MAHASAGAR
Vol.22, No.4 (December), 1989, pp.165-172

VOLUME TRANSPORT AND ESTUARINE FEATURES AT COCHIN INLET

JOMON JOSEPH AND P.G. KURUP*

Centre for Earth Science Studies, Regional Centre, Cochin-682018

ABSTRACT

The volume transport of water at Cochin inlet is controlled by tidal range and duration, quantity of freshet and intrusion of saline water. It is seen that, for tides of almost equal duration and range, the volume transport under flood tide during south-west monsoon is comparatively lower than that during other seasons. It is comparatively higher at ebb tides during monsoon. The freshwater fraction is slightly higher in Ernakulam channel than Mattanchery channel. Freshwater fraction is very large during south-west monsoon (0.71 in July, 1985) and the least during pre-monsoon (0.22 in March, 1986). The freshwater content increases from September (0.29) to October (0.47) and decreases thereafter. Dilution factor is high (4.00 to 4.55) during pre-monsoon and low during south-west monsoon. Computed values of Stratification-Circulation parameters for Cochin inlet show high values during monsoon. In July and August the estuary can be classified as saltwedge type or highly stratified; in September to January and June partially mixed conditions prevail while during the rest of the months, well mixed conditions exist.

Key-words: Volume transport, dilution, flushing, stratification, Cochin inlet.

In recent years, considerable environmental changes have been brought about in the Cochin estuarine system as a result of rapid urbanisation, industrialisation and harbour development. The presence of Cochin harbour (9°58' N & 76°15' E) makes this estuary an important centre of commercial shipping and fisheries. The navigational channels of Cochin harbour consist of an approach channel and two inner channels – the Ernakulam and the Mattanchery on either side of the Willingdon Island. Major perennial rivers which discharge freshwater directly into this estuarine system are Periyar and Muvattupuzha. A second inlet of the estuarine system exists at Azhikode and a major part of the discharge from Periyar enters the sea through this inlet. A large number of industries located on the banks of Periyar discharge effluents into this river. The dilution and flushing characteristics of this estuary have great influence on the transportation and disposal of waste materials including industrial pollutants and dredged spoil. The present study attempts to discuss volume of water transport at Cochin inlet during different phases of tide, dilution and flushing characteristics

* School of Marine Sciences, Cochin University of Science and Technology, Cochin 682016.

based on data collected in the Ernakulam and Mattanchery channels and monthly variations of estuarine features based on salinity-circulation parameters.

Hourly observations on hydrographic parameters were made at 0.5m below the surface, middle depth and 0.5m above the bottom of the estuary at stations 1-7 (Fig.1) during spring and neap tides for various months during 1985-86. The current velocity was measured using a Direct Reading Digital Current Meter and salinity using Salinity-Temperature-Depth (STD) Meter developed by the Central Institute of Fisheries Technology. The accuracy of water current speed, direction and salinity are ±2 cm/sec, ±5° and ±0.01 ppt respectively. The tidal data for the period of study were collected from Cochin Port Trust.

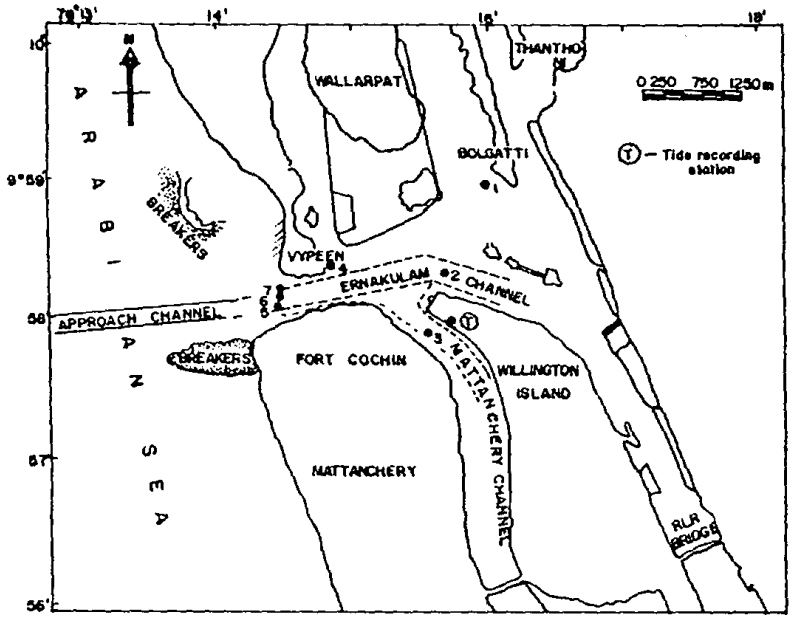

Fig.1. Map showing location of stations 1-7.

