J. mar. biol. Ass. India, 1992, 34 (1 & 2) : 103-109

PHYSICO-CHEMICAL CHARACTERISTICS IN THE COASTAL ENVIRONMENT OF VISAKHAPATNAM — A CASE STUDY*

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ABSTRACT

Physico-chemical paramters such as salinity, temperature, pH, dissolved oxygen, biochemical oxygen demand, nitrite, ammonia, phosphate, silicate, chlorophylls and particulate organic carbon are monitored in harbour (4 stations) area and in coastal (9 stations) region over a period of one year. Temporal, vertical and horizontal variations of these parameters showed interesting results. The annual averages of nutrients, chlorophyll and particulate organic carbon of harbour area are found to be relatively higher when compared with those of coastal stations both at surface and bottom indicating a flow of organically rich pollutants from the harbour into the coastal region. This is also supported by a decreasing trend observed from harbour to the coastal region in the same transect. It can therefore be concluded from these studies that the harbour waters are polluted with nutrients and organic matter due to the discharge of industrial effluents and domestic sewage. These findings are in agreement with the earlier reports of mass mortality of fish, occurrence of phytoplankton blooms and eutrophication conditions in the harbour.

INTRODUCTION

SEVERAL reports appeared on hydrography (Varadarajulu and Tippu Abdul Khader, 1976), distribution of dissolved oxygen and nutrients (Ganapati *et al.*, 1956 ; Bhavanarayana and LaFond, 1957 ; De Sousa *et al.*, 1981 ; Sarma *et al.*, 1982), and plant pigments and particulate organic carbon (Radhakrishna *et al.*, 1982 ; Sasmal *et al.*, 1985) in coastal regions of Bay of Bengal. Most of the studies reported so far in harbour and coastal environment of Visakhapatnam are biological in nature (Ganapati and Rama Sarma, 1958 ; Ganapati and Subba Rao, 1959 ; Ganapti, 1969 ; Ganapati and Raman, 1973, 1976 a, b ; Premila and Umamaheswara Rao, 1977 ; Ganapati and Raman, 1979 ; Subba Rao and Venkateswara Rao, 1980 ; Raman and Ganapati, 1983). However, no systematic information is available on the concentration levels of several physico-chemical parameters and their interrelationships so as to assess the extent of chemical pollution in harbour and coastal waters of Visakhapatnam. This paper incorporates the results of our investigation on hydrography, nutrients, chlorophyll and particulate organic carbon (POC) in this region.

MATERIALS AND METHODS

Area of investigation and station locations are shown in Fig. 1 and 2. About 12×10^6 tonnes of cargo consisting of iron and manganese ores, fertilizers, rock phosphate, oil and petroleum products, food grains, coal, coke, etc. are handled through Visakhapatnam harbour (Visakhapatnam Port Trust, 1983-84). A major part of the city's sewage and most

* Presented at the 'Symposium on Tropical Marine Living Resources' held by the Marine Biological Association of India at Cochin from January 12 to 18, 1988.

