Indian Journal of Marine Sciences
Vol. 16, December 1987, pp. 218-222

Variation of Physico-Chemical Characteristics with Tide in Visakhapatnam Harbour Waters, East Coast of India

V S RAMA RAJU, V V SARMA, T V NARASIMHA RAO & R VIJAYA KUMAR
National Institute of Oceanography, Regional Centre, Andhra University Campus, Visakhapatnam 530 003, India

Received 16 *October* 1986; *revised received* 25 *May* 1987

Variations in physico-chemical parameters (DO, BOD, NO_2, SiO_4, PO_4, suspended solids, salinity and currents) observed in the waters of main channel of Visakhapatnam Harbour over a tidal cycle in different seasons from Feb 1982 to Jan 1983 are presented. In general, tidal variations in these parameters in surface waters show increasing trend during flood tide and decreasing trend during ebb tide. However, the nutrient concentrations at st C (entrance channel) show the reverse trend. The wide fluctuations in physico-chemical parameters at st A (northwestern arm) may be attributed to the closeness of the station to the discharge point of industrial pollutants. No significant variation is found during a tidal cycle in bottom water. Variations in wind during different seasons influence the current speeds in addition to tide in the Visakhapatnam harbour. The net cross sectional discharges through the mouth of harbour into the sea during premonsoon, monsoon and postmonsoon seasons are 26.51, 47.30 and 19.64 $m^3 s^{-1}$ respectively.

The nature of pollutants discharged and the main features of topography of the Visakhapatnam Harbour have been described earlier[1]. The impact of pollution on the quality of water in this harbour has been studied[2] but no information seems to be available on the variation of physico-chemical parameters with the tide. The present study has been undertaken mainly to understand this aspect and to calculate the net discharge of pollutants through the harbour mouth.

Materials and Methods

Visakhapatnam harbour (Fig. 1) extends 4 km from the northwestern arm to the outer harbour which is connected to the open sea through the entrance channel. Industrial effluents are discharged into the harbour through the northwestern arm and domestic sewage joins the harbour through south lighter canal at the turning basin. Water samples were collected at monthly intervals from sts A, B and C along the main channel of the harbour (Fig. 1). Surface samples were collected with plastic bucket and bottom ($\approx$ 10 to 15 m) samples with Niskin bottles. Collections were made at 2h intervals over a tidal cycle, once monthly from Feb. 1982 to Jan. 1983. Current measurements were also made at these stations as well as at the harbour mouth (st D). Digital current meter (NIO, Goa) was used for current measurements at surface, 5m and near the bottom (10 to 15 m) over a tidal cycle at 1h interval. Standard analytical methods[3] were used for the determination of salinity, dissolved oxygen (DO), nitrite, phosphate and silicate. For the determination of nutrients, the samples were diluted with deionised water. Suspended solid was determined by filtration using Whatman filter paper No. 42 and BOD by the direct method.

Results and Discussion

April, August and November are chosen to represent premonsoon, southwest monsoon and postmonsoon seasons respectively. Variations in physico-chemical parameters during a tidal cycle at sts A, B and C are given in Fig. 2. Monthly variations of these parameters are shown in Fig. 3 by taking the average values for entire tidal cycle.

