STUDIES ON THE EFFECT OF POLLUTION, WITH SPECIAL REFERENCE TO BENTHOS, IN COCHIN BACKWATERS

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This is to certify that this thesis is an authentic record of the work carried out by Mrs. K.N. Ramani, M.Sc. under my supervision at the Regional Centre of the National Institute of Oceanography (C.S.I.R.), Cochin and that no part thereof has been presented for the award of any other degree.

14/2/79

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CHAPTER I

STUDIES ON THE EFFECT OF POLLUTION, WITH SPECIAL REFERENCE TO BENTHOS, IN COCHIN BACKWATERS

INTRODUCTION

Pollution is essentially a biological phenomenon perhaps older than the history of man. Natural or manmade, environmental pollution is assuming enormous proportions, increasing considerably day by day, with the advent of civilisation and urbanisation, industrially or otherwise, the world over. Technological advances man has achieved tend to upset the ecological balance on this tiny planet to the disasters of man himself. The problem has been recurring and challenging, reaching even the courts of law. A trend of global awareness on pollution is sounded strongly in recent times. Inland waters, estuaries and even the world oceans should not be expected to have an unlimited capacity to absorb increasing amount and variety of waste substances and energy from our civilization.

Studies on the estuaries in India date back to the beginning of this century. Annandale (1907), Alcock (1911) and Kemp (1917) described the fauna of Ganges delta. Chilka lake was studied by Annandale and Kemp (1915) and Sewell (1924). Ayyar and Panikkar (1937) studied the brackish water fauna of Madras. Chandra Mohan (1963) and Chandra Mohan and Rao (1972) made observations on Godavari estuary. Vellar estuary of Porto Novo was studied by Seshaya (1959), Ranga Rajan (1959) and Krishnamurthi (1972) - all from the east coast. On the west coast, Mandovi estuarine system of Goa was studied by Das et al (1972), Singbal (1973), Parulekar et al (1973) and Varma et al (1975).

Even though these studies contributed considerably to a better understanding of our estuaries especially their hydrography and productivity, pollution aspects were not attempted seriously.

David (1959), Gopalakrishnan et al (1970), Basu (1966) Ganapati et al (1951) and Ganapati et al (1973 and 1976) studied pollution aspects in Kulti, Hooghly and Godavari estuaries and Vizakapatnam harbour respectively all on the east coast of India. However, contributions from the west coast are meagre.

Fig.1: Cochin Backwaters with location of observation stations 1-7 around Willingdon Island, A-D at Vaduthala and I-IV from Kalamasseri to Barmouth for studies on Pollution from Sewage, Retting of Coconut husk and Industrial Effluent Discharge respectively.

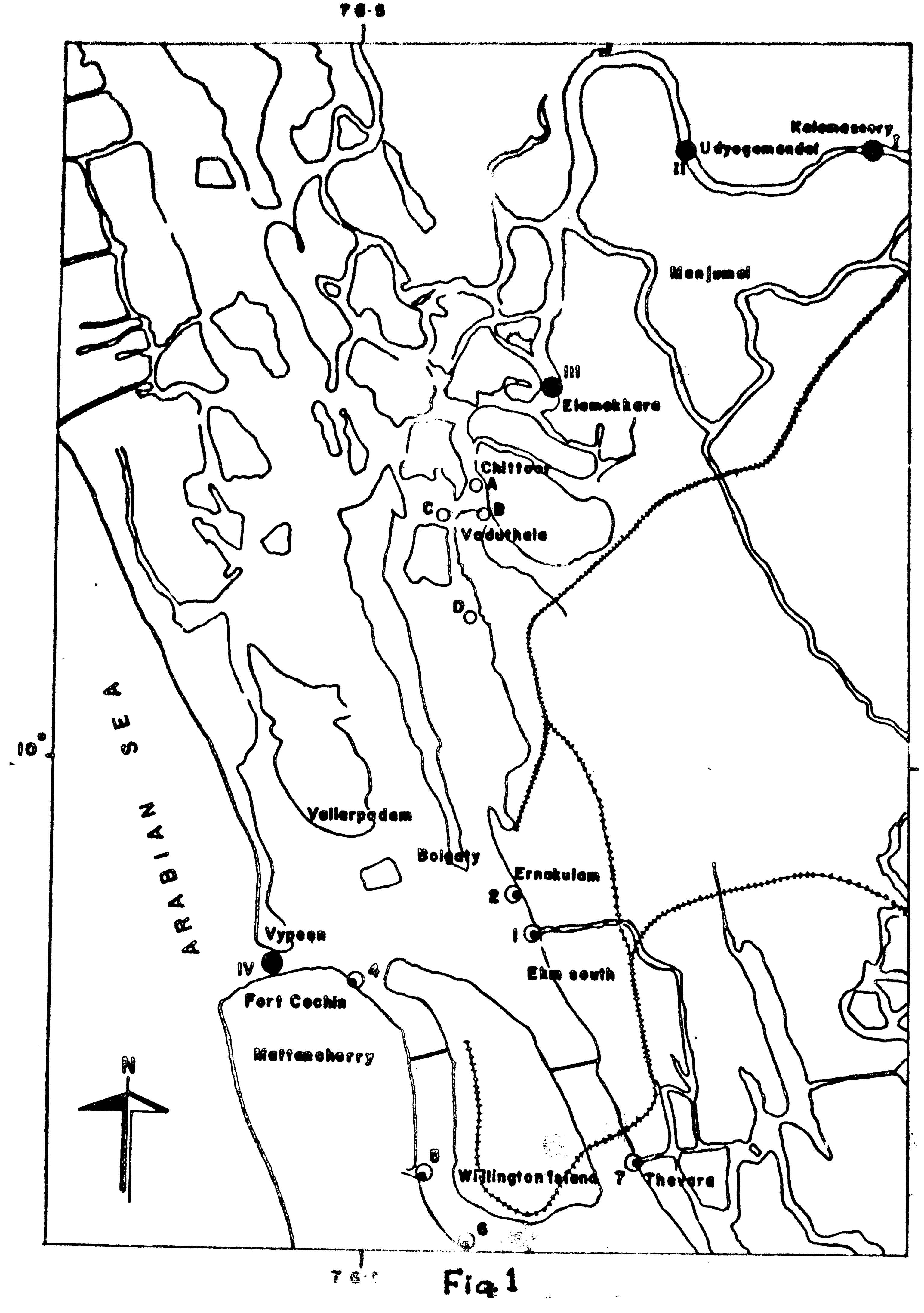
76·5
Kalamassery
Udyogamandal
II
I
Manjumal
III
Elamakkara
Chittoor
A
C
B
Vaduthala
D
ARABIAN SEA
10°
Vallarpadam
Bolgaty
Ernakulam
2
1
Vypeen
IV
4
Ekm south
Fort Cochin
Mattancherry
N
5
Willington Island
7
Thevara
6

Fig. 1

Kerala, the south west State of India, is studded with over a dozen large and small backwaters or estuaries along its western border. While providing waterfront for large or small industries these estuaries located around the river mouths form large landlocked receptors for inland water, often polluted as well due to indiscriminate discharge of industrial, agricultural or domestic effluents. Located along 9°58'N and 76°15'E on the south west coast of India, Cochin backwaters (Fig.1) contributes to the largest of these estuaries in Kerala receiving the two major rivers Periyar and Pampa with their tributaries and opening ultimately into the Arabian Sea. On the west coast, Cochin backwater system forms one of the better studied estuaries in India. General hydrography of the estuary has been studied by Ramamritham and Jayaraman (1963), Darbishire (1967), Haridas et al (1973) and Shynamma and Balakrishnan (1973). The tidal fluctuations have been covered by George and Krishna Kartha (1963) and Qasim and Gopinathan (1968 & 1969), distribution of nutrients by Sankaranarayanan and Qasim (1969) and Manikot and Salih (1974), salinity by Gopinathan and Qasim (1971), sediments by Murty and

Veerayya (1972), phosphate generation by Reddy and Sankaranarayanan (1972), organic production, phytoplankton ecology and related aspects by Qasim and Reddy (1967), Qasim et al (1969), Qasim (1970) and Devassy & Bhattathiri (1974). These studies though important were not pollution oriented. Present attempt is an interdisciplinary approach to investigate the nature and extent of pollution from different sources in Cochin backwaters.

Considerable number of factories and related establishments forming an industrial complex are located in the upper reaches of the estuary from Varapuzha about 10 km from Cochin barmouth to Alwaye, while lower down are the retting grounds at Vaduthala and nearby places at about 5 km from the barmouth. Municipal wastes from the city population of over 5 lakhs, effluents and solid waste from several fish processing factories and other land washings around Willingdon Island reach the estuary more near its lower reaches close to the barmouth. Cochin estuary is the biggest in the state providing water front for the largest number of industries from the small retting grounds of Vaduthala to the huge fertilizer factories of Udyogamandal and receiving the highest quantity of town sewage and land drainage. The estuary contributes itself as nursery ground for shrimps and related fishery as well. Study of this estuary should therefore contribute to a typical environment as regards pollution problems in the tropics and hence the scope of the present investigation. Moreover, scientific study on environmental pollution in the estuary has not been initiated till recently (Unnithan, Vijayan, and Remani, 1975). The data collected for an year (1974-75) of investigation on sewage pollution around Willingdon Island, another year (1975-76) of study on pollution due to retting coconut husk in Vaduthala and a third year (1976-77) of observation on pollution from industrial effluent discharge in Kalamassery Industrial Complex (Udyogamandal), in Cochin backwaters, are presented and discussed. Three published contributions (Unnithan, Vijayan and Remani, 1975, Vijayan, Unnithan and Remani, 1976 and Unnithan, Vijayan, Radhakrishnan & Remani, 1977) in line with the study are also included.

ACKNOWLEDGEMENTS

I am grateful to Dr. R.V. Unnithan, Scientist under whose guidance and supervision this work was carried out from the Regional Centre of the National Institute of Oceanography (CSIR), Cochin-18. I am also thankful to Dr. S.Z. Qasim, Director, National Institute of Oceanography for providing facilities for the work. Thanks are also due to Shri K. Veerabhadra Rao and Dr. Y. Radhakrishna for confirming the identification of bivalves and polychaetes respectively. The award of CSIR Research Fellowship during the tenure of which this work was carried out, is also gratefully acknowledged. I owe a special debt of gratitude to my colleagues in the Regional Centre of N.I.O., Cochin, for the kind help and encouragements extended to me in the various stages of this work.

MATERIAL AND METHODS

Details on materials and methods, location of stations, area of collection etc. regarding the investigation on organic pollution around Willingdon Island for an year (1974-75) are given in the published contributions (Unnithan *et al.* 1975) and Vijayan *et al.* 1976) which are included in the present work.

For the investigation on pollution due to retting of coconut husk at Vaduthala in the backwaters, three observation stations (A, B, C), each 2-4 metres in depth were fixed equidistant to one another in the retting zone. Of these the third station was located close

Fig.2: Location of observation stations in A, B, C & D
(I,II,III & IV).

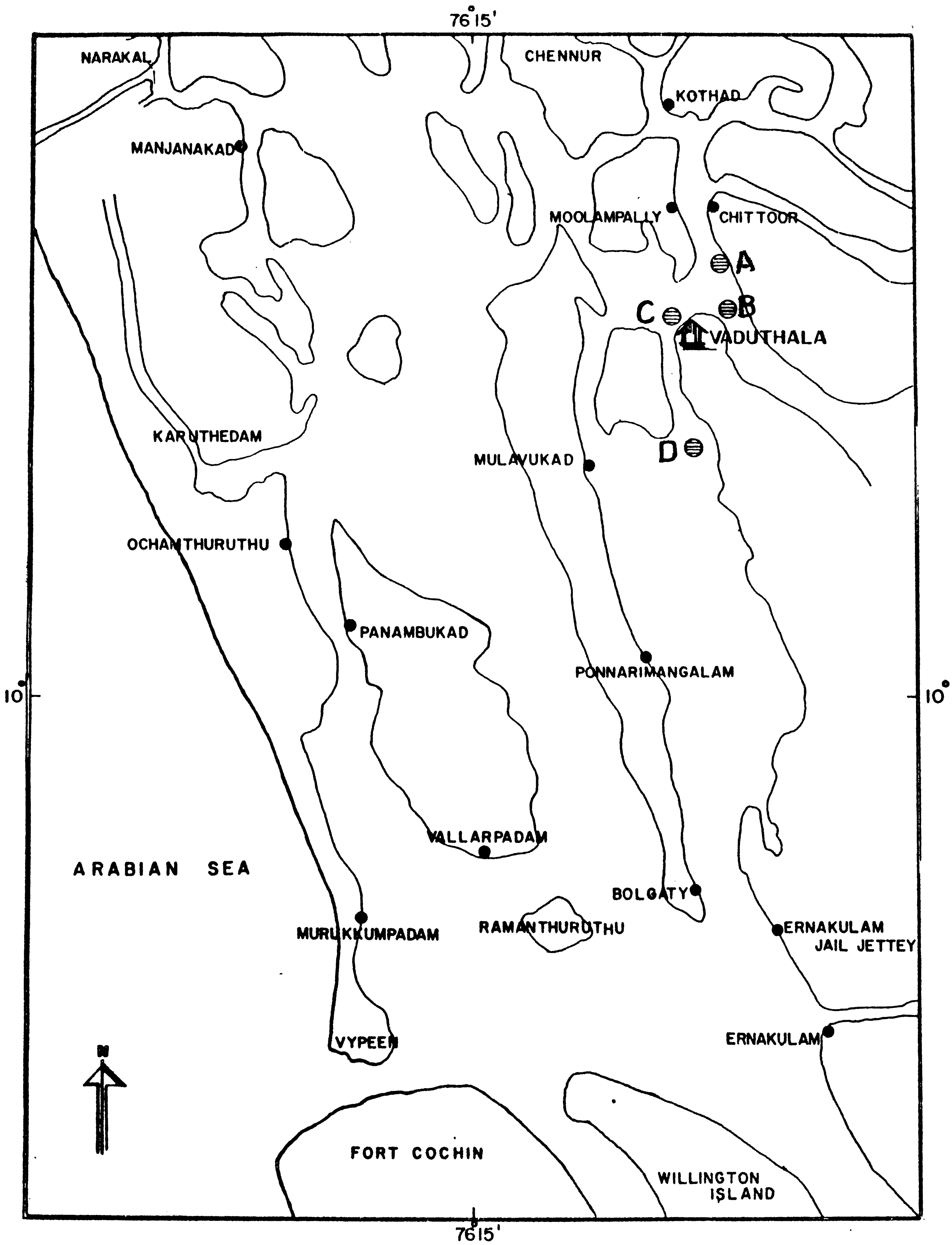
76°15'
NARAKAL
CHENNUR
KOTHAD
MANJANAKAD
MOOLAMPALLY
CHITTOOR
A
C
B
VADUTHALA
KARUTHEDAM
D
MULAVUKAD
OCHAMTHURUTHU
PANAMBUKAD
PONNARIMANGALAM
10°
10°
VALLARPADAM
ARABIAN SEA
BOLGATY
MURUKKUMPADAM
RAMANTHURUTHU
ERNAKULAM
JAIL JETTEY
N
VYPEEN
ERNAKULAM
FORT COCHIN
WILLINGTON
ISLAND
76°15'

Fig. 2

to the husk processing plant. A 'clean' (unpolluted) station (D) sufficiently away from the retting ground was also sampled, for comparative studies (Fig.2). Monthly observations on temperature, salinity, oxygen, total sulphide, BOD_5, organic carbon, organic nitrogen, grain size and benthos were undertaken from the three stations in the polluted area and the clean station nearby, continuously for twelve months, from July 1975 to June 1976.

For the studies on Pollution from industrial effluent discharge in the backwaters, four transects in the area extending from Kalamassery to barmouth were selected (Fig.1). Transect I located upstream at Kalamassery formed the control station (I). Second transect was at Udyogamandal (Eloor, Station II) immediately downstream the industrial complex and about 15 km up the barmouth, which formed the main effluent discharging site for the chain of industrial establishments (Unnithan et al. 1977). The third transect (recovery zone, station III) was located at Elamakara midway between barmouth and Kalamassery (Station I). Transect IV was at the barmouth (Station IV) which was common (station 3) for investigation (1974-75) referred earlier. Monthly sampling for an year (December 1976-November 1977) was undertaken from the 4 stations for the various parameters as referred above and also for pH, COD (dichromate reflux method, APHA, 1960), suspended solids and heavy metal monitoring in the mud and benthic animals of the estuary. Effluent samples were also analysed for COD (Permanganate method, ICES, 1972), alkalinity (backtitration method, APHA 1960) ammonia (indophenol blue method of Koroleff, 1969) and BOD_5.

Water samples were collected with a plastic bucket from surface while sampling was done with a Hytech water sampler from the bottom of each station according to their depths for the estimation of temperature, salinity, dissolved oxygen, bio-chemical - oxygen demand and total sulphide. Bottom sampling was done with the van Veen grab (0.05 m^2) at each station for bottom fauna. Two grab samples were taken from each station fortnightly around Willingdon Island and monthly from the retting grounds. Preliminary sieving was made on board the work boat "Neendakara". All organisms which were retained by a 0.5 mm mesh sieve (Birkett et al. 1971) were collected and preserved in 5% neutral formalin for further study. All the animals in each sample were sorted and identified. A small portion of the mud sample from each station was subjected to grain size analysis, organic nitrogen and carbon estimations. Salinity was estimated by Mohr Knudsen method (Barnes, H. 1959). Dissolved Oxygen was estimated using Winkler method (Strickland and Parson, 1965).

Biochemical Oxygen Demand (BOD_5) was measured by unseeded dilution method (American Public Health Association, 1960).

Suitable portion of the sample was diluted with water which was saturated with oxygen. The dissolved oxygen content (Winkler method) was determined immediately after dilution and also after 5 days incubation at 20°C. The 5 day BOD (Mg/L) was obtained from the equation:

$$BOD_5(mg/L) = \frac{\text{Initial D.O-Final D.O} \times 300\ ml}{\text{Ml of waste/bottle}}$$

Total sulphide was measured asfollows, using the standard procedure suggested by American Public Health Association (1960). Water samples were preserved using zinc acetate and the sulphide in it was fixed as zinc sulphide. From the precipitated sample, hydrogen sulphide wa was generated using Conc. Hcl in an inert atmosphere of carbon dioxide. The evolved hydrogen sulphide was dissolved in distilled water and titrated against standard sodium thiosulphate solution using starch as indicator after adding a known volume of standard iodine solution.

Organic carbon in mud was estimated by wet oxidation method (Wakeel and Riley, 1957). The mud samples were washed with distilled water on a sintered glass funnel (Porosity 4). After drying at 105°C the samples were ground to pass through 100 mm mesh sieve. Weighed out samples were heated with chromic acid in a bath of boiling water for 15 minutes. The chromic acid remaining after reduction was determined volumetrically with standard ferrous ammonium sulphate using ferrous phenanthroline indicator. The organic carbon values were multiplied by the factor 1.724 to obtain an estimate of organic matter present in the sample.

For grain size analysis, sediment samples were subjected to wet sieving and pipette method. The sediment samples were dispersed in presence of sodium hexametaphosphate and passed through an Endecott sieve of mesh size 0.062 mm. The residue was dried and weighed. The suspension passing through the sieve was subjected to pipette analysis (Krumbein and Petty John, 1938).

Organic nitrogen was determined using Kjeldahl method (Barnes, 1959). The mud samples were decomposed by digestion with Conc. H_2SO_4 in presence of a catalyst when the nitrogen is converted into ammonium sulphate which after making the digest alkaline, is distilled off into a solution of boric acid and titrated with standard acid.

Concentrations of copper, zinc, cobalt, nickel and manganese in mud samples and mussels were estimated. The mussels (after removing the shell) and mud samples were dried in an oven at 60°C. The metals were estimated in the dried material after wet digestion with perchloric acid and nitric acid as per the methods given in the "Manual of methods in aquatic environment research" (FAO, 1975). The elements were estimated using the atomic absorption spectrophotometer (Hilger and Watts Atmospek H.1550).

CHAPTER II

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Organic Pollution in Cochin Backwaters*

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As part of the investigations on pollution in Cochin backwaters, hydrography, bottom and fauna of Cochin Harbour area were studied from 6 polluted (sewage and particulate matter) and one 'clean' station during August to October 1974. Increase in organic content and bacterial activity in both bottom water and sediment, as indicated by high BOD_5 values (6·21 to 280·40 mg/litre), low and fluctuating oxygen values (<0·05 to 3·81 ml O_2/litre) in the bottom water, high hydrogen sulphide content in the bottom water of the sewage affected stations, and the difference (quality, quantity and distribution) in macrofaunal communities as opposed to those seen in the 'clean' area, indicated the influence of sewage discharge on the environmental factors and fauna of the area.

LOCATED along 9°58'N and 76°15'E on the south-west coast of India the Cochin backwater system forms a tropical positive estuary[1] which provides excellent conditions for rich animal life. Considerable work has been done on the hydrography and productivity of this estuary[1-11]. The Cochin Corporation sewage system empties its municipal waste and other particulate organic matter into the estuary through major canals (Fig. 1), viz. Padiyathukulam canal (station 1), canal from Ernakulam market (station 2), Kalvathi canal from Fort Cochin (station 4), Rameswaram canal from Mattancherry (station 5), Pulimuttu canal from Palluruthy (station 6) and Thevara canal (station 7). The present paper, while initiating pollution studies in Cochin backwaters, presents briefly an account of the localized effect on the environmental factors and bottom fauna that may be of importance for the assessment of the extent of pollution in the estuary consequent on sewage discharge.

Materials and Methods

Area of the backwater system between Aroor and the barmouth was selected for the present study. The sites where each canal referred above opens into this portion of the backwater system was fixed as a collecting station with an additional site (station 3) near the barmouth for the study of hydrography, bottom and benthic fauna. Stations 1, 2, 4 to 7 receive sewage effluents in varying proportions into the backwater system through the network of canals while station 3 is relatively free and unaffected by sewage discharge. Sewage discharge at station 6 is comparatively low keeping the area more or less clean as regards organic pollution. Both surface and bottom samples and bottom fauna were collected at fortnightly intervals from each station. A plastic bucket was used for collecting water samples from the surface. As the bottom was shallow enough water samples from the bottom were collected using a Meyer type water sampler. Salinity was determined by Mohr Knudsen method. Winklers method (accuracy ±0·05 ml O_2/litre) was used for the estimation of dissolved oxygen. Biochemical oxygen demand was determined in accordance with the procedure of American Public Health Association[12] and iodometric method was used for the estimation of hydrogen sulphide. Bottom sampling with the van Veen Grab (0·05 m^2) was made at each station for bottom fauna. Some preliminary sieving was made on board the

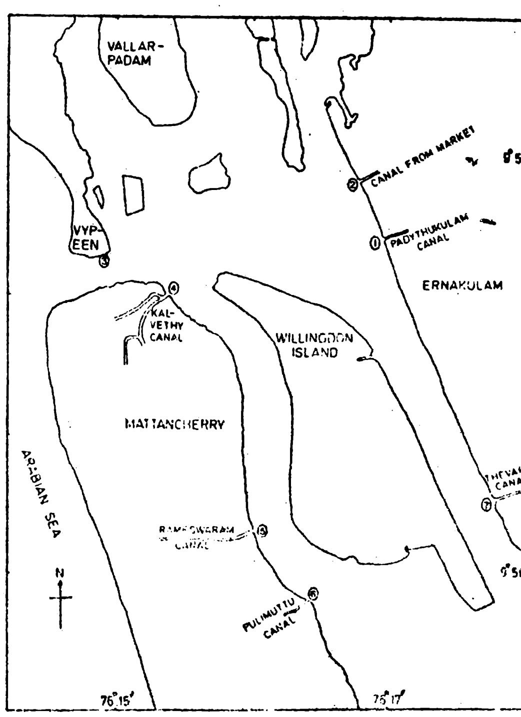

Fig. 1—Location of stations 1 to 7 in Cochin backwaters

*Paper presented at the 3rd All India Symposium on Estuarine Biology held at Cochin in February 1975.

work boat. All organisms which were retained by a 0·5 mm mesh sieve were collected and analysed numerically groupwise.