The accurate value of net water transport can be found out from continuous observations for a fortnight period. Since such continuous observations are of great practical difficulties, the present study is limited to the estimation of the volume transport of water at different phases of tides across the Cochin inlet. The net volume of water exchanged across the inlet was calculated using the average current velocities at the cross sectional area. The cross sectional area of Cochin inlet (4805m^2) was determined by obtaining the bottom profile using lead sounding (10m interval) corrected to mean sea level (Fig.2). Monthly variations of dilution and flushing characteristics at five selected stations (Stns. 1-4,6) in the Ernakulam, Mattanchery and entrance channels are estimated. Monthly

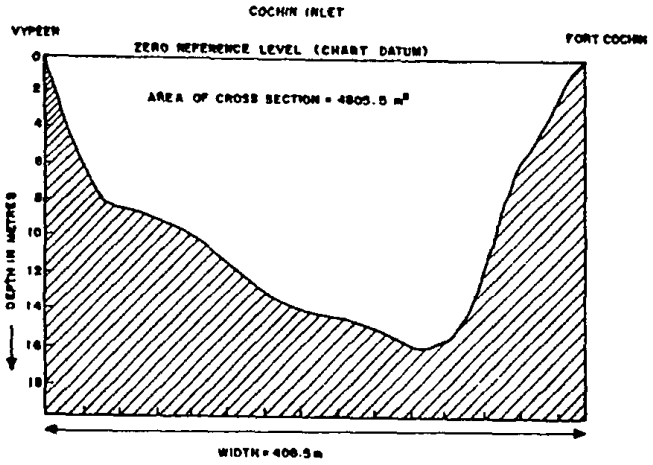

Fig.2. Cross sectional area of Cochin inlet.

variations of estuarine features are discussed based on the method of Hansen and Rattray using Stratification-Circulation diagram.

Volume transport across Cochin inlet: According to the law of conservation of volume, transport of water through the upstream section must equal the transport through the down stream section of the estuary (Swenson and Chuang, 1983). Raju, Varma and Pylee (1979) studied the tidal prism values at Cochin inlet at spring tide during different seasons. The values of volume transport at Cochin inlet at different phases of tides during 1985-86 are presented in Table I.

The largest magnitude (68.37×10^6 m^3) of volume transport is found during spring ebb in November and the least (6.25×10^6 m^3) during neap flood in October. These values depend on several factors viz. tidal range and duration, quantity of freshwater discharge, intrusion of saline water, etc. For tides of almost equal duration and range, it is found that the volume transport during flood tide in south-west monsoon season is comparatively lower than that during other seasons. On the pre-monsoon days (e.g. 10.4.85 and 22.5.85), the volume transports during spring floods are found to be 54.73×10^6 m^3 and 66.62×10^6 m^3 respectively, while on monsoon days (e.g. 19.7.85) the value is 44.82×10^6 m^3 under more or less equal tidal range (about 101 cm) and duration (about 8h). The volume transport is higher at ebb tides during south-west monsoon season, e.g. 30.41×10^6 m^3 on 11.7.85, when the tidal range was only 14cm.

Dilution and Flushing: River discharges into the estuary very seasonally, sometimes quite drastically, and this is reflected in the salinity distribution and flushing of effluents within the estuary. The amount of freshwater contained at any location in the estuary is obtained using the equation $F = \frac{S_o - S_n}{S_o}$, where 'F' is the fraction of freshwater, 'S_n' the salinity at

Table I — Volume transports for ebb and flood periods across Cochin inlet during different phases of tide.