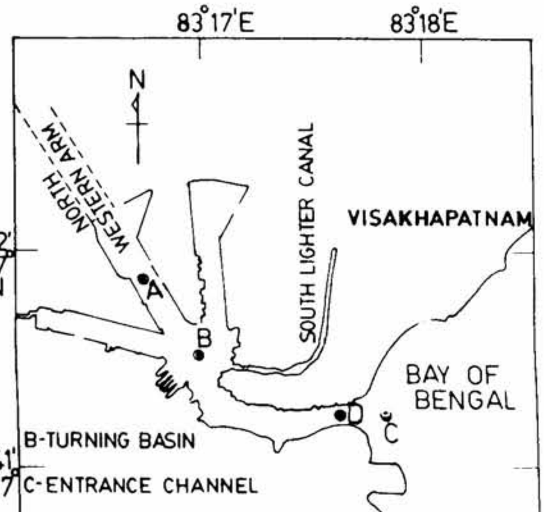

Fig. 1 — Station location map

Dissolved oxygen — Significant fluctuations in DO values of surface water with tide are seen at different stations. Surface DO increases with flood tide and decreases with ebb tide. The high concentrations (supersaturated values) of DO in surface waters indicate the prominance of plankton production[4] over the other factors such as incursion of seawater during high tide and fresh water flow during southwest monsoon season. The low DO values at sts B and C during low tide support the earlier conclusion[2] that highly polluted water flows towards the sea during the ebb period. The change in DO concentration at sts B and C during a tidal cycle in the monsoon season is not significant (1 $ml.l^{-1}$) probably due to the increased turbulance and mixing. Wide fluctuations are noticed at st A due to the closeness of the station to effluent discharge points. It is reported earlier that DO content of both bottom and surface of the sewage receiving waters in Cochin backwater[5] was always fluctuating due to availability of decomposing materials. However, the tidal fluctuations in DO concentrations of bottom water are not

