

Estuarine Characteristics of the Lower Reaches of the River Periyar (Cochin Backwater)

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Lower reaches of river Periyar were studied to assess longitudinal extent of salt water intrusion into the system during different seasons and also its effect on the flushing of pollutants introduced by the industries. During SW monsoon season due to the influx of a large volume of fresh water longitudinal salinity gradient could be noticed only up to a few stations upwards from the barmouth. During postmonsoon season the estuary behaved like a partially mixed estuary with the saline intrusion extending further upstream up to 17 km. In the premonsoon season the intrusion length extended further upstream beyond 21 km. A steady down stream dilution of any pollutant introduced could be expected during these seasons. Fluoride concentration showed high values ($>1.5 \text{ mg.l}^{-1}$) during Nov. to May and minimum from July to Sept. The high values observed may be due to the effect of pollutants containing fluoride discharged into the river.

The Cochin backwater estuarine system is a part of the lower reaches of the river Periyar, which is one of the largest perennial rivers of this region. The hydrographic studies¹⁻⁴ so far made are on physical and biological aspects and mainly centred around the Cochin harbour. However there is no attempt to evaluate the extent and nature of the salt water intrusion into the estuarine region and its variation from season to season with respect to varying tidal prisms at the Cochin harbour inlet and fresh water influx into the estuarine system. The present study pertains to intrusion of salt water into the estuarine region, assessment of its longitudinal extent in different seasons, and its effects on the flushing of pollutants introduced into the system from the industrial belt. As very little information is available^{5,6} on the distribution of fluoride in Indian waters, in this study the fluoride concentration is estimated in the Cochin backwater system and the river Periyar.

Materials and Methods

Monthly surveys (1982-83) were conducted from the Cochin harbour mouth towards upstream, a distance of about 21 km (Fig. 1), during the spring tide. From each of the 13 stations water samples were collected at the peak of high tide for the estimation of salinity, inorganic phosphate⁷, fluoride⁸ and dissolved reactive silicate⁷. The direction and speed of the currents were measured at 1 m interval from surface to 1/2 m above bottom after anchoring the boat at all the stations. Also current measurements were made from sts 9 and 13 at hourly interval during the spring tide for 1 complete tidal cycle.

This estuarine system is largely influenced by the influx of fresh water, which, in turn, is controlled by the rainy season facilitating the division of the observation period into 3 distinct periods, viz. premonsoon (Feb.-May), monsoon (June-Oct.) and postmonsoon (Nov.-Jan.).

Results

Distribution of saline water entering into this region is depicted in Fig. 2. Major incursion of saline water occurs from Jan. to May when the salinity is $>30 \times 10^{-3}$. Even at a distance of about 18 km from the

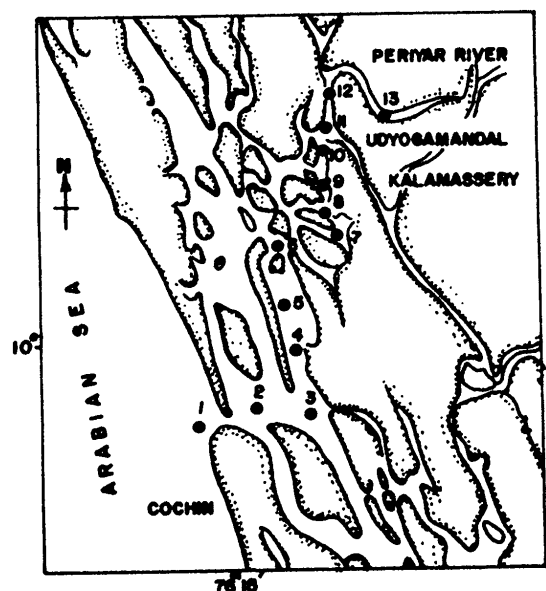


Fig. 1—Station positions

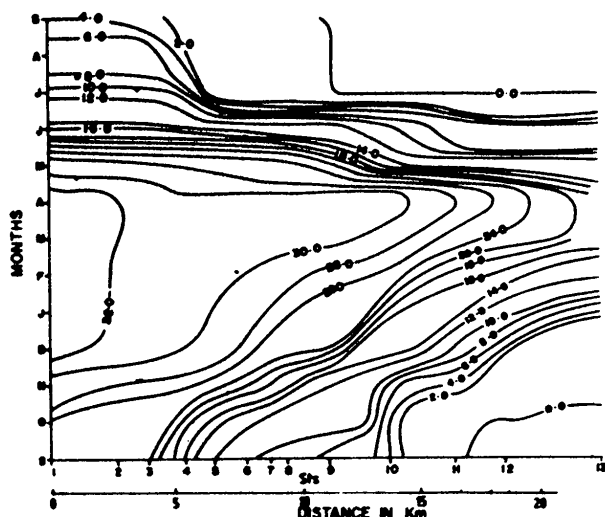


Fig. 2—Extent of saline water penetration from the estuarine mouth (Isohalines give the salinity of 2×10^{-3} intervals)