Date	Phase of tides	Tide levels (cm)	Duration (h)	Average cross sectional area (m^2)	Average velocity ($m.sec^{-1}$)	Volume transport ($\times 10^6$ m^3)
10.04.85	SF	011-114	0825-1631	5038.41	0.3748	54.73
17.04.85	NE	081-049	1156-1604	5071.03	0.2760	20.56
13.05.85	NE	073-054	0715-1150	5062.86	0.1330	10.54
22.05.85	SF	006-106	0708-1502	5054.69	0.4843	66.62
11.07.85	NE	078-064	0717-1205	5095-54	0.3620	30.41
19.07.85	SF	-(002)-099	0612-1400	5017.80	0.3317	44.82
05.08.85	NF	018-090	0755-1520	5026.01	0.3284	43.08
17.09.85	SF	028-092	0718-1335	5050.60	0.4613	51.83
23.09.85	NE	076-057	0730-1328	5075.11	0.2433	24.80
08.10.85	NF	068-070	1120-1500	5087.37	0.1004	06.25
16.10.85	SF	045-089	0640-1352	5079.19	0.2002	18.92
07.11.85	NE	104-072	0700-1420	5164.98	0.2377	31.60
13.11.85	SE	088--(013)	1022-1730	5013.84	0.5235	68.37
06.12.85	NE	102-053	0550-1244	5124.13	0.2115	25.59
12.12.85	SE	096- -(004)	0947-1710	5009.80	0.4908	64.01
15.01.86	NF	036-075	0950-1510	5034.20	0.2044	19.26
28.01.86	SF	060-091	0810-1300	5115.96	0.1617	13.40
13.03.86	SF	034-100	0800-1420	5079.19	0.3917	44.41
18.03.86	NF	016-086	1018-1820	5013.80	0.2500	34.11
11.06.86	SF	011-094	0733-1543	5022.01	0.2948	43.17
16.06.86	NF	047-089	1111-1811	5083.28	0.2482	31.79

SF - Spring flood, SE - Spring ebb, NF - Neap flood, NE - Neap ebb

any location inside the estuary and 'S_o' the salinity of the 'source' water (Ketchum, 1969 and Officer, 1976). Using this method, Qasim and Sen Gupta (1981) studied average seasonal dilution and flushing characteristics of the Mandovi and Zuari estuaries. Sankaranarayanan, Varma, Balachandran, Pylee and Joseph (1986) calculated average seasonal freshwater fraction and dilution factor at lower reaches of river Periyar during the period 1982-83.

For the salinity of the 'source' water, the values at a station about 8 km away from the mouth of the estuary are taken. Table II gives the freshwater fraction (F) and dilution factor (R) inverse of freshwater fraction at different stations for various months. It is seen that the freshwater content is minimum at station 6 and maximum at station 1 during all months. Also, the freshwater content is slightly higher in the Ernakulam channel (stn 2) than the Mattanchery channel (stn 3), indicating greater influence of freshwater discharge on the Ernakulam channel.

Table II — Fresh water fractions (F) and Dilution factors (R) at different stations during 1985-86.

Months		1985 Apr	May	Jul	Aug	Sep	Oct	Nov	Dec	1986 Jan	Mar	Jun
Sea	(S‰)	36.21	36.43	32.35	32.43	34.45	34.57	35.13	35.68	36.21	36.09	33.48
	S‰	25.05	25.16	2.20	2.88	18.35	8.40	17.05	20.70	23.81	25.80	16.89
Stn: 1	F	0.31	0.31	0.93	0.91	0.47	0.76	0.51	0.42	0.34	0.29	0.50
	R	3.23	3.23	1.08	1.10	2.13	1.32	1.96	2.38	2.94	3.45	2.00
	S‰	27.15	27.75	12.20	12.60	26.05	19.20	23.80	25.31	27.00	28.31	21.83
Stn: 2	F	0.25	0.24	0.62	0.61	0.24	0.44	0.32	0.29	0.25	0.21	0.35
	R	4.00	4.17	1.61	1.63	4.17	2.27	3.13	3.45	4.00	4.76	2.86
	S‰	27.35	28.85	12.30	12.90	26.34	20.10	24.09	26.42	27.92	29.23	22.01
Stn: 3	F	0.24	0.26	0.61	0.60	0.23	0.42	0.31	0.26	0.23	0.19	0.34
	R	4.17	3.85	1.62	1.67	4.35	2.38	3.23	3.85	4.35	5.26	2.94
	S‰	27.30	28.40	6.33	8.40	23.55	18.90	22.40	28.60	26.50	28.21	20.59
Stn: 4	F	0.25	0.22	0.80	0.74	0.32	0.45	0.36	0.20	0.27	0.22	0.38
	R	4.00	4.55	1.25	1.35	3.13	2.22	2.28	5.00	3.70	4.55	2.63
	S‰	29.00	30.35	13.50	15.90	27.90	24.20	30.40	30.60	30.30	29.40	24.80
Stn: 6	F	0.20	0.17	0.58	0.51	0.19	0.30	0.15	0.14	0.17	0.19	0.26
	R	5.00	5.88	1.72	1.96	5.26	3.33	6.67	7.14	5.88	5.26	3.85
Average	$\bar{F}$	0.25	0.24	0.71	0.67	0.29	0.47	0.33	0.26	0.25	0.22	0.37
Average	$\bar{R}$	4.00	4.17	1.41	1.49	3.45	2.13	3.03	3.85	4.00	4.55	2.70