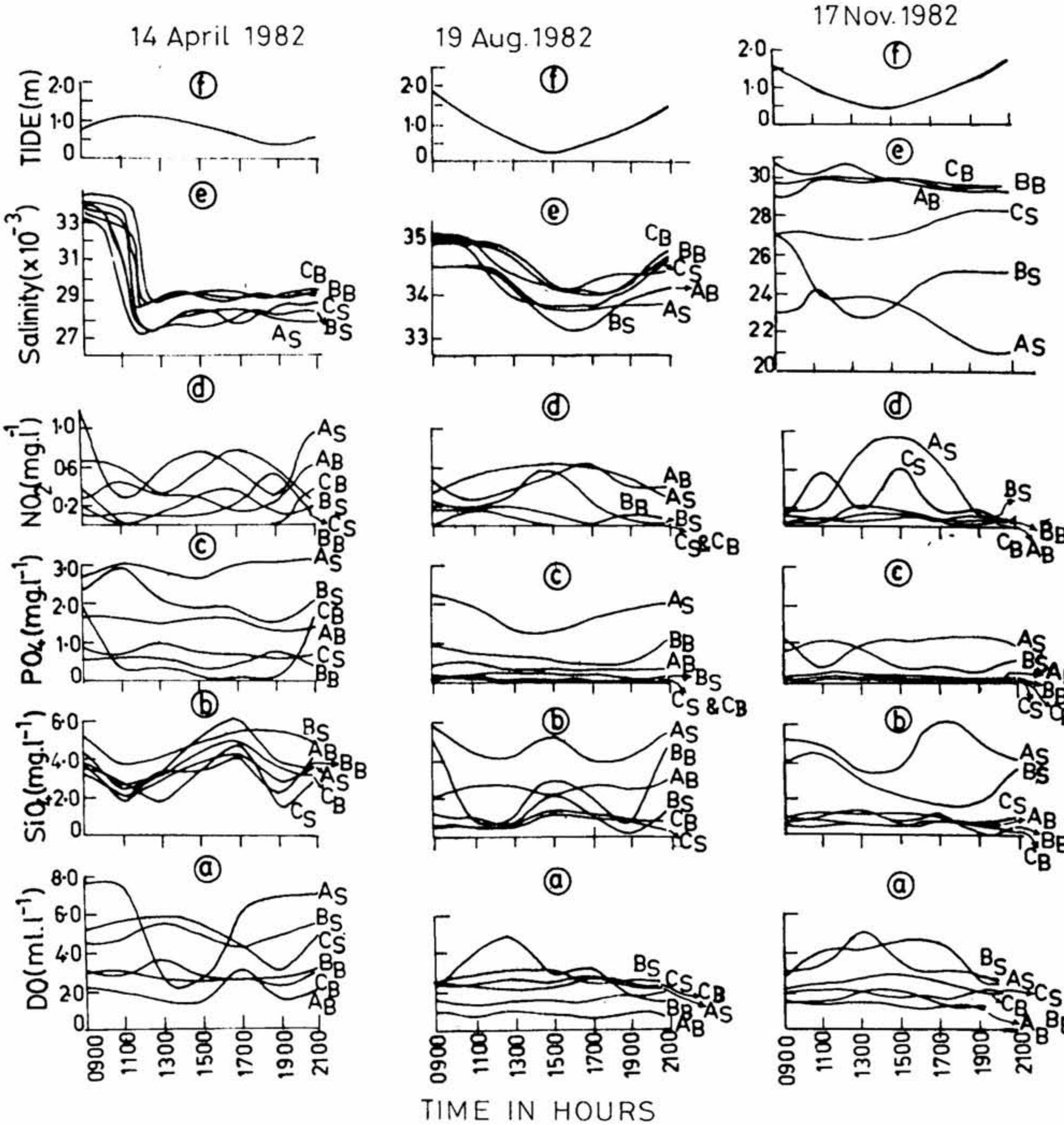

Fig. 2 — Physico-chemical parameters in relation to tide (A, B, C — stations; S — surface; B — bottom)

significant. The difference in DO values (2-4 $ml.l^{-1}$) between surface and bottom at all stations is appreciable in the premonsoon and postmonsoon seasons whereas the difference is < 1 $ml.l^{-1}$ in southwest-monsoon season. Lowest DO concentrations in the bottom water (1.5-2 $ml.l^{-1}$) are found during premonsoon season when the combined effect of high temperature and rapid decomposition of organic matter occurs[6]. This agrees with the results reported earlier for the premonsoon months at Visakhapatnam harbour[1] and Cochin backwaters[5]. In the coastal waters off Bombay[7] it is reported that decrease in DO may be due to combined effect of temperature, photosynthetic action and biochemical oxidation of wastes entering the marine environment. DO supersaturated values (100-120%) at sts A and B in the postmonsoon season indicate the prominance of phytoplankton production during this period[5].

