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Suspended Matter Distribution in Beypore Estuary

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Suspended matter concentration (SMC) in the Beypore Estuary during pre-monsoon and monsoon periods from ten stations during 1987-1988 are presented. Variations in suspended matter load at different water levels over the tidal cycles were monitored at one station. Relatively higher values were obtained during monsoon months compared to pre-monsoon period. The highest value of 143 $mg.l^{-1}$ was observed during September 1987 while the lowest value of 2 $mg.l^{-1}$ was obtained during January 1988. Inverse relationship between suspended matter concentrations and salinity was observed during monsoon months. However, the relationship did not hold good during post-monsoon and summer months. Observations during tidal cycles have shown that bottom waters always registered higher values in suspended matter load, most probably due to the re-suspension of bottom mud owing to scouring effect of tidal currents. Sediment content was found to co-vary with the increase in salinity during summer months. Material brought in through river run off contributes mainly to the suspended matter load in monsoon period while particles of marine origin have the major share during summer season.

Key words: Suspended matter, Beypore estuary

Suspended matter in rivers play a vital role in transporting land material to sea. It is estimated that $2x10^{10}$ g of suspended sediments are being transported to ocean by rivers every year (Holeman, 1968). Sand, silt, clay, debris from agricultural land and inorganic matter from weathering of rocks are the main constituents of the suspended matter in the rivers and estuaries. In addition, estuaries receive suspended matter from inshore seawater and from re-suspension of settled mud. Particulate matter generated from biological production also contributes to suspended matter in estuaries (Biggs, 1970). It is observed that the industrial effluents discharged into the estuarine zones usually contain high levels of suspended sediment. Suspended matter present in fresh water flocculates and creates zones of turbidity maxima after coming into contact with seawater. Primary production is usually inhibited by the turbidity and sedimentation destroys spawning grounds of fish. High concentrations are detrimental to river fish due to clogging in their respiratory organs.

Recently, data on suspended matter distribution is extensively used as a tool to trace surface water circulation in estuaries and coastal regions (Klemas *et al.*, 1977). Since their concentration near the tidal inlets is influenced by the tides, their distribution pattern can also be used as a natural tracer for understanding tidal currents (Muralikrishna, 1985). Further, since suspended sediments are the main scavengers of pollutants in the aquatic environment, knowledge on the distribution of suspended matter will reveal information on pollutant concentration and dispersion at a particular area. An understanding of the sources and sinks of suspended matter will be of great use for the rational management of the estuaries. Extensive studies on suspended matter distribution in the estuaries and coastal regions were carried out worldwide (Gibbs, 1976; Allen *et al.*, 1976; Schubel & Carter, 1976 and Biggs, 1970). However, only a few studies have been carried out on the suspended matter concentration in the riverine and estuarine waters of India (Varma *et al.*, 1975; Cherian *et al.*, 1974;

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Balachand, 1994; Nair *et al.,* 1987 and Kurian, 1987).

The Beypore estuarine system is formed at the lower part of Chaliyar River (Fig.1). It is a tropical, shallow, positive estuary and opens to the Arabian Sea in a north-westerly direction. The 169 km long Chaliar River and its tributaries contribute to the major part of the suspended sediment load in the Beypore Estuary. This paper deals with the spatial and temporal distributions of suspended matter in Beypore Estuary and in the lower reaches of Chaliyar River during different seasons. Since the suspended matter concentrations are closely related to the changing salinities and the tidal currents, hourly concentrations were also measured. Variations in concentration of suspended matter over tidal cycles near the mouth of the estuary during the study period were monitored every month and the results are presented here.

Materials and Methods

Surface water samples were collected from 10 stations during June, July, August, September and October in 1987 and January, February and March in 1988 from Beypore estuary and Chaliyar River. Fig.1 shows the locations of the sampling stations. A fibreglass boat fitted with an outboard engine was used for the sample collection. Surface water samples were collected using a clean plastic bucket while a Van Dorn water sampler was used for collection from mid depth and near bottom levels. Samples were collected once every month except during August, September and October 1987. Fortnightly samplings were carried out during this period. Variations in concentration of suspended matter over tidal cycle were monitored every month at a station near the Fisheries Harbour (Station 3, 1.8 km upstream) by analyzing water samples collected every hour from surface, mid depth and near bottom. Water samples were filtered through pre-weighed Millipore filter paper of 0.45 μm pore size and a diameter of 47 mm. Filtration was carried out at 25 cm mercury vacuum and the volume of samples filtered varied from 500 to 1000 ml. After filtration, the filters were rinsed with distilled water till chloride free, dried at 60°C, cooled in desiccator and weighed. The difference in the initial and final weights gave the suspended matter load. Simultaneously, a blank also was run using filtered water sample and corrections made accordingly. Salinity was measured using a Salinity-Temperature-Depth (STD) meter and the values obtained were crosschecked by the Mohr-Knudsen titration method as described by Grasshoff (1976). Current measurements were made using a direct reading current meter of SEA model CM 300. Variations in water level were recorded from a graduated staff fixed at the port premises in the estuary.