Data collected during August to October 1974 were analysed and discussed.

Results and Discussion

Sewage from the town consists of waste water and domestic sewage. It is generally, fresh water contaminated by dissolved and particulate matter in varying degrees.

Temperature — Temperature (Table 1) is more or less uniform at all stations during the period of observation, ranging between 26·1° and 31·2°C at the surface and 24·6° and 31·1°C at the bottom. Temperature gradients between the surface and the bottom water of the sewage affected areas are low while in the station 3 the range is high. It may be due to the homogeneous mixing of sewage water and estuarine water in sewage affected areas.

Salinity — The time of observation (August to October) is the end of monsoon and usually the salinity is low. During the peak of the south-west monsoon low salinity value <1‰ in the entire estuary was observed[6]. Sewage water draining into the estuary is rapidly mixed with extra estuarine water entering the canal during high tide. In the Cochin backwaters the tides are of mixed semi-diurnal type and various environmental features are greatly influenced by the tidal rhythm[13]. Salinity (Table 1) of stations 1, 2, 5 and 7 is mainly influenced by the quantity of sewage water dis-

TABLE 1 — SURFACE AND BOTTOM PARAMETERS AT 7 FIXED STATIONS

Station*	Surface parameters			Bottom parameters				
	Temp. °C	Salinity ‰	O_2 ml/l	Temp. °C	Salinity ‰	O_2 ml/l	BOD_5 mg/l	H_2S mg/l
				2-8-1974 (TIDE: HIGH)				
1	26·4	0·39	3·07	26·3	0·37	2·08	56·37	0·22
2	26·4	0·39	3·23	26·2	0·11	2·01	75·32	0·31
3	26·1	0·75	3·61	24·6	19·52	3·37	6·21	nil
4	26·5	0·57	3·52	26·4	0·75	2·75	21·22	nil
5	27·1	0·39	4·12	26·9	0·39	2·70	41·23	0·20
6	26·9	0·39	4·01	26·8	0·39	3·00	12·18	nil
7	26·9	0·39	3·81	26·7	0·39	2·05	70·31	0·22
				10-9-1974 (TIDE: LOW)				
1	29·6	7·32	4·01	29·5	7·83	1·50	150·7	1·12
2	29·7	7·02	3·82	29·6	8·77	0·80	220·6	2·25
3	28·4	12·90	4·51	25·8	31·67	3·80	9·72	nil
4	29·3	12·72	4·00	29·1	13·84	2·61	25·81	0·04
5	30·2	9·52	3·91	29·8	11·62	2·52	120·7	0·83
6	30·5	7·32	4·46	29·9	20·70	3·01	18·51	nil
7	30·6	6·04	3·72	30·3	7·32	1·05	180·21	2·06
				26-9-1974 (TIDE: HIGH)				
1	28·8	1·37	3·75	28·1	1·37	2·01	118·8	0·5
2	28·1	0·54	2·76	26·2	0·54	0·88	225·4	2·03
3	26·3	2·74	4·08	25·2	19·54	3·31	8·41	nil
4	27·1	0·55	3·64	26·9	1·69	2·00	40·42	0·05
5	28·2	0·54	4·02	27·9	1·11	1·32	150·1	1·81
6	28·0	1·37	4·36	27·8	1·02	2·54	18·21	nil
7	27·9	0·70	2·76	27·5	0·90	0·66	232·4	1·78
				8-10-1974 (TIDE: LOW)				
1	29·0	2·74	3·12	28·9	2·74	1·06	192·5	1·40
2	30·0	2·56	2·92	29·8	2·56	<0·05	280·4	3·41
3	28·3	4·54	4·01	28·1	5·81	3·81	6·84	nil
4	30·0	4·36	3·36	29·1	4·72	2·56	35·41	0·30
5	29·7	4·18	3·98	29·5	4·22	2·40	120·1	0·81
6	30·0	4·21	4·36	27·5	4·47	3·04	18·12	nil
7	30·4	1·47	3·44	30·1	1·84	2·01	220·16	1·58
				29-10-1974 (TIDE: HIGH)				
1	30·5	8·69	4·52	30·3	9·42	2·08	129·1	0·53
2	30·5	8·87	4·34	30·1	12·85	1·98	192·2	1·06
3	28·4	20·25	4·01	27·9	27·29	2·93	9·12	nil
4	29·1	16·09	4·19	28·4	22·23	2·42	28·11	nil
5	30·3	13·03	3·63	29·9	20·79	2·20	89·5	0·42
6	30·4	11·94	4·21	29·8	12·30	3·01	20·5	nil
7	31·2	4·36	3·18	31·1	5·26	2·18	170·6	0·68

*Depth (m) at station 1, 1·2; 2, 1·5; 3, 7·0; 4, 4·5; 5, 4·5; 6, 6·0; 7, 2·5.

charged. Though enormous sewage is discharged at station 4 the salinity is not much affected because of the influence of the high saline water always available near the barmouth. The extension of high saline water at the barmouth has also been commented on elsewhere[10]. During low tide, the sewage water flushes and spreads into the estuary resulting in localized low saline conditions, except for areas very near the barmouth.

Oxygen — Oxygen content of bottom waters of stations 1, 2, 5 and 7 is dependent largely on the quantity of sewage and tidal rhythm (Table 1). Tidal mixing stirs the waste considerably into the water from top to bottom during high tide and the tidal current regularly sweeps away the suspended wastes, as observed at station 4 where enormous amount of organic waste is discharged through Kalvathi canal but the oxygen deficiency is remarkably reduced by the influence of tidal flow and current effects.

Effect of sewage discharge at stations 1, 2, 5 and 7 is clearly seen from the oxygen content, colour and nature of the substratum. During low tide the oxygen value reaches to <0·05 ml O_2/litre at station 2 because of high content of decomposing organic matter discharged from the market.

Heavy load of settled organic matter together with dissolved organic substances will reduce the amount of oxygen available especially at stations 1, 2 and 7.

Lowest oxygen values are usually found at the sewage canal opening areas, presumably due to pollution and to high natural deposition of organic wastes. It has been observed[14] that the influx of waste from forest industry may reduce the dissolved oxygen content of the water. Similarly due to the decomposition of municipal waste deposited at the bottom, the oxygen content may be reduced, affecting adversely the living resources at the sewage opening stations.

Biochemical oxygen demand — High content of domestic sewage discharged at stations 1, 2, 4, 5 and 7 may settle at the bottom and undergo decomposition causing oxygen depletion. The rapid degradation of organic material is indicated by the high biochemical oxygen demand (BOD_5) in the bottom water of sewage affected areas. A high BOD_5 indicates large bacterial populations consuming the available oxygen. Highest BOD_5 values are seen at stations 1, 2, 5 and 7. The highest value recorded during the observation is 280·4 ppm at station 2.

Correlation coefficient calculated between the mean oxygen (ml/litre) and mean BOD_5 (mg/litre) is −0·9586, which is significant at 0·1% level indicating that BOD_5 and oxygen are very highly negatively correlated.

Low values of oxygen and high values of BOD_5 at stations 1, 2, 5 and 7 are suggestive of organic pollution to a more remarkable extent at these areas than in stations 4 and 6 where the values are greater indicating a marginal zone of pollution. Maximum values of oxygen is shown at station 3. This is a more or less pollution free zone near the barmouth.

Hydrogen sulphide — Organic wastes discharged may undergo decomposition using the available oxygen resulting in anaerobic condition and formation of hydrogen sulphide in and near the bottom. Measurable amounts of hydrogen sulphide are observed in the bottom waters of the stations 1, 2, 4, 5 and 7. Highest values obtained are 3·41 and 2·25 mg/litre at stations 2 and 7 respectively. Stations 3 and 6 are devoid of hydrogen sulphide (Table 1).

Data for dissolved oxygen and hydrogen sulphide show a relationship, i.e. lower oxygen values, high BOD_5 and higher values of hydrogen sulphide indicate the effect of sewage discharge. Heavy impact of sewage pollution is observed at stations 1, 2 and 7.

Fauna — Bottom fauna from 7 stations show considerable quantitative and qualitative variation as illustrated by the polychaetes, crustaceans and molluscs collected (Table 2). It is observed that benthic animals reflect not only the conditions at the time of sampling but also those earlier[15]. There is an enormous increase in the total number of animals mostly polychaetes and crustaceans, in station 3 as compared to other stations. This region may therefore be considered unaffected according to faunal patterns. It is apparent (Table 2) that the least numbers of animals were found in stations 1 and 2. This decrease in the number of animals at these 2 stations should be attributed to the increase of sewage inflow and may be considered as polluted zones. Stations 4, 5 and 6 should be included under marginal zones as they show sufficient representations of the fauna but not the maximum. Maximum BOD_5 value, high hydrogen

TABLE 2 — DISTRIBUTION OF BOTTOM FAUNA AT SEVEN FIXED STATIONS

Station	Number of observations	Polychaeta			Crustacea			Mollusca		
		Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean
1	5	120	2240	620	0	300	60	0	60	12
2	5	20	1980	440	0	80	16	20	40	16
3	5	100	2200	980	1100	30560	8364	20	240	56
4	5	60	4500	1052	0	40	16	0	60	12
5	5	80	6520	2356	20	120	32	20	40	16
6	5	120	1720	644	60	100	32	0	0	0
7	5	940	2800	1238	20	240	88	20	120	56

sulphide and minimum oxygen value reflect the characteristics of a polluted zone. High value of BOD_5 in station 2 indicates an increase in organic content and bacterial activity and consequent decrease of oxygen content and hence decrease in the number of animals. A respective decrease in BOD_5 values in the healthy zone, i.e. station 3 shows considerable increase in the number of animals.

Qualitatively too the benthic animals indicate level of pollution. Polychaetes being a considerably tolerant group of animals are present in all the stations. The mean value of polychaetes in the healthy zone, i.e. station 3 is found to be much less when compared to that of a strictly marginal zone such as station 5. This area being unpolluted, animals other than polychaetes successfully join the struggle for survival and reduce the number of polychaetes. Polychaetes dominate in number in the polluted zones as they form the most suitable tolerant group of benthic animals of the area. With the increase in pollution level, even the most tolerant benthic animals like polychaetes may be wiped off completely from the polluted zone due to anaerobic conditions. However, the prevalence of effective environmental factors such as tidal rhythm and monsoonal inflow are discouraging to such a situation in the Cochin backwaters. These factors should maintain to a considerable extent the pollution level to tolerant condition for the minimum indicator organisms to survive. Crustaceans and molluscs are few or absent in the marginal and polluted zones as compared to the healthy zone mainly because the pollutants of the sewage inflow may promote the disappearance of representatives of the fauna which have occurred here earlier and stimulated the development and growth of new fauna afresh.

Quantitative variations in the composition of animals may be correlated with the distribution of detritus carried by the sewage discharge; crustaceans being heterophagus in feeding habits, consume the polluted detritus available resulting in accelerated growth rate. However, accumulation of pollutants beyond the tolerance level affects the survival of the species and consequent reduction in total number is noticed. The presence of more crustaceans in the healthy zone (station 3) than in polluted and marginal zones may reasonably be attributed to this phenomenon. An enormous increase in the number of polychaetes is noticed in the marginal zones. The inflow of sewage into the backwaters, as stated for heated effluents[16], may lead to an increase of initial growth rate and precocious maturity, resulting in shortening of life cycles and consequent increase in the number of animals. This increase in number can also partly be due to the greater tolerant capacity as against other groups of animals which would have disappeared from these areas due to the effect of pollution. Here a relationship between disappearance and mass development of organisms is indicated.

In the polluted and marginal zones bivalves are lesser in number than those of the healthy zones. Molluscs being mostly filter feeding in habit, concentrate more pollutants than other animals. Hence in the polluted zones they are not able to tolerate the increase of pollutants beyond a level, and a consequent decrease in number results.

The demarcation of polluted, unpolluted and marginal zones based on different parameters studied in the present investigation is provisional and may be open to criticism in their being too 'loose'. With more intensive collection and analysis of data around the season, this classification of convenience should prove realistic and useful for effective control operations to follow.

From the present study it may be concluded that organic pollution to a considerable extent exists in the Cochin backwater, especially in areas where the Padiyathukulam canal (station 1) and the canal from market (station 2) join the backwater. The extent of pollution in these areas is well above tolerance level of the estuarine fauna. Continued discharge of sewage effluents at the present rate may affect the ecosystem and estuarine life of the harbour and the harmful effects may extend to the neighbouring inshore waters as well. Hence control operations are necessitated. Distal areas near the barmouth remain more or less free from pollution due to effective dilution by the open sea water especially during high tide. A marginal zone of pollution is also suggestive in the proximal areas of the harbour. Collection and analysis of data round the season should provide a more effective picture on organic pollution in the harbour.

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Effect of Organic Pollution on Some Hydrographic Features of Cochin Backwaters

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Some hydrographic features of Cochin backwaters were studied from September 1974 to August 1975 in 7 stations of which 6 receive sewage discharge in varying quantities and one is a 'clean' station near the barmouth. Thermal gradient of the waters was more largely dependent on the depth of the station than on the sewage discharge. Seasonal and tidal variations in salinity were more evident during monsoon than in pre- or postmonsoon periods. No significant change in salinity was noticed due to discharge of sewage. Significant seasonal and tidal fluctuations in the values of oxygen were observed. Lowest oxygen values were seen during premonsoon periods when temperature was 32·6°C at surface and 32°C at bottom. Dissolved oxygen content varied proportionately with sewage discharge. High temperature and rapid decomposition of organic waste during premonsoon accelerated pollution effect. BOD_5 varied with stations, season and tide. Oxygen consumption of the bottom waters of polluted areas was 12 to 13 times as high as that in barmouth. In polluted areas fluctuating increase of BOD_5 values was noticed with the commencement of premonsoon while a decreasingly fluctuating trend prevailed with monsoon. BOD_5 at low tide was higher than at high tide in the polluted area. High sulphide content reaching to a maximum of 4·92 mg/litre was observed at the bottom of polluted stations especially during low tide of premonsoon periods.

COCHIN backwaters receive either directly or indirectly the sullage waters and municipal sewage from the city. The total consumption of drinking water in this urban area is roughly 14 million gallons/day of which a high percentage joins the drainage and reaches the backwater system through a network of canals. Part of the sewage of the city is treated in a mechanically aerated and activated sludge process treatment plant maintained by the State Public Health Engineering Department. Capacity of this plant is only 1 million gallon per day. Rest of the sewage and sullage water mixed with domestic waste is carried along the 6 major canals and drained into the backwaters. These canals vary from 0·5 to 1·5 m in depth. The drainage contains turbid liquid with a considerable amount of putrescible organic material both dissolved and suspended of domestic origin. Hydrobiochemical studies of Cochin backwaters have been the subject of several investigations. However, except for the preliminary studies on organic pollution[1], there is no previous account on the effects of organic pollution on the hydrographic features of Cochin backwaters.

Materials and Methods

The general object of this study was to investigate the effect of organic pollution of the waters around Cochin harbour and adjacent areas. Observations were made round the seasons (premonsoon = January to April, monsoon = May to October and postmonsoon = November to December) at fortnightly intervals of which one was at low tide and the other at high tide, from September 1974 to August 1975. Five parameters, viz. temperature, salinity, dissolved oxygen of both surface and bottom waters, biochemical oxygen demand (BOD_5) and total sulphide content in bottom waters, were chosen. The location of sampling stations 1 to 7 is same as reported earlier[1]. The depth (m) at these stations is as follows: 1, 1·2; 2, 1·5; 3, 7; 4, 4·5; 5, 4·5; 6, 6; and 7, 2·5. Of these station 3 which is 50 m away from the shore receives practically no sewage, while the others which are 200 m from the shore receive municipal sewage in varying quantity and quality, though remarkably low at station 6.

Water samples were collected with a plastic bucket for surface sampling while sampling was done with a Hytech water sampler from the bottom of each station according to their depths. Salinity was estimated by Mohr Knudsen method. Winkler procedure was used for the determination of dissolved oxygen. Biochemical oxygen demand and total sulphide were measured by standard procedure suggested by American Public Health Association[2]. Total sulphide was determined as follows: Water samples were preserved using zinc acetate as zinc sulphide. From the precipitated sample hydrogen sulphide was generated using concentrated hydrochloric acid in an inert atmosphere of carbon dioxide. The evolved hydrogen sulphide was dissolved in distilled water and titrated against standard iodine solution using starch as indicator.

Results and Discussion

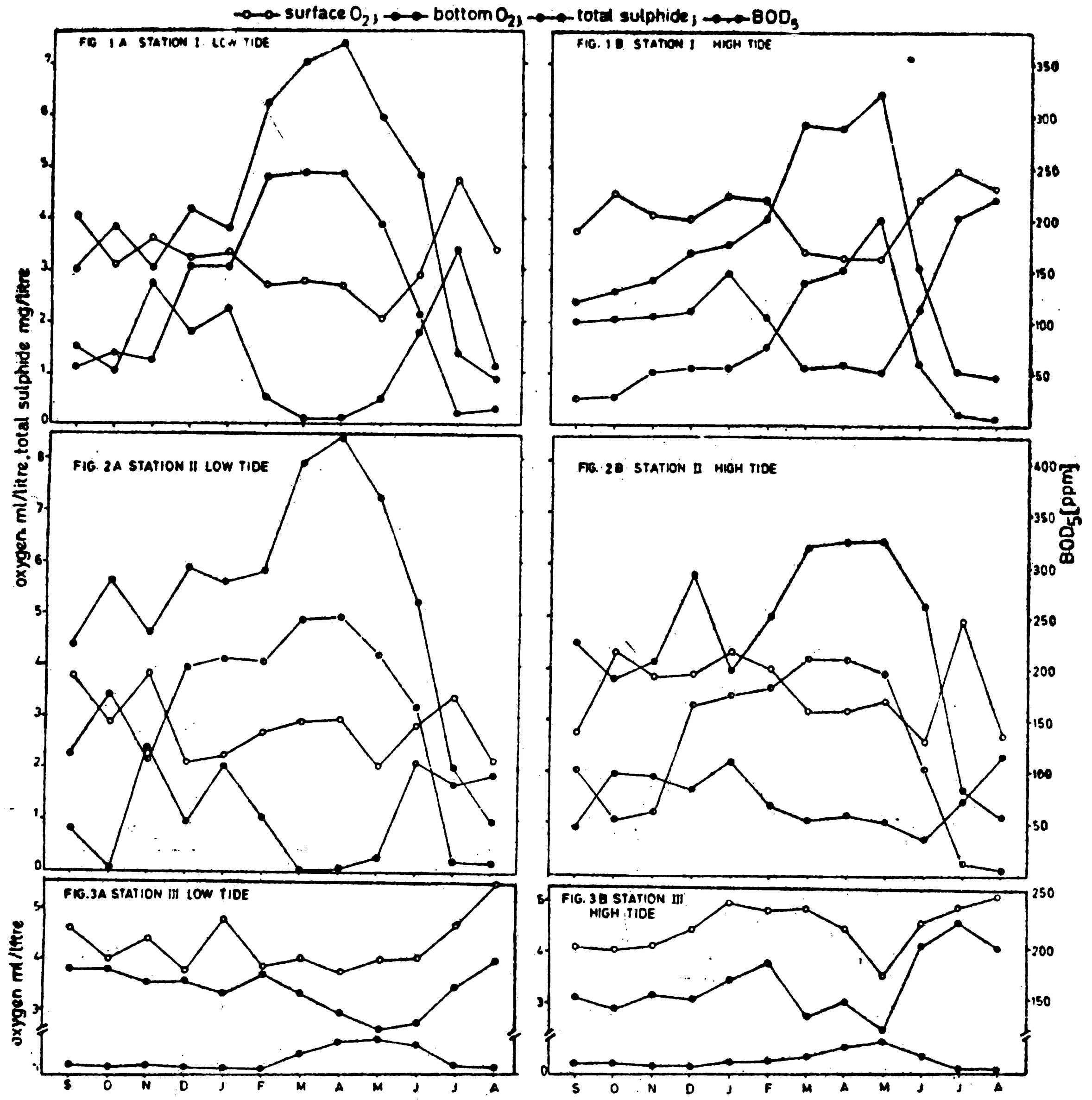
Temperature — Seasonal changes in the surface temperature are well marked in the backwaters. Values of seasonal changes in surface temperature vary from 4° to 5·4°C, lowest being 25·8°C and highest being 32·6°C. As regards bottom temperature the values range between 3·7° and 5·7°C with 25·2° and 32·2°C being the lowest and highest temperatures. During premonsoon period the temperature is high at all stations and this situation prevailing during both high and low tides. Difference between the surface and bottom temperature of highly polluted areas (stations 1 and 2) vary between 0·1° and 0·3°C during high tide of March to May, and during low tide the temperature variation is between 0·1° and 0·9°C. At the 2 deeper areas (stations 3 and 6) the thermal gradients between surface and bottom are high because of greater depth (above 6 m). Sewage discharge to the backwaters does not seem to have any significant effect on the temperature. On the other hand, temperature has considerable effect on the oxygen content and BOD of the sewage receiving areas.

Salinity — Seasonal and tidal variations in the salinity are well pronounced during the year. The overall change in salinity at the bottom of station 3 from 34·31‰ in April to 1·11‰ in July clearly indicates the variations occurring near the mouth of backwater. Variations are more evident during monsoon than in pre- or postmonsoon periods. During monsoon heavy rainfall washes the sewage from the canals and deposits solid waste at the areas of sewage discharge. The sewage draining into the estuary mixes with the saline water from top to bottom during high tide and forms a homogeneous mixture. This is evident from the very little difference in salinity between surface and bottom at sations 1, 2, 4, 5 and 7. No significant change in salinity is noticed due to the discharge of sewage.

Dissolved oxygen — Concentration of dissolved oxygen was measured at the stations throughout the year. Significant seasonal and tidal fluctuations in the values of oxygen of both surface and bottom waters were seen with stations (Figs. 1 to 7). Lowest oxygen contents were usually found during premonsoon periods when the temperature reached 32·6°C at the surface and 32°C at the bottom. Dissolved oxygen content of both bottom and surface of the sewage receiving areas was always fluctuating due to the availability of decomposing materials such as detritus mixed with organic gyttja at the bottom and suspended decomposing material in the water column. Owing to the high temperature during premonsoon months (March-April) the process of decomposition is accelerated with the uptake of dissolved oxygen. It is stated that oxygen consumed by decomposition of organic matter is often reflected in the disappearance of oxygen from the deeper strata of the water body[3]. It is also known that the oxygen content is always low at the bottom waters[4]. In the Cochin estuary as observed from the 7 stations oxygen content was less than 0·05 ml/litre at the polluted stations 1 and 2 (Figs. 1 and 2) during March and April. Therefore, the worst of pollution effect is usually experienced during premonsoon periods when the combined effect of high temperature and rapid decomposition of organic material occurs. This agrees with the results reported for the premonsoon month at Visakapatnam harbour[5]. With the commencement of monsoon the sewage gets diluted and considerable amounts of organic material are deposited in the canal opening areas. The suspended materials are washed away by the tides and flushing fresh water.