barmouth and beyond this high saline water can be traced to a distance of > 25 km from the barmouth. At st 1 salinity value remains high ($> 25 \times 10^{-3}$) just after the monsoon. However at st 13 the salinity value shows only a gradual increase from 0 to $> 20 \times 10^{-3}$ from Dec. to May. The vertical salinity gradient is very small ($< 3 \times 10^{-3}$) during this season.

With the onset of the monsoon fresh water or very low saline water of $< 1 \times 10^{-3}$ salinity is traceable even to a distance of 5 km from the barmouth. While the salinity at st 1 varies from 19 to 3×10^{-3} , the salinity at st 13 is 0 most of the period except in early June. During this period actually a fresh water regime would be established towards the head of the estuary after 5 km from barmouth (Fig. 3B). The vertical salinity gradient at stations near the barmouth is $> 10 \times 10^{-3}$ showing saline incursion through the bottom during high tide.

During the postmonsoon period a gradual increase in salinity could be noticed at all stations as the season progresses. While at st 1 salinity value increased to nearly 30×10^{-3} , at st 13 it increased from 0 to 2×10^{-3} . Similar gradual increase of salinity took place at all the intermediate stations (Fig. 3C). The salt water intrusion was restricted to a distance of about 19 km during this season.

The flow pattern studied, at the peak of the high tide, shows that the direction of current is towards the estuary at all the stations during the 3 seasons. However the current observations taken at sts 9 and 13 for a complete tidal cycle showed the complete reversal of the tidal current according to the tide. The speed of the current varied from 10 to 42 $\text{cm} \cdot \text{sec}^{-1}$ at different regions of the estuary during the 3 seasons. Maximum speed was recorded near the narrow regions of the estuary especially at sts 7, 8 and 13. Generally the speed

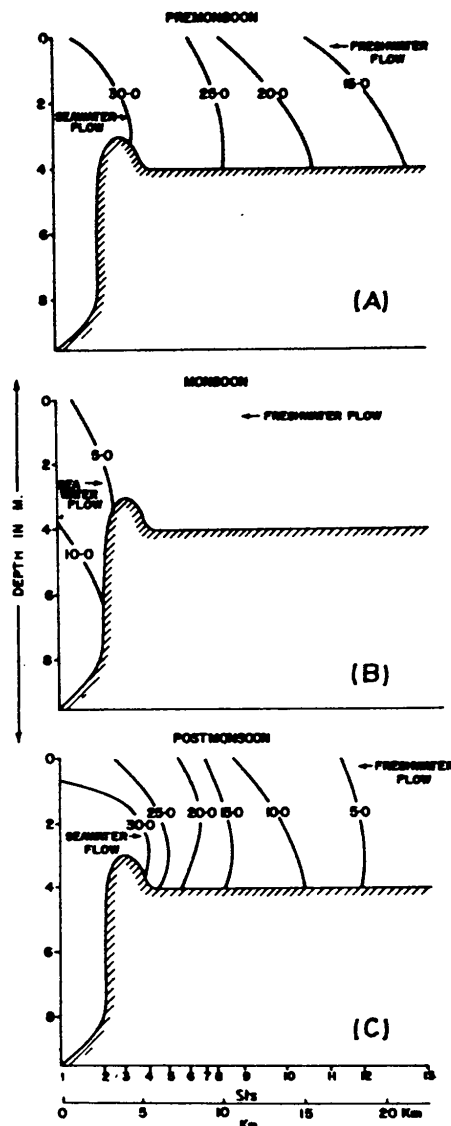


Fig. 3—Occurrence of seawater and fresh water flow in a longitudinal section along the Cochin backwater system during different seasons (Values indicate salinity $\times 10^{-3}$)

increased from surface to 1-2 m depth layers and then reduced to the bottom. The water in the estuary remains partially mixed when the river water run-off was small and moderate. At high fresh water influx the stratification is pronounced at sts 1 to 5.