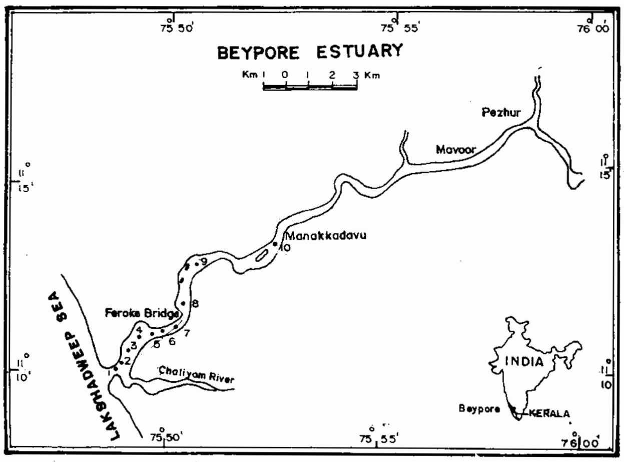

Fig. 1. Location map of the study area.

Results and Discussion

Suspended matter concentration (SMC) and salinity values recorded during the monthly surveys are given Table 1. Station-wise distribution of suspended matter in sub-surface water samples in Chaliar River and Beypore Estuary is given in Fig.2 and the corresponding salinity distributions are depicted in Fig.3. It was observed that in June, the suspended matter content ranged between 3 to 14 mg.l^{-1} among different stations. Highest concentration was observed at the station near Fisheries Harbour (station 3). A decreasing trend in suspended matter concentration was observed towards bar mouth. A similar trend was observed

Table 1. Range and average values of suspended matter concentration (SMC) and salinity during different months

Month	Suspended matter concentration (mg. l^{-1})			Salinity (ppt)		
	Maximum	Minimum	Average	Maximum	Minimum	Average
June 1987	14.00	3.00	8.20	11.92	3.21	6.39
July 1987	25.00	6.00	15.20	35.21	1.20	11.70
August 1987 (I)	85.00	23.00	62.40	26.93	3.10	13.12
August 1987 (II)	115.00	40.00	86.20	0.19	0.06	0.10
September 1987	143.00	38.00	93.50	11.92	3.21	6.39
October 1987	12.00	3.00	7.40	0.10	0.03	0.04
January 1988	12.00	2.00	6.60	32.15	14.80	23.16
February 1988	9.00	3.00	5.10	33.20	19.70	27.27
March 1988	12.00	5.00	7.40	33.94	26.51	30.66

in July also and the maximum concentration of 25 mg.l^{-1} was obtained at harbour station 3. Comparatively higher SMC was noticed during the months of August and September at all stations. This could be attributed to the high influx of river water with heavy load of eroded material from land. During first survey in August, SMC ranged between 23 and 85 mg.l^{-1}, with an average value of 62 mg.l^{-1}, while during the second survey the range was between 40 and 115 mg.l^{-1}, with an average value of 84 mg.l^{-1}. During September a maximum value of 143 mg.l^{-1} was obtained at station near Road Bridge (station 8) while a minimum value of 38 mg.l^{-1} was registered at the bar mouth station (station 1). During the post monsoon period a medium SMC was noticed. In the month of October the range of concentration was 3 and 12 mg.l^{-1} with an average value of 7.4 mg.l^{-1}. Similar pattern was observed during January, February and March and the average suspended matter concentration was 12, 9 and 12 mg.l^{-1} respectively.

