CHAPTER 3

HYDROGRAPHY

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The study of the hydrographical parameters of the estuarine environment is of great importance while attempting to characterise the general features, distribution pattern and relative abundance of nutrients. Equally significant are these studies with regard to pollution control, harbour design, marine traffic routing etc. The hydrographical conditions in an estuary mainly depend on the intrusion of seawater associated with tides and influx of fresh water from rivers. The precipitation/evaporation processes also have profound effects on the hydrographical changes. In addition to these factors, the bottom topography and the geographical shape of an estuary have added influence on the hydrographical conditions in the estuary.

The hydrography of the Cochin estuary has been investigated by several workers (Ramamirtham & Jayaraman, 1963; George & Kartha, 1963; Qasim & Reddy, 1967; Qasim et al., 1968; Sankaranarayanan & Qasim, 1969; Josanto, 1971; Wellershaus, 1971; Haridas et al., 1973; Shynamma & Balakrishnan, 1973; Manikoth & Salih, 1974; Joseph, 1974; Lakshmanan et al., 1982; Sankaranarayanan et al., 1986). The information available includes seasonal distribution of temperature, salinity, dissolved oxygen, pH, alkalinity and nutrients of the region as a
whole or part. In recent years, the Cochin estuary has been a centre of intense activities with regard to hydrological changes and it was considered important to obtain more and detailed information on the range of variation and distribution of the hydrographical features. The present study on the hydrography attempts to elucidate data on the seasonal and spatial distribution of temperature, pH, salinity and dissolved oxygen for the period of survey (June 1985 to May 1986); the methods of sampling and analysis are given in Chapter 2.

3.1. Temperature

The distribution of temperature in an estuary is dependent on the mixing of inflowing river water and tidally influenced seawater; processes like exchange of heat with atmosphere and any localised phenomena are also likely to influence the distribution.

Temperature at surface and bottom at different locations during the period of survey are given in Table 1. Distribution and seasonal variation of temperature at surface and bottom are represented by drawing isolines as chart of stations versus time (Fig. 2). Temperature varies from low values of 25.3°C at surface and bottom during August, 1985 to high values of 33.4°C at surface and 32.6°C at bottom both during April 1986. The low monsoonal values increase gradually and reach maximum values during the premonsoon period. Seasonal variation of temperature at surface was less pronounced in the southern part of the estuary (25.3° - 30.7°C) between stns. 6 and 9 than on the northern parts (25.3° - 33.4°C) between stns. 1 and 4. The seasonal variation of bottom temperature which was nearly similar to that at surface is mainly due to the climatic setting for this tropical region. The observed low monsoonal values in the barmouth region may be
Fig. 2. Time series curve of temperature (°C) at surface (a) and bottom (b).
and intrusion of cold saline water from Arabian sea into the deeper layers of baromouth region. This feature had also been observed by earlier workers (Ramamirtham & Jayaraman, 1963; Sankaranarayanan & Qasim, 1969).

The northern parts of the estuary exhibited slightly higher temperatures compared to the southern parts giving rise to horizontal gradients, more pronounced in April (The difference in temperature is about 4.0°C). Relatively the higher temperatures recorded on the northern parts of the estuary may be partly due to low influx of fresh water from Periyar river during premonsoon, while in the southern parts large amount of colder river waters (≈27°C) flow into the region. Stn. 2 located on the northern part registered the maximum value of temperature difference, 3°C between surface and bottom waters during March 1986 giving rise to pronounced vertical gradient.

The formation of such vertical gradients have been observed by Lakshmanan et al. (1982) in the lower reaches of Periyar. The present investigations bring out the presence of such a phenomenon not only in the lower reaches of Periyar but also extending to the other parts of the northern arms of the estuary.

3.2. Salinity

Salinity has been recognised as the parameter in studying the mixing processes and intrusion of saline waters into estuaries by tidal action. The mixing and diffusion phenomena occurring in estuaries are largely influenced by salinity distribution pattern. In estuaries wide fluctuations in salinity are generally observed, usually lower than seawater, but in regions with high evaporation and little rainfall estuarine salinity level may exceed 35 x 10^-3.
Results on salinity at surface and bottom at stns. 1-9 during the period of survey are given in Table 2; time series curves of surface and bottom salinity of these stations are given in Fig. 3.

The Cochin estuarine system was largely influenced by the influx of freshwater from rivers and intrusion of seawater into the estuary via the barmouth. In the northern region along stns. 1 to 4 during monsoon, low salinity values varying between 7 and $12 \times 10^{-3}$ at the surface and higher values ranging from 15 to $27 \times 10^{-3}$ at the bottom were encountered. The high vertical salinity gradient at Cochin barmouth region indicates a distinct stratification during this period. Sankaranarayanan *et al.* (1986) also found that stratification develops at the mouth of the estuary, when large volumes of freshwater flow into the estuary. A gradual increase in salinity could be observed as the season progresses to postmonsoon and premonsoon. The highest value ($35 \times 10^{-3}$) was recorded at surface and bottom of stns. 1 to 4 during premonsoon. This was mainly due to the intrusion of seawater through the barmouth. It was also observed that during premonsoon the vertical salinity gradient tend to be minimal.