Biochemical oxygen demand — Importance of BOD_5 in the assessment of pollution effect of an environment has been stressed[6-8]. It is the dissolved or suspended organic material in the waste that gives biochemical oxygen demand to the polluted waters. BOD recorded in the present study (Figs. 1 to 7) varies with season and stations. Values obtained for stations 1 and 2 reveal (Figs. 1 and 2) that the oxygen consumption of the bottom waters is 12 to 13 times as high as those measured in bottom at the barmouth (Fig. 3). At barmouth (station 3), BOD_5 increases gradually with commencement of premonsoon and shows a decreasing trend with monsoon periods, while a similar but fluctuating trend exists with the other stations though the BOD_5 value at any of these stations is always higher than at the barmouth. Maximum uptake of oxygen is observed in the bottom where the organic wastes are decomposing. There are marked differences in the values of BOD_5 of different seasons in all the stations. With the onset of premonsoon, high temperature regime is initiated which lasts up to the beginning of monsoon. Consequent thermal effect accelerates the bacterial degradation process of the waste resulting in the multiplication of bacteria and uptake of dissolved oxygen. Subsequently monsoon waters wash the sewage with heavy organic matter which is deposited in the estuary while lighter particles are washed away with the fresh water outflow. Though the BOD_5 values tend to remain more or less the same during the early monsoon month (May) marked decreasing trend is seen from June onwards. Analysis of high and low tide BOD_5 values of sewage receiving areas reveals that BOD_5 at low tide is usually higher than at high tide while it is more or less the same in the barmouth. It is observed that BOD values fluctuate with station and time. The former variations are due to the quantity and quality of the sewage while the latter type of variations are usually due to monsoon and tidal effects. Highest BOD_5 values recorded are at stations 1, 2, 4, 5 and 7. At station 4, during premonsoon BOD_5 value is 11 to 12 times as high as that measured during monsoon periods in the same station (Fig. 4). This indicates the effect of monsoonal flow to a remarkable extent resulting in the dilution of the sewage at this station which is not far away from the barmouth. Similarly in station 2 the BOD_5 value reaches above 400 ppm during premonsoon month (April) while the value decreases to below 50 ppm during monsoon month (August) in low tide (Fig. 2A). Obviously the monsoonal run off is heavy to a noticeable extent of dilution of the polluted area.

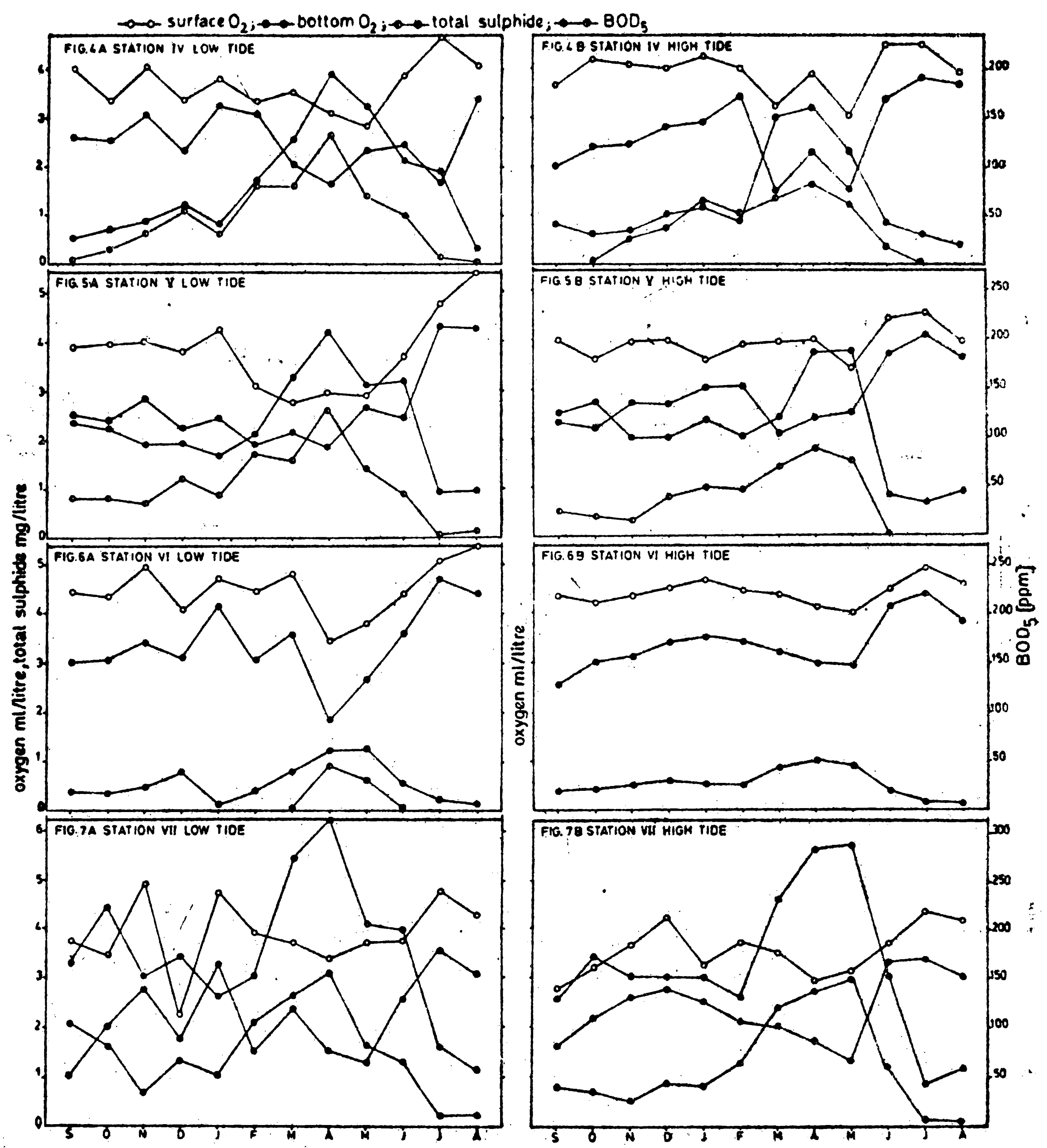
Total sulphide — No measureable amount of sulphide is observed at the barmouth (station 3) while high total sulphide content is observed in the bottom waters of heavy sewage discharged areas, (stations 1 and 2) when the oxygen concentration is very low (Figs. 1 to 7). Reports[9] are available on odour and colour of the mud samples as indicators



Figs. 1-3 — Distribution of O_2 (surface and bottom), BOD_5 (bottom) and sulphide (bottom) during low tide (A) and high tide (B) at stations I to III

of high sulphide content in polluted areas. The odour and colour of mud samples of sewage discharged areas in the present study also indicate presence of high sulphide content. Maximum value of sulphide recorded at these stations is 4·92 mg/litre during low tide. The sulphide concentrations in all stations except 3 (Fig. 3) and 6 (Fig. 5B) fluctuate in proportion to the availability of varying quantity of decomposing sewage. Only during premonsoon period at station 6 measurable amount of sulphide is noticed (0·86 mg/litre at low tide; Fig. 5A).

Comparing the sewage receiving and 'clean' stations, it is apparent that they differ in dissolved oxygen content and BOD. Bacterial oxygen consumption is significantly higher in the outfall stations like 1 and 2 than the 'clean' station as evidenced by high BOD values. The waters of polluted stations show high BOD_5 (420·6 ppm) and total sulphide (4·92 ppm) values and low oxygen (0·05 ml/litre) values during summer months. These values are remarkably different from even the standard values for effluents dischared into inland waters which are 30 ppm for BOD_5 and 2 ppm for sulphide. Initiated by the decomposing sewage, the anoxic conditions of the water just above the bottom are apparently confined to the small area for a short time and due to the tidal mixing the water never becomes depleted of oxygen permanently. However, this is indicative of localized pollution which is beyond the assimilative capacity and tolerance level of the estuary.



Figs. 4-7 — Distribution of O_2 (surface and bottom), BOD_5 (bottom) and sulphide (bottom) during low tide (A) and high tide (B) at stations IV to VII

In stations 4 to 7 BOD values are not as high as in stations 1 and 2 and not as low as in station 3 indicating that they remain as partly polluted locations seasonally. It is observed that seasonal change in temperature of the water has very significant effect on dissolved oxygen and hence on BOD_5 values as well. This is more pronounced in premonsoon than in monsoon and postmonsoon periods. Most adverse conditions of pollution occur during premonsoon when the temperature is between 31° and 32·6°C. Depletion of dissolved oxygen to a greater extent occurs in highly polluted areas (stations 1 and 2) during premonsoon period. Higher BOD_5 values occur during low tide than at high tide in the sewage polluted areas. Organic pollution has significant effects on D. Oxygen BOD_5 and sulphide content of the estuarine waters while the temperature and salinity are not significantly affected.

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EFFECT OF ORGANIC POLLUTION ON BENTHOS AND THE BOTTOM AROUND WILLINGDON ISLAND IN COCHIN BACKWATERS

Considerable quantity of sewage effluents from the rather thickly populated city of Cochin (population over 5 lakhs) reaches the Cochin backwaters through a net work of large and small canals and by rainwater washings. Pollution from sewage discharge in Cochin backwaters has been reported (Unnithan et al. 1975). Its effect on some hydrographic features, such as salinity, temperature, oxygen, biochemical oxygen demand and sulphide content of the waters of Cochin estuary has also been documented (Vijayan et al. 1976). Using these parameters an attempt is made here to show how benthic communities respond to stress of pollution around Willingdon Island in Cochin backwaters.

Effects of sewage on the bottom fauna are observed to be mostly indirect and depended on the deposition, concentration and rate of decomposition of organic matter. The decomposition of the sewage on the bottom of the estuarine system has contributed largely to a change in the bottom ecology. Abiotic environmental factors such as salinity, temperature, oxygen and the type of substratum have been stated (Muus, 1967) to determine the composition and distribution of the fauna, as they have definite functional effect on the living organisms of an area. Some of the animals though belonging to different species and communities may tolerate the individual or cumulative effect of pollution to a remarkable extent so as to remain associated together in a given environment while another area may be identified as a "Pollution free" zone based on the variations in the abiotic factors and the consequent biota existing there. This type of identification of the existence of animal associations forming a spectrum of species, was well demarcated in Cochin backwaters. According to the difference in the range of the abiotic factors and degree of pollution tolerance (Table 1), the distribution of the bottom fauna of the estuary may be divided into three types, viz. 1) a spectrum of species of high dominance which favour pollution, 2) indifferent species and 3) those which avoid polluted areas. Each of these types have assemblages of animal species belonging to widely different taxa. That is, changes in benthic associations may better indicate the distribution and the level of pollution than the occurrence or absence of an individual species (Gaufin

& Tarzwell, 1952, Hynes, 1966). The dominant benthic community consisting of polychaetes Prionospio polybranchiata, Paraheteromastus tenuis, Lycastis indica Dendronereis aestuarina and the crustacean Apseudes chilkaensis (Tanidaceae) which are apparently resistant to the stress conditions associated with the sewage deposited bottom, indicates the polluted zone. Similarly Diopatra neapolitana, Sthenelais boa, Lepidonotus tenuisetosus, all polychaetes, were found to occur together with seaanemones, brittle stars and the isopod Cirolana fluviatilis in the healthy zone. When the pollution of the bottom was slight, some species were benefited by the enrichment of the bottom as illustrated by the polychaetes Nephthys polybranchia, N. oligobranchia Lumbriconereis polydesma, L. simplex and the bivalve Pandora flexuosa which were seen together to dominate in the transitional zone.

Polluted zone species:- Polychaetes were found to be the most tolerant group among the benthic animals collected. The most prevalent polychaete found in the heavy sewage discharging sites in the estuary was Prionospio polybranchiata recalling a close relative Prionospio malmgreni, reported to be wide spread in solid waste dumping grounds of New York Bight (Pearce, 1972). Prionospio polybranchiata (Spionidae) was distributed in all the stations throughout the seasons as evidenced by the frequency of occurrence, though density is considerably high especially in the strictly polluted areas (Stn. 1 and 2). Percentage distribution of P. polybranchiata in each station e.g. stations 1 and 2, (18%) and station 3, (1.3%) indicated the tolerant nature of the species. The fact that tolerant indicator species may concentrate themselves in highly polluted areas was evidenced by their high population density in stations 1 and 2. Moreover, this species comprised 68 to 80% of the total polychaetes collected from the polluted areas. According to Butler et al. (1972) indicator species are useful in identifying persistant physical and chemical changes in the environment. Hence, P. polybranchiata may be proposed as an indicator species occurring in heavily sewage affected areas of Cochin backwaters. The species occurred in a temperature range of 25.2 - 32.2°C more or less euryhaline as observed in a wide range of salinity from 0.39 to 32.26‰ and in the oxygen range of 0.05 - 4.40 ml/l i.e. from almost anaerobic to aerobic condition. Also with the BOD values ranging from 6.12 - 420.6 mg/l and sulphide content 0 - 4.92 mg/l, their ability to survive in strictly polluted conditions was obvious.

The abundance of this species in the polluted environment may also be related to its mode of feeding. The epibiontic and suspension feeding species seem to suffer especially from pollution, while it appeared to favour deep burrowing limivorous species such as capitellids and oliogochaetes and some selective deposit feeders such as spionids (Paul bagge, 1968). The polychaete P. polybranchiata which belongs to the family Spionidae is a selective deposit feeder. This species which occurred in large numbers in polluted habitat could also be found in limited numbers in cleaner stations. However, on the basis of abundance, wide tolerance capacity and feeding habit, the polychaete P. polybranchiata has been observed to have tolerated to a remarkable extent the stress conditions due to pollution prevailing in the retting grounds. The species may therefore be considered as a pollution indicator.

certain other species of polychaetes also showed affinity towards the polluted area. The frequency data (table 2) shows that Paraheteromastus tenuis (Capitellidae) Lycastis indica (Nereidae) Dendronereis aestuarina (Nereidae) and Scyphoproctus djiboutiensis (Capitellidae) occur frequently in large numbers in polluted areas but not in all the seasons. Hence they may be included among pollution tolerant species though not as indicator organisms. The frequency (table 2) shows that Parahetero-mastus tenuis (Capitellidae) was distributed in all the polluted stations, though the population density shows a maximum in the strictly polluted area. They were found in an oxygen range of $< 0.05 - 4.40$ ml/l and preferred a habitat where sulphide values were 0 - 4.92 mg/l. Though this species was tolerant to high ranges of salinity, temperature, low oxygen, high BOD_5 and high sulphide, the population density was not as high as that of P. polybranchiata. This precluded the possibility of its being treated as an indicator species. P. tenuis (Capitellidae) is limivorous in feeding habit. Species preferring this mode of feeding occur largely on the bottom where the organic content is high and oxygen content low. That is, as observed elsewhere for Capitellidae (Paulibagge, 1969), in the present study also, a large number of limivorous species were noticed in the bottom samples from the polluted zone. Scyphoproctus djiboutiensis (Capitellidae), Lycastis indica (Nereidae) and Dendronereis aesturina (Nereidae) show remarkable affinity towards polluted habitat. The frequency table shows that their occurrence was limited to areas where oxygen depletion and sulphide content reached maximum (table 1). In the healthy zone (Station 3) they were almost absent except for the casual occurrence of a few specimens which may well be explained as accidental.

Crustaceans were second in the order of abundance. (31 to 39%) in polluted areas like stations 1 and 2 showing an indifference to polluted habitat. However, *Apseudes chilkensis* of the order *Tanaidacea* occur abundantly almost throughout the season in polluted stations and constituted 96 to 99.6% of the crustaceans. Unlike *Apseudes gymnophobia* of the same order, *A. chilkensis* occurred in temperature ranges of 25.2 - 32.9°C salinity 0.39 - 33.42‰, oxygen < 0.05 - 4.40 ml/l, BOD_5 6.12 - 370 mg/l and sulphide 0 - 4.89 mg/l.

Indifferent species:- When compared to the pollution tolerant species of benthos those indifferent to pllution show a low affinity towards the polluted habitat, though they were not totally absent in the polluted areas. Their distribution pattern showed that even though they could tolerate the pollution effect to a limited extent, they preferred cleaner environment. Frequency data (Table 2) shows that *Nephthys polybranchia*, *Nephthys oligobranchia* (Nephthyidae), *Lumbriconereis polydesma* (Nereidae) *Glycera alba*, (Glyceridae) *Glycera longipinnis* (Glyceridae), alba and *Branchio capitella singularis* (Capitellidae) show no specific correlation with pollution. Most of the above species occurred seasonally from December - August, in the temperature range of 25.2 - 32.0°C, salinity 0.39 - 33.59‰, oxygen < 0.05 - 4.74 ml/l, BOD_5 6.61 - 420.6 mg/l and sulphide 0 - 4.92 mg/l. Obviously they were able to tolerate pollution effect to some extent. However, the frequency data gives their maximum occurrence in marginal and healthy zones; hence they may be treated as a species indifferent to pollution.

Pandora flexuosa was more or less present in all the stations though their population density was comparatively high in the semihealthy zones. Bivalves Modiolus striatulus, Tellina sp. and Arca fusca were more or less absent in the polluted areas, since they were sensitive to anoxic conditions. The continuous availability of sewage effluents at the highly polluted areas created a loose and soft substratum. The filter-feeding bivalves find it considerably difficult to attach themselves and maintain their position in the sediment surface whereas favourable environment was provided in the marginal zones for the survival and growth of the bivalves.

Healthy zone species:- Distribution of polychaetes showed that certain species were completely absent from the polluted areas. They (Diopatra neapolitana (Eunicidae), Lepidonotus tenuisetosus and Sthenlais boa (Aphroditidae)) occurred only in the clean areas (Station 3) and revealed their inability to tolerate anaerobic conditions of relatively high sulphide or similar effective pollution factors.

Among these species occurrence of D. neapolitana, a tubicolous polychaete observed in high population density in the healthy zone (Station 3), should be emphasised, as it suggests itself a negative indicator of pollution in the estuary.

Among decapods, prawns showed very little affinity towards polluted areas. Alpheus paludicola, Alpheus rapax and Athanas polymorphus of the family Alpheidae were observed in lesser numbers in the marginal zones than in healthy zone (Station 3). In the healthy station they occurred maximum. The population density of Penaeus indicus, Palaemon styliferus, Caridina sp., and Metapenaeus lasiensa, were negligible in all the stations except in Station 3.

The frequency table shows that the crabs such as Viaderiana sp., Neorhynchoplax sp., Scylla serrata and Halicarcinus sp. were completely absent in strictly polluted areas and very rarely occurred in the marginal zones. Their population densities were comparatively high in the healthy zone (Station 3). The population density of C. fluviatilis was much higher than that of S. variegata. When compared to other crustaceans, C. fluviatilis showed a comparatively higher preference to adhere to the clean habitat.

As with other macrofaunal taxa the amphipods were almost completely absent in polluted stations like 1 and 2. Only stray specimensof the amphipod Grandidierella gilesi were observed in these areas, while their abundance was noticed in the bar mouth. Amphipods Hyale hawaiensis, Eriopisa chilkaensis, Photis digitata and Grandidierella bonnieri were completely absent in the polluted areas. In general, the distribution of amphipods emphasised that their abundance was directly related to high oxygen and low sulphide content suggesting that these small crustaceans may be relatively more sensitive to the effects of sewage discharge.

Sea anemones, Echiuroids such as Ochaetostoma septemyotum, some sipunculids and brittle stars were distributed in the barmouth area (Station 3) and were absent in the polluted zones. Being stenohaline groups these animals should have restricted themselves to a region of higher salinity near the barmouth which is a healthy zone instead of the less saline and polluted areas where anaerobic conditions prevail due to high sulphide content. The very few fish larvae collected were only from the barmouth indicating their total avoidance of polluted areas. However, gobid fish like Trypauchen vagina which could tolerate pollution to some extent was occasionally found in the mud samples of the marginal zone.

Nature of the bottom:- It hasbeen well established that the qualitative and quantitative distribution of benthic

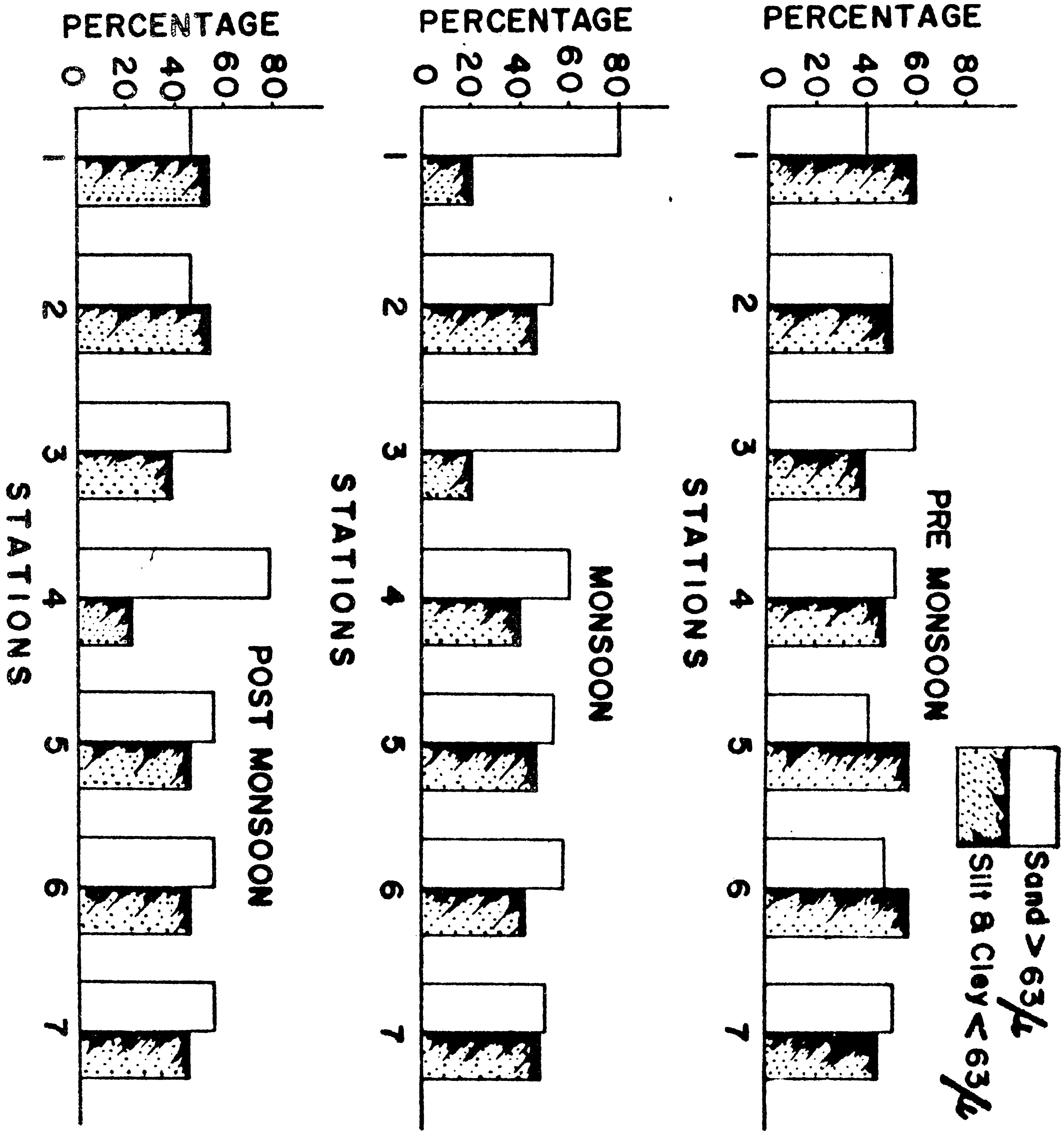

PERCENTAGE
0 20 40 60 80
STATIONS
1 2 3 4 5 6 7
PRE MONSOON
MONSOON
POST MONSOON
Sand > 63μ
Silt & Cley < 63μ

Fig.3

fauna has a direct relationship with the type of the bottom, and the physical nature of the substratum acts as a limiting factor to a great extent (Sanders, 1958, Bloom & Simmon, 1972). This is fully illustrated by the present observation in Cochin backwaters. Percentage composition of sand, silt and clay in the seven stations during pre,post and monsoon periods is given in Fig.3. The colour, texture and composition of the sediment in polluted stations vary from those of the healthy station. In all the seasons the sediment of healthy station was found to be coarse with higher percentage of sand. In the polluted stations, the substratum was predominantly of fine texture. The blackening of the sediment of polluted stations indicates a reduced environment with high sulphide content (Hynes, 1966). During premonsoon in polluted stations, the substratum was black due to high percentage of silt and clay with organic gyttja. However, at station 2, the percentage of sand seemed to be high, which may be explained as due to recent sudden dumping of sand with waste material in and around the sampling site at the time of collection. Percentage of sand was high in monsoon months in all the stations. During post monsoon in stations 1 and 2, silt and clay predominated the bottom, but in stations 4-7 the percentage of sand was found to be high. Pollution load at the latter stations was much less than station 1 and 2. Moreover, these stations being nearer to barmouth the lighter particles of clay and silt may be flushed away from these sites by the tidal effect more frequently than elsewhere. It was noticed that, polychaetes, crustaceans and bivalves exhibit a diminishing trend of distribution in the silt and clay substratum except for some species which tolerated pollution effect. These tolerant species preferred black silty clay substratum.