The Cochin estuarine region is considered as a single system. Salinity values at all the stations are averaged for each month. Since the estuary is tide dominated and remains homogeneous for a greater part of the year, longitudinal variations in salinity are considered insignificant. It is seen that the freshwater fraction attains maximum value during south-west monsoon period (0.71 in July, 1985) and is the least during pre-monsoon period (0.22 in March 1986). The freshwater content increases from September (0.29) to October (0.47) and decreases thereafter. Higher values of dilution factor (4.00 to 4.55), occur during pre-monsoon season when the freshwater flow is negligible.

Stratification and circulation parameters: Hansen and Rattray (1965, 1966) used the dimensionless theoretical parameters $\frac{\delta_s}{S_o}$ and $\frac{U_s}{U_f}$ for the classification of estuaries, where $\frac{\delta_s}{S_o}$ is the stratification parameter, defined as the ratio of the surface to bottom difference in salinity (δ_s) to the mean cross sectional salinity (S_o), and $\frac{U_s}{U_f}$ is the circulation parameter, which is

the ratio of the net surface current to the mean cross sectional velocity. All the above parameters are tidally averaged. The values of these parameters calculated at Cochin inlet for each month are presented in Table III. Generally higher values of stratification and circulation parameters are found during monsoon months. The highest value (1.692) of stratification parameter was found in July and the lowest (0.0754) in November, 1985. Similarly the highest value (2.27) of circulation parameter was found in July and the lowest (0.82) in May.

Table III – Stratification and circulation parameters at Cochin inlet.

Months	δ_s	S_o	$\frac{\delta_s}{S_o}$	U_s	U_f	$\frac{U_s}{U_f}$
1985						
Apr	2.13	27.57	0.077	25.78	22.61	1.14
May	2.68	28.95	0.093	28.86	35.09	0.82
Jul	15.40	9.10	1.692	82.13	36.20	2.27
Aug	18.04	12.38	1.457	46.53	28.10	1.66
Sep	9.74	25.23	0.386	34.50	33.19	1.04
Oct	18.95	22.47	0.843	64.87	42.03	1.54
Nov	2.19	29.04	0.0754	39.46	27.95	1.41
Dec	3.16	29.72	0.106	51.49	39.44	1.32
1986						
Jan	3.20	29.05	0.110	34.23	30.11	1.14
Mar	2.68	28.41	0.097	27.10	28.73	0.96
Jun	13.09	23.73	0.556	43.08	28.45	1.92

In the Stratification-Circulation diagram of Hansen and Rattray, seven types of estuaries are delineated. Type 1, represents well mixed estuary in which the net flow does not reverse with depth and the upstream salt transfer is by diffusion. Type 1a is laterally homogeneous well mixed estuary, whereas 1b shows appreciable stratification. For Type 2, the net flow reverses with depth and both advection and diffusion contribute to the net upstream salt flux. Type 2a and 2b have the same stratification boundary as type 1. In Type 3, estuaries differentiated by the salt transfer is primarily advective. In Type 3a, the lower layer is so deep that circulation does not extend to the bottom (e.g. Fjords). Type 4 estuaries are characterised by the presence of arrested saltwedge (Dyer and Ramamoorthy, 1969; Dyer, 1973; Bowden, 1978 and Officer, 1983).

The Stratification-Circulation parameters for various months at Cochin inlet are plotted in the diagram of Hansen and Rattray (Fig.3). At Cochin inlet, the estuarine features vary from month to month. In July and August, the estuary is characterised as saltwedge type or highly stratified; in September, October, December, January and June it is moderately stratified or partially mixed and during the rest of the months, it is well mixed.