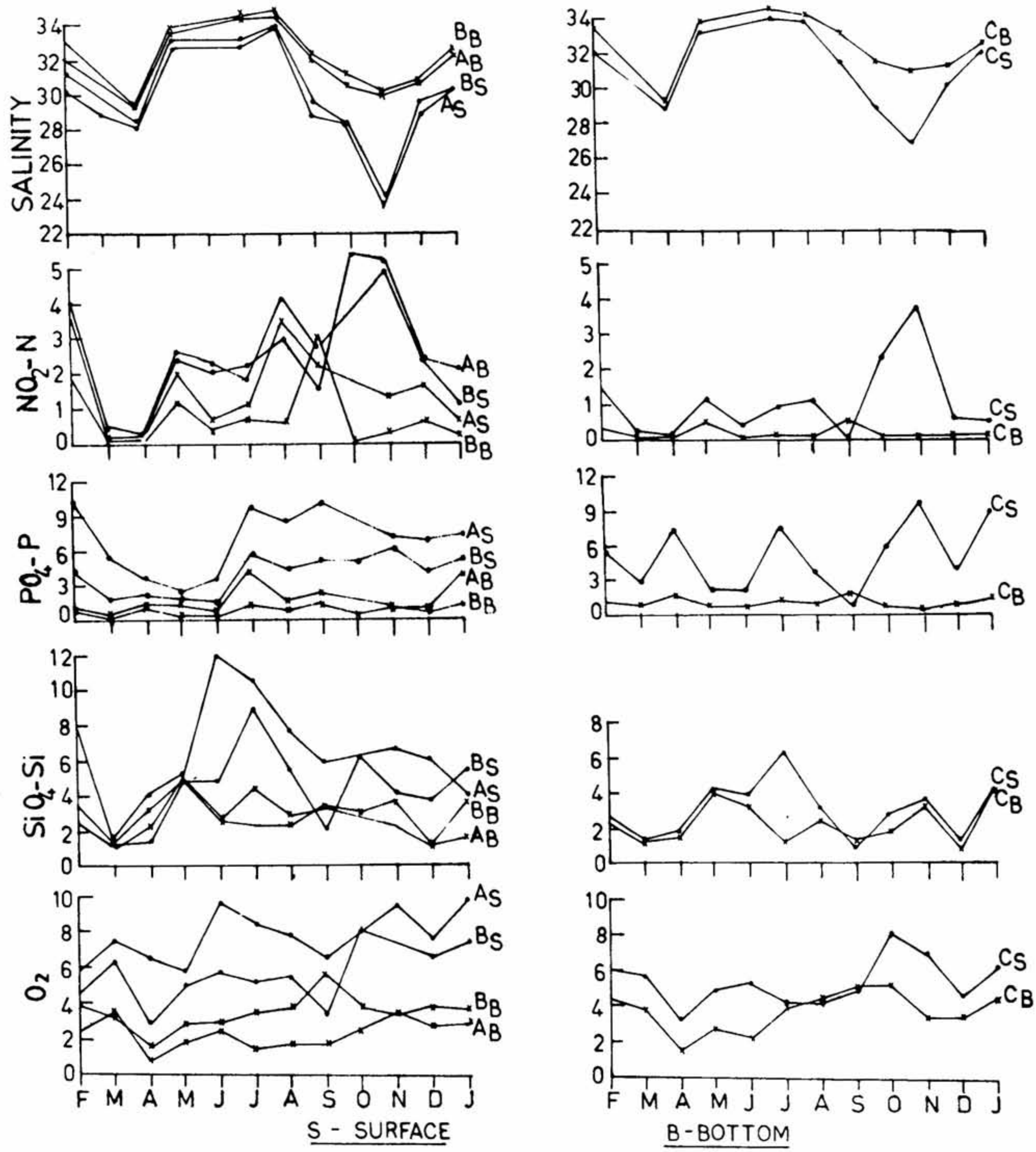

Fig. 3 — Monthly variations of physico-chemical parameters at different stations

Biochemical oxygen demand — No marked variation is noticed in BOD values during the high tide and low tide. High values of BOD (6-8 $ml.l^{-1}$) and DO values at sts A and B indicate the eutrophic conditions in the harbour water. Low values of BOD at st C (2-4 $ml.l^{-1}$) indicate the remarkable dilution and dispersion of these pollutants.

Nutrients — Concentrations of all nutrients (NO_2, PO_4 and SiO_4) in surface water showed variations with tide (Fig. 2). The values of phosphate decrease during the ebb tide and increase during the flood tide at sts A and B. On the other hand, though no pronounced variation is found during the tidal cycle, the concentration of phosphate-P in surface waters at st C (Fig. 2c) indicates increasing trend with the low tide and decreasing trend with flood tide. No significant change in phosphate concentration is noticed with the tide in bottom water. Nitrite and silicate also show more or less the same trend as that of phosphate indicating that the effluent mixed high nutrient water moves with the tide mostly in the surface layer.

In general, the surface values of these nutrients are very much higher than the bottom values (Fig. 3) except in August. Increased mixing of water caused by the increased wind and wave action in August explains the more or less uniform values of nutrients from surface to bottom. Seasonal variation of these nutrients (Fig. 3) shows 2 major peaks in April and November concomitant with 2 plankton peaks reported by Ganapati and Raman[4] and in turn possibly related to the insolation during different seasons. The peak in August is possibly due to the land run off which brings domestic sewage and industrial effluents into the harbour water.

Suspended solids — The limited data available from August to January for the suspended solids indicate an increase in the values from the southwest monsoon (av. 36.1 $mg.l^{-1}$) to postmonsoon season (av. 61 $mg.l^{-1}$). High values of suspended solids in postmonsoon season may be partly due to the increased dredging operations carried out in the harbour and high biological production.

Salinity — Surface salinity (Fig. 2e) increases with flood tide and decreases with the ebb tide indicating the influence of effluent mixed water in the harbour channel. At st A the large fluctuations (27.3-33.6 $\times 10^{-3}$) in surface salinity values noticed are probably due to the closeness of station to the outfall of industrial effluents into the channel. Tidal variations at st C during premonsoon season reveal that the surface salinity changed from 28.5×10^{-3} at ebb tide to about 32.5×10^{-3} flood tide.