Table-1. THE RANGES OF SOME ABIOTIC PARAMETERS OF THE SAMPLING STATIONS OF MACROBENTHOS AROUND WILLINGDON ISLAND

	Depth range meters	Temperature range °C	Salinity range ‰	Oxygen range ml/L	Biochemical Oxygen Demand ppm	Total Sulphide range mg/L
	1.	2.	3.	4.	5.	6.
COELENTERATA						
Sea anemone	4.5 - 7.00	27.0 - 31.4	0.752 - 34.31	1.85 - 4.08	7.06 - 210.12	nil
POLYCHAETA						
Lepidonotus tenuisetosus (Gravier)	2.5 - 7.00	28.0 - 30.2	29.51 - 31.69	1.35 - 3.47	8.18 - 86.00	nil
Sthenelais boa Johnston	7.00	28.0 - 30.1	[illegible] - 33.06	2.68 - 3.47	7.21 - 14.7	nil
Diopatra neapolitana Delle Chaije	4.5 - 7.00	25.2 - 31.0	1.11 - 33.60	1.49 - 4.74	6.12 - 150.12	nil
Lumbriconereis simplex Southern	2.5 - 7.00	25.7 - 32.0	1.11 - 33.60	1.49 - 3.84	13.12 - 281.0	0 - 2.81
Lumbriconereis polydesma Southern	2.5 - 7.00	25.2 - 30.3	0.39 - 31.98	1.05 - 4.74	6.12 - 198.6	0 - 2.08
Ancistrosyllis constricta Southern	1.6 - 7.00	25.8 - 31.4	0.58 - 33.59	<0.05 - 4.74	7.06 - 350.12	0 - 4.92
Glycera longipinnis Grube	1.2 - 7.00	27.4 - 30.9	3.14 - 31.46	0.56 - 4.14	6.62 - 310.72	0 - 4.18
Glycera alba Rathke	1.2 - 7.00	25.2 - 31.2	0.58 - 32.36	1.01 - 4.74	6.12 - 320.9	0 - 4.26

Table- (contd.)

	Depth range metres	Temperature range °C	Salinity range ‰	Oxygen range ml/L	Biochemical Oxygen Demand ppm	Total sulphide range mg/L
Lycastis indica Southern	1.2 - 6.00	25.7 - 32.2	0.39 - 32.88	<0.05 - 4.40	20.5 - 370.2	0 - 4.89
Dendronereis aestuarina Southern	1.2 - 4.5	26.2 - 31.0	0.752 - 31.11	0.89 - 4.40	40.12 -291.12	0 - 4.12
Perinereis cavifrons Ehlers	1.2 - 7.00	25.2 - 31.4	0.981 - 33.59	1.00 - 4.74	6.12-310.2	0 - 4.12
Nephthys oligobranchia Southern	1.2 - 7.00	25.6 - 32.0	0.39 - 33.59	<0.05 - 4.74	7.27-420.6	0 - 4.92
Nephthys polybranchia Southern	1.2 - 7.00	27.4 - 31.2	0.39 - 33.42	1.05 - 4.84	6.61-324.2	0 - 4.20
Prionospio pinnata Ehlers	1.2 - 6.00	27.4 - 30.4	1.02 - 32.92	2.35 - 4.14	6.62-190.14	0 - 1.62
Prionospio polybranchiata Fauvel	1.2 - 6.00	25.2 - 32.2	0.39 - 32.36	0.05 - 4.40	6.12-420.6	0 - 4.92
Owenia sp.	1.2	26.2 - 28.5	0.58 - 2.07	1.14 - 4.74	12.6 - 50.26	0 - 0.11
Parheteromastus tenuis Monro	1.2 - 6.00	25.2 - 32.2	0.39 - 32.36	0.05 - 4.40	16.72 -394.2	0 - 4.92
Scyphoproctus singularis Fauvel	1.2 - 4.5	27.3 - 30.8	7.21 - 29.09	1.01 - 2.35	60.12- 320.9	1.12-4.26
Scyphoproctus djiboutiensis Gravier	1.20-7.00	25.2 30.9	0.57 - 32.95	0.67 - 4.40	6.61- 286.0	0 - 3.04

	Depth range meters	Temperature range °C	Salinity range %°	Oxygen range ml/L	Biochemical Oxygen Demand ppm	Total Sulphide range mg/L
Pulliella armata Fauvel	1.20.	27.1	0.581	3.39.	70.82	0 - 0.19
CRUSTACEA						
Apseudes chilkensis Chilton	1.2 - 7.00	25.2 - 32.2	0.39 - 33.42	<0.06 - 4.40	6.12 - 370.2	0 - 4.89
Apseudes gymnophobia Barnard	1.2 - 7.00	25.2 - 31.0	0.58 - 33.06	0.32 - 4.77	6.84 - 361.2	0 - 4.81
Cirolana fluviatilis Stebbing	4.5 - 7.00	25.2 - 30.8	0.752 - 32.52	3.09 - 4.74	6.64 - 60.12	0 - 0.12
Synidotea variegata Collinge	2.5 - 7.00	25.2 - 29.0	1.11 - 30.92	2.72 - 4.74	6.12 -150.11	0 - 0.91
Ericopisa Chilkensis (Chilton)	4.5 - 7.00	25.6 - 28.5	1.11 - 29.81	2.24 - 4.40	6.12 - 98.41	nil
Hyale hawaiensis (Dana)	4.5 - 7.00	25.2 - 28.9	1.11 - 31.92	3.11 - 4.74	7.21 - 31.21	nil
Photis digitata Barnard	4.5 - 7.00	25.7 - 30.1	0.58 - 31.98	1.69 - 3.84	7.06 - 92.16	0 - 1.12
Grandidierella bonnieri Stebbing	7.00 -	28.6	29.5	3.37	8.18	nil
Grandidierella gilesi Chilton	1.2 - 7.00	25.2 - 31.0	0.752 - 33.26	1.36 - 4.74	6.12 -170.32	0 - 1.37
Viaderiana sp.	2.5 - 7.00	25.9 - 31.2	0.39 - 32.18	1.05 - 4.74	8.18 -268.61	nil
Neorhynchoplax sp.	2.5 - 7.00	25.2 - 31.1	1.11 - 32.92	2.18 - 4.74	7.21 -170.6	nil
Scylla serrata (Forskal)	7.00	26.2	18.21	3.59	6.12	nil

Table-1 (contd.)

	Depth range meters	Temperature range °C	Salinity range %°	Oxygen range ml/L	Biochemical Oxygen Demand ppm	Total sulphide range mg/L
Haliocarcinus sp.	4.5	29.1	13.84	2.61	25.81	0.04
Eriphia smithii Macleay	4.5	28.4	9.22	2.48	162.1	0.89
Macrophthalamus sp.	2.5	31.1	5.26	2.18	170.6	0.68
Penaeus indicus H. Milne Edwards	7.00	29.9	31.04	3.70	12.01	nil
Metapenaeus lysianassa (de Man)	1.5 - 7.00	30.1 - 30.8	12.86 - 30.39	1.98 - 3.35	19.22 - 20.12	nil
Palaemon styliferus H. Mile Edwards	2.5 - 7.00	25.2 - 29.0	19.54 - 31.08	2.78 - 3.11	8.41 -150.11	0 - 0.91
Alpheus paludicola Kemp	7.00	28.9	31.92	3.11	7.22	-
Alpheus rapax ((Fabricus)	4.5	30.3	28.12	1.90	100.11	1.81
Athanas polymorphus (Kemp)	1.5 - 4.5	27.0 - 31.0	0.972-31.11	1.15 - 3.39	76.4 - 324.2	0.21 - 4.20
Cardina sp.	6.00	27.8	1.02	2.54	18.12	-
Oxyrides striaticauda Kemp	2.5 - 6.00	27.0 - 28.6	0.572- 4.65	2.59 - 4.74	9.68 - 192.6	0 - 6.61
SIPENCULOIDEA	4.5 - 7.00	25.2 - 30.9	19.54 -34.31	1.90 - 3.81	7.21 - 161.6	0 - 1.81
ECHIUROIDEA Ochaetostoma septemyotum Dutta Gupta, Menon Johnson	7.00	28.5	23.28	2.68	32.16	nil

Table-1 (contd.)

	Depth range meters	Temperature range °C	Salinity range ‰	Oxygen range ml/L	Biochemical Oxygen Demand ppm	Total Sulphide range mg/L
MOLLUSCA						
Pandora flemosa Sowerby	1.2 - 7.00	26.2 - 31.2	0.39 - 32.52	<0.05 - 4.40	6.62 - 280.4	0 - 3.41
Modiolus striatulus (Hanley)	2.5 - 7.00	25.2 - 31.1	1.11 - 33.26	2.18 - 4.40	7.06 - 170.6	0 - 1.21
Tellina sp.	1.5 - 7.00	26.3 - 28.5	0.57 - 31.98	0.67 - 3.81	7.06 - 262.1	0 - 0.5
Cryptomya philippinarum (Adams)	1.2 - 7.00	26.9 - 30.9	0.752- 31.82	1.80 - 3.81	7.06 - 260.1	0 - 0.89
Arca fusca Bruguiere	2.5 - 7.00	27.6 - 31.1	5.26 - 33.26	2.18 - 2.68	87.21 - 170.6	nil
ECHINODERMATA Brittle star	4.5 - 7.00	27.4 - 30.8	29.09 - 33.26	2.24 - 3.70	7.06 - 120.22	nil
FISH LARVAE Hemirhamphidae	1.5	30.3	9.42	2.08	129.1	0.55
Sola ovata Richardson	7.00	28.1	1.37	2.01	118.8	0.5
Trypauchen vagina (Bloch and Schneider)	4.5 - 6.00	27.4 - 30.9	0.58 - 31.46	2.18 - 4.29	19.24 - 165.1	0 - 1.58

Table - 2: FREQUENCY OF OCCURRENCE OF MACROBENTHOS AROUND WILLINGDON ISLAND

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7
COELENTERATA							
Sea anemone	0/24	0/24	9/24	2/24	0/24	0/24	0/24
POLYCHAETA							
Lepidonotus tenuisetosus (Gravier)	0/24	0/24	2/24	0/24	0/24	0/24	1/24
Sthenelais boa Johnston	0/24	0/24	4/24	0/24	0/24	0/24	0/24
Diopatra neapolitana Delle Chiaje	0/24	0/24	16/24	6/24	2/24	3/24	0/24
Lumbriconereis simplex Southern	0/24	0/24	7/24	6/24	5/24	1/24	3/24
Lumbriconereis polydesma Southern	1/24	0/24	12/24	6/24	5/24	7/24	6/24
Ancistrosyllis constricta Southern	5/24	2/24	14/24	9/24	9/24	6/24	3/24
Glycera longipinnis Grube	3/24	0/24	1/24	1/24	0/24	5/24	0/24
Glycera alba Rathke	3/24	1/24	6/24	3/24	5/24	3/24	0/24
Lycastis indica Southern	7/24	8/24	0/24	3/24	3/24	2/24	7/24
Dendronereis aestuarina Southern	7/24	3/24	0/24	0/24	2/24	1/24	3/24
Perinereis cavifrons Ehlers	5/24	2/24	12/24	2/24	3/24	3/24	2/24
Nephtys oligobranchia Southern	2/24	1/24	6/24	2/24	9/24	8/24	8/24

Table-2 (contd.)

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7
Nephthys polybranchia Southern	1/24	1/24	1/24	4/24	7/24	12/24	10/24
Prionospio pinnata Ehlers	1/24	0/24	1/24	4/24	2/24	7/24	0/24
Prionospio polybranchiata Fauvel	22/24	17/24	8/24	13/24	16/24	14/24	22/24
Owenia sp.	2/24	0/24	0/24	0/24	0/24	0/24	0/24
Paraheteromastus tenuis Monro	13/24	4/24	2/24	6/24	5/24	2/24	12/24
Branchiocapitella singularis Fauvel	2/24	1/24	0/24	1/24	0/24	0/24	0/24
Scyphoproctus djiboutiensis Gravier	5/24	3/24	2/24	3/24	6/24	3/24	15/24
Pulliella armata Fauvel	2/24	0/24	0/24	0/24	0/24	0/24	0/24
CRUSTACEA							
Apseudes chilkensis Chilton	10/24	10/24	5/24	9/24	6/24	7/24	13/24
Apseudes gymnophobia Barnard	3/24	1/24	9/24	1/24	4/24	1/24	5/24
Cirolana fluviatilis Stebbing	0/24	0/24	10/24	5/24	1/24	0/24	0/24
Synidotea variegata Collinge	0/24	0/24	10/24	0/24	0/24	0/24	1/24
Eriopisa chilkensis (Chilton)	0/24	0/24	1/24	1/24	1/24	0/24	0/24
Hyale hawaiensis (Dana)	0/24	0/24	4/24	1/24	0/24	0/24	0/24
Photis digitata Barnard	0/24	0/24	3/24	4/24	0/24	1/24	0/24

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7
Grandidierella bonnieri Stebbing	0/24	0/24	1/24	0/24	0/24	0/24	0/24
Grandidierella gilesi Chilton	2/24	0/24	18/24	10/24	2/24	3/24	3/24
Viaderiana sp.	0/24	0/24	2/24	0/24	5/24	0/24	15/24
Neorhynchoplax sp.	0/24	0/24	7/24	1/24	0/24	1/24	1/24
Scylla serrata (Forskal)	0/24	0/24	1/24	0/24	0/24	0/24	0/24
Halicarcinus sp.	0/24	0/24	0/24	0/24	0/24	1/24	0/24
Eriphia smithii Macleay	0/24	0/24	0/24	0/24	0/24	1/24	0/24
Macrophthalmus sp.	0/24	0/24	0/24	0/24	0/24	0/24	1/24
Penaeus indicus H. Milne Edwards	0/24	0/24	1/24	0/24	0/24	0/24	0/24
Metapenaeus lysianassa (de Man)	0/24	1/24	1/24	0/24	0/24	0/24	0/24
Palaemon styliferus H. Mile Edwards	0/24	0/24	1/24	0/24	0/24	0/24	1/24
Alpheus paludicola Kemp	0/24	0/24	1/24	0/24	0/24	0/24	0/24
Alpheus rapax (Fabricus)	0/24	0/24	0/24	0/24	1/24	0/24	0/24
Athanas polymorphus (Kemp)	0/24	1/24	0/24	0/24	1/24	0/24	2/24
Caridina sp.	0/24	0/24	0/24	0/24	0/24	1/24	0/24
Ogyrides striaticauda Kemp	0/24	0/24	0/24	0/24	0/24	4/24	2/24
SIPUNCULOIDEA	0/24	0/24	9/24	4/24	1/24	0/24	0/24

	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7
ECHIUROIDEA							
Ochaetostoma septemyotum Dutta, Gupta, Menon and Johnson	0/24	0/24	1/24	0/24	0/24	0/24	0/24
MOLLUSCA							
Pandora flexuosa Sowerby	4/24	1/24	4/24	4/24	7/24	5/24	8/24
Modiolus striatulus (Hanley)	0/24	0/24	5/24	2/24	1/24	0/24	1/24
Tellina sp.	0/24	0/24	5/24	0/24	1/24	0/24	1/24
Cryptomya philippinarum (Adams)	2/24	1/24	1/24	0/24	1/24	0/24	2/24
Arca fusca Bruguiere	0/24	0/24	1/24	0/24	0/24	0/24	1/24
ECHINODERMATA							
Brittle star	0/24	0/24	9/24	3/24	3/24	0/24	0/24
FISH LARVAE							
Hemirhamphidae	0/24	0/24	3/24	0/24	0/24	0/24	0/24
Solea ovata Richardson	0/24	0/24	2/24	0/24	0/24	0/24	0/24
Trypauchen vagina (Bloch and Schneider)	0/24	0/24	1/24	1/24	1/24	1/24	0/24

CHAPTER III

EFFECT OF POLLUTION FROM RETTING OF COCONUT HUSK IN VADUTHALA (COCHIN BACKWATERS)

The Retting Grounds

The extensive backwaters located between the Arabian Sea and the midland of Kerala are the sites for retting coconut husk. Cochin backwaters which is the biggest estuary in the state contributes to several such retting zones. Vaduthala (Fig.2) one of such retting zone started about five years ago in Cochin backwaters was selected for the present study. Located about five kilometers upstream from the bar-mouth, it has access by road as well. Close to the retting ground is also established a fibre processing plant, the largest of its kind in Cochin, though the plant works only seasonally (premonsoon). The retting zone presents itself as a pocket of large water mass into the mainland from the main backwater stream at Vaduthala. In this area, extending to about 2000 sq. metres, nearly forty wells, each 4-8 ft. deep are made into which raw coconut husk brought by land or water is piled in thousands closely one above the other and kept immersed in the water. The husk thus immersed in water is kept for six or more months depending on the age of the husk. After the due date the husk is removed from the wells which are again filled with fresh coconut husk for retting. This process of retting has been continuing since past five years in the Vaduthala site referred. The husks removed from the well are dried and processed for fibres to manufacture coir. The practice of retting of coconut husk in several such wells in the limited area at Vaduthala, has converted a considerable section of the backwaters around the retting ground into virtually foul smelling more or less stagnant water mass black in colour which provides an excellent site for mosquito breeding and posing social problem in the environs. Black mud accumulates at the bottom ofthe retting ground while close to the processing plant the bottom has heavy accumulation of pith dumped from the plant. Strong smell of hydrogen sulphide also prevails around the area indicating a polluted environment. It is known that before the establishment of the retting ground and the processing plant, animal life in this area was normal as in the main stream of backwaters up and down the retting zone. Main source of aquatic pollution in this area is from the retting of coconut husk.

The process of retting is brought about by pectinolytic activity of microorganisms especially bacteria and fungi liberating large quantities of organic substances like pectin, pentosan, fat and tannin into the medium. Polyphenols get constantly leached out. Polyphenols and pectin are major constituents representing respectively as much as 75 to 76 and 16 to 17 gm per kilogram of husk material (Jayasankar, 1966 and Bhat, 1969). The pectinolytic activity has been attributed to bacteria such as Micrococcus, Aerobacter, Bacillus, Arthrobacter, Eschrichia, Paracolobactrum and by the yeast Rhodotorula and Cryptococcus (Jayashankar, 1966). Pseudomonas sp. and Micrococcus sp. are associated with the leaching out of polyphenols (Jayashankar and Bhat 1966). Offensive odours resembling those of H_2S emanate from the retting zones during the decomposition of pectin. In the retting grounds the smell and presence of black mud due to reduction of sulphur compounds indicates the presence of sulphide. The conversion of sulphate (SO_4^{2-}) to sulphide (S^{2-}) involves the reduction reaction by organisms which can utilize sulphate salts as nutrients for production of cellular protein. The initial sulphate reduction reactions have been investigated in species of the dissimilatory sulphate reducing bacteria, Desulfovibrio and Desulfotomaculum

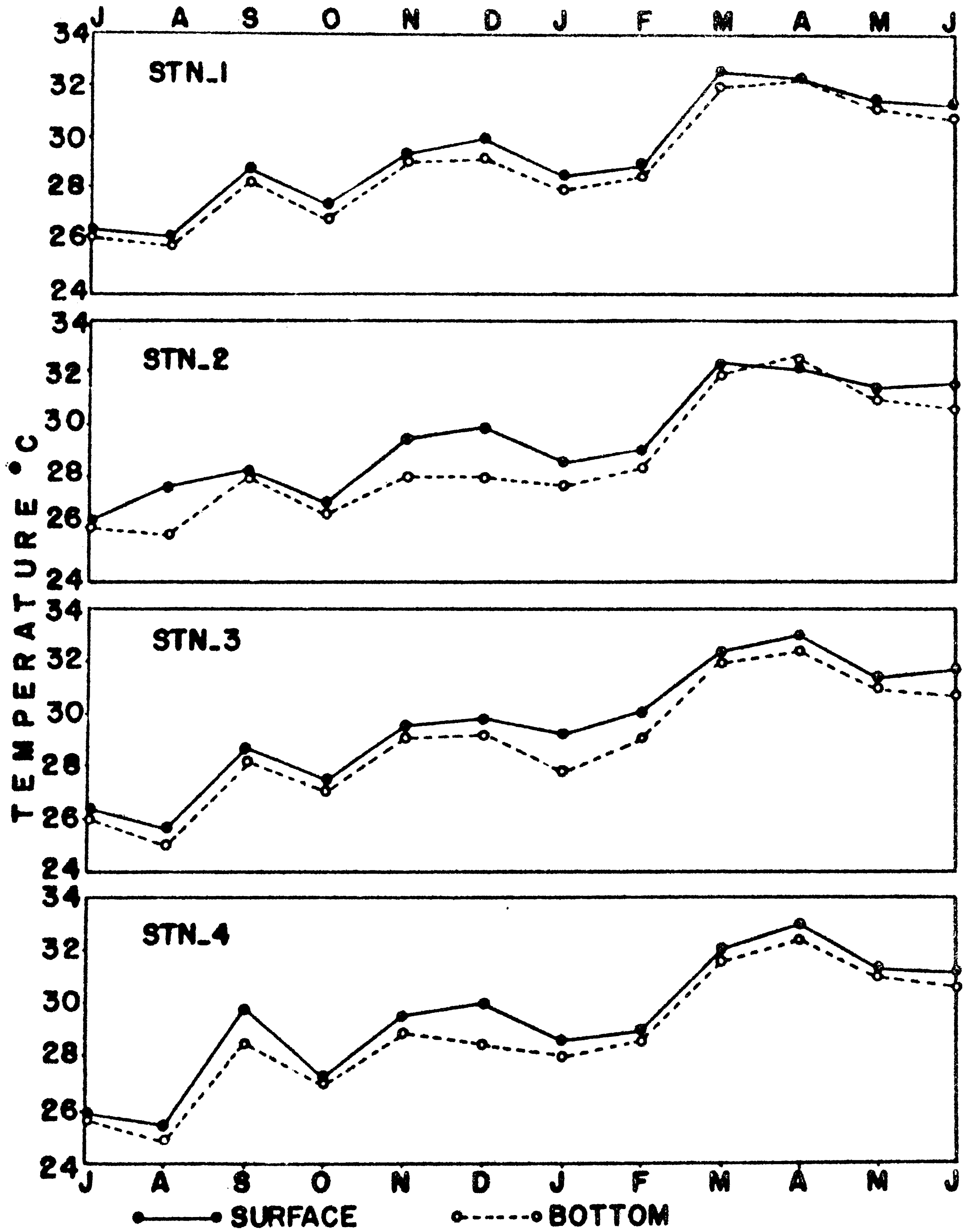
(Patric Dugan, 1972). High quantities of sulphide is produced by the decomposition of pectin in the retting zone and convert this area to a barren noxius zone.

HYDROGRAPHY

Pollution due to retting of coconut husk was observed to have varying effect on the hydrographic featuresof Cochin backwaters. Data on temperature, salinity, oxygen, BOD_5, total sulphide, fauna and the bottom are presented and discussed below.

