et.al*, 2004). In the present study, the higher PHC concentration in the waters at Kaliveli region gives a great concern, because the Kaliveli coastal lake which lies approximately 16 km north of Puducherry, is one of the largest wetlands in peninsular India, a wetland of both national and international importance by the IUCN. This has further been identified as one of the most seriously threatened wetland of substantial socio-economic and cultural value in India. Kaliveli is connected to the sea by Yedayanthittu estuary and has a good salinity gradient useful for a large array of water birds, amphibians, reptiles, mollusks and fishes. This area is classified as an important bird area, an important point for winter migrants like Storks (*Ciconia ciconia*). Besides the crested pochard, which is considered to be rare species in South India is found in thousands in Kaliveli Tank. These waterfowl arrive in late August and early September and depart in mid April after spending their winter in India.

4. Conclusion

The area adjacent to the sampling stations has a number of sensitive areas like bird sanctuary, historical sites and beaches. The present study reveals the facts that there is a decreasing trend in the concentration of dissolved oxygen from Kalpakkam onwards (5.2mg/l) down upto Nagapattinam (2.3mg/l) and the neritic coastal water at Kaliveli is highly polluted with petroleum hydrocarbons (1772.50ug/l) followed by Ponnaiyar river region, Coum river region and Puducherry region. The health of coastal environment and marine biota can be affected by low oxygen level and the petroleum hydrocarbons. Assessment of petroleum hydrocarbons along with various hydrodynamic conditions prevailing in this region are to be

modeled in detail and continuous pollution monitoring studies is useful for decision makers, coastal managers in improving the status of marine environment. There is also a lack of awareness among local people about ecological importance and protection status of Kaliveli wetlands which should be improved through socio-economic studies.

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