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DIURNAL VARIATION OF SOME PHYSICO-CHEMICAL FACTORS IN COCHIN BACKWATER DURING SOUTH WEST MONSOON

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Abstract

Major changes in the hydrobiological conditions of Cochin Backwater are controlled by the tidal movements and also by the amount of freshwater discharged into the system during the S. W. Monsoon. Whereas the salinity changes are affected mostly by the tidal incursions, those of temperature and oxygen are influenced by tide and time of the day. The oxygen values are found to remain undersaturated during monsoon period. This may be due to the utilisation of oxygen for the decomposition of dead planktonic organisms brought down by flood tide or silt loaded fresh water. The decomposition is greater when the fluctuations in salinity are wider. The inorganic phosphate has no direct relationship with the time or tide but the nitrite values appear to follow high salinity values particularly along the bottom.

Introduction

Cochin Backwater is a tropical estuary (Pritchard, 1952, 1967; Balakrishnan, 1957; Josanto, 1971) with well connected rivers and lagoons on one side and Laccadive Sea on the other side. Physico-chemical conditions of this estuary are controlled by freshwater drainage and precipitation during monsoon and sea water incursion during high tide. Several authors have established that during pre-monsoon period homogeneous marine condition prevails in the estuary particularly towards its mouth. However, this homogeneity is disrupted by the heavy rains and consequent fresh water discharge at the onset of South West Monsoon. This period is therefore unique as far as the hydrobiological conditions of this estuary are concerned. The diurnal variation in the physicochemical factors of Cochin Backwater at the onset of S. W. Monsoon has not been studied so far. The present paper is an account of the investigations carried out during the early part of the S. W. Monsoon.

Materials and Methods

Water samples for temperature, salinity, dissolved oxygen, inorganic phosphate and nitrite were collected from the three different depths (0, 4, 8 m) of a station situated in the Ernakulam Channel (Cochin Harbour) in the months of June and July 1972. It may be noted that the station selected for investigation lies in close proximity with Station 3 worked out by Sankaranarayanan and Qasim (1969) and Station 2 reported by Qasim and Gopinathan (1969). The collections were made on days when high high-water coincided with dusk. The water samples were taken every three hours on board 'M.V. SAGITTA' from 1800 to 1800 hours using a Petersen type nonmetallic water bottle designed (by K.P.B.) for the purpose. Variation in the tide levels were noted from a fixed mark. An ordinary calibrated thermometer was used for recording the temperature. The samples for oxygen were immediately fixed. Nutrient samples were transferred to polythene bottles, preserved using chloroform and kept in darkness. Analysis were done on the following day. Methods described in Strickland and Parsons (1965) were adopted for various estimations.

RESULTS

There was heavy rainfall during early May 1972 followed by light intermittent rains till the actual S. W. Monsoon commenced in the last week of June.

Tide

Figs. 3a, b and c represent the tidal amplitudes observed on the days of collection. It shows that the period between high high-water (HHW) and low high water (LHW) is about 15 hours with a tidal range of 53 to 64 cm and the period between LHW and High low-water (HLW) is comparatively short with a narrow tidal range of 5 to 8 cm.

Temperature

The temperature at 0 and 4 m was maximum at 1500 hours and minimum at 0600 hours. But at 8 m it was maximum at 0600 hours and minimum in between 1200 and 1500 hours. Highest temperature values were recorded at the surface and lowest values at 8 m. A comparison of Figs. 2a, b and c shows that during the second observations the temperature at all depths were distinctly lower than those of the corresponding layers of other observations. The range of diurnal variations was different in all the layers and also in all the observations. (1.3, 2.5 and 1.0°C in the first, 0.7, 0.8 and 1.4°C in the second and 0.8, 0.8, and 2.4°C in the third at 0, 4 and 8 m respectively). In the first observation temperature at 0 m was higher than that of 8 m through out 24 hours. During the last stage of ebb of LLW and early stage of subsequent flood tide (between 1800 and 0600 hours) the temperature at 0 and 4 m in the first observation overlapped; the temperature at 8 m showed a gradual increase and lost the vertical thermal gradient in the second observation; and the temperature of all layers were almost uniform in the third observation. During the rest of the period (0600 to 1800 hours) a distinct stratification was evident at all depths in the first two observations and in the third observation the temperature at 8 m dropped suddenly and a clear vertical thermal gradient was established.