The spatial distribution of suspended matter in the Beypore Estuarine system is dependent on a multitude of factors. Compared to the reported average concentration of 40-160 mg.l^{-1} in the Muvattupuzha River (Balachand, 1994) which receives effluents with high suspended solids from a newsprint factory, suspended matter load in Beypore Estuary and Chaliyar River was found to be low. During the period under review, the major industrial establishment in the study area viz. the Mavoor Ryons Factory was not operative and hence contribution towards SMC by industrial effluents was negligible. However, the values are comparable to the suspended matter load in Vembanad Lake, which varied from 0 to 25 mg.l^{-1} during March with 10 mg.l^{-1} concentration in the near coastal waters (Sankaranarayanan & Stephen, 1978). This information agrees well with the observations made based on satellite derived data

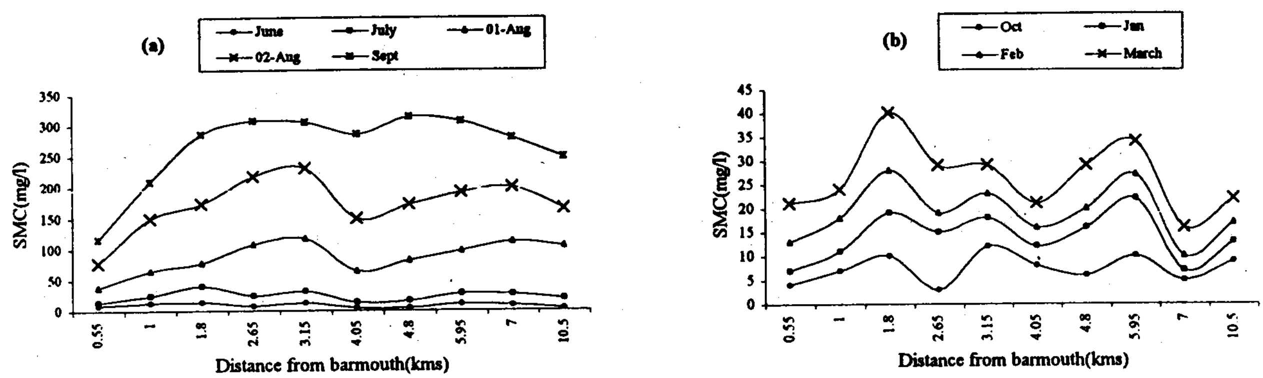

Fig. 2. Longitudinal distribution of suspended matter content (SMC) in Beypore estuary

Table 2. Range and average values suspended matter concentration (SMC) and salinity over tidal cycles

Month	Depth	SMC ($mg.1^{-1}$)			Salinity (ppt)		
		Maximum	Minimum	Average	Maximum	Minimum	Average
June 1987	S	5.74	1.53	3.92	19.00	1.20	4.07
	M	96.08	3.38	21.95	32.13	2.68	17.80
	B	195.94	2.65	46.88	34.07	6.33	22.32
July 1987	S	10.22	1.06	5.95	9.18	1.84	4.31
	M	16.10	2.38	7.95	33.69	7.66	25.65
	B	26.80	3.56	11.20	34.16	22.66	30.23
August 1987 (I)	S	8.74	0.62	4.95	16.55	2.24	8.90
	M	44.90	3.22	12.20	34.23	1.68	20.88
	B	40.80	2.84	16.29	35.61	7.57	24.08
August 1987 (II)	S	123.00	4.20	49.21	0.06	0.03	0.05
	M	137.88	34.23	63.92	0.06	0.03	0.06
	B	169.46	14.50	86.96	0.09	0.06	0.06
September 1987 (I)	S	140.12	6.68	33.15	0.47	0.08	0.14
	M	326.44	9.08	105.73	1.80	0.08	0.42
	B	488.22	74.66	189.72	3.53	0.08	0.84
September 1987 (II)	S	117.10	4.16	31.29	0.70	0.07	0.22
	M	170.18	17.24	70.65	1.56	0.08	0.48
	B	202.76	112.76	104.04	6.20	0.08	1.15
October 1987	S	33.00	0.54	11.43	0.48	0.09	0.22
	M	67.26	7.94	25.70	1.39	0.24	0.93
	B	115.78	23.02	49.27	2.02	0.16	1.33
January 1988	S	10.36	4.60	7.58	23.06	15.37	19.41
	M	14.72	0.24	8.61	29.85	17.88	25.32
	B	18.38	4.80	11.97	30.15	20.99	26.49
February 1988	S	18.54	2.76	10.62	33.25	20.10	27.80
	M	28.53	6.62	14.87	33.40	23.50	29.42
	B	54.92	7.14	20.98	33.70	24.53	29.74
March 1988	S	34.84	4.78	11.38	32.38	23.08	28.80
	M	49.80	9.26	20.11	32.68	25.18	29.97
	B	68.78	11.40	33.14	32.98	23.82	29.72