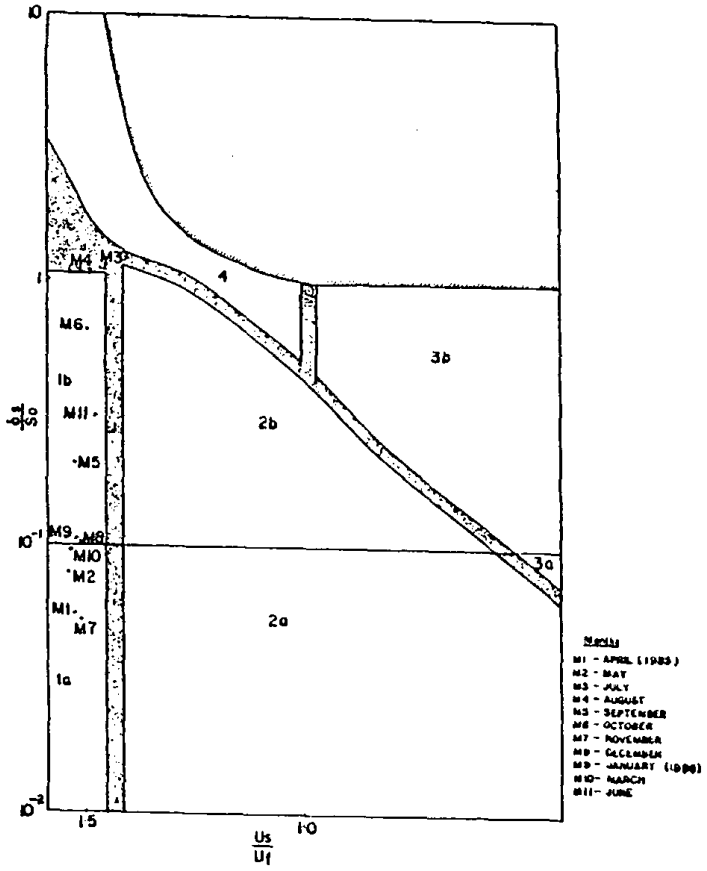

Fig.3. Stratification-Circulation diagram at Cochin inlet

ACKNOWLEDGEMENTS

The authors are grateful to the authorities of Port Trust, Cochin for providing tide data. The financial support given by U.G.C., New Delhi is gratefully acknowledged.

REFERENCES

Bowden, K.F., 1978. Mixing processes in estuaries: *Estuarine Transport Processes*, edited by Bjorn Kjerfve, University of South Carolina Press, Columbia, **7**: 11-36.

Dyer, K.R., 1973. *Estuaries: A Physical Introduction*, John Wiley, London, 140 pp.

Dyer, K.R. and K. Ramamoorthy, 1969. Salinity and water circulation in the Vellar estuary. *Limnology and Oceanography*, **14**: 4-15.

Hansen, D.V. and M. Rattray, 1965. Gravitational circulation in straits and estuaries. *Journal of Marine Research*, **23**: 104-122.

Hansen, D.V. and M. Rattray, 1966. New dimensions in estuary classification. *Limnology and Oceanography*, **11**: 319-326.

Ketchum, B.H., 1969. Eutrophication: Causes, consequences and correctives. In: Eutrophication of estuaries. *National Academy of Sciences*, Washington D.C., 197-209.

Officer, C.B., 1976. *Physical Oceanography of Estuaries (and Associated Coastal Waters)*, John Wiley and Sons, New York, 465 pp.

Officer, C.B., 1983. Physics of estuarine circulation, *Ecosystem of the World 26, Estuaries and Enclosed Seas*, Edited by Bostwick, H. Ketchum, Elsevier Scientific Publishing Company, Amsterdam, 15-41.

Qasim, S.Z. and R. Sen Gupta, 1981. Environmental characteristics of the Mandovi-Zuari estuarine system in Goa. *Estuarine, Coastal and Shelf Science*, **13**: 557-578.

Raju, V.S.R., P.U. Varma and A. Pylee, 1979. Hydrographic characteristics and tidal prism at the Cochin harbour mouth. *Indian Journal of Marine Sciences*, **8**: 78-84.

Sankaranarayanan, V.N., P.U. Varma, K.K. Balachandran, A. Pylee and T. Joseph, 1986. Estuarine characteristics of the lower reaches of the river Periyar (Cochin Backwater). *Indian Journal of Marine Sciences*, **15**: 166-170.

Swenson, E.M. and W.S. Chuang, 1983. Tidal and subtidal water volume exchange in an estuarine system. *Estuarine, Coastal and Shelf Science*, **16**: 229-240.