Dilution and flushing—The amount of fresh water (f) at any given location in the estuary in terms of salinity (S) at the same location is given⁹—

$$f = \frac{S_0 - S_n}{S_0}$$

where S_0 is salinity of the coastal seawater and S_n , salinity at any location inside the estuary. The fresh water fraction at different stations along the estuary

was calculated for different seasons (Fig. 4). The fresh water fraction was very large during the monsoon at almost all stations except at 1 and 2 where it was 0.69 and 0.89. During the postmonsoon seasons the fresh water fraction increased from 0.17 at st 1 to 0.86 at st 10 in a gradual way and is maximum there after. In the premonsoon season there was a gradual increase from 0.04 at st 1 to 0.63 at st 13 and was very low as compared to other seasons.

The dilution factor, inverse of the fresh water fraction, showed during premonsoon conditions a gradual decrease from 14.28 at st 4 to 1.58 at st 13. During monsoon period this factor was 1.47 at st 1 and 0 at st 13. During postmonsoon period it was 5.88 at st 1 and gradually decreased to 1.02 at st 11 and 0 at st 13.

Distribution of inorganic phosphate—During premonsoon high concentration of inorganic phosphate (Fig. 5) was seen at sts 13 ($81 \mu\text{mol.l}^{-1}$) and 12 ($63 \mu\text{mol.l}^{-1}$) and from st 12 down the estuary there was reduction in the concentration and reached a value of $3 \mu\text{mol.l}^{-1}$ at st 1. During monsoon the distribution was irregular. While very low values below $10 \mu\text{mol.l}^{-1}$ could be observed at sts 10 and 13, between sts 9 and 3 values above $17 \mu\text{mol.l}^{-1}$ reaching a value of approximately $50 \mu\text{mol.l}^{-1}$ at st 8 could be recorded, and after that at stations near to barmouth the concentration was below $10 \mu\text{mol.l}^{-1}$. In the postmonsoon months, a picture almost similar to that of premonsoon could be noticed with a difference that the maximum value ($88 \mu\text{mol.l}^{-1}$) was at st 11 instead at st 13. The phosphate level showed a gradual decrease from st 11 to st 1.

Silicate—Average silicate concentration varied from 0.37 to 5.96, 0.21 to 4.73 and 0.03 to 2.66 mg.l^{-1} respectively in monsoon, postmonsoon and premonsoon seasons from barmouth to upstream (Fig. 6). There was a general decrease in the silicate content from Oct. to May. In the upper reaches of the river where the salinity influence is less the silicate levels were relatively uniform throughout the year. The major changes in the silicate content of estuarine waters are due to the difference in dilution and the highest concentration is observed during the SW monsoon season when the fresh water discharge is maximum. During premonsoon season when the river discharge is minimum the longitudinal variation in the silicate content was minimum ($0.03\text{-}2.66 \text{ mg.l}^{-1}$). Sankaranarayanan *et al.*¹⁰ observed atypical behaviour of dissolved silicate in this region. They have also reported substantial removal of silicate by precipitation at different salinity ranges as compared to other areas.

Fluoride—There is a general increase in the fluoride

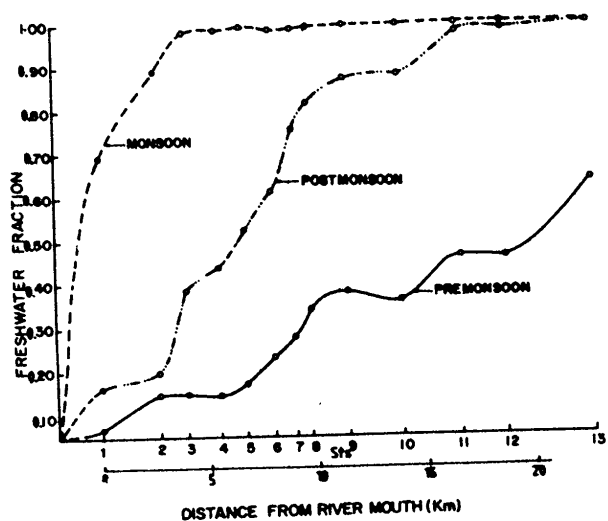


Fig. 4—Distribution of fresh water fraction during different seasons

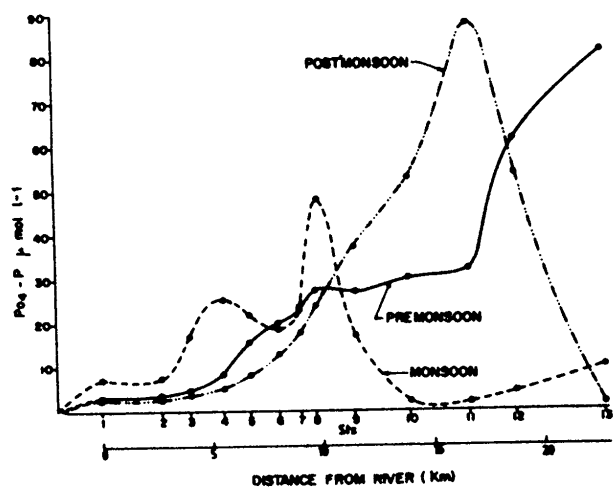


Fig. 5—Concentration of phosphate in a longitudinal section along the Cochin backwater system during different seasons of the year