(Kurian, 1987). Observations carried out by Nair *et al.* (1987) revealed that the contribution of SMC by the two tributaries joining the Chaliyar River was not so significant during pre-monsoon months. Only during monsoon months higher concentrations were observed in both estuary and river. Hence it is quite possible that due to small drainage area, the contributions of suspended matter load by the rivers joining the Beypore

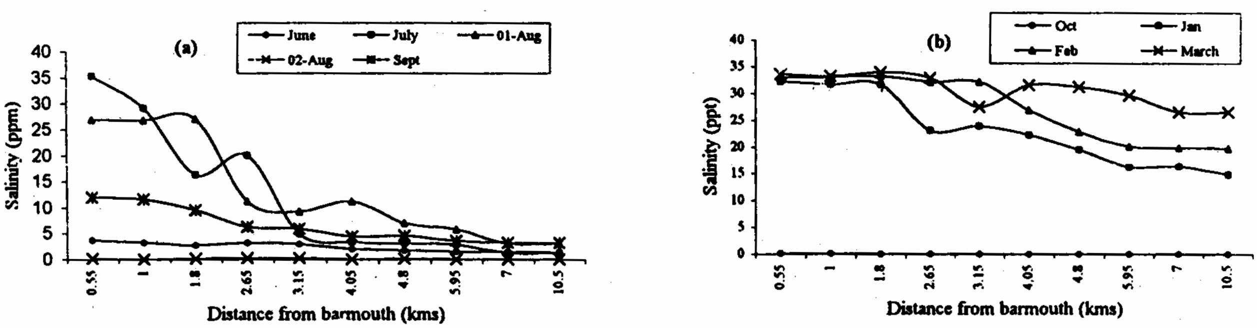

Fig. 3. Longitudinal distribution of salinity in Beypore estuary

Estuary is far less, except during its full spate in monsoon. It was observed that when precipitation was less, even during June and July period, input from river discharge was not significant and the high concentration of suspended matter observed at station near Fisheries Harbour could be due to the resuspension of bottom mud by the disturbances caused by the intense fishing activity concentrated in the area. Relatively higher concentrations of suspended load obtained during summer months might not have been derived from the river, as the river discharge was very low during that time compared to the monsoon months. Comparatively high SMC obtained during summer months might have come along with the intrusion of seawater during flood tide from inshore.

During the study period, salinity values varied widely in space and time (Fig.3). In the beginning of June, except for the first 2 km zone from the bar mouth, the estuary became fresh water dominated with increasing river discharge. During June 1987, the salinity at different stations was around 5 ppt while the bottom salinity near the bar mouth was 25 ppt. The saline water intrusion due to tidal force was found only up to 3 km upstream. Stratification was observed near the bar mouth region and the vertical salinity gradient was 20 ppt. Studies conducted by James & Sreedharan (1983) in the estuary during monsoon have shown the extent of salinity intrusion up to the Fisheries Harbour (1.8 km upstream) which was in agreement with the present observations. However in July, saline incursion was observed up to 2.65 km upstream. In July also a pronounced stratification was observed near to the bar mouth region. However almost clear fresh water was observed in the estuary during June and July and a medium load of SMC was noticed. During the first survey period in August, a clear stratification was observed up to the Road Bridge station (4.80 km up stream). The salinity distribution in the Beypore Estuary reveals that it behaves like many other tropical estuaries. The main factors controlling the salinity distributions are the tidal current and the fresh water brought in by the rivers. During peak monsoon period, the estuary became fresh water dominated. The estuary became well stratified during monsoon months with distinct salinity gradient. During summer months the effect of saline water intrusion was observed up to 22.5 km upstream. The inverse relationship observed between SMC and salinity during monsoon months is not so prominent during post-monsoon and summer months.

Range and average values of SMC and salinity over surface, mid depth and bottom water over the tidal cycle at the station near Fisheries Harbour (Station 3) for the months of June, July, August, September 1987 and January, February and March 1988 are given in Table 2. Average SMC and salinity in different layers over the tidal cycles are depicted in Fig.4 & 5 respectively. It was

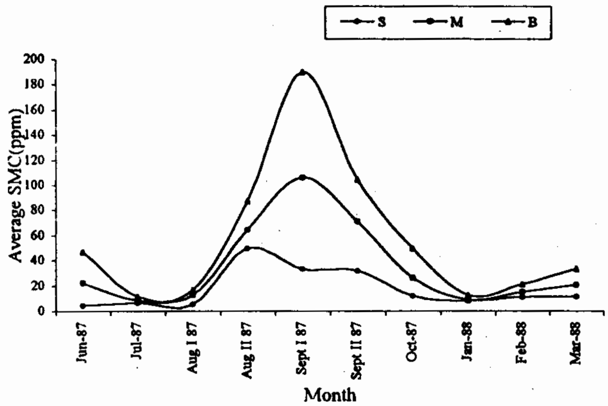

Fig. 4. Average SMC in Surface, Middle & Bottom Layers.