Temperature:

Mean values of bottom and surface temperature at each of the observation stations for the twelve months are given in the Table (3). Seasonal changes in temperature, a characteristic feature of the hydrography of estuarine waters was well marked in the area of study. Temperature was generally high in premonsoon than in post-monsoon and monsoon averaging about 32°C (Fig.4). During premonsoon the surface temperature was higher than the bottom at all stations. Fluctuations in temperature were noticed more in surface waters than in the bottom. Valuesof seasonal change in surface temperature varies from 3.6°C to 5°C and generally fall to the lowest of 25.4 to highest of 33°C. As regards bottom temperature the values ranges between 4°C to 7°C with the minimum 25°C to a maximum of 32.6°C.



J A S O N D J F M A M J
STN_1
STN_2
STN_3
STN_4
34
32
30
28
26
24
TEMPERATURE °C
SURFACE
BOTTOM

is minimised due to vertical mixing. Similarly the present observation stations remaining shallow, the difference of thermal gradient is not very high, and is maintained at the minimum due to vertical mixing. Tidal variation in temperature was not considerable in the retting grounds.

Hence it may be stated that pollution from retting of coconut husk doesnot seem to have any significant effect on the temperature although the temperature affects the dissolved oxygen content and BOD_5 of this area contributing to pollution hazards.

Salinity:

Seasonal and tidal variations in salinity were pronounced during the year. The highest salinity values both in surface and bottom were recorded in all the stations during premonsoon. Highest salinity value at the surface was 22.38‰ and 25.8‰ in the bottom. A drop in salinity was noticed during the monsoon reaching to 0.21‰ indicating dilution and mixing of water by heavy rainfall and land washing. Since the few observation stations are close to each other, difference in salinity values between the stations both at the surface

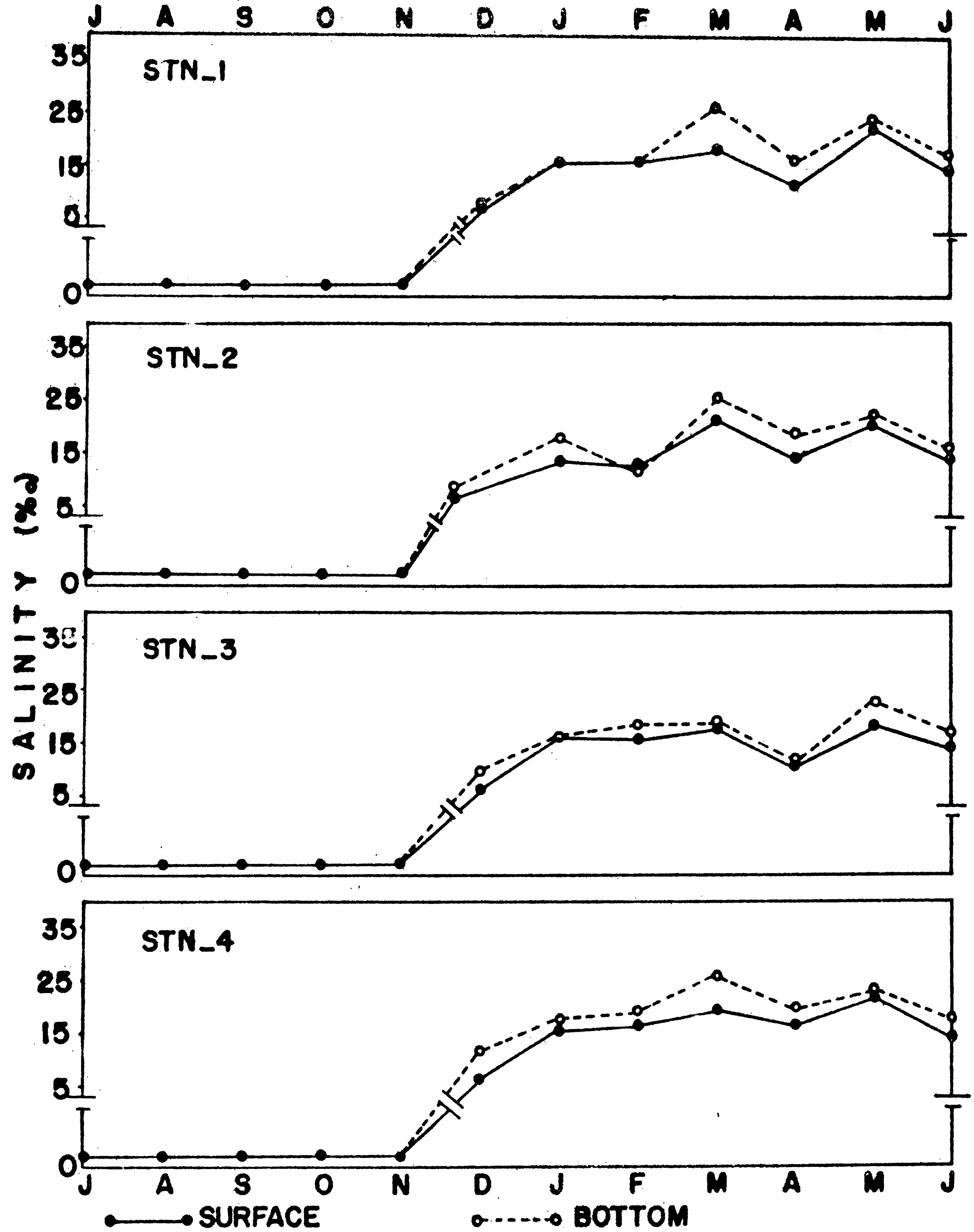

J A S O N D J F M A M J
STN_1
STN_2
STN_3
STN_4
SALINITY (‰)
35
25
15
5
0
SURFACE
BOTTOM

Fig. 5

and bottom were not considerable (Fig.5).

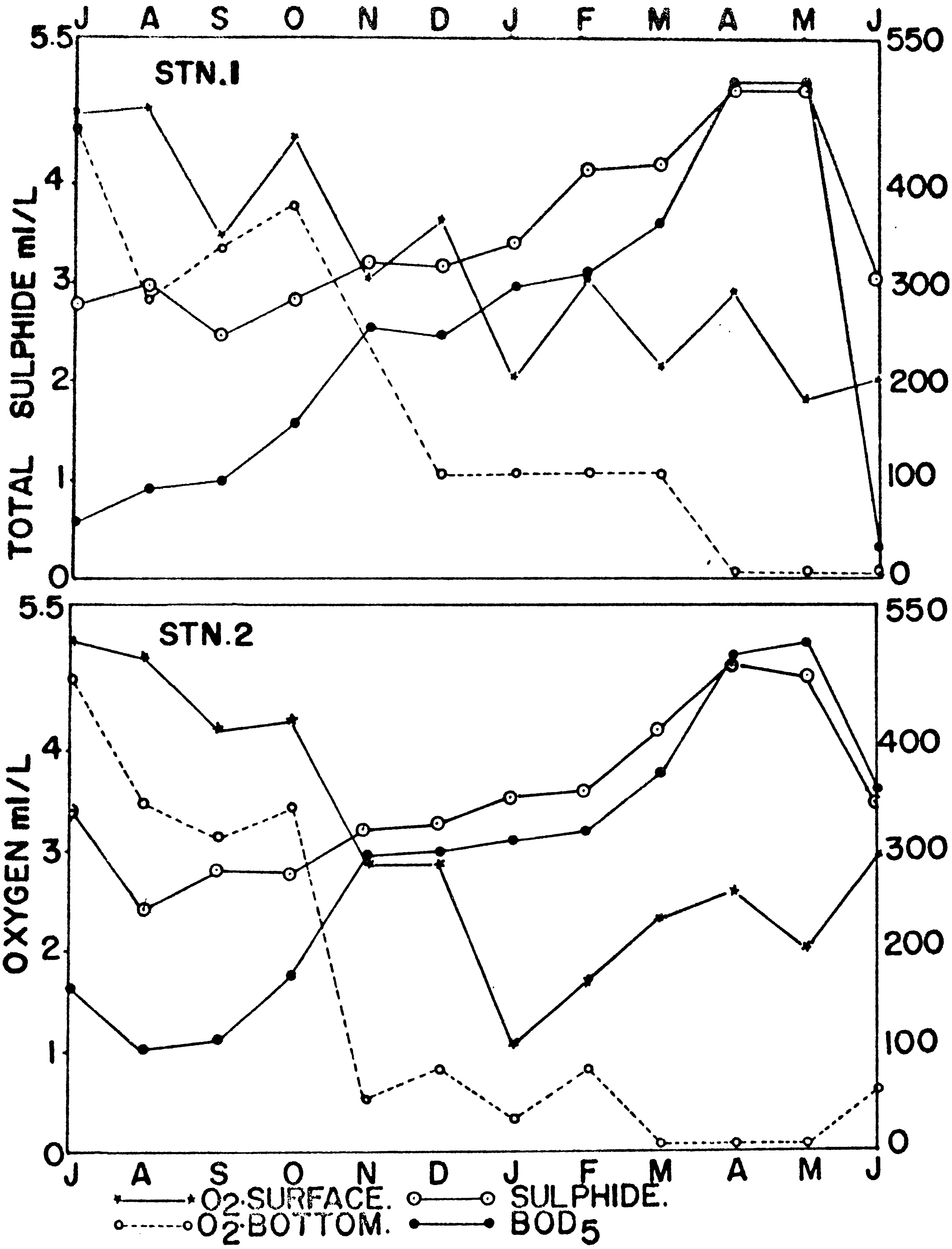
Salinity gradients between bottom and surface at the stations do not seem to be considerable except during premonsoon. Maximum salinity gradient is observed during premonsoon at station 1 (0.22 - 7.61%°), station 2 (0 - 4.33%°), station 3 (0.1 - 4.89%°) and station 4 (0.18 - 7.91%°). The observation stations being far away from the barmouth an intrusion of saline water from the sea into the area of observation even during high tide was reduced. However, the traceable difference in vertical gradient noticed was during monsoon months and may be explained as due to monsoonal effects.

Ramamritham and Jayaraman (1963) have observed a difference of more than 20%° between the surface and bottom values of salinity in the backwaters around the waters of Willingdon Island during premonsoon. Kurian (1974) and Vijayan et al. (1976) also have observed high values of salinity gradient during premonsoon. The observation stations of these authors being in and around the barmouth, the overall change in salinity indicates the variations occurring near the mouth of the backwaters whereas such effects are not pronounced in the far away retting ground stations.

Thus it is more or less clear that no significant change in salinity was noticed due to pollution from the retting of coconut husk.

Dissolved Oxygen:

It is observed that dissolved oxygen concentration is one of the critical environmental factors indicating the quality of waters, since oxygen is one of the most significant constituents of natural waters. Quality of the water could be assessed by a series of oxygen determinations of water samples (Huchinson 1957). During the present study special emphasis was laid on the dissolved oxygen content which was observed to be considerably less in the polluted areas (Stations 1,2 and 3) in contrast to the unpolluted zone (Station 4). Concentration of dissolved oxygen was measured at the four stations throughout the year (Figs. 6 & 7). Fohrenbach (1969) observed that the oxygen content can be a reflection of organic loading, nutrient input and biological activity. The depletion of oxygen in the stations 1,2 and 3 may be due to the effect of organic pollution from retting of coconut husk. In this area the oxygen consumption showed well marked seasonal variations. Lowest oxygen content recorded was during premonsoon reaching <0.05 ml/l. During this period tidal influence



STN.1
STN.2
J A S O N D J F M A M J
5.5
4
3
2
1
0
550
400
300
200
100
0
TOTAL SULPHIDE ml/L
OXYGEN ml/L
O2 SURFACE.
SULPHIDE.
O2 BOTTOM.
BOD5

Fig.6

minimised the flow of waters keeping this area sluggish. The fibres and other putrisible organic particles were sedimented and putrifaction of this initiated the depletion of dissolved oxygen. According to Von Brand (1946) critical oxygen concentrations are higher at higher temperatures. The present observation also showed that the lowest oxygen content was reached both in the surface and bottom, especially during premonsoon when the temperature reached to maximum of 32 to 33°C at the surface and 30 - 32.6°C at the bottom. The rate of oxidation of organic matter is influenced by temperature and the presence of suitable bacteria (Hynes, 1960). Hence accelerated decomposition of coconut husk occurred at high temperatures, due to heavy consumption of oxygen; oxygen content reached upto $<$0.05 ml/l in stations 1 and and 2 and upto 0.8 ml/l in station 3 creating almost anoxic conditions. However, oxygen content in Station 4 which was pollution free zone was high during all the seasons when compared to the other three stations. Serious pollution effect was noticed in stations 3, 2 and 1 progressively during premonsoon due to the effect of high temperature and decomposition of heavy load of organic matter resulting in depletion of oxygen.

During monsoon and postmonsoon the oxygen values were significantly higher than those in premonsoon (Table 3) in all the stations. During monsoon due to the torrential flow of rain water, organic matter is prevented from settling to the bottom and is flushed out into the free zone aerating and diluting the polluted waters considerably. Hence the water contained dissolved oxygen to a considerable extent during monsoon periods.

Oxygen content of the bottom water was always observed to be considerably lower than surface water. This may be attributed to the higher rate of oxygen consumption for the decomposition of coconut husk mixed with organic gyttja in the bottom and the suspended decomposing material in the overlying waters immediately above.

Ramamritham and Jayaraman (1963), Kurian (1974), Haridas et al (1973), Unnithan et al (1975) and Vijayan et al (1976) have all contributed to the knowledge on the distribution of oxygen in Cochin backwaters. However, except the last two groups of authors all the others have worked on the general distribution of oxygen in the backwaters at large without any special reference to pollution.

Biochemical oxygen demand (BOD_5)

A measure of the amount of oxygen required to oxidise the organic matter in a sample in 5 days at 20°C is known as BOD_5. Reish (1959), Mcnulty (1961) and Pauli Bagge (1969) have emphasized the importance of BOD_5 in the assessment of pollution of an environment. Dissolved or suspended organic material in the waste gives Biochemical oxygen demand to the polluted waters. BOD_5 values range from around 1 mg/l for natural waters to 300-500 mg/l for untreated domestic sewage (Health Hazards of Human Environment WHO 1972).

Influence of pollution from retting of coconut husk on the environmental factors was revealed by an increase in the organic content and bacterial activity in both bottom water and sediment as indicated by the high BOD_5 values, at times exceeding those for untreated domestic sewage (Table 3). The high BOD_5 values at the polluted stations 1,2 and 3 are indicative of large load of organic matter and bacterial populations consuming the available oxygen.

BOD_5 value was found to vary considerably with stations and seasons (Figs.6 & 7) depending upon certain factors such as temperature and availability of organic lead. Dissolved oxygen was closely correlated with BOD_5 i.e. lower the DO higher the BOD_5 and *vice versa*. This trend continued throughout the seasons. However, with the beginning of premonsoon an increasing trend of BOD_5 values was noticed reaching upto 513.76 mg/l. Subsequently a fall to about 34.36 mg/l in BOD_5 with the commencement of monsoon was observed which obviously indicated the effect of monsoonal flow. Unpolluted station 4, showed low BOD_5 values compared to other stations in all the seasons, reaching a minimum of 16.91 mg/l and a maximum of 89.31 mg/l. During premonsoon BOD_5 in polluted stations were ten to fifteen times higher than those recorded during monsoon, which showed heavy consumption of dissolved oxygen due to rapid decomposition of organic matter at high temperature. Highest BOD_5 values were recorded at high temperatures of about 30° to 33°C Also highest BOD_5 occurred when the oxygen content was critically low as < 0.05 ml/l, which indicated that oxygen consumption in polluted areas was four to five times higher than in the healthy area.

There were remarkable differences in the values of BOD_5 in premonsoon, monsoon and postmonsoon in all the stations. During the early monsoon month (May) the values tend to remain more or less the same as that of the

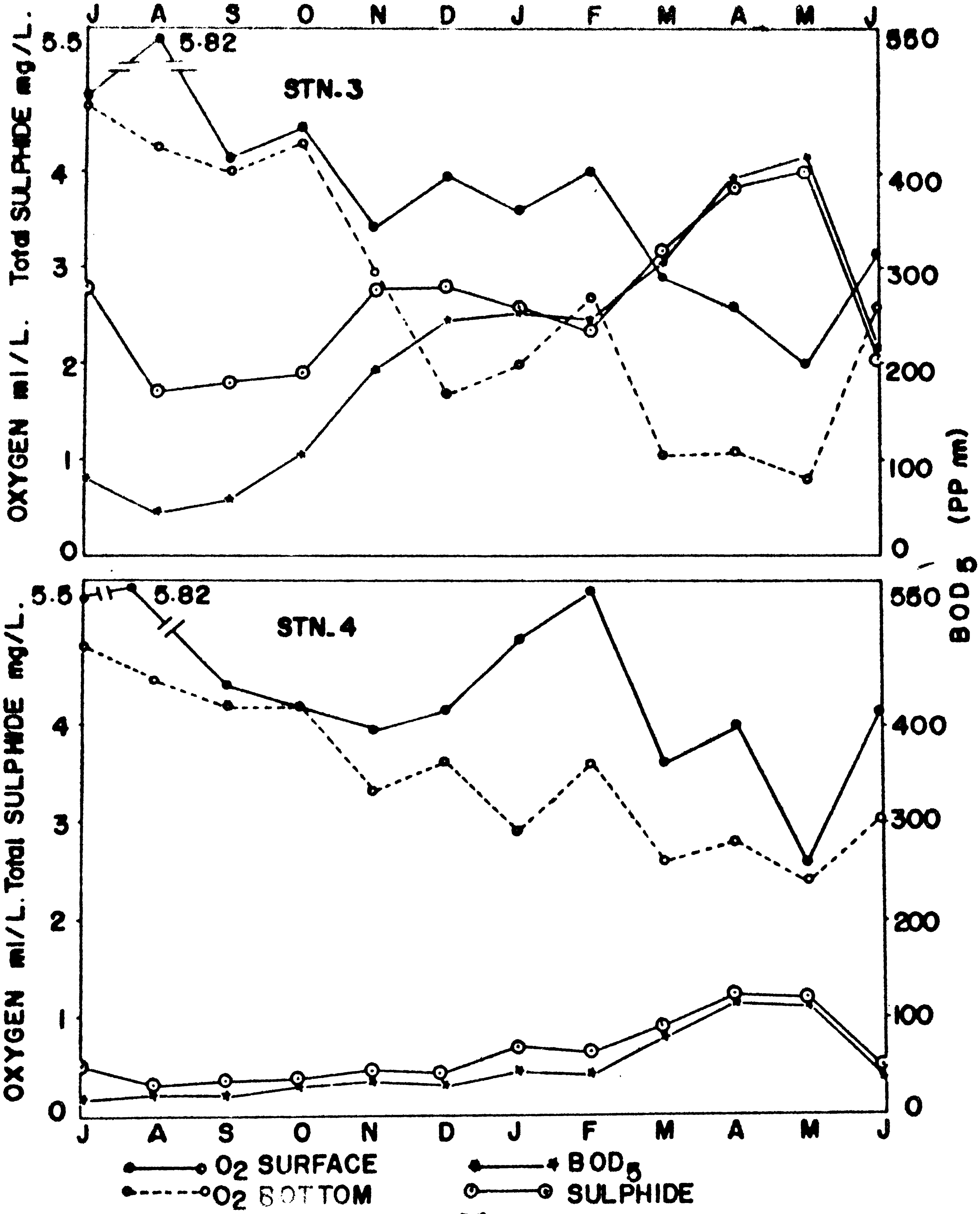

STN. 3
STN. 4
5.82
OXYGEN ml/L. Total SULPHIDE mg/L.
BOD 5 (PP m)
J A S O N D J F M A M J
O2 SURFACE
O2 BOTTOM
BOD5
SULPHIDE

Fig. 7

premonsoon. However, a decreasing trend was noticed from June onwards. The maximum values of BOD_5 at the three polluted stations did not vary considerably from one another as the organic load at these stations were more or less the same in quality and quantity. Whereas around Willingdon Island it was observed that BOD_5 values fluctuate with station and time due to the quality and quantity of sewage, monsoonal and tidal effects, (Vijayan et al 1976). Highest values of BOD_5 recorded earlier were 280.4 ppm (Unnithan et al 1975) 400 ppm (Vijayan et al 1976) both in premonsoon at station 2 which is more near to the barmouth than the present area of investigation in Cochin backwaters. Maximum BOD_5 value (513.76 mg/l) which is the highest recorded, was observed in the polluted stations of the present area of study. The retting grounds cover an area of about 2000 sq. metres of stagnant water body which do not receive sewage inlets or similar canals and the region being far away from the barmouth tidal influence was also reduced to a considerable extent. Monsoonal dilution seems to be the only effective factor reducing the pollution effect.

Total Sulphide:

In the retting grounds sulphate present in the surrounding water is reduced to sulphide by bacterial action resulting in the black coloured bottom and aquatic medium as observed at the stations 1,2 and 3.

The odour and colour of mud and water samples of the area also indicated presence of high sulphide content.

Measurable quantity of total sulphide was noticed in the bottom of stations 1,2 and 3 when the oxygen content was critically low (Table 3, Figs. 6 & 7). The total sulphide value recorded in the healthy station 4 was negligible when compared to that of polluted stations 1,2 and 3. A maximum of only 0.96 mg/l and a minimum of 0.32 mg/l of total sulphide were recorded from the healthy station. During premonsoon period the sulphide value rise to amaximum of 4.97 mg/l in stations 1 to 3. This value is remarkably high from even from the standard value of 2 ppm for effluents discharged into inland waters. With the commencement of monsoon a drop in the sulphide value was noticed which reached upto 1.72 mg/l. The sulphide value seems to increase proportionately with the fall in oxygen content and rise in temperature. A similar trend of relationship has been observed earlier (Unnithan et al. 1975) in the backwaters. The maximum sulphide value recorded, during the present study is 4.97 mg/l when the dissolved oxygen reached the minimum of $<$ 0.05 ml/l and the temperature 31 to 33°C.

High temperature accelerated the rate of decomposition resulting in the formation of more or less anoxic condition. The organic components of sulphur such as sulphates and sulphites may be reduced to sulphides by heterotrophic bacteria, large populations of which were observed at these stations especially during premonsoon periods. Hence sulphide pollution which results from oxygen depletion suggests itself as a remarkable phenomenon of the retting ground observed throughout the season though especially high during premonsoon. In fact the sulphide pollution was observed to be considerably hazardous to aquatic life of the retting grounds.

Among the parameters studied, oxygen depletion and sulphide production were observed to be the most effective due to pollution from retting of coconut husk. Pollution effects did not seem to affect temperature and salinity factors considerably though temperature indirectly affected the depletion of oxygen and production of sulphide. Sulphide produced was smelt at great distances from the retting grounds particularly in summer months when high temperature regime favoured rapid decomposition of organic matter. Aquatic fauna especially fishes have a narrow tolerance capacity for oxygen depletion. The decline in fish catch especially since the establishment of retting grounds may in all probability be due to the avoidance of a low oxygen environment by the fishes and similar susceptible biota of the area.

Table-3: MEAN VALUES OF TEMPERATURE, OXYGEN, SULPHIDE AND BOD_5 IN THE FOUR STATIONS

	Stn.1(A)	Stn.2(B)	Stn.3(C)	Stn.4(D)
Monsoon				
Temperature	27.6	27.5	27.4	27.3
Oxygen	3.66	3.07	3.97	4.21
Sulphide	2.78	2.98	2.07	0.38
BOD	87.75	182.51	100.64	25.18
Post-monsoon				
Temperature	29.4	29.0	29.2	28.6
Oxygen	1.04	0.66	2.32	3.46
Sulphide	3.17	3.24	2.79	0.42
BOD	253.55	297.31	220.38	33.98
Pre-monsoon				
Temperature	30.5	30.4	30.4	30.4
Oxygen	0.45	0.25	1.53	2.86
Sulphide	4.33	4.21	3.32	0.85
BOD	333.43	404.26	323.55	67.85

THE BOTTOM

The nature of the bottom of polluted stations (1-3) differed considerably from that of the healthy station(4). Large deposits of pith fibres and organic gyttja accumulated at the polluted sites. Sediment of the retting ground wasblack in colour, malodorous due to production of H_2S indicating oxygen deficiency. Blackening of the mud is due to local chemical reaction resulting in the reduction of sulphate into sulphide (Hynes 1966). The sediments of the polluted stations were observed to be of fine texture in contrast to the coarser sediment with a particle size >63 μ containing lesser quantitiesof organic material in the healthy station. Bottom of the healthy station is mainly composed of sand particles whereas silt and clay predominated in the polluted areas.