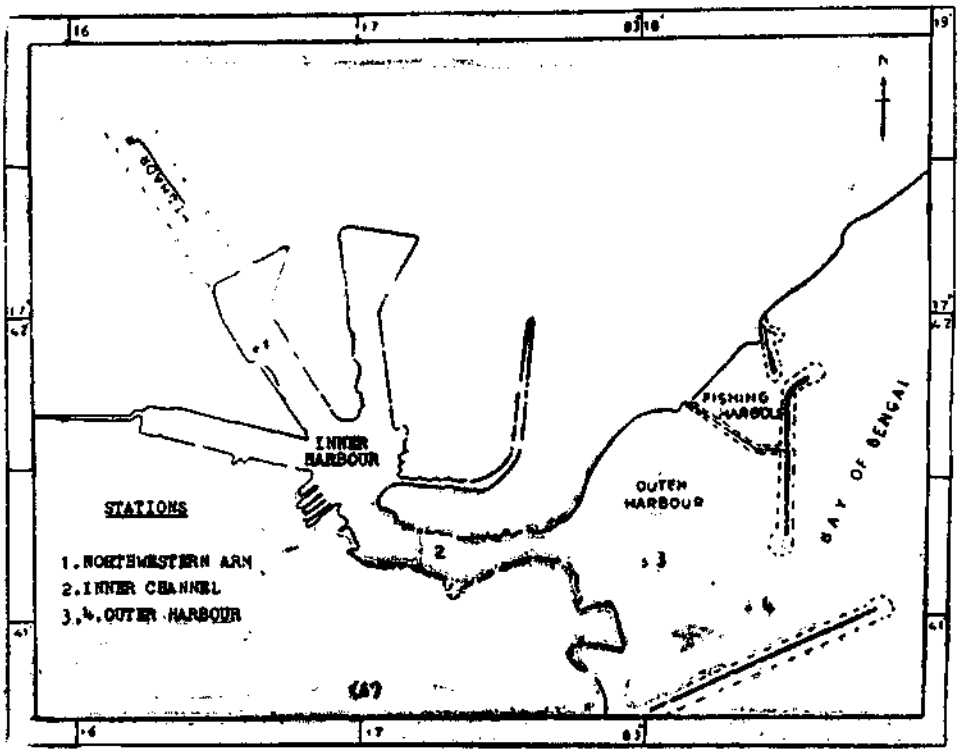

FIG. 1. Location of stations in Visakhapatnam Harbour area.

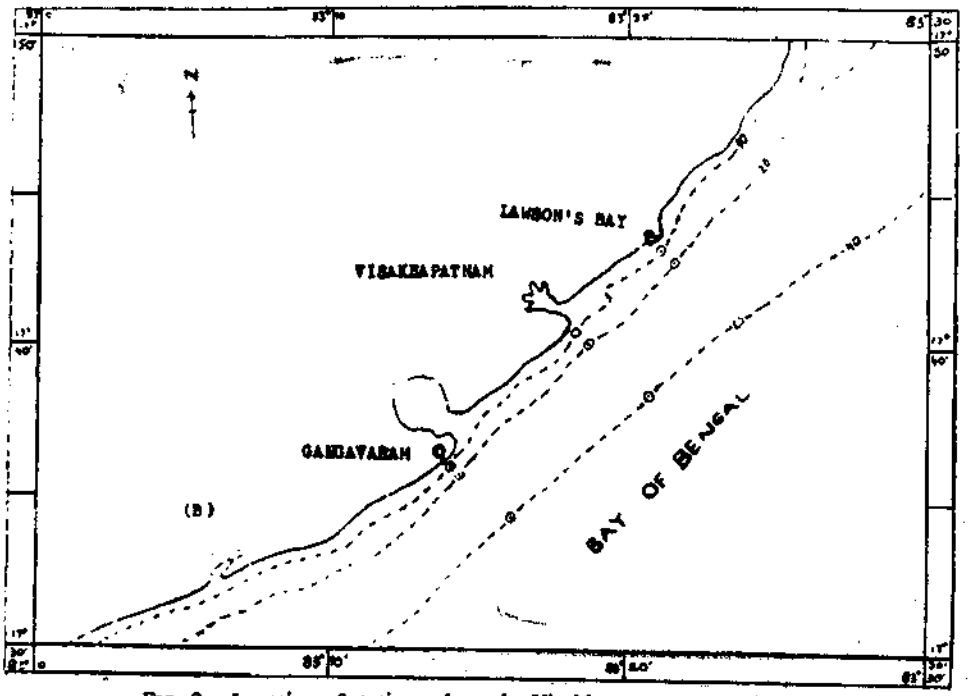

FIG. 2. Location of stations along the Visakhapatnam coastal area.

of the industrial effluents (of fertilizer complex, zinc smelter, petroleum refinery, etc.) are drained into the inner harbour through ' Meghadrigedda ' stream. Extensive low lying swampy areas with mangrove and scrubs vegetation are found bordering the north and northwest periphery of the harbour. The inner harbour is mostly a restricted area and has no effective means of flushing out the effluents into the open sea due to inadequate tidal flushing and near stagnant conditions prevailing in this area.

Water samples were collected once in a month both in harbour (Jan. - Dec. 1986) and coastal region (Sept. 1986 - Aug. 1987). Surface samples were collected with a clean plastic bucket and subsurface samples with the help of a Van-dorn Water Sampler.

pH of sea water was measured with a Toshniwal digital (Type CL 46) pH meter. The Chemical analysis was carried out employing standerd methods (Grasshoff, 1976 ; Strickland and Parsons, 1972).

Results and Discussion

Data on hydrography, nutrients, chlorophyll *a* and particulate organic carbon in both harbour and coastal waters (Tables 1, 2) revealed interesting results in temporal and spatial variation.

Both the horizontal and vertical currents in the Bay of Bengal have predominant influence on the chemical composition and seasonal changes of nutrients. From January to July the currents in this region flow in a general northeast direction and from August to December the flow is reversed. In addition, there is a vertical displacement of water near the coast. That is, during October and November a shoreward sinking motion is observed whereas in March and April this circulation is reversed and upwelling occurs. All these physical parameters together with the utilization of nutrients by organisms influence the chemical composition along Visakhapatnam Coast (Ganapati *et al.*, 1956).