Salinity

Data regarding the distribution of salinity showed that there was a conspicuous difference in the diurnal variation at different depths (Figs. 1a, b and c). A well defined stratification was found to exist during the first observation. However, at 4 m a tongue of saline water with low temperature was observed at 1800 hours. The range of variation was 4.9, 13.07 and 8.07 ‰ with maximum values of 18.96, 27.85 and 26.82‰ at 0, 4 and 8 m respectively. It may be seen from the figures that the salinity dropped to minimum values at all depths by about 0600 hours. The LLW attained on the day of collection was at about 0250 hours. Similarly, the maximum salinity was reached at 1200 hours and the LHW was at 1010 hours. There was a uniform decrease in salinity values at all depths during HLW with a distinct stratification at all layers. In the second observation the maximum salinity values recorded at 0, 4 and 8 m were 0.81, 3.2 and 14.20 ‰ respectively. The range of variation was insignificant at 0 and 4 m but was pronounced at 8 m. As the ebb progressed the salinity at 8 m gradually declined until it overlapped with that of 4 and 0 m. This condition persisted only for about 4 hours, for the bottom salinity showed an increase with the advancement of high tide and maintained a high value during the rest of the period. Simultaneously, a slight increase in salinity was observed at 4 m depth also. This, however, did not persist because it was found to merge that of the surface even before the commencement of subsequent ebb. It may be noted in this connection that the surface salinity remained at 0.81‰ throughout the 24 hour period. In this observation also it was found that the low salinity continued to exist even after the commencement of flood and high salinity during the subsequent ebb at 8 m. The third observation reveals that the salinity even at 8 m was only 2.30‰ at HHW and those of 4 and 0 m were only less than 1.00‰. However, at 0600 hours an abrupt increase in salinity was noticed at 8 m which reached maximum value by about 1500 hours and thereafter showed a sharp decline. The range of variation was negligible at 0 and 4 m but was considerable at 8 m. In this observation again, it was found that almost freshwater existed at all depths even after the high tide had advanced half way through and high salinity prevailed at 8 m during subsequent ebb as noticed in previous cases.

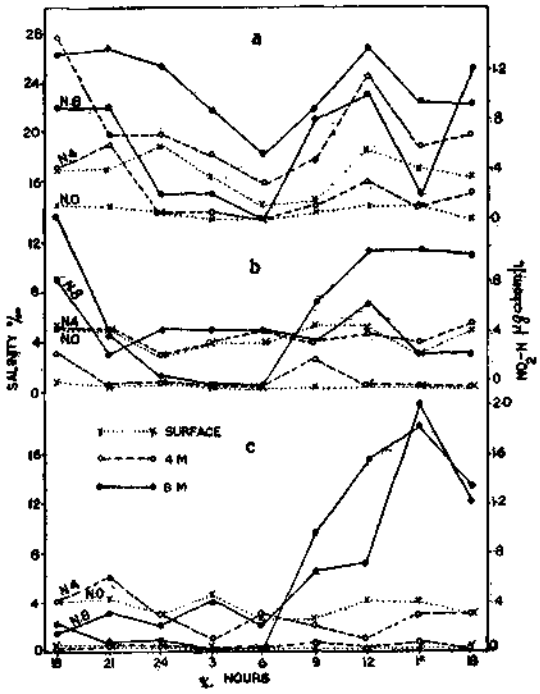

Fig. 1a, b, c : Salinity (‰) and Nitrite (NO_2-N) µg - atom/L during June 20-21, July 5-6 and July 21-22 respectively. N.O, N.4 and N.8 represent NO_2-N at surface, 4 m and 8 m respectively.