Considerable seasonal variations were noticed in the texture of the sediments of the four stations. In the healthy station(4), the percentage of sand was high all through the seasons when compared to that of the three polluted stations (Fig.8). During the premonsoon percentage of silt and clay in the polluted stations were considerably high indicating intense effect of pollution during this season. During post monsoon also though the percentage

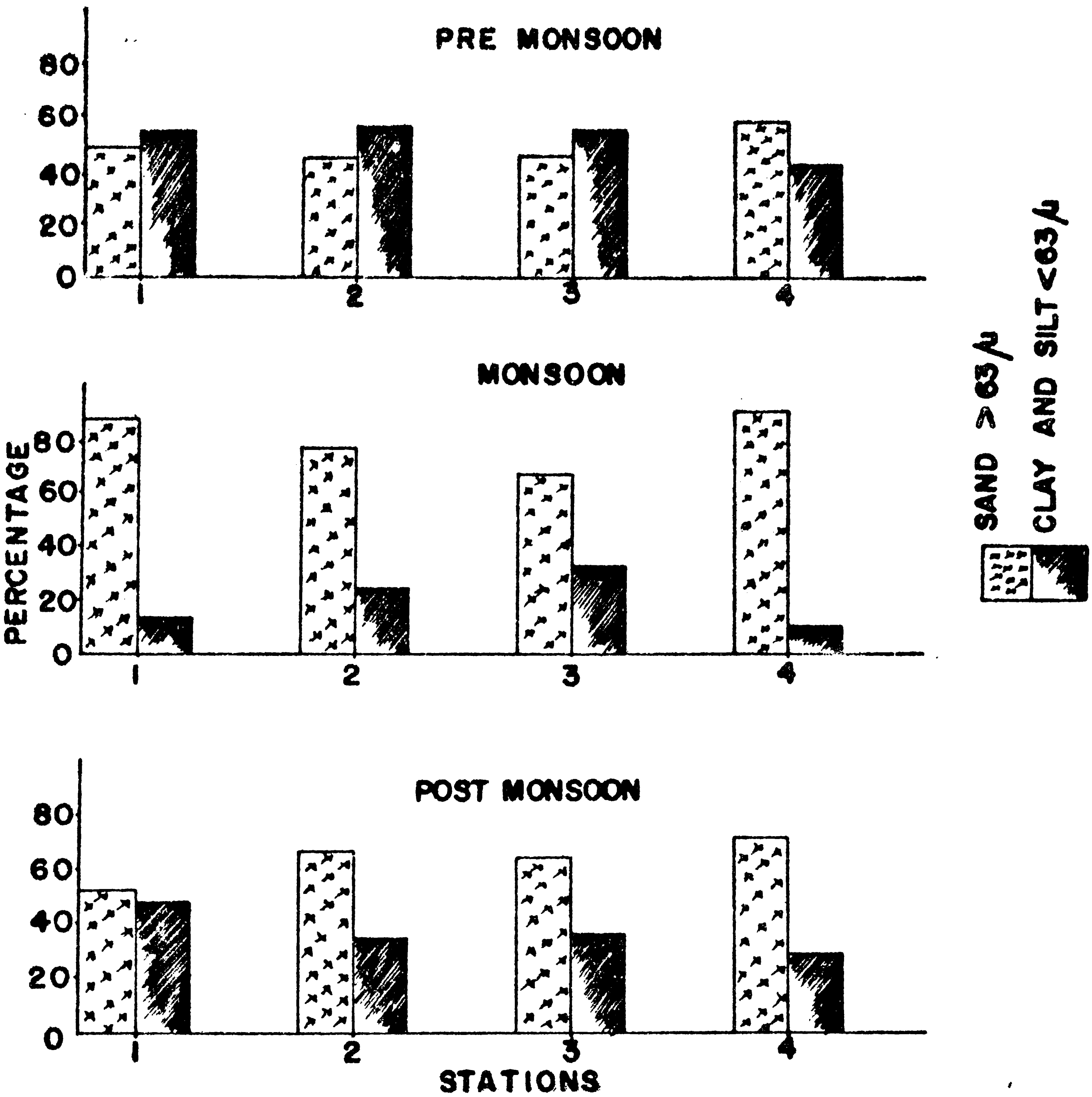

PRE MONSOON
MONSOON
POST MONSOON
PERCENTAGE
STATIONS
0
20
40
60
80
1
2
3
4
SAND >63μ
CLAY AND SILT <63μ

Fig.8

of silt and clay were slightly less than that of pre-monsoon, a more or less similar trend was observed in the polluted stations. Sand predominated the bottom of all the stations with a low percentage of silt and clay during monsoon mainly because the rain water flushes away the lighter particles of silt and clay with organic matter resulting in a subsequent change in the type of the bottom.

The quantitative and qualitative distribution of the macrobenthic fauna of the retting grounds showed a direct relationship with the type of the bottom. The physical nature of the substratum acts as a limiting factor to a great extent in the distribution of the fauna (Sanders 1958, Bloom and Simon 1972). It was observed that the polychaetes, crustaceans and molluscs which contributed to the major groups of animals collected, exhibit a diminishing trend of distribution in the silt and clay substratum of the retting ground except for some pollution tolerant species. These species were observed to prefer black silt clay bottom habitat which is rich in organic matter. This may be due to the fact that sediments are not merely the substrate in which benthic organisms exist but also for many of them the main source of food (Bordovskiy, 1964, 1965). The deposit feeding benthic species in the silt and clay substrate of the polluted stations favoured the organic rich bottom. However, a sandy bottom was preferred by polychaetes as illustrated by their high population density and diversity of species in the healthy station. A similar trend in the distribution of polychaetes was observed by Parulekar (1973) in the distribution of macrobenthic fauna in the inner shelf of central west coast of India.

Crustaceans being detritophagous, their abundance is more correlated with the availability of the detritus in the substratum rather than the physical nature of the bottom. However, in the present observation a decreasing trend of abundance of the crustaceans was noticed in the polluted stations, though these stations have silt and clay bottom with large quantities of organic detritus. Obviously accumulation of pollutants beyond the tolerance level affects the survival of the crustacean fauna which otherwise should have been abundant in these areas. Similarly though the loose and soft substratum of retting ground is suitable for the burrowing polychaetes, the diminishing trend noticed in their distribution in the polluted stations may presumably be due to the anerobic conditions and presence of H_2S in the interstitial space prevailing in these stations. Pauli Bagge (1969) has given a more or less similar observation stating that though low consistency of the deposits of the polluted area favours extensive vertical penetration, the anaerobic condition and presence of hydrogen sulphide in the interstitial space probably limit their activity.

In the silt clay bottom of the polluted stations molluscs showed a lesser numerical abundance. The filter feeding molluscs might have difficulty in maintaining themselves in the soft silt clay substratum of the polluted stations as observed by Pauli Bagge (1968). Charles (1975) also maintains that invertebrates which are unable to maintain a stable position at the sediment water interface may sink below the oxidized zone. Subsequently these animals may die due to their inability to maintain connection with the aerated surface. Thus lack of oxygen and presence of hydrogen sulphide are observed to be the limiting factors in their distribution. The 'support' problem is especially critical for suspension feeders because they may sink loosing contact with the enriched surface waters.

It is observed that small sized bivalves (Pandora flexuosa) dominate the silt clay bottom of polluted stations whereas in the sandy bottom of unpolluted station (4) bivalves of large sizes dominate with very few representatives of the small individuals collected from the polluted zone. This dominance of small sized bivalves in a muddy environment has been interpreted as an adaptation reducing the force per unit area applied by the animals (Stanley 1970, Levington and Bambach 1970, Rhoads 1970, and Fams, 1972). However, according to Raff and Raff (1970), Rhoads and Morse (1971), other factors may also be involved. Dissolved oxygen concentration may be rather poor in the water over fine mud. Because of their high surface to volume ratio, small animals will be favoured where oxygen is limited as observed in the present study. Moreover, as observed by Rhoads and Morse (1971) self limiting conditions such as oxygen deficiency and prevalence of hydrogen sulphide concentration in the muddy bottoms of the retting ground may promote the dominance of dwarf suspension feeders capable of remaining on the surface of soft substrates. The rich detritus associated with the clay bottoms resuspended by the deposit feeders may lead to clogging and reduced efficiency in the suspension feeding mechanism. Also the individuals would sink into the substrate and die when they exceed a critical size.

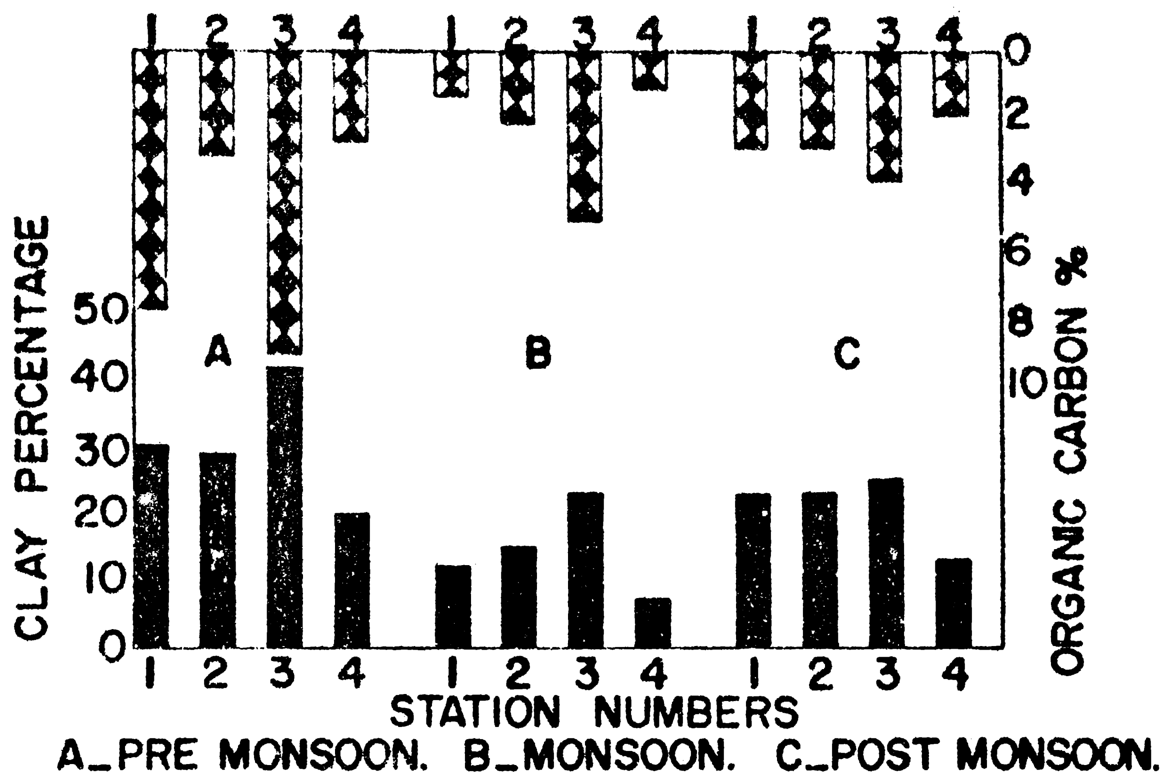
From the foregoing discussion it is more or less evident that the bottom of the retting grounds has been considerably affected. Retting of the coconut husk has increased the organic content of the bottom with a subsequent additional deposition of silt in the polluted stations. It may be stated that the high percentage of silt in the polluted stations along with the particulate materials such as pith, fibres, and other organic aggregates may clog the gills of fishes, subsequently leading to considerable depletion in the local fisheries. Moreover, the deposition of retting ground wastes in the bottom is also responsible for the disturbed bottom conditions and poor fauna of the retting grounds.

ORGANIC CARBON

The colour and texture of the sediment of polluted stations were found to vary considerably from that of healthy station. This was mainly due to variation in the degree of concentration of organic carbon of the stations which is dependent on the grain size distribution of the sediment.

It was noticed that the percentage of organic carbon (Table 4) varied with seasons and stations. Stations 1-3 had heavy concentrations of organic carbon when compared to that of station 4. Accumulation of organic materials from the retting of coconut husk contributed to the high percentage of organic carbon in Stations 1-3. There was considerable seasonal variation in the percentage distribution of organic carbon in all the stations (Fig.9). The percentage distribution of organic carbon was observed to be high during pre and post monsoons when compared to that of monsoon in all the four stations while the highest percentage was recorded during premonsoon and the postmonsoon values were slightly lesser than that of premonsoon. However, in station 4, in all the seasons the percentage of organic carbon was comparatively lesser than that of polluted

Fig.10


1 2 3 4 1 2 3 4 1 2 3 4
CLAY PERCENTAGE
0 10 20 30 40 50
ORGANIC CARBON %
0 2 4 6 8 10
A
B
C
STATION NUMBERS
A_PRE MONSOON. B_MONSOON. C_POST MONSOON.

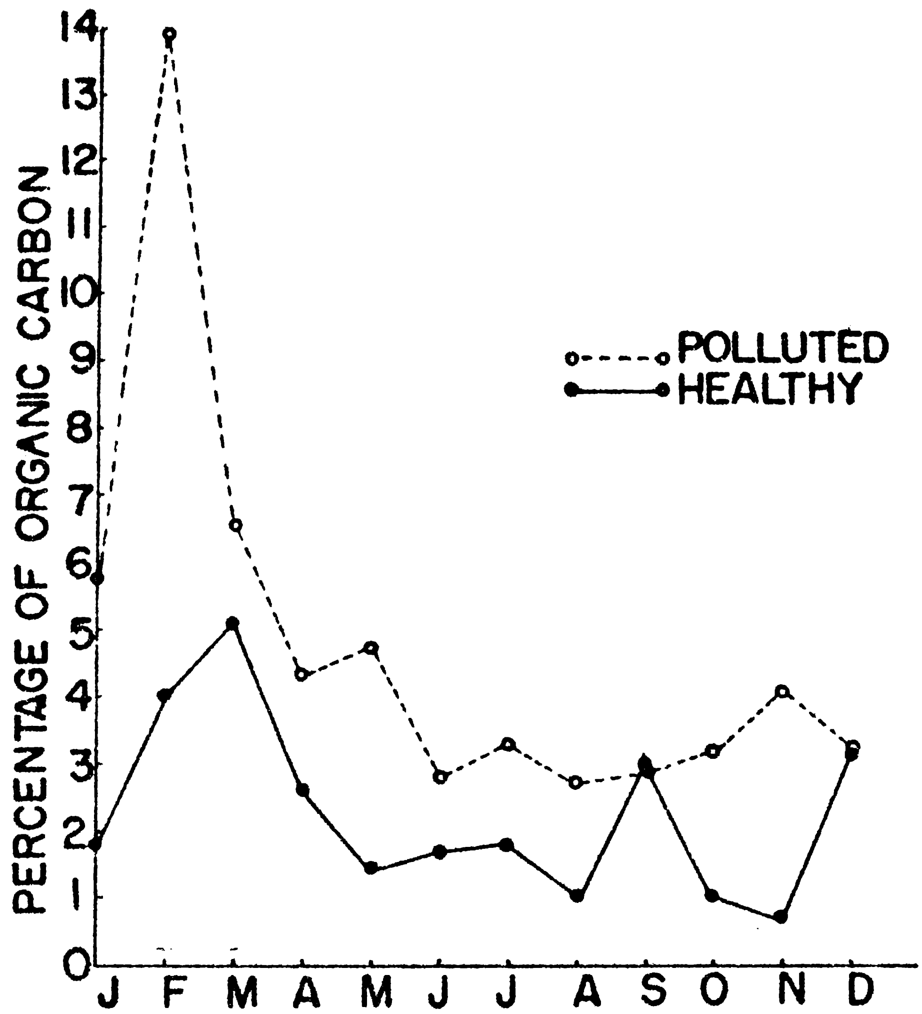

PERCENTAGE OF ORGANIC CARBON
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
J F M A M J J A S O N D
POLLUTED
HEALTHY

Fig.9

stations (1-3). Obviously the polluted stations maintained a higher percentage of organic matter throughout the seasons.

It may be noticed that the percentage of carbon is inversely proportional to the texture of the sediment. Similar relationships were observed by Krumbein (1939), Trask (1939), Van Andel & Postma (1954) (1954), Subba Rao (1960, 1967), Naidu (1968) and Murty et al (1969). The highest percentage of organic carbon was observed during premonsoon in the polluted stations (1-3) where the texture of the sediment was very fine composed of a higher percentage of silt and clay with organic gyttja. In the healthy station (4) the substratum was coarse, composed of sand contributing to a decrease in the percentage of organic carbon. High values of organic carbon in Stations 1-3 may be attributed to the decrease in grain size and consequent protective action of clay and porosity of sand (Kunen, 1990). In the present study it was also noticed that the high and low percentages of organic carbon parallels with the fine and coarse texture of the sediment. Organic carbon was observed to increase with the increase in clay fractions in all the stations. In this connection it may be noticed that station 3 shows a higher concentration of organic carbon and proportionate clay content (Fig.10) during premonsoon, compared to the other polluted stations 1 and 2. The husk processing plant which is seasonal (premonsoon) in operation being located close to station 3, explains for this difference noticed between stations during premonsoon. The grain size of the clay fraction is considered to retard the organic carbon from rapid decomposition (Victor Rajamanickam, 1973), which suggests that organic carbon is predominantly adsorbed by clay particles (Bader, 1962). This pattern of proportionality of organic carbon with clay content of the sediments was noticed in lakes Ontario, Erie and Huron (Kemp, 1971). Fine sediments show a better tendency to enclose organic matter and protect it against oxidation than coarse grained sediments which would explain for the higher percentage of organic carbon with clay in the polluted stations. In addition to the lower rate of decomposition, similarity in the settling velocity of organic matter and fine sedimentary material must have facilitated the accumulation of high organic carbon. The low percentage of organic matter in all the stations during monsoon may be due to the flushing of light particles of clay along with the organic matter by the rain water.

According to Driscool (1975) lower pH and dissolved oxygen values occur over fine grained organic rich sediments than above coarse grained organic poor sediments. That is both dissolved oxygen and pH of the bottom are in part dependent upon characteristics of the sediments. Sverdrup et al. (1942) and Driscoll (1975) have stated that the lower dissolved oxygen concentrations over fine grained sediment may reflect the increasing abundance of organic material in the sediments. In the present study it was noticed that the concentration of organic carbon increased with decreasing oxygen and increasing sulphide contents in the fine grained sediments of the polluted stations. During premonsoon a reducing environment is created in these stations, with an oxygen value reaching to < 0.05 ml/l due to the rapid decomposition of organic matter at high temperatures, utilizing the available oxygen. Consequent on the formation of the reducing environment, high sulphide and BOD_5 values were noticed. Carey (1967), Hargrave (1969), Pamatmat (1971a, 1971b) and Smith (1973) have demonstrated that chemical and biochemical oxygen demand of ocean and lake bottom increases with increasing temperature. A part of the organic carbon in the polluted stations seemed to get adsorbed and protected from oxidation by the clay particles. The high concentrations of clay particles in polluted stations were responsible for the heavy concentration of organic carbon in these stations during pre-monsoon. In, the Healthy station an oxidising environment was available throughout the seasons resulting in low concentration of organic carbon.

Kaplan et al (1963) has observed that organic carbon value decreases in an oxidising environment. Hence during monsoon, with the provision of an oxidising environment a decrease in organic carbon concentration was noticed. Ganapaty et al (1973) have stated that the discharge of domestic waste into harbour waters of Visakhapatnam has created practically anoxic conditions for marine life with the accumulation of 6.0%* of organic carbon and production of H_2S. Sanders (1958) also has observed that large concentrations of organic matter may reduce the O_2 content in the sediments and can ultimately limit the environment for deposit feeders.

Similarly, the high percentage of organic carbon observed in the polluted stations 4-3 may have affected the distribution and abundance of fauna in the retting grounds. The anoxic conditions created by the decomposition of organic matter and production of sulphide of the polluted areas may favour the deposit feeding benthic animals to a considerable extent.

Table-4: PERCENTAGE OF ORGANIC CARBON AND ORGANIC MATTER

	St.1		St.2		St.3		St.4	
	Organic carbon	Organic matter	O.C.	O.M.	O.C.	O.M.	O.C.	O.M.
J	4.5	7.8	2.5	4.1	7.3	12.6	1.8	3.1
F	17.5	30.0	3.1	5.3	21.1	36.4	4.0	6.9
M	9.4	16.2	3.4	5.9	7.1	12.2	5.1	8.8
A	4.4	7.5	3.3	5.5	5.5	9.5	2.5	4.5
M	3.4	5.8	3.0	5.2	7.7	13.3	1.4	2.6
J	2.2	3.8	2.2	3.7	4.1	7.1	1.6	2.9
J	2.3	4.0	2.1	3.6	5.2	9.5	1.8	3.1
A	1.2	2.1	2.4	4.1	3.7	6.4	1.0	1.7
S	1.5	2.6	0.8	1.4	6.4	11.0	0.3	0.5
O	0.6	1.0	3.0	5.2	5.7	9.8	1.0	1.7
N	3.9	6.9	4.0	7.6	4.1	7.1	0.7	1.2
D	2.1	3.6	2.8	4.8	4.6	7.8	3.1	5.3

ORGANIC NITROGEN AND C/N RATIO

The organic nitrogen compounds include nitrogen in combination with carbon and other elements, animal and plant protein, urea and uric acid as animal metabolic wastes. The measure of total nitrogen content is however, a valuable indication of the productivity of a body of water for most of the substances will ultimately be transformed into states which can enter into production of living matter (Reid George 1967). Here, in the retting grounds, an attempt was made to study the distribution of organic nitrogen and pattern of C/N ratio in the sediment since bottom isthe main source of food for benthic animals. C/N ratio of the bottom mud is of considerable value in assessing the dietary requirement of the animal since it is an effective measure of the percentage of proteins in the food. In cases where the diet shows ahigher C/N ratio, there is protein deficiency.

In the retting grounds, the waste materials such as pith and coconut fibres accounted for most of the organic carbon and nitrogen. The observation showed that the percentage of organic nitrogen values (Table 5) varied with stations and seasons. The mean values of nitrogen (Table 6) shows that the organic nitrogen content was high during premonsoon in all the stations except station 2. High nitrogen content during premonsoon may be probably owing to the accumulation of organic matter in this area due to the absence of flushing.

A decrease in organic nitrogen content was noticed during post monsoon and monsoon in all the stations. During monsoon the torrential flow of rain water flushes away the organic detritus resulting in a drop in organic nitrogen values as low as 0.070%. In station 2 the percentage of organic nitrogen was low when compared to those of other three stations. This may be either due to the quantitative difference in the organic input or due to decomposition.

The observation showed that in stations 1-3 (polluted) the organic nitrogen content was low with respect to organic carbon when compared to the fourth station. In stations 1-3 with high organic carbon content the percentage of organic nitrogen was found to be not proportionate to organic carbon content indicating an unbalanced food supply for the organisms.