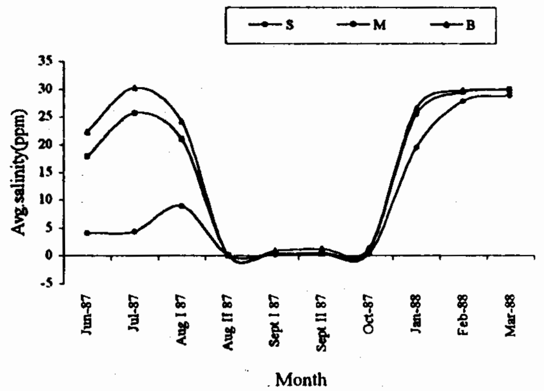

Fig. 5. Average Salinity in Surface, Middle & Bottom Layers.

observed that SMC in near- bottom water always registered high values compared to surface and mid depth. Distinct monthly variations were manifested in the average sediment load in the water column. Wide variations in SMC were observed during monsoon months. The mean SMC in water column during June was 24.3 $mg.l^{-1}$ while during July and first half of August, the concentrations were 8.33 and 11.0 $mg.l^{-1}$ respectively. During second half in August and during both surveys in September, the monsoon was in its full spate and an increased sediment load was observed. Maximum average sediment load of 105 $mg.l^{-1}$ was observed during first half of September. The mean sediment load was 66.33 and 68.33 $mg.l^{-1}$ during August and second half of September. The post monsoon period registered medium SMC values and during October the mean concentration was 28.67 $mg.l^{-1}$. During pre-monsoon months contribution by rivers gradually decreased and by January the mean SMC value was only 9.33 $mg.l^{-1}$. However the average value of 26.1 $mg.l^{-1}$ obtained during February was found to increase to 32.8 $mg.l^{-1}$ in March.

Observation on salinity manifests 3 distinct salinity structures from June 1987 to March 1988. In June, surface salinity was very low (average 4.07 ppt) and an increasing trend was noticed towards mid depth and bottom levels (17.7 and 22.31 ppt respectively). During July and first half of August, the same features were observed. However, during second half of August, September and October, it was observed that the saline water incursion due to tidal force was not so prominent and the entire water column had near fresh water characteristics as evidenced by very low salinity values. Fresh water input gradually decreased and by January onwards the saline water intrusion due to tidal force became prominent and salinity in surface, mid-depth and bottom layers increased. June, July and first half of August with low saline surface water, marked the initial phase of dilution due to precipitation. Monsoon was in its full spate during August and second half September and the entire estuary was filled with muddy fresh water. SMC also was maximum during this period in the entire water column. The effect due to tidal currents was maximum in the bottom layers and due to scouring action, bottom sediments were brought into suspension and maximum SMC was found in the near bottom region. With the increase in current speed, both during high and low tide, scouring up of bottom sediments takes place at an enhanced rate. Investigations made on the suspended matters in the Miramichi Estuary (Willey, 1976) showed that the suspended particulate matter got settled at the bottom sediments in February when tidal currents were at minimum. The texture of the bottom sediments and its rheological behavior matter a lot in deciding the nature of the re-suspension process in estuaries. Dyer (1978) has pointed out that hysterisis between maximum current velocity and the suspended matter is an important factor in determining the turbidity maxima. Certain temporal increase in suspended matter concentration in estuaries was attributed to the increased wave action and shallowness of the estuary (Postma, 1967; Varma *et al.*, 1975). Vertical advective flux of sediments associated with tidal and non-tidal currents taking place in estuaries can also contribute to the SMC (Schubel, 1976). The higher concentration of suspended matter observed occasionally during tidal cycle can be attributed to the entrainment from deeper layers owing to one or several physical factors such as waves and currents operative in that area. It was also noticed that the net sediment content over tidal cycle varied considerably over months. Increase in SMC was found to co-vary with the increase in salinity during pre-monsoon period.

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