Dissolved Oxygen

In the first observation the surface layer showed minimum value for dissolved oxygen at 0300 hours, after which it steadily increased reaching the maximum at 1800 hours. The variation in oxygen concentration at 4 m followed almost an identical trend although the change was not uniform. At 8 m the minimum value was observed again at 0300 hours but the maximum was recorded at 1500 hours. The highest values for dissolved oxygen were found at the surface and lowest at 8 m. The range of variation was 2.0, 2.7 and 2.0 ml/l at 0, 4, and 8 m respectively. The oxygen values showed a decline in all layers during the period between HHW and LLW and an increase at other times, particularly at 0 and 4 m. Although an increase in oxygen value was noticed at 8 m also, it was not uniform. In the second observation the variation in oxygen values at 0 and 4 m were only 0.3 and 0.7 ml/l respectively whereas at 8 m it was 1.7 ml/l. The highest dissolved oxygen values at 0 and 4 m were observed in the evening and lowest in the early hours of the day. But at 8 m the reverse of this condition has been observed. A clear stratification was found at 0, 4 and 8 m at the beginning of ebb of LLW. However, towards the end of the ebb and at the beginning of the subsequent flood, the stratification became less evident. But at 8 m depth, the oxygen concentration showed a sharp decline at 0600 hours which continued upto 1500 hours, thereby developing a pronounced stratification (Fig. 2 b). In the third observation the oxygen values at 0, 4 and 8 m were almost uniform till 0600 hours. But with the advancement of high tide, the value at 8 m showed a progressive decline until the minimum was reached at 1200 hours. From 1500 hours a remarkable increase in Oxygen values were observed. The range of variation in dissolved Oxygen was 0.4, 0.4 and 2·4 ml/l at 0, 4 and 8 m respectively (Fig. 2 c).

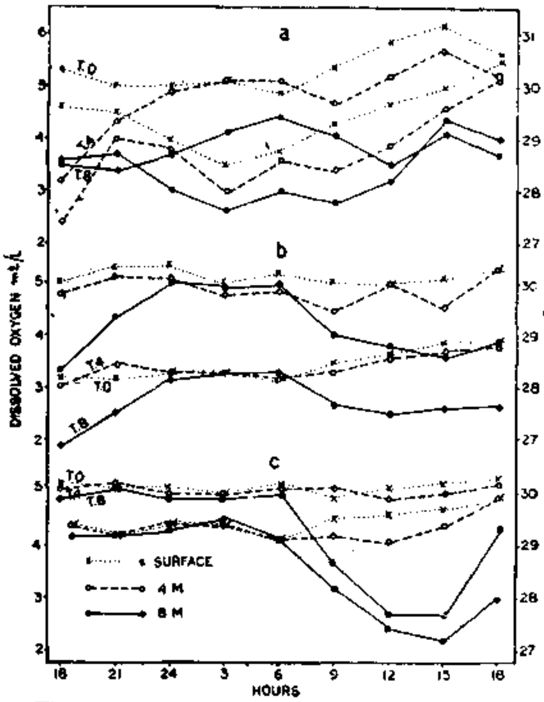

Fig. 2 a, b, c : Dissolved oxygen ml/L and Temperature in °C during June 20-21, July 5-6, and July 21-22 respectively. T.O, T.4 & T.8 represent Temperature in °C at surface, 4 m and 8 m respectively.

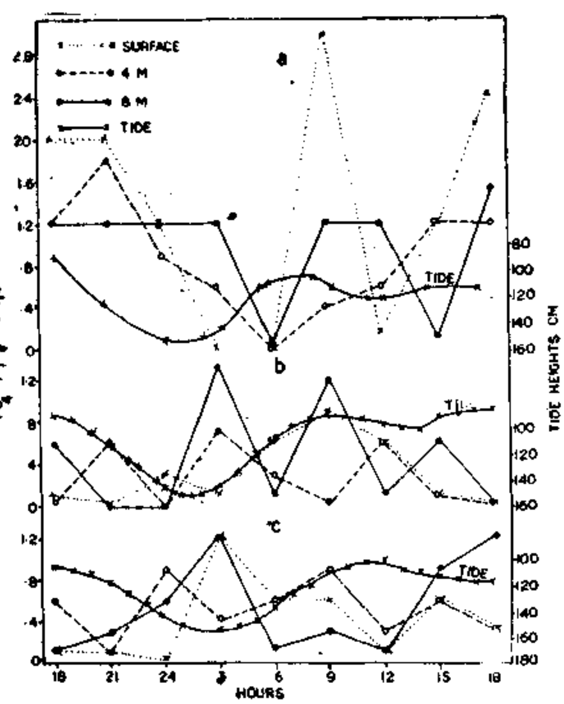

Fig. 3 a, b, c : Inorganic phosphate (PO_4-P) μg-atom/L and Tide Heights in cm during June 20-21, July 5-6 and July 21-22 respectively.