Salinity at st A is lower (Fig. 3) than that of the other 2 stations during all months. The average salinity gradient between surface and near bottom is 0.3×10^{-3} m^{-1} during postmonsoon and $0.1 \times 10^{-3} . m^{-1}$ during premonsoon season. The salinity gradient is negligible ($0.03 \times 10^{-3} . m^{-1}$) during southwest monsoon indicating well mixed conditions. The high vertical gradient found in the harbour water during postmonsoon season is possibly due to the presence of the inflow of the southerly flowing diluted water along the shore of Visakhapatnam from the Head of the Bay[8] coupled with the local rainfall (682 mm during Oct. and Nov. 1982) and surface run off.

Currents — The depth mean maximum current speeds observed at st A during the period of observation (Feb.-Dec. 1982) both for flood and ebb currents range from 7-24 $cm. sec^{-1}$. At st B, the current speeds range from 10—23 $cm. sec^{-1}$ in ebb tide and 9-26 $cm . sec^{-1}$ during flood tide while at st C, these values vary from 12-13 $cm. sec^{-1}$ in ebb tide and 12-26 $cm. sec^{-1}$ in flood tide. At st D (mouth of the harbour) the current speed varies between 10 and 25 $cm. sec^{-1}$ in ebb tide and 9 and 28 $cm. sec^{-1}$ during flood tide. In general the highest ebb and flood currents (23, -24 $cm. sec^{-1}$ at st A; 19, -20 $cm. sec^{-1}$ at st B; 30, -26 $cm. sec^{-1}$ at st C; and 22, -28 cm. sec^{-1} at st D respectively) are noticed during July under the combined effect of wind, tide and surface run off. Agarwala[9] reported that the mean monthly wind velocity is maximum during July (4.1 $m.sec^{-1}$) at Visakhapatnam with mean resultant direction 229°. Apparently the variation in wind during different seasons has considerable influence on the current in addition to the tide in the Visakhapatnam harbour.

An attempt has been made to compute the net cross sectional discharges through the harbour mouth as per the procedure given by Kjerfve[10]. The current values at st D are used for this purpose. The ebb flow is considered as positive and flood flow as negative. The currents at st D are averaged for each hour of observation vectorially to get the time varying depth averaged velocity. This averaged velocity is then cross correlated with the water depth during the same hour of observation and averaged to obtain the net discharge per unit cross sectional width ($m^2 . s^{-1}$) normal to cross section at st D. Thus the total net cross sectional discharges ($m^3 . s^{-1}$) through the mouth of the harbour are 26.51, 47.30 and 19.64 during premonsoon, monsoon and postmonsoon seasons respectively. The maximum discharge observed in monsoon leads to increased flushing of the effluents introduced into the harbour.

Acknowledgement

The authors wish to express their gratitude to

Dr. B N Desai for his keen interest in these studies. Thanks are also due to Mr S Kannan and Mrs A Syamala for their technical assistance.

References

1 Ganapati P N & Raman A V, *Curr Sci*, **42** (1973) 490.
2 Sarma V V, Raju G R K & Bose Babu T, *Mahasagar-Bull* Natn Inst Oceanogr, **15** (1982) 15.
3 Anon, *Manual of methods in aquatic environment research*, Fisheries Technical Paper No. 137 (1975) 135.
4 Ganapati P N & Raman A V, *Indian J Mar Sci*, **5** (1976) 251.
5 Vijayan M, Ramani K N & Unnithan R V, *Indian J Mar Sci*, **5** (1976) 196.
6 William R E, *Engng Bull Purdue Univ*, **47** (1963) 733.
7 Zingde M D, Trivedi S K & Desai B N, *Indian J Mar Sci*, **8** (1979) 271.
8 LaFond E C, *Proc Indian Acad Sci*, **46** (1957) 1.
9 Agarwala K S, *Indian J Met Geophys*, **4** (1953) 76.
10 Kjerfve B, in *Estuarine hydrography and sedimentation*, edited by K R Dyer (Cambridge University Press, Cambridge) 1979, 186.