Salinity and Temperature

Salinity showed an increasing trend from harbour to coastal waters and also from surface to bottom. Relatively low salinity in harbour waters can be attributed to the influx of industrial effluents and domestic sewage and the resultant dilution. It exhibited a gradual increase reaching its maximum in April-May followed by a decrease and reaching a minimum during October-November in both harbour and coastal waters. The low values during June-November can be attributed to the effects of SW and NE monsoons. A large vertical salinity gradient observed during the period of sinking (Oct.-Nov.) may be due to the combined effect of land drained from the prevailing monsoonal rains and the southerly flowing northern dilute waters which are having their influence not only on the offshore waters, but also in the coastal waters (LaFond, 1957 ; Varadarajulu and Tippu Abdul Khadar, 1976). Increase of salinity from January to May is due to the influx of highly saline Southern Bay of Bengal water when runoff subsides and the current reverses in January. This is further augmented by the upwelling of deeper and high saline water during March and April.

Temperature recorded relatively higher values in summer (May) and lower values in winter (December). The temperature maximum extends upto August and then decreases gradually reaching the minimum during Dec.-Jan. This can be inferred due to climatic changes. The surface water temperature are relatively higher than the bottom waters.

pH

pH showed an increasing trend from harbour to coastal waters. Relatively low pH in the inner harbour is due to the drainage of acidic

TABLE 1. *Seasonal variations of some physico-chemical parameters in harbour and coastal (surface) waters of Visakhapatnam*

Station	Season	Salinity (‰)	Temp. (°C)	pH	DO	BOD	NO_3-N	NO_2-N	NH_4-N	PO_4-P	SiO_4-Si	Chl.a	POC
					mg. lit^{-1}		μgat. lit^{-1}					$mg.m^{-3}$	$mg.Cl^{-1}$
LH.	A	31.04	29.4	7.59	9.35	17.90	33.00	6.44	52.10	56.00	42.10	37.90	2.86
	B	30.77	30.5	7.26	9.49	9.50	15.50	4.66	31.00	86.20	129.00	137.00	4.46
	C	20.50	27.5	7.39	6.55	6.13	35.40	5.80	38.90	173.00	97.70	112.00	3.38
	D	29.07	27.3	7.48	8.53	16.10	26.20	2.04	21.30	82.70	48.00	77.60	3.22
O.H.	A	31.44	29.0	7.91	6.94	7.30	19.40	1.48	17.00	14.00	17.60	7.94	2.94
	B	31.32	29.4	7.88	8.12	7.36	9.45	2.36	8.15	36.80	48.50	55.80	4.20
	C	22.83	27.9	7.83	3.12	4.61	25.10	1.81	42.00	45.60	40.10	35.90	2.53
	D	30.37	26.7	7.89	6.81	12.80	10.60	0.95	6.36	25.50	16.80	27.90	3.16
G.T.	A	31.68	26.4	8.08	4.53	..	8.87	0.46	4.63	0.33	10.80	2.46	1.33
	B	31.26	28.6	8.09	5.19	..	8.86	0.38	4.01	0.42	11.60	3.19	1.55
	C	26.50	28.3	8.11	5.47	..	6.92	0.61	4.29	1.71	10.70	2.82	1.43
	D	28.31	26.0	8.14	4.94	..	7.95	0.35	3.72	0.99	12.00	2.84	1.76
H.T.	A	31.66	26.7	8.09	3.93	0.56	11.70	0.90	8.58	1.91	9.41	3.14	1.48
	B	31.41	28.5	8.12	5.16	0.88	11.50	0.83	5.97	1.39	11.30	6.61	1.81
	C	26.39	27.6	7.97	5.26	0.68	8.27	1.02	5.51	3.09	11.00	1.63	1.56
	D	28.47	26.3	8.19	5.13	0.70	7.33	0.34	4.49	2.46	8.40	4.65	1.69
L.T.	A	32.42	26.7	8.09	4.31	..	9.08	0.48	4.22	0.48	9.07	1.79	1.30
	B	32.38	28.5	8.11	4.71	..	8.85	0.48	4.03	0.38	11.00	3.26	1.71
	C	26.69	28.0	7.93	5.36	..	9.87	0.17	4.77	1.55	9.28	2.52	1.38
	D	28.55	26.2	8.09	4.70	..	7.02	0.10	4.09	0.90	11.40	2.43	1.64

LH. = Inner Harbour. O.H. = Outer Harbour. G. T. = Gangavaram Transect. H.T. = Harbour Transect.
L.T. = Lawson's Bay Transect. A = Premonsoon. B = SW Monsoon. C = NE Monsoon. D = Postmonsoon.