Inorganic Phosphate

In the first observation maximum value was recorded at surface and minimum at 4 m. It was virtually absent at all depths at 0600 hours. The phosphate values were less in the second observation in all depths than in the first. As in the previous observation it was absent from all depths on more than one occasion. In the third observation the inorganic phosphate was maximum both at surface and 8 m. The pattern of distribution was irregular in all observations. (Fig. 3 a, b, and c). The maximum value observed during this investigation was 3.0 μg atom PO_4-P/L at surface at 0900 hours (Fig. 3 a).

Nitrite

The concentration of Nitrite was maximum at 8 m and minimum at surface in all the observations. In the first observation it was absent at all depths at 0600 hours like the inorganic phosphate. The highest concentration of 2.0 μg atom NO_2-N/L was observed during the third observation and the lowest during the second. The over all values of nitrite was less than that of inorganic phosphate. Even though the pattern of distribution of Nitrite was irregular at 0 and 4 m, it varies with the salinity factor at 8 m (Fig. 1 a, b and c).

DISCUSSION

During 1972, the actual monsoonal rains commenced only in the last week of June. But even before the onset of the S. W. Monsoon, the homogenity that prevailed in the estuary during the premonsoon period was disrupted by a sudden and unusual downpour during early May, after which there was a paucity of rain till late June. The absence of heavy and continuous rains during this interval resulted in the stratification encountered in the first observation. When there is continuous rain the stratification in the upper layer will obviously be destroyed, whereas it continues to exist at the bottom especially during the high tide as revealed by subsequent observations.

The tides of the estuary are of a mixed semidiurnal type as described by Dietrich (1963). Two flood and two ebb tides which differ in amplitude and duration as observed by Qasim and Gopinathan (1969) were present on the days of observation. The continued seaward flow of surface water found in the second and third observations may be attributed to the fresh water pressure from the source of the estuary. Nevertheless, it is not of a sufficient magnitude as to cause a piling up of fresh water in the Ernakulam Channel, as shown by the tidal amplitudes during the monsoon and premonsoon periods.

From the data it could be seen that river water is warmer than the seawater, as earlier observed by Qasim and Gopinathan (1969). The temperature at 4 m is nearer to the surface values than to 8 m showing the extent to which the river water influences the 4 m layer. The stratification at 4 and 8 m is evident only during the period between LLW and HHW (0600 hours to 1800 hours) in the second and third observations indicating that influence of the cold sea water is more in the bottom layers than the warm river water during the period. The general fall in temperature recorded in the second observation points to the fact that during continnuous rain, the atmosphere may cool down and this may affect the temperature, particularly at the surface. It agrees with the result obtained by Nair (1971) in Kayamkulam Estuary. The unusual occurrence of low temperature at 4 m at 1800 hours in the first observation is associated with high salinity and may be due to 'entrainment' (Bowden, 1967) which is short lived. The low temperature at 8 m at 1500 hours in the third observation may be due to the incursion of a tongue of cold upwelled sea water occurring during flood tide of LHW. Because of the fresh water pressure, the upwelled water is pushed back to the sea even before the commencement of low tide leading to LLW. The presence of warm water of low salinity at 1800 hours supports this view. In the present investigation the diurnal range at 8 m is found to be higher than that of surface which differs from that obtained in Vellar Estuary by Rangarajan (1958). This may be due to the inflow of cold sea water into the estuary. Rao and George (1959) have attributed the low temperature encountered in Korapuzha Estuary during September to the intermittent rains resulting in heavy influx of cooler fresh water which is not inconsistent with the present observation. Ramamirtham and Jayaraman (1963) report that there is an overall decrease in surface temperature in Cochin Backwater in June and July and that there is not much difference between surface and bottom temperature in the beginning. But the present observation shows that there is perceptible difference between surface and bottom temperature and that it varies with tide. Sankaranarayanan and Qasim (1969) have stated that with the onset of monsoon the temperature drops considerably and that stratification exists at station 3. But the present study shows that such stratification is not a regular feature.