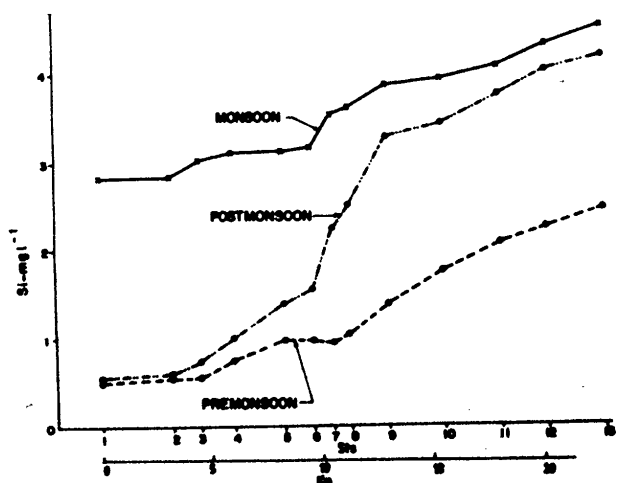


Fig. 6—Concentration of silicate in a longitudinal section along the Cochin backwater system during different seasons of the year

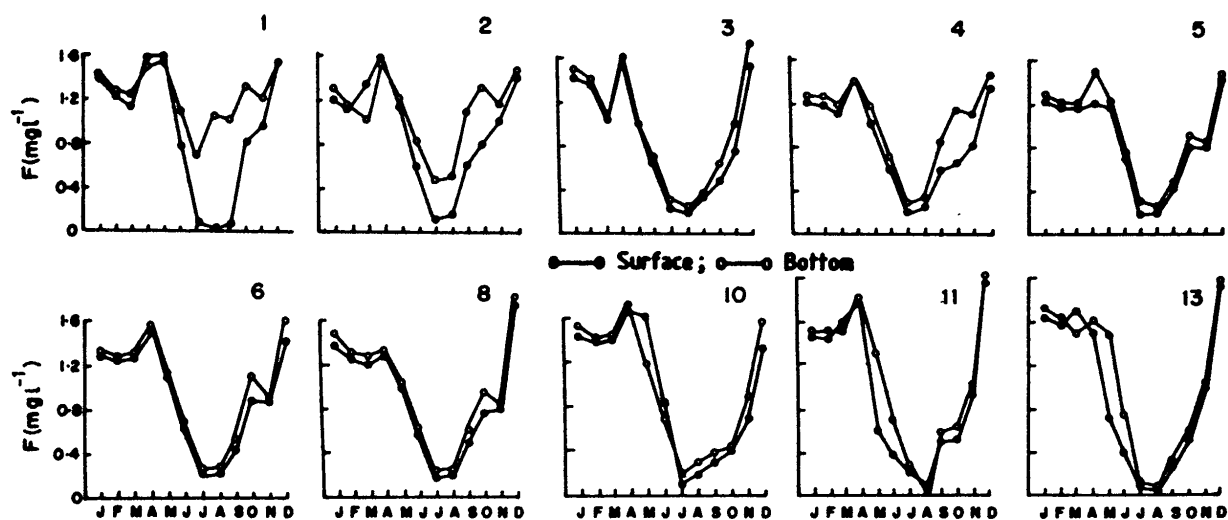


Fig. 7—Distribution of fluoride at various stations during different months

(Fig. 7) concentration (0.5 to > 1.5 mg.l^{-1}) from Oct. at all stations. Maximum concentration is observed during Dec. to April. From May the values begin to decrease and minimum concentrations (< 0.5 mg.l^{-1}) are observed at all stations except at st 1 during July to Sept. At st 1 fluoride content is high (> 0.5 mg.l^{-1}) at the bottom. During this season the fresh water influx through the river is maximum. The extent of seawater incursion into the estuarine system during different months of the year considering the index of seawater penetration as 1×10^{-3} is shown in Fig. 3. Fluoride values at sts 8 to 13 are markedly high (> 1.5 mg.l^{-1}) during Dec. to April (Fig. 7) and there is a general decrease in the concentration towards the river mouth. High concentration of fluoride observed is due to the effect of pollutants discharged from the fertilizer factory situated upstream near to st 13. It is also believed that the Aluminium Factory, which is also in the vicinity of the fertilizer factory, uses cryolite as one of the raw materials and this may be contributing fluoride substantially to the environment. The effect is conspicuous during the time of the year when the fresh water discharge through the river is minimum. Station near to the river mouth also shows higher levels than the usual seawater concentration except during March, but the values are less than the values observed at stations upstream. This indicates clearly the contribution from the river and afterwards dilution by the time the effluent mixed water reaches the river mouth.