In the southern region, along stns. 5 to 9 low values of salinity ranging between 0 to $10 \times 10^{-3}$ at surface and 0 to $12 \times 10^{-3}$ at bottom were observed during monsoon. This was brought about by the combined effect of land drainage from the prevailing monsoonal rains causing high freshwater discharge from the river and the intrusion of salt water. Fresh water conditions were observed at surface at stns. 8 and 9 during monsoon. As the season advances to postmonsoon and premonsoon higher values ranging from 10 to $22 \times 10^{-3}$ at surface and 12 to $24 \times 10^{-3}$ at bottom were observed.
Fig. 3. Time series curve of salinity (×10⁻³) at surface (a) and bottom (b).
and low discharge of freshwater into the estuary. The vertical salinity gradient is minimum in the southern region during all seasons.

Time series curves of bottom salinity at the northern region of the estuary indicate that the effect of seawater influx through stn. 1 (Azhikode outlet) has a significant influence on the hydrography up to stn. 2. However, the effect of seawater influx through stn. 4 (Cochin barmouth) was more pronounced and covers a large area between stns. 2 and 4, which is evidenced by the pattern of the isohaline contour distribution at stns. 2-4 (Fig. 3b). Hence the net effect of seawater intrusion on the hydrography of the northern regions are largely influenced by the influx of seawater through stn. 4 than from stn. 1. When comparing the bottom distribution to that at surface, an added feature was the freshwater dilution occurring between stns. 2 and 3, evidenced by the vertically inclined isohaline pattern along the longitudinal section between the two stations.

Eventhough, influx of large amount of freshwater occurs between stns. 7 and 8, the dilution of seawater was not as pronounced as that observed on the northern regions. This is due to the nature of the semi-enclosed waterway by the construction of Thanneermukkam bund on the southern side of the estuary. The stationwise salinity variation for a given time interval at surface was significant, the changes at the bottom being very sharp.

3.3. Dilution of seawater

Fractional estimates on freshwater content in estuaries can be applied for the determination of dilution of seawater. Bowden (1980) suggested that the amount of freshwater removed by flushing is the same as that is being added by river discharge. The important
processes which bring freshwater to the estuarine system are land runoff, precipitation and river discharge.

The amount of freshwater present at any given location in an estuary in terms of salinity (10^{-3}) of the same location can be formulated as \( F = 1 - \frac{S_1}{S_2} \)

Where \( F \) is the fraction of freshwater in the sample, \( S_1 \) is the salinity of the sample collected from the location inside the estuary and \( S_2 \) is the salinity of the coastal water (Officer, 1976). Fig. 4 gives the surface and bottom freshwater fractional values as plotted against the stations for the three seasons.

The northern part of the estuary exhibits wide seasonal variation in freshwater content both at surface and bottom. During monsoon stn.1 traced a value of 0.47 at surface and 0.25 at bottom. With the advent of postmonsoon, values gradually decreased and during premonsoon the waterway turned to near saline conditions (fraction value 0.01). Generally bottom values at all stations are lower than surface values for all seasons.

A significant feature is that during premonsoon, bottom layers denoting saline water conditions prevailed over the entire bottom region of the northern parts of the estuary \( (F \approx 0.01) \). This gives rise to stratification with surface layers containing higher freshwater fractions in the northern parts during premonsoon.

Equally significant are the features on the southern regions where both surface and bottom layers trace nearly the same values for freshwater fractional distribution indicating a well mixed zone in these parts of the estuary.
Fig. 4. Seasonal distribution of freshwater fraction at surface (a) and bottom (b).
3.4. pH

Many of the life processes are dependent on and are sensitive to the hydrogen ion concentration in the surrounding medium. The pH of a medium depends on many factors like photosynthetic activity, rainfall, nature of dissolved materials, discharge of effluents, sewage into it etc. Variation in pH due to chemical and other industrial discharges renders a stream unsuitable not only for recreational purposes but also for the rearing of fish and other aquatic life (Webb, 1982). George (1979) has stated that the tolerance range for most biological organisms is quite narrow and critical. Low values of pH may cause rapid corrosion of hulls of ships whereas high values bring about incrustation and brittleness to pipes. Significantly, close monitoring of pH value for acidic or alkaline discharges enable to identify zones of pollution and other quality conditions for use of water (Clark et al., 1977).

Data on pH of Cochin estuary are given in Table 3. Distribution pattern of pH at surface and bottom waters at all stations during the period of survey as time series curves is given as Fig. 5. The range of values varies from 6.6 at surface of stns. 8 and 9 to 8.2 at surface of stns. 3 and 4. It is also evident from the figure that pronounced seasonal variations are observed in pH distribution.