According to Longbottom (1970) proportionate correlation exists in the organic nitrogen or carbon and number of benthic organisms. Present observation showed that the above correlation is applicable only upto acertain level beyond which a diminishing trend in distribution of benthic organisms was noticed with increasing concentration of organic nitrogen and carbon. In stations 1-3 (polluted) the maximum percentages of organic nitrogen and carbon were found to occur during premonsoon, when the abundance of benthic animals was noticed. Longbottom (1970) maintains that the above correlation requires either that the food resource is limiting or its concentration is proportional to its input. However, in the present study it was noticed that the limiting conditions of organic nitrogen and carbon ~~and carbon~~ in the detritus, which is the source of food for benthic organisms, were seldom due to the continuous input of organic wastes. So in stations 1-3 such a correlation existed only upto a certain level beyond which the high concentrations of organic nitrogen and carbon did not seem to imply great significance of biological productivity indicating a polluted habitat. This is further strengthened by the fact that in station 4 (unpolluted) an abundance of benthic organisms was noticed throughout the seasons. The above correlation holds true for this area.

Carbon nitrogen ratio:

C/N ratio varies with sediment type, depth of burial and analytical procedure (Kaplan & Rittenberg, 1963). Trask (1939) obtained an average of C/N ratio 8.0 in sediments of Channel Island area of California while Emery and Rittenberg (1952) found a C/N ratio of 13.0 in California basin sediments. The uncertainty of the measurement prompted Emery and Rittenberg to suggest 10.0 as an average. Parson and Strickland (1962) in their samples of ocean detritus found C:N ratio to range from 5.4:1 in the surface to 2.3:1 in deeper waters. The C/N ratio in detritus collected at three sites in Southampton water had a range of 5 to 17:1, 6 to 16:1 and 6 to12:1 (Trevallion 1967). In Cochin backwaters the C:N ratio in detritus ranged between 5 and 10.5:1 (average 7.6) (Qasim and Sankaranarayanan 1972). In the present study C/N ratio (Fig.11, Table 7) was found to be high in stations 1-3 (polluted) when compared to station 4 (unpolluted). The C/N ratio during the three seasons in stations 1-4 is shown in the table. In stations 1-3 for the high C/N ratio the contributing factors may be organic waste and decomposing coconut husk. Gucleur and Gross (1964) have reported high C/N ratio in Chesapeak Bay due to the contribution of forest humus and wood fibres. The high C/N ratio in the above stations may also be due to the relative loss of organic nitrogen

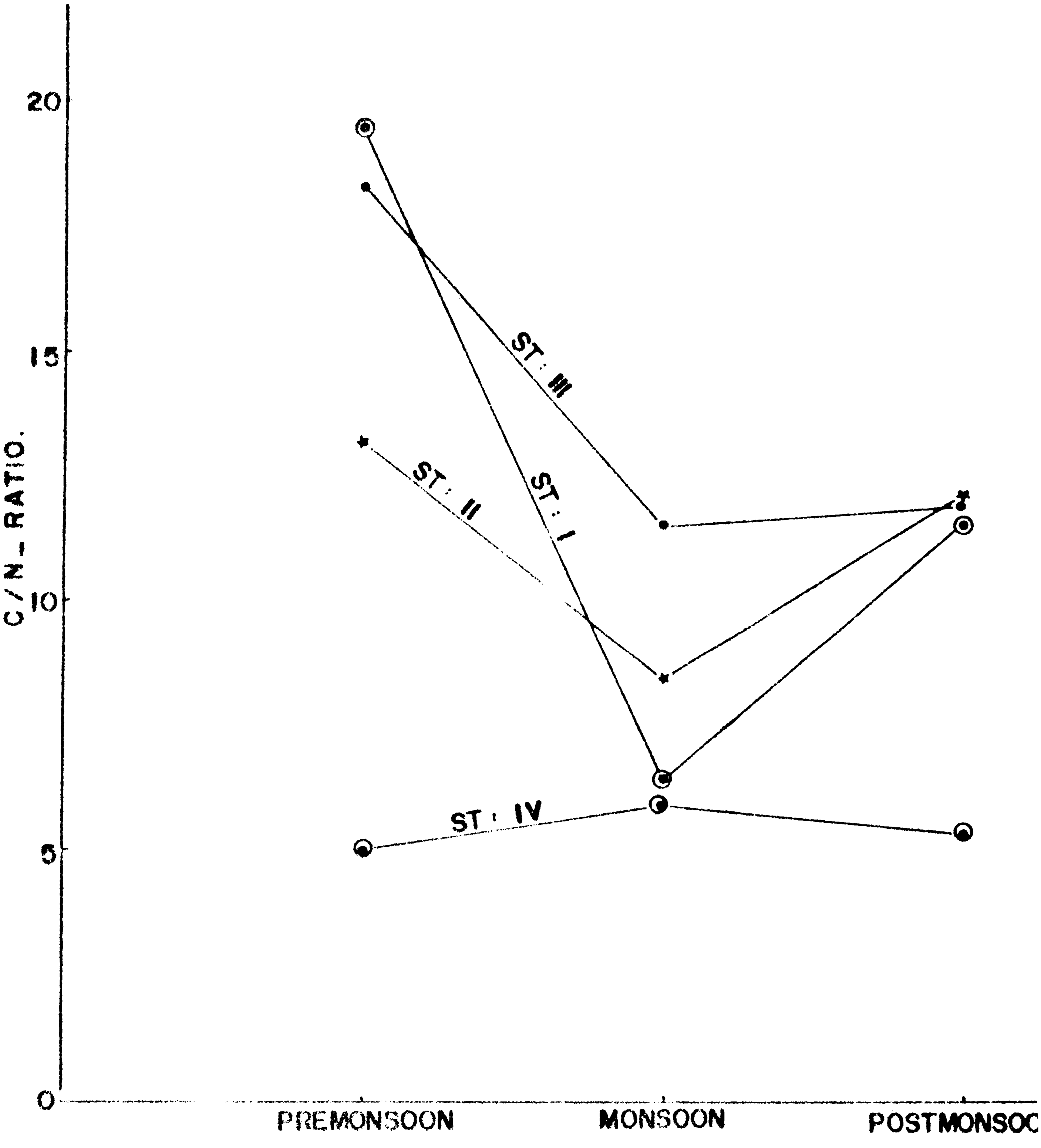

20
15
10
5
0
C / N _ RATIO.
ST : III
ST : II
ST : I
ST : IV
PREMONSOON
MONSOON
POSTMONSOC

Fig.11

with respect to carbon. According to Holm Hansen (1972) nitrogen has a tendency to be lost at a faster rate than organic carbon.

In stations 1-3 the highest (19.5) C/N ratio was recorded during premonsoon and lowest (6.4) during monsoon. In station 4 the C/N ratio was found to be low in all the seasons, the range of C/N ratio between three seasons is low i.e. 5.0 to 5.9.

Bordovisky (1959) suggested an increase of C/N ratio observed by many investigations and is believed to be due to the degradation of complex proteins and subsequent diffusion of ammonia, nitrate etc. to the overlying waters. During this degradation process the available oxygen is consumed resulting in its depletion. This is illustrated in the present study by the fact that there exists a correlation between O_2 content and C/N ratio - higher the C/N ratio was high during premonsoon when O_2 content falls to < 0.05 ml/L. In aerated conditions during monsoon the C/N ratio was found to be low. In station 4 aerated conditions were found in all the seasons with low C/N ratio when compared to other three stations.

The present study showed that in polluted stations (stations 1-3) the concentration of organic nitrogen was low with respect to high organic carbon content resulting in a high C/N ratio. High C/N ratio of mud is an indication of low food value. Since detritus is the main food source for benthic animals, the high C/N ratio of sediment in stations 1-3 indicates low food value which may be effective for the low abundance of benthic organisms compared to station 4.

Table-5:

PERCENTAGE OF ORGANIC NITROGEN

Month	Station 1	Station 2	Station 3	Station 4
January	0.280	0.140	0.490	0.520
February	0.700	0.210	0.740	0.650
March	0.600	0.350	0.430	0.695
April	0.240	0.315	0.380	0.580
May	0.190	0.140	0.610	0.495
June	0.280	0.210	0.390	0.245
July	0.420	0.175	0.490	0.295
August	0.070	0.315	0.280	0.070
September	0.385	0.070	0.520	0.140
October	0.070	0.490	0.495	0.215
November	0.385	0.380	0.350	0.240
December	0.140	0.210	0.380	0.480

Table-6:

MEAN VALUES OF ORGANIC CARBON AND ORGANIC NITROGEN

	Premonsoon		Monsoon		Postmonsoon	
	Org.C%	Org.N%	Org.C%	Org. N%	Org. C%	Org. N%
St.1	7.84	0.402	1.56	0.245	3.0	0.262
St.2	3.06	0.231	2.10	0.252	3.60	0.295
St.3	9.74	0.530	5.02	0.435	4.35	0.365
St.4	2.96	0.588	1.14	0.195	1.90	0.360

Table-7:

C/N ratio

Stations	Premonsoon	Monsoon	Postmonsoon
1	19.5	6.4	11.5
2	13.2	8.4	12.1
3	18.3	11.5	11.9
4	5.0	5.9	5.3

BENTHOS

Distribution ecology of benthic species in relation to pollution

Polychaetes, crustaceans and molluscs constituted the major groups of animals distributed in the four stations. Distribution pattern of these animals in the four stations showed considerable qualitative and quantitative variations. An enormous increase in all the four varieties of animals was noticed in the healthy station 4 when compared to the other three stations. It was observed that least population density of animals is found in stations 1 and 2 which are heavily polluted. This reduction in the distribution of animal population may be considered as one of the main pollution effects. In station 3 which is a marginal zone the fauna was comparatively higher in number than in the polluted zones (stations 1 and 2). This may be due to the fact that when the level of pollution of bottom was low some species probably are benefited by the slight enrichment of the bottom. Moreover, as referred earlier proportion of organic carbon and silt clay content was much higher in this station than in others. These animals contributed to the abundance of benthos in the given area.

The quantitative variation of the animals distributed in the four stations may be well illustrated by the percentage of animals in each station as given below:

Station 1	Station 2	Station 3	Station 4
5%	6%	11%	78%

The considerably decreasing trend in the population density of animals in stations 3,2 and 1 respectively when compared to station 4, shows the quantitative distribution which also indicates the level of pollution.

Among the few groups of benthic animals polychaetes were found to be the most tolerant and dominant group of animals occurring in high population densities in the polluted stations 1 and 2. Of the total animals in each station the percentage of polychaetes collected is given below:

Station 1.	Station 2.	Station 3.	Station 4.
45%	70%	28%	2%

Tolerant indicator species of polychaetes are observed to dominate in stations 1 and 2 which account for the high population density of polychaetes in these areas.

A rich crustacean fauna contributing to 92% of the total fauna of the station, mostly amphipods was recorded in station 4 when compared with the other three stations. In station 3, 69% of the total collection included crustaceans. However, in stations 1 and 2 a much lesser percentage (34%, 22%) was noticed. Crustaceans being detritophagous in feeding habit, their distribution is more related to the availability of detritus. Even though detritus was present in all the stations, the crustaceans were presumably not able to tolerate pollution effect beyond certain limit in stations 1 and 2. The accumulation of pollutants beyond the tolerance level affects the survival and consequent reduction in the total number (Unnithan et al 1975) as noticed in stations 1 and 2. Fincham (1969) suggested that the distribution of shallow water amphipods may be correlated with pollution and related factors such as low levels of dissolved oxygen. This is well illustrated in the present study by the low oxygen values recorded in the polluted stations and the resulting reduction observed in the number of amphipods. Further Pearce (1972) based on his studies in New York Bight suggests that these small crustaceans may be more sensitive to the effects of pollution than polychaete worms and certain bivalve molluscs.

The molluscan fauna of the area was limited and characterised by a few bivalves. In stations 1(8%), 2(3%) and 3(6%) the bivalves were comparatively lesser in number than in station 4(21%). Pauli Bagge (1969) stated that soft bottom is unfavourable for the filter feeders, since they may have difficulties in maintaining their positions in the sediment surface. Also those which are epibiontic cannot find suitable substrata for attachment. Hence nature of the bottom may be an important factor which limits the distribution of the bivalves. The loose and soft substratum of the retting grounds may be unfavourable for the bivalves. Among bivalves certain species showed a better tolerance level.

The abundance of organisms in the estuary has been stated (Desai and Krishnan Kutty 1967) to decrease progressively towards the more estuarine zone. Observations of Unnithan et al (1975) support this view as regards the abundance of fauna of the interior estuary compared with that of bar mouth. The latter treated the bar mouth as a healthy station, while the other stations were far interior in the estuary, for organic pollution studies. However, the stations of the retting grounds in the present study were considerably close to one another and far interior from the bar mouth. The fourth station which was treated as a healthy one was not very far from the other three polluted stations to lose its estuarine conditions and hence not expected to show a high variation in the faunal abundance, but here a high quantitative variation of fauna was observed between the healthy and the other three stations. Salinity data of the four stations do not show much of a variation, hence salinity factor has very little influence on the distribution of benthic animals in the retting grounds.

Kurian (1974) states that there is always supersaturation as regards oxygen at the surface, seldom affected by the distribution of dissolved oxygen in the estuary. The two studies referred above are not very much applicable to the faunal pattern of the retting grounds since a different pattern of envirormental stress is prevalent in the retting grounds and the latter refers to a localised area in the vast estuary. Oxygen deficiency and production of sulphide was found to affect considerably the abundance of fauna of the retting grounds. During premonsoon oxygen value reached to < 0.05 ml/l and a subsequent reduction in the fauna was noticed. Correlation of these factors with faunal distribution is described elsewhere.

Seasonal variation in the distribution of fauna was also noticed. The population density of animals in the polluted stations (1,2 and 3) was very much less when compared to the healthy station (station 4) in all the seasons. Kurian (1974) stated that maximum number of animals occurs immediately after the onset of monsoon and a second maximum during the premonsoon. This holds true in the case of the healthy station (4) (table 8). But in stations 1 and 2 the lowest population density was observed during premonsoon, obviously due to the effect of pollution. Being a marginal zone at station 3 certain species of animals were benefited by the slight enrichment and consequently ahigher population density was observed here when compared to the heavily polluted stations 1 and 2. During post monsoon, abundance of animals was higher than that of premonsoon in polluted stations. However, the maximum intensity of fauna was observed during monsoon in these stations mainly due to the dilution and aeration of the area by the flushing of rain water.

The least abundance of animals noticed during premonsoon in the polluted station should be attributed to the effect of pollution due to accelerated decomposition of coconut husk at higher temperature of premonsoon and a subsequent depletion of oxygen and associated ill effects.

Table-8:

Percentage of animals of the total collections in each station during the three seasons

	Premonsoon	Monsoon	Postmonsoon
Station 1	7.78	10.50	9.24
2	10.92	11.65	11.58
3	15.80	7.57	14.58
4	65.50	70.28	64.60

Seasonal variations in the qualitative abundance of certain species of animals were noticed in the polluted stations. During premonsoon capitillids (Table 9) and spionids (polychaetes), and mosquito larvae were found to predominate in stations 1-3. Abundance of molluscs was very much less in the polluted stations in all the seasons when compared to healthy station.

Table-9:

Percentage of capitellids in stations 1-4, during three seasons

	Premonsoon	Monsoon	Postmonsoon
Station 1	70.82	65.58	81.52
2	62.23	46.49	71.42
3	59.34	21.02	45.46
4	36.36	0.77	30.38

Capit llids being deep burrowing and limivorous in feeding habit and spionids being selective deposit feeders were observed extensively in the polluted stations.

As the mosquito larvae are favoured by the rich supply of particulate organic matter (Hynes, 1966) on which they feed, they were observed the maximum during premonsoon in the polluted stations.

In the benthic ecology studies of the retting grounds the main factors considered are, ranges of environmental parameters within which the benthic animal species occur, frequency of their occurrence and type of the substratum. Observations showed that ecological groups of organisms may be distinguished on the basis of their reactions to pollution. Accordingly in the present study the benthic animals were separated into three groups; (a) species which were favoured by pollution with their maximum occurrence in polluted areas. (b) Indifferent species which showed an incomplete affinity to polluted habitat though they are not totally absent in the polluted areas. Their distribution pattern showed that even though they tolerated pollution effects to some extent they preferred a cleaner environment. (c) Species which avoided pollution, which were almost absent from polluted areas. Pauli Bagge (1969) refers to a similar classification of benthic animals in relation to pollution in salt kallifjord (West Sweden).

The general distribution pattern of benthic animals in the present study showed that, there was a decreasing trend in the distribution of polychaetes, crustaceans and molluscs in the silt clay substratum of polluted stations where mostly anoxic conditions prevailed. However, the pollution favouring species are found to prefer fine silt clay substratum of high organic content. Their maximum population density was noticed during premonsoon when almost anoxic condition prevailed. Species which avoid pollution were found in a substratum where sand predominated whereas indifferent species were observed to have less regard for the substrate. They occurred both in polluted and healthy bottom though the preference was for the latter.

Anger (1975) and Cognetti (1971) have referred a similar pattern of distribution of benthic animals in relation to pollution in western Baltic and Sivarno harbour (Italy) respectively. Distribution of some important individual species are given below:

Polychaetes:

Lumbriconereis polydesma Southern

Station	Frequency of occurrence	Percentage of occurrence
1	0/12	0
2	0/12	0
3	0/12	0
4	2/12	0.5

Environmental ranges:

Temperature °C	Salinity	O_2 ml/l	BOD ppm	Total sulphide ppm
31.8 -	22.56 -	2.40 -	48.71 -	0.32 -
32.5	25.82	2.92	82.74	0.92

The distribution of Lumbriconereis polydesma is confined to the healthy station. Even in this station the population density of the species was low and its occurrence was noticed only when the salinity was comparatively high. This species seems to be a stenohaline form and occurs in high population densities in highly saline waters. In the sewage polluted area of Cochin backwaters the occurrence of this species was recorded. However, high population density was noticed in bar mouth (healthy station) when the salinity reached 32.59‰. In the present study salinity seems to be a factor limiting the distribution and abundance of this species in the healthy station.

Lumbriconereis simplex Southern

Frequency of occurrence		Percentage of occurrence
Station 1	0/12	0
2	0/12	0
3	0/12	0
4	[illegible]/12	2

.... contd.

Environmental ranges:

Temperature °C	Salinity ‰	O_2 ml/l	BOD ppm	Total sulphide ppm
31.8 - 32.5	19.20 - 25.28	2.6 - 2.8	78.41 - 89.31	0.89 - 0.96

The distribution of L. simplex was limited to the healthy station. It may be considered as a species which avoid pollution. The environmental ranges within which they occur indicates their preference for healthier environment.

Glycera alba Rathke

Station	Frequency of occurrence	Percentage of occurrence
1	1/12	1.30
2	1/12	0.30
3	2/12	0.70
4	4/12	15

Environmental ranges

Temperature °C	Salinity ‰	O_2 ml/l	BOD ppm	Total sulphide ppm
28.0 - 32.6	0.21 - 25.82	$<$ 0.05 - 5.15	40.12 - 499.59	0.68 - 4.96

Glycera alba was found to occur in all the stations, but the percentage of occurrence was high in station 4. This species though occurs in low population densities in polluted stations, was observed to be indifferent to pollution. Pauli Bagge (1969) while studying the effects of effluents from wood-processing industries on the fauna of salt Kallifjord (W. Sweden) has recorded *G. alba* as species indifferent to pollution. It seems to be rather tolerant of low salinities and oxygen content.

Schyphoproctus djiboutiensis Grever

Station	Frequency of occurrence	Percentage of occurrence
1	3/12	4
2	4/12	3.5
3	6/12	10
4	0/12	0

Environmental ranges:

Temperature	Salinity	O_2	BOD	Total sulphide
°C	‰	ml/l	ppm	ppm
25.0 -	0.21 -	<0.05 -	40.12 -	0.68 -
29.6	25.82	5.15	499.39	4.96

This is a pollution favouring species. Being a capitellid, limivorous (non-selective suspension feeders) habit is benefited by high organic content of the bottom. It was absent in the healthy zone due to the lack of favourable conditions.

Dendronereis aestuarina southern

Station	Frequency of occurrence	Percentage of occurrence
1	4/12	4
2	5/12	3.2
3	5/12	14
4	2/12	1.5

Environmental ranges:

Temperature °C	Salinity ‰	O_2 ml/l	BOD ppm	Total sulphide ppm
25.9 - 32.4	0.21 - 18.75	< 0.05 - 5.15	19.75 - 498.71	0.32 - 4.96

This is a pollution favouring species, and seems to be tolerant to low salinities. A comparatively high percentage and frequency of occurrence in polluted conditions indicates their ability to tolerate anaerobic conditions of relatively high sulphide content.

Perinereis cavifrons Ehlers

Station	Frequency of occurrence	Percentage of occurrence
1	0	0
2	0	0
3	2/12	1.5
4	7/12	36

Environmental ranges:

Temperature	Salinity	O_2	BOD	Total sulphide
°C	%°	ml/l	ppm	ppm
25.8 -	0.21 -	0.05	16.91 -	0.41 -
33.0	25.82	5.15	302.14	2.81

Among the polychaetes collected in the healthy station, the percentage of this species was found to be the highest. The environmental ranges within which they occurred and the frequency table indicates that their occurrence is limited to highly aerated conditions.

Near barmouth (sewage pollution studies) this species was noticed to occur in high population densities, indicating their affinity towards cleaner environment.

Nephthys polybranchia Southern

Station	Frequency of occurrence	Percentage of occurrence
1	1/12	0.2
2	1/12	0.2
3	1/12	1.3
4	6/12	9.8

Environmental ranges

Temperature	Salinity	O_2	BOD	Total sulphide
°C	%°	ml/l	ppm	ppm
27.7 -	11.87 -	$<$0.05 -	318.61 -	2.51 -
32.6	15.97	3.61	498.71	4.96

This is a species which is indifferent to pollution. Though their presence is noticed in the polluted stations, high population density and comparatively high percentage of occurrence in the healthy station points out their preference for a healthier environment.

Nephthys oligobranchia Southern

Station	Frequency of occurrence	Percentage of occurrence
1	0/12	0
2	0/12	0
3	1/12	1.0
4	6/12	4

Environmental ranges:

Temperature °C	Salinity ‰	O_2 ml/l	BOD ppm	Total sulphide ppm
28.0 - 28.7	15.97 - 16.87	2.01 - 2.71	48.71 - 248.10	1.71 - 2.48

This species shows affinity towards healthier environment and not tolerant to very low salinity conditions with preference for aerated conditions.

OWENIA SP.

Station	Frequency of occurrence	Percentage of occurrence
1	2/12	1.50
2	2/12	1.3
3	1/12	0.5
4	6/12	3.5

Environmental ranges:

Temperature	Salinity	O_2	BOD	Total sulphide
°C	%°	ml/l	ppm	ppm
27.0 -	0.21 -	0.05	110.76 -	2.76 -
32.5	23.64	4.32	513.76	4.97

This is a species indifferent to pollution. Tubicolous form, tube coated with sand, and small pieces of coconut fibres. Seems to prefer coarser substratum; with high percentage of particles.

Parahateromastus tenuis Monro

Station	Frequency of occurrence	Percentage of occurrence
1	12/12	68%
2	12/12	61%
3	8/12	40%
4	7/12	21%

Environmental ranges:

Temperature	Salinity	O_2	BOD	Total sulphide
°C	%°	ml/l	ppm	ppm
26.2 -	0.21 -	<0.05 -	31.76 -	0.32 -
32.0	25.82	5.82	513.76	4.97

Paraheteromastus tenuis (Capitellidae) is found to be the most dominant among the polychaetes recorded in the areaof study. The frequency data show that in stations 1 and 2 P. tenuis occurs throughout the seasons when compared to stations 3 and 4. The percentage of occurrence of this species was high in the polluted stations indicating their tolerant capacity to the stress conditions of pollution. The range of environmental factors within which they occur shows that they are tolerant to wide range of temperature and salinity and found to survive in an almost anerobic conditions with an O_2 value of <0.05 ml/l and BOD_5 reaching to 513.76 ppm. The occurrence of this species in an O_2 range of <0.05 to 5.82 ml/l and sulphide 0.32 - 4.97 ppm indicates its capability to thrive in a minimum to maximum aerated conditions.