TABLE 2. *Annual average of physico-chemical parameters in harbour and coastal waters of Visakhapatnam*

Station	Depth (m)	Salinity (‰)	Temp. (°C)	pH	DO	BOD	NO_3-N	NO_2-N	NH_4-N	PO_4-N	Si O4-Si	Chl-a	POC
					mg. lit^{-1}		μg at. lit^{-1}					$mg.m^{-3}$	mg.C. $lit.^{-1}$
I.H.	S	29.20	28.9	7.42	8.72	12.70	25.90	5.47	39.20	92.30	82.20	82.20	3.57
	10	31.26	27.9	7.74	4.96	6.45	14.70	3.23	24.60	38.30	41.60	10.40	3.25
O.H.	S	30.39	28.4	7.88	6.66	8.24	14.80	1.70	15.60	29.80	31.30	33.50	3.35
	20	31.68	27.6	8.02	5.77	5.53	10.70	0.68	9.33	8.52	22.30	4.19	3.15
G.T.	S	30.17	26.9	8.10	5.01	..	9.22	0.43	4.17	0.83	12.50	2.85	1.55
	40	31.76	26.0	8.12	4.21	..	10.10	1.26	4.31	1.70	12.70	1.16	1.38
H.T.	S	30.57	27.0	8.11	4.86	0.72	9.24	0.76	6.17	1.99	9.40	4.42	1.69
	40	32.68	26.1	8.09	4.71	0.51	7.96	0.82	5.56	1.59	13.50	0.83	1.52
L.T.	S	30.48	27.3	8.07	4.71	..	9.52	0.37	4.20	0.83	9.62	3.24	1.57
	40	32.37	26.7	8.05	4.26	..	8.64	0.82	3.99	2.06	16.70	1.16	1.38

I.H. = Inner Habour. O.H. = Outer Harbour.
G.T. = Gangavaram Transect. H.T. = Harbour Transect.
L.T. = Lawson's Bay Transect. S = Surface

effluents from fertilizer and zinc smelter units through the 'Meghadrigedda' River that finally joins with the northwestern arm of the harbour. While the pH increases from surface to bottom in the harbour, it showed a decreasing trend with depth in coastal waters. The decrease in pH in coastal waters may be attributed to an increase in ΣCO_2 because of oxidation of organic matter in the water column.

DO and BOD

The surface water in harbour, in general, is super saturated with dissolved oxygen, because of the occurrence of several planktonic blooms (Ganapati and Raman, 1979). A steady increase in oxygen concentration during July to November may be attributed to the influx of considerable volumes of Northern Indian river waters (Ganapati and Subba Rao, 1967). Relatively high value of DO in harbour when compared with the coastal waters are attributed to intense photosynthetic activity occurring in the harbour which is also supported by relatively higher values of chlorophyll. Comparatively lower values of DO in coastal waters may be due to offshore divergence (Satyanarayana *et al.*, 1987). Lower values of DO at the bottom can be attributed to the consumption of oxygen for the oxidation of organic matter.

BOD showed a gradual decreasing trend from harbour to coastal region. The magnitude of BOD values (5.53 - 12.70 mg. lit^{-1}) in general indicate moderate pollution in the harbour. Relatively higher BOD and DO values in surface waters indicate eutrophication conditions wherein high concentrations of domestic sewage and industrial wastes are associated with high plankton growth.

Nutrients, Chlorophyll and POC

The concentration of nitrogen compounds (NO_3-N, NO_2-N, NH_4-N) are, in general, relatively higher during pre-monsoon/monsoon and lower during postmonsoon seasons. However, PO_4-P, SiO_4-Si, Chlorophyll *a*, and POC exhibited maximum during monsoon and minimum during premonsoon seasons. This may be probably due to the combined effect of the upwelling in premonsoon and intense precipitation and land drainage in monsoon seasons.

It is interesting to note that while all the nutrients showed relatively higher concentrations in surface in the harbour, they exhibited relatively higher concentrations in bottom in coastal waters. Surface enrichment and bottom depletion of nutrients in the harbour waters can only be attributed to the discharge of domestic sewage and industrial effluents. Chlorophyll and POC exhibited relatively higher concentrations in surface when compared with the bottom waters of harbour and coastal region.

While salinity and pH exhibited an increasing trend, temperature, DO, BOD, nutrients, chlorophyll and POC showed a decreasing trend from harbour to coastal region. The concentration levels of nutrients, chlorophylls and POC are relatively higher in harbour transect when compared with the Gangavaram and Lawson's Bay transects in the coastal Region. The horizontal decrease in concentration levels of nutrients, chlorophylls and POC from inner to outer and harbour transect in the study region clearly indicates the discharge of the pollutants in the harbour and their gradual dispersion in the coastal region.

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