The diurnal variation in salinity is different in all the three observations. In the first a pronounced stratification is clearly discernible except at the time of 'entrainment' at 4 m. A perusal of the different curves will show that the salinity of the water flowing past the Station is progressively lowered even after the commencement of the high tide and vice versa. This clearly shows that the salinity conditions of the estuarine water do not produce any immediate change at the reversal of the tidal phase. Spencer (1956) has observed identical conditions existing in Swan River, Australia. In the third observation the presence of a tongue of saline water of low temperature and low oxygen concentration at 8 m indicates the penetration of upwelled sea water into the estuary. The decline of salinity and increase of temperature and oxygen after 1500 hours shows that the upwelled water is being diluted by the river water even before the commencement of low tide. In the last two observations vertical gradient in salinity was conspicuous only at 8 m indicating that the egress of fresh water largely takes place through the upper layers. It may also be seen that there are occasions when the entire channel is flushed with fresh water. A comparative study of the salinity curves will show that in the first the salinity gradient is well established at all depths. This may be due to the absence of heavy rains after the downpour in early May. But when the monsoon starts in June the salinity gradient shifts to the bottom layers. It may also be inferred that the water movement in the estuary is of an ocillatory type with influx of fresh water from the source and infiltration of sea water from the mouth, the intensity of mixing being mainly dependent on the pressure of fresh water. Rao and George (1959) have observed that salinity in Korapuzha Estuary is largely controlled by tides but with the onset of S.W. Monsoon it drops to 0.5‰ and this condition dominates till September. From the present study it is seen that even during the peak period of the monsoon a fairly perceptible salinity gradient exists in bottom layers. This may be due to the bottom topography of Cochin Backwater. Ramamirtham and Jayaraman (1963) have reported that surface salinity in Cochin Backwater begins to decrease after late May. These authors have also recognised the existence of a tongue of upwelled sea water in the estuary during July. George and Kartha (1963) have observed that the surface salinity in Ernakulam Channel drops suddenly in May and that fresh water remains in surface till September/October. Sankaranarayanan and Qasim (1969), Qasim and Gopinathan (1969) reported stratification exists during monsoon and the bottom mixing is prevented. But the present observations show that dilution takes place at all levels and the entire estuarine system or at least the Ernakulam Channel gets flooded with fresh water during LLW period in active monsoon (Fig. 1 c).

The maximum oxygen value is recorded at surface and the minimum at 8 m depth, except at the time of 'entrainment'. A comparison of the values with those given by Fox (1907) shows that the estuarine water is undersaturated at all depths. This undersaturation is probably due to the utilisation of oxygen for the decomposition of organic matter brought in by the tidal currents and silt-loaded riveer water (Rochford, 1951). Among the marine organisms that are carried into the estuary during high tide, many are likely to perish in those layers where the magnitude of salinity variation is very great. The consumption of oxygen for the decomposition of these dead organisms accounts for the low oxygen concentration at 8 m in the first observation. The higher oxygen values obtained in the surface layers during the second and third observations could be attributed to the presence of fresh water. However, these values are also below the saturation level. The sharp decline of oxyen values at 8 m in the third observation may be due to the presence of a tongue of upwelled sea water. A rise in oxygen value with increasing salinity at 8 and 4 m may be attributable to the fresh entry of cold water of high salinity into the estuary during high tide when the depletion of oxygen due to decomposition is comparatively less.

In the Vellar Estuary, Rangarajan (1958) has observed lowest oxygen values at the surface at 0400 hours and noted its increase with time and tempxnyue. Here oxygen values were higher at the surface than at the bottom. In many respects the present observati agrees with conditions in the Vellar estuary. It is seen that normally the oxygen values tend to decrease with increase of salinity. In this, our observations differ from that of Shah (1967) who found a similar trend in oxygen and salinity values. Whenever a positive relationship exists between them it may be due to the fresh entry of sea water at a time when the decompostition of organic matter is less. Though the present observation agrees with the report of Sankaranaraynan and Qasim (1969) in the existence of vertical oxygen gradient with high surface and low bottom values during monsoon, it differs from the observation of Qasim and Gopinathan (1969) on the variation of oxygen content at the surface.

The concentration of inorganic phosphate neither follows any definite pattern nor shows any correlation with the time and tide at any depth. Nevertheless, it is quite evident that more inorganic phosphate occurs when stratification prevails and the values are low during freshets. It would appear that at a given time the concentration varies indiscriminately at different depths or at a particular depth at different times. The inorganic phosphate concentration in different layers is thus not related to the physico-chemical parameters so far studied.

The present observations confirm the findings of Shah (1969) that the nitrite values are less than that of phosphate and the maximum value occurs at the bottom.

REFERENCES

BALAKRISHNAN, A. 1957. Variation of salinity and temperature in Ernakulam Channel. *Bull. cent. res. Inst. Univ. Trav.*, 5(2): 7-9.

BOWDEN, K. F. 1967. Circulation and diffusion. Pp. 15-36. *In*: G. H. Lauff (Ed.) '*Estuaries*' Publ. No. 83 AAAS, Washington.

DIETRICH, G. 1963. *General Oceanography An Introduction.* Inter Science Publ. N. Y. 588 pp.

FOX, C.J.J. 1907. On the coefficients of absorption of the atmospheric gases in distilled water and sea water. *Counseil Internat. p. l 'Explor. de la Mer, Pub. de Circonstance*, 41 : 27.

GEORGE, M. J. AND K.N.K. KARTHA 1963. Surface salinity of Cochin Backwater with reference to tide. *J. mar. biol. Ass. India*, **5**(2) : 178-184.

JOSANTO, V. 1971. The bottom salinity characteristics and the factors that influence the salt water penetration in the Vembanad Lake. *Bull. Dept. Mar. Biol. Oceanogr. Univ. Cochin*, **5**: 1-16.

NAIR, G. S. 1971. Some observations on the hydrology of Kayamkulam Estuary. *Ibid.* **5**: 87-96.

PRITCHARD, D.W. 1952. Estuarine Hydrography. Pp. 243-282. *In*: H.E. Landsberg (Ed.), *Advances in Geophysics*, Vol. 1. Academic Press, Inc., New York, N.Y.

——— 1967. Observations of circulation in coastal plain Estuaries in '*Estuaries*'. (Ed.) George H. Lauff, Publ. No. 83, AAAS, 37-44.

QASIM, S.Z. AND C. K. GOPINATHAN 1969. Tidal cycle and the environmental features of Cochin Backwater. *Proc. Indian Acad. Sci.*, **69** (6) : 336-348.

RAMAMIRTHAM, C.P. AND R. JAYARAMAN 1963. Some aspects of hydrographical conditions of the Backwaters around Willington Island (Cochin). *J. mar. biol. Ass. India*, **5**(2) : 170-177.

RANGARAJAN, K. 1958. Diurnal tidal cycle in Vellar Estuary. *J. zool. Soc., India*, **10** : 54-67.

RAO, S.V.S. AND P.C. GEORGE 1959. Hydrology of the Korapuzha Estuary, Malabar, Kerala State. *J. mar. biol. Ass. India*, **1**(2) : 212-223.

RAO, T.S.S. AND V.C.C. RAO 1962. Studies on diurnal variations in the hydrographical conditions off the Waltair Coast. *J. mar. biol. Ass. India*, **4** (1) : 23-43.

ROCHFORD, R.J. 1951. Studies in Australian estuarine hydrology. 1. Introductory and comparative features. *Aust. J. mar. Freshwat. Res.* **2** : 1-116.

SANKARANARAYANAN, V.N. AND S.Z. QASIM 1969. Nutrients of Cochin Backwater in relation to environmental characteristics. *Marine Biol.*, **2** : 236-247.

SHAH, N.M. 1967. Diurnal changes in certain oceanographic features in the Laccadive Sea off Cochin in September. *Bull. Dept. Mar. Biol. Oceanogr.*, **3** : 17-27.

SPENCER, R. S. 1956. Studies in Australian hydrology. II. The Swan River. *Aust. J. mar. Freshwat. Res.*, **7** : 193-253.

STRICKLAND, J.D.H. AND T.R. PARSONS 1965. A manual of sea water analysis. *Bull. Fish. Res. Bd. Canada*, **125**.