Natural pH values are traced during monsoon month, at surface when freshwater influx occurs. The pH increases seasonally up to postmonsoon period. The maximum value of pH was recorded at surface during postmonsoon in the barmouth region. This is attributed to the near marine condition and the excessive photosynthetic activity of algae, which results in depletion of the amount of CO₂ and hence
Fig. 5. Time series curve of pH at surface (a) and bottom (b).
increase of pH value. The high phytoplanktonic production during postmonsoon in Cochin backwaters was recorded by earlier workers (Silas & Pillai, 1975; Nair et al., 1975). With the onset of monsoon rapid variation was observed in the vertical at the barmouth region (stns. 3 and 4 - pH 7.1 - 8.2; 7.0 - 8.2 respectively).

The northern region recorded higher pH values than the southern region throughout the period of survey. It is also significant that the values gradually decrease from the barmouth region to the southern tip of the estuary. This may be due to the reduced influence of the seawater intrusion. In the northern region the value ranged from 7.0 to 8.0 at surface and 7.4 to 8.2 at bottom during monsoon. The values at the bottom are higher than those at the surface. This significant vertical gradient at barmouth region is due to the combined effect of the influx of low pH freshwater at surface and intrusion of high pH saline water through the Cochin barmouth at the bottom.

The difference in variation of pH between surface and bottom in the northern region during postmonsoon and premonsoon is not well defined. In the southern region the values ranged from 6.6 to 8.2 at surface and 7.0 to 8.0 at bottom.

3.5. Dissolved Oxygen

Dissolved oxygen (DO) is an important water quality parameter in assessing water pollution. Though atmospheric oxygen is abundant, its solubility in water is low 9.94 ml l⁻¹ at 1°C, and 5.28 ml l⁻¹ at 30°C in freshwater and 7.97 ml l⁻¹ at 1°C and 4.41 ml l⁻¹ at 30°C in seawater of salinity 33 x 10⁻³ (Riley & Chester, 1971,a). The depletion of oxygen content leads to undesirable obnoxious odours under anaerobic conditions (Doudoroff Shumway & Peter, 1970; Nelson, 1978),
The concentration and distribution of oxygen in natural waters depend on various factors such as temperature, partial pressure of the gas in the atmosphere and salinity. Chemical behaviour (Schwoeder, 1980) and rate of depletion of oxygen (Wahby et al., 1978) have been used to investigate the quality of water bodies. Studies on salinity dependent oxygen solubility may help to elucidate the various physical, chemical, and biological processes taking place in estuarine waters (DeSousa & Sen Gupta, 1986).

Results of DO at surface and bottom at all stations are given in Table 4. Distribution pattern of DO at surface and bottom as time series curves is represented in Fig. 6. Both seasonal and spatial variations are again well reflected in the DO patterns. On the northern regions DO values range from 4.75 to 6.56 ml l\(^{-1}\) at surface and 4.71 to 5.86 ml l\(^{-1}\) at the bottom during monsoon. The values decreased as the season advanced to postmonsoon and premonsoon. The premonsoonal values vary between 4.06 to 6.13 ml l\(^{-1}\) at surface and 3.07 to 4.71 ml l\(^{-1}\) at bottom. The lowest values (3.07 - 3.23 ml l\(^{-1}\)) were recorded along stns. 2 and 3 during premonsoon: this may be interpreted as the combined effect of low solubility of oxygen in high saline waters (31 - 34 x 10\(^{-3}\)) and waste discharged from fishing industries located on the northern parts.

Higher oxygen values were observed on the southern parts of the estuary. The high monsoonal values (7.07 to 8.50 ml l\(^{-1}\)) at the surface along stns. 6 to 9 gradually decrease during premonsoon (6.98 - 7.73 ml l\(^{-1}\)). Relatively higher values observed at the southern region as compared to the northern region may be due to the higher solubility of oxygen in less saline waters. High values
Fig. 6. Time series curve of dissolved oxygen (ml l⁻¹) at surface (a) and bottom (b).
of DO in the southern regions during monsoon with the low saline content and lower values of DO in the northern regions during pre-monsoon with high saline water signify the solubility process.

Thus, the salient features of the study may be summarized as given below.

The net effect of varying amount of lighter freshwater flowing from Periyar river over the heavier seawater from Arabian sea intruding into the deeper layers of barmouth region during different seasons causes to exhibit a pronounced seasonal and spatial variation of temperature and salinity in the northern part of the estuary. A pronounced vertical salinity gradient thus develops at Cochin barmouth region during monsoon. During non-monsoonal months this region becomes more or less homogeneous. For the corresponding periods, the southern parts of the estuary is observed as well mixed. Lower values of salinity in the southern regions is due to the combined effect of land drainage from the prevailing monsoonal rains causing high freshwater discharge from the rivers and relatively weak intrusion of salt water.

A pronounced seasonal variation of pH is observed with higher values during postmonsoon which may be attributed partly to marine conditions and partly to the excessive photosynthetic activity of algae. The influx of low pH fresh water at surface and intrusion of high pH saline waters through the Cochin barmouth along the bottom layers is a significant factor regulating the pH values in the estuary.

Again, both seasonal and spatial variation of DO is observed; during premonsoon low DO is observed as a result of the low solubility of oxygen in high saline water and waste discharge from fishing industries located on the northern parts. High DO is observed during