P. tenuis being limiverous (non selective suspension feeder) in feeding habit is benefited by large quantities of organic matter. The abundance of this species is proportionate with the higher percentage of organic matter. They occur in a range of 1.07 - 36.39% of organic matter and it is observed that the population density of this species increases with increasing percentage of organic matter. P. tenuis is found to favour a black sulphide silt clay bottom with organic gyttja. In support of the above facts, P. tenuis can be proposed as an indicator species.

Prionospio polybranchiata Fauvel

Station	Frequency of occurrence	Percentage of occurrence
1	11/12	16%
2	10/12	25%
3	7/12	21%
4	6/12	7%

Environmental ranges:

Temperature	Salinity	O_2	BOD	Total sulphide
°C	‰	ml/l	ppm	ppm
26.0 -	0.21 -	<0.08 -	31.75 -	0.42 -
33.0	25.82	5.15	513.76	4.97

Prionospio polybranchiata (Spionidae) shows considerable tolerant capacity against other species of polychaetes.

Pearce (1968) while studying a sewer sludge disposal area of New York Bight to determine what effects these dumping activities have had on marine resources found that numerically the spionid polychaete Prionospio malmgreni is the most abundant widespread in the dumping grounds and may reflect a preference for coarser substrates with high organic content or more intensive larvae in the area. In the present study, Prionospio polybranchiata a close relative of P. malmgreni was observed to be present in high population densities in Stations 1-3 where the percentage of organic matter was high. According to Pauli Bagge spionids, selective deposit feeders are favoured by pollution. The environmental ranges within which they occurred shows that they are tolerent to polluted conditions. The frequency and percentage of occurrence indicates that the abundance of P. polybranchiata in all the stations is found to be much less when compared to Parahateromastus tenuis which prevents the possibility of including this as an indicator species. P. polybranchiata is reported as an indicator of a sewage pollution area of Cochin backwaters. During the above study this species was noticed to be highly tolerent to pollutant conditions. But in the present study their occurrence is limited to a certain extent by the large quantities of cellulose material and a subsequent change in the nature of the substratum. Nevertheless, this species favours pollution, i.e. remarkably tolerant to conditions of high sulphide and low oxygen content. The low population density of the species in the healthy station may be due to the lack of sufficient food and competition with other benthic animals.

CRUSTACEA

Apseudes chilkensis Chilton (Tanaidacea)

Environmental ranges:

Temperature	Salinity	Oxygen	BOD	Total sulphide
°C	‰	ml/l	ppm	ppm
25.8 -	0.21 -	< 0.05 -	16.91 -	0.32 -
32.6	25.82	5.82	499.59	4.92

Station	Frequency of occurrence	Percentage of occurrence
1	8/12	40
2	5/12	38
3	7/12	42
4	1/12	0.14

Apseudes chilkensis is observed to be a pollution favouring species occurring in high population densities in polluted stations. The environmental ranges within which they occurred indicates their ability to thrive under stress conditions of pollution. *A.chilkensis* has been reported as a pollution favouring species in the sewage pollution studies in Cochin backwaters. This species was observed with beginning of post monsoon and reached to comparatively high population densities during premonsoon.

Amphipoda

Grandidierella gilesi Chilton

Environmental ranges:

Temperature °C	Salinity ‰	Oxygen ml/l	BOD ppm	Total sulphide ppm
25.4 - 33.0	0.21 - 25.28	2.96 - 3.62	31.75 - 194.57	0.42 - 2.78

Station	Frequency of occurrence	Percentage of occurrence
1	2/12	3.2
2	4/12	22.2
3	1/12	2.9
4	8/12	85.7

Grandidierella gilesi is observed to be a healthy zone species which occurred in high population density in the healthy zone. The distribution of this species in the polluted station was found to be scanty. This species was found to be more or less absent during monsoon, appeared by the end of postmonsoon and a peak period was noticed during premonsoon; when the salinity was high. Pearce (1972) while studying benthic fauna in the sewage disposal areas of New York Bight found an almost complete absence of Amphipods in the sludge disposal areas. He suggests that these small crustaceans may be more sensitive to the effects of pollution than many species of polychaete worms and certain bivalve molluscs. The diminishing trend in the distribution of C. gilesi in the polluted station may be attributed to a similar effect.

Photis digitata Barnard

Environmental ranges:

Temperature	Salinity	Oxygen	BOD	Total sulphide
°C	%o	ml/l	ppm	ppm
29.1 -	0.21 -	0.52 -	31.75 -	0.41 -
29.5	23.64	2.96	296.5	4.97

Station	Frequency of occurrence	Percentage of occurrence
1	0/12	0
2	1/12	1%
3	0/12	0
4	1/12	0.3%

Photis digitata was found to be completely absent from stations 1 and 3. The response of this species to the polluted conditions cannot be described on the basis of such an irregular pattern of distribution. The occurrences of this species were too low to be significant in stations 2 and 4.

Mosquito larvae:

Environmental ranges:

Temperature	Salinity	Oxygen	BOD	Total sulphide
°C	‰	ml/l	ppm	ppm
25.4 -	0.21 -	<0.05 -	16.91 -	0.32 -
32.6	0.98	5.41	502.14	4.96

Station	Frequency of occurrence	Percentage of occurrence
1	10/12	43.3
2	5/12	21.1
3	8/12	48.1
4	5/12	7.5

Mosquito larvae were found to occur in high population densities in polluted stations (1-3) when compared to the healthy station. Shallow and more or less stagnant waters of the retting yard may serve as a breeding ground for mosquitos. According to Kleine (1972) this Diptera larvae are most widespread in relation to pollution as they are independent of dissolved oxygen in water and are the most tolerant of polluted conditions. They take atmospheric oxygen through respiratory siphons or tubes. Mosquito larvae have been reported in grossly polluted areas by Kaiser (1951), Gaufin and Tarzwell (1956), and Kleine (1972). The occurrence of high percentage of mosquito larvae in retting yard may be due to the availability of considerable quantity of organic detritus which forms their food. According to Hynes (1966) mosquito larvae are, presumably favoured by rich supply of particulate organic matter on which they feed.

CRABS

Viaderiana sp.

Environmental ranges:

Temperature	Salinity	Oxygen	BOD	Total sulphide
°C	%°	ml/l	ppm	ppm
32.1 -	22.47 -	∠0.05 -	19.75 -	0.32 -
32.5	25.28	2.4	378.6	3.54

Station	Frequency of occurrence	Percentage of occurrence
1	0	0
2	1/12	0.7
3	0	0
4	1/12	0.4

In the area of study *Viaderiana* sp. is found to be absent except a few specimens collected in stations 2 and 4. In sewage pollution studies this species was found in comparatively high percentage in the healthy station. But in the present study, crabs were represented by only two species and that too in negligible percentages. Hence it can be presumed that the distribution of these animals also governed by factors other than pollution.

Neorhynchoplax sp.

Environmental ranges:

Temperature °C	Salinity ‰	Oxygen ml/l	BOD ppm	Total sulphide ppm
28.4 - 30.7	0.21 - 17.12	2.61 - 4.70	31.75 - 216.48	0.42 - 2.78

Station	Frequency of occurrence	Percentage of occurrence
1	0/12	0
2	0/12	0
3	1/12	0.08
4	1/12	0.2

Due to the low frequency and percentage of occurrence the description of the distribution of the species in relation to pollution is not attempted.

MOLLUSCA

Pandora flexuosa Sowerby

Environmental ranges:

Temperature °C	Salinity ‰	Oxygen ml/l	BOD ppm	Total sulphide ppm
25.0 - 32.5	0.21 - 25.28	<0.05 - 5.82	37.5 - 302.14	0.42 - 4.97

Station	Frequency of occurrence	Percentage of occurrence
1	7/12	95.4
2	5/12	93
3	8/12	94
4	2/12	19.4

Though molluscs were found to be very poorly distributed in the polluted stations, the bivalve Pandora flexuosa occurred in high population densities in stations 1-3 (polluted). The peak period of this species was noticed with the commencement of post monsoon. The slight enrichment of the bottom and the change in the nature of the substratum just after a recovery period of monsoon may be favourable for this species. In sewage pollution studies this species have been reported as a pollution tolerant species with high population density, under same conditions.

Psammobia sp.

Environmental ranges:

Temperature	Salinity	Oxygen	BOD	Total sulphide
°C	‰	ml/l	ppm	ppm
25.9 -	0.21 -	<0.05 -	60.75 -	2.75 -
31.2	23.64	4.59	248.5	4.97

Station	Frequency of occurrence	Percentage of occurrence
1	3/12	1.5
2	-	-
3	-	-
4	-	-

The occurrence of this species in the area of study was not frequent except for a few specimens collected in station 1. Hence the description of this species in relation to pollution is not attempted.

Modiolus striatulus (Hanley)

Environmental ranges:

Temperature	Salinity	Oxygen	BOD	Total sulphide
°C	‰	ml/l	ppm	ppm
28.0 -	15.99 -	1.06 -	78.41 -	0.89 -
32.5	25.28	2.6	292.6	3.41

Station	Frequency of occurrence	Percentage of occurrence
1	3/12	1.9
2	0	0
3	0	0
4	6/12	34.3

Modiolus striatulus is a healthy zone species, absent in polluted stations except a negligible percentage in station 1. The anoxic conditions and the presence of high sulphide content may have probably limited their occurrence in the polluted stations.

Effect of pollution on the Benthic Fauna

Investigating on the effect of pollution Gunther and Mckee (1960) reported that the effects of effluents may be direct producing a specific adverse response in the organism or may be indirect affecting the environment or the food chain upon which the well being of an organism depends. In the present study it was observed that pollution effect was mostly indirect even though direct effects existed to a limited extent. It was observed to be more or less similar to the effect from the discharge of pulp mill effluent in Salt Kallefjord West Sweden (Pauli Bagge, 1969). Considering the localised effects of pollution from the retting of coconut husk, it may be said that the serious effects are noticed during premonsoon when the temperature is rather high. High temperature accelerates the process of disintegration of coconut husk producing hydrogen sulphide and causing depletion of oxygen in the aquatic environment. However, a recovery period was observed during the monsoon due to flushing by rain water and land washings.

Direct effects due to pollution in the retting grounds centres round an avoidance reaction by the local fishes than any pronounced lethal effect, though the possibility of fish mortality in the initial phase of the establishment of retting ground is not ruled out. Particular attention was paid to the avoidance reaction of fresh water fish by Hogland (1961). He found that sulphite waste liquor may have an influence on fish and their behaviour even when present in very low concentrations. Depletion of fish catch in the retting area should be attributed to the fact that fishes avoid this oxygen depleted area loaded with pollutents such as fibres and pith which have detrimental effect on the distribution of fishes. Their gills get clogged by the pith and movements adversely affected by the fibres. Reduction in the swimming endurance has a discouraging effect on the normal activity of the fish thereby reducing the chances of survival in the polluted waters. Under such conditions the fishes would tend to avoid a trip through a rather low oxygen content area. Jones (1952), Grand (1964) and Hynes (1966) have also reported such a repellent reaction of fishes due to low oxygen concentrations. Commensurate with the establishment of the retting of coconut husk industries in the backwaters, the once continuous stock of biota should have been separated by the pollution block created.

The indirect effects from pollution are more considerable when compared to direct effects. In the retting ground, pollution load directly affects the substratum contributing to a basic change in its character which indirectly affects the benthic fauna of the area. According to Sinderman (1972) mass mortality and drastic or subtle changes in the flora and fauna of an area either in terms of reduced abundance or disappearance of certain species are the best two indications of the environmental degradation. Mass mortality of fishes or any other biota was not observed in the present area of investigation. However, environmental degradation was well illustrated in terms of reduced abundance of benthic fauna of the polluted stations 1,2 and 3 respectively when compared to the healthy station 4. In the given area the decaying of coconut husk on the bottom created a rather reducing environment to another benthic life. Waldichuk (1960) also has observed such a change in the bottom ecology due to deposition of pulp mill waste in British Columbia. It was observed that in the retting grounds polychaetes were the most tolerant organisms found to dominate the benthic fauna when compared to others such as crustaceans and molluscs. In general the benthic fauna was found to be less abundant in the polluted stations. Maus (1967) stated that abiotic environmental factors largely determine the composition and distribution of the fauna. Studies on the hydrography of the retting grounds showed that the distribution of the fauna was considerably influenced by depletion of oxygen, high rate of production of sulphide, high BOD_5, etc. Another indirect effect noticed was that the area was characterised by high dominance of certain species of animals. Dominant species were apparently resistant to stress conditions associated with decaying of coconut husk, i.e. the pollution effect was inducive to select the tolerant species to dominate. The fish population of the area was also indirectly affected. The selective removal of certain species from this area and the associated changes in the population structure disrupt the trophic relationships so that the total effect is far reaching.

From the present study it is observed that the decaying of coconut husk results in the formation of a black layer of organic material which besides affecting the production of benthic fauna also spoils the spawning grounds for some of the more common fishes such as *Mugil* sp., *Etroplus* sp., *Ampassis* sp., *Chanos* sp. etc. inhabiting the area.

Adverse effects of pollution from retting of coconut husk on the fauna of the area may be summarised as an increase in the organic content with low and fluctuating oxygen values, high BOD_5 and sulphide resulting in decline of the abundance of fauna, high population density of tolerant indicator organisms and decline in the fish catch of the area.

Indicator Species

The use of marine invertibrate animals or populations as pollution indicators was first suggested by Wilhelmi (1916). He found that the Polychaete *Capitella capitata* behaves similarly in marine waters of Germany as the Oligochaete *Tubifex* sp. of the fresh-waters. Based on his studies on benthic communities near outfall sewers in Copenhagen harbour, Blegvad (1932) divided the area into polluted, semipolluted and unpolluted zones.

Indicator organisms are used primarily to identify rather than to measure environmental changes. The cause for these changes may be the result of varying mixtures of pollutants or may be of unknown causes (Butler *et al.* 1972). A natural environment is characterized by balanced biological conditions comprising of life of all trophic levels. In an unhealthy environment pollutants eliminate the more sensitive organisms from more tolerant successful species to increase in numbers and dominate the community. As stated by Reish (1972) if the pollutant concentration is considerable the accumulated effect may be fatal to the surviving species as well, leaving an area totally devoid of macroscopic life, hence the importance of knowledge on what are the species present in a polluted environment. While indicating pollution it helps in evaluating the extent and effect of pollution.

Change in the marine environment is reflected by the species composition and population of the bottom fauna. Benthic organisms reflect not only conditions at the time of sampling but also conditions that have been prevailing (Reish 1957). The unusually high population density of the tolerant indicator species is suggestive of pollution, while sensitive indicator organisms may suggest pollution by their absence. In the retting grounds under study in Cochin backwaters the polychaete species Paraheteromastus tenuis is proposed as an indicator species. This species occurred throughout the seasons in all the stations. Its population density, however, was very high especially in polluted areas (Table 10), indicating that the changes in the environment due to retting of coconut husk favour this proliferation.

The polychaete P. tenuis (capitellidae) is observed to be very hardy tolerating adverse conditions of the environment to a maximum extent. It survives well in oxygen content of <0.05 ml/l - 5.82 ml/l, salinity range 0.21 - 25.82‰, temperature range of 26.2 - 33.2°C, BOD_5 of 31.76 - 313.76 mg/l and sulphide content of 0.32 - 4.97 mg/l. The occurrence of P. tenuis in the environment of low oxygen content such as 0.05 ml/l and in the high oxygen content of 5.82 ml/l observed during the period of collection indicates that the species can thrive well in an environment of high anaerobic to well aerated conditions. Also the high BOD_5 and sulphide content in which the animal was observed reflects its tolerant capacity to survive in an area of high organic load with less biological activity. When compared to other species of animals the population density of P. tenuis was very high even in summer months when the chances of water getting diluted and aerated by rainwater flushing or similar sources was very little. This character also distinguishes P. tenuis as an indicator species.

Pauli Bagge (1969) has observed that the nature of the bottom is closely related to the type of feeding of bottom dwelling animals and that the presence of limivorous species in high population density indicates pollution. In the given environment, disintegration of coconut husk and deposition of pith on the bottom changes the nature of substratum affecting adversely most of the macrofauna. Investigations of Blegvad (1914), Hunt (1925), Enequist (1949), Savilov (1957), Tur paeva (1957) and Sanders (1960) have shown that Capitellidae include species which are limivorous (non-selective deposit feeders) in feeding habit. P. tenuis belongs to this family and is limivorous. It may feed on the considerable quantity of decaying detritus and bacteria resulting from the retting of coconut husk. Pauli Bagge (1969) has observed that the high number of limivorous species in bottom samples may indicate polluted conditions. Similarly P. tenuis, a limivorous benthic polychaete was observed in high population density (Table 10) in the retting grounds under study, suggesting that the area is heavily polluted.

Table-10:

Station	Frequency	Individuals in m^2 maximum	Individuals in m^2 minimum	Total number of individuals in m^2	Percentage of P. tenuis
1	12/12	1900	240	8000	68
2	12/12	8000	300	16200	61
3	8/12	5500	40	7620	40
4	7/12	1100	60	1700	26

P. tenuis comprised the major percentage of the total polychaete population in the present study. In the highly polluted stations 1 and 2 the percentage of *P. tenuis* were 61 to 68, While it was only 40% in the third station which is semi-healthy. In the fourth healthy station this species contributed to only 16% of the total polychaetes. Thus it may be observed that increase in population of the indicator species is directly correlated mainly with the intensity of pollution, higher the extent of pollution higher the percentage contribution of the indicator species. Low percentage of *P. tenuis* in the fourth station also indicates that the status of nutrient of the sediment is low. The bottom of this station was observed to be sandy with little organic matter (healthy) when compared with the other three stations which are polluted.

Soft sulphide clay bottom usually does not harbour many benthic animal species. Stations 1 and 2 which are highly polluted have sulphide clay bottom, where the polychaete *P. tenuis* predominated the benthic fauna. While presuming that lack of competition is one of the factors assisting this species to dominate, enrichment of the bottom seems to be beneficial to this species to a remarkable extent. _P. tenuis_ was found to be well sheltered in the loose sediment bottom and was able to utilise the detritus, bacteria and nutrient rich environment, provided. Moreover, the species is euryhaline, able to survive in an environment with little oxygen or even in anoxic conditions and can tolerate concentration of hydrogen sulphide to some extent. Above mentioned features are common to species which favour to polluted bottoms (Henriksen, 1967). Also according to Pauli Bagge (1969) epibiontic and suspension feeding species seem to suffer especially from pollution while it appears to favour deep burrowing limivorous species such as capitellids, oliogochaetes and some selective deposit feeders such as spionids. _P. tenuis_ the capitellid, deep burrowing limivorous polychaete thus confirms itself as an indicator of pollution of the retting grounds of Cochin backwaters.

In areas of Cochin backwaters polluted by sewage discharge, indicator species proposed was _Prionospio polybranchiata_ which belongs to the family spionidae. This species is a selective deposit feeder benefited by the enrichment of organic bottom detritus of the estuary. But in the retting grounds P. tenuis is selected as an indicator species. It may be that the difference in the local abiotic factors of the two water bodies vary considerably to choose their own indicator species. The benthic communities especially their percentage survival may be affected by these basic abiotic factors which are characteristically different in these two polluted zones, the harbour area and retting zone. This precludes the possibility to develop a common indicator species valid for all polluted localities even when the final nature of the pollution is more or less the same.

Bacteriological observations

Studies on the bacteriological flora of the retting grounds were also included in the general programme of work and accordingly collections were undertaken from the stations A,B and C of the retting grounds (Fig.1) during pre, post and monsoon seasons of the year 1975-76 (Fig.2).

Surface water samples were collected in sterile glass bottles directly from the environment. Mud was collected in a van Veen grab from which middle portion of the sample alone was taken. Usual aseptical processes were employed. The samples were carried in iced condition and were plated within three hours of collection in appropriate media. For the study of heterotrophic bacteria sea water agar medium with water of suitable salinity was tried. Fresh water agar (FWA) was also employed. Parker's thiosulphate agar was used for the study of Thiobacilli.

For chlorobacteriaceae (green sulphur bacteria) and Thiorhodaceae (Purple sulphur bacteria) the following medium was used:

Green sulphur bacteria: basic salts medium plus ferrous sulphate 0.2% of sodium sulphite, 0.5% sodium bicarbonate and pH 7.5.

For purple sulphur bacteria: basic salts medium plus purple sulphur basteria medium were used: 0.1% sodium sulphite, 0.5% sodium bicarbonate and pH 8.0. Desulphovibrio was isolated using Desulphovibrio medium. Sulphate reducers were isolated with sulphate reducing medium of Gunkel and Oppenheimer. Cellulose decomposers were isolated using cellulose degrading medium of Kadota. E. coli was isolated using sodium desoxycholate agar, EMB agar and Basto EC media. Faecal streptococci was isolated using KF agar.

The results of the studies are incorporated in Table 12. Earlier accounts on bacterial activity related to retting of coconut husk (Bhat, 1969, Jayasankar 1966), Jayasankar & Bhat 1964, Jayasankar & Bhat 1966, Jayasankar & Menon 1961, Pandalai, Nair & Menon 1957, Varrier & Mudgil, 1947) are mainly concerned with the bacterial flora on the coconut husk during the process of retting whereas in the present study a brief account of the bacterial flora of the mud and water of the retting ground is given.

The general bacterial flora showed wider range of genera representing different groups. The heterotrophs showed marked flustuations in water as well as in mud in all the stations. The peak was observed in post monsoon season in all the stations while they declined in numbers during monsoon. Premonsoon however, gave an intermediate picture. The abundance of heterotrophs during postmonsoon may be attributed to the high amount of organic matter. The sulphur cycle was well represented by the groups such as Thiorhodaceae and Chlorobacteriaceae which are typical of any shallow water estuarine environment like the one under study. The low pH of 5.5 - 6 (acidic conditions) accounts for the growth of Thiobacilli. They were present only in mud and not in water because the organic matter and anaerobic conditions required for their growth was available only at the bottom. The large number of cellulose decomposers are obviously a fact common to such environment. They were abundant in premonsoon, obviously due to the exposure of fibres. The presence of E. coli and coliforms are not significant and also not important from the point of view of retting.

Table 11: **BACTERIAL FLORA OF THE RETTING GROUNDS**

St.	Source	Season	Heterotrophs No./gm	Thiobacilli	Chlorobacteriaceae	Thiorhodaceae	Desulphovibrio	Other sulphate reducers	Cellulose decomposers	*E.coli*	Faecal Streptococc.
1	Mud	Premonsoon	95×10^4	44 colonies in 10^2 dilution in mud (average)	Growth occurred in one gm of mud in 10 days (average)	Growth occurred in 1 gm of mud inoculation in 11 days (average)	1 gm of mud inoculation produced growth in 13 days (average)	Present in 1 gm of mud in 10 days (average)	41×10^3 (average)	+	+
2			55×10^4								
3			102×10^4								
	Water		19×10^3								
	Mud	Monsoon	(average)	-	-	-	-	-	2.9×10^2 (average)	-	-
1			49×10^4	+	+	+	+	+	+		
2			22×10^4								
3			77×10^4								
	Water		36×10^3 (average)	-	-	-	-	-	-	-	-
	Mud	post-monsoon									
1			112×10^4	+	+	+	+	+	+	-	-
			102×10^4								
			201×10^4								

CHAPTER XV

Pbn.3

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Incidence of Fish Mortality from Industrial Pollution in Cochin Backwaters

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Incidence of mortality of fish *Ambassis gymnocephalus* (Lac.), due to industrial pollution, is reported from the upper reaches of Cochin backwaters. The effluents carrying a heavy load of ammonia at the rate of 432-560 ppm, which is far above the accepted lethal limit of 2·5 ppm, pouring into the incidence area together with many other pollutants such as acids and suspended solids in varying quantities, have changed the hydrographic conditions to extreme toxic proportions so