Fluoride content of the river water at zero chlorinity collected from the upstream of the industrial belt showed a concentration from 0.18 to 0.24 mg.l^{-1} . This value is slightly higher than what has been reported for the river water from other regions^{5,11}. As already discussed there is a higher concentration of fluoride at

station downstream of the industrial belt during Dec. to April. Absence of higher values at these stations during May to Oct. is due to the greater dilution by fresh water flow.

Fluoride data from the estuary and the river when plotted against chlorinity showed no definite relationship. A linear relationship between fluoride and chlorinity was reported from the estuary when the fresh water containing no fluoride mixes with seawater¹¹. Water samples of lower chlorinity showed a marked variation showing a higher fluoride-chlorinity ratio than chlorinities above 15×10^{-3} indicating contributions from the river.

The secondary maximum observed at chlorinities between 10 and 14×10^{-3} is also believed to be due to the effect of fluoride containing pollutant at the upstream stations during Dec. to April, when the chlorinity values increased from 0 to $> 10 \times 10^{-3}$ due to the decrease in the fresh water flow.

Discussion

Changes in the characteristics of this estuarine system reveal its dependence on the monsoonal cycle of this region. SW monsoon season accompanied by a large volume of fresh water influx into the estuarine system creates stratification at the mouth of the estuary during the flood tide. At stations nearer to the barmouth the direction of flow was controlled by the nature of the tide. Seawater dominated up to st 2 and from there onwards fresh water dominated. Qasim and Sen Gupta¹² observed a salt wedge extending up to a distance of 10 km in Mandovi and 12 km in Zuari rivers during monsoon which is totally absent in this system during this period. The horizontal salinity gradient could be noticed only up to a few stations upwards from barmouth. Eventhough the inorganic

phosphate concentration was generally low compared to the other seasons, there was an accumulation, between sts 3 and 9. This also depicted in the fresh water fraction which does not show much variation between these stations. This showed that even though the pollutant introduced near st 11 gets diluted, the flushing was less during the season, because seawater dilution factor was very negligible beyond st 3 towards the head of the estuary reaching zero value. Therefore any pollutant introduced into the estuary from factories located near sts 11 and 12 would only get diluted by the fresh water influx and would be cradled back and forth according to the tidal current up to st 3 near to barmouth, where it would get progressively mixed with seawater and get diluted further and flushed out of the estuarine system. High concentration of phosphate and fluoride observed between the sts 4 and 9 may be due to the effect of cradling of river water mixed with the effluent discharge in between tidal regimes.

During the postmonsoon period, the salinity gradient along the longitudinal axis of the estuary increases (fresh water fraction curve in Fig. 4). This showed that with the reduction in the river discharge intrusion of saline water was taking place more interior into the estuary (up to 17 km from barmouth). The slight vertical gradient of salinity with an upstream current from surface to bottom showed that the estuary behaved as a partially mixed estuary during the season. The fresh water fraction curve and the phosphate distribution also showed that there was partial mixing of river water and seawater. From the steep gradient of phosphate curve after st 11 up to st 4, it was evident that there was a progressive dilution downstream after the discharge point.

Comparatively high horizontal gradient of salinity from the barmouth to st 13 and beyond and less vertical gradient, with the flow pattern showing a steady upstream current from top to bottom at all the stations, showed that the estuary during the

premonsoon condition is a mixed estuary. This is also quite evident from the distribution of phosphate and fresh water fraction from st 13 downstream. A steady dilution of any pollutant introduced at sts 11 and 12 could be expected downstream up to barmouth.

As the estuary is a tide dominated one it is responding to the vagaries of the monsoon in a great way. The deepening of the harbour entrance channel has increased the tidal prism resulting in greater incursion of seawater into the estuary during the flood tide. Indiscriminate reclamation of the estuarine water area near the harbour entrance for various activities of the harbour has also helped in the horizontal extension of seawater into the river Periyar thereby increasing the salinity of the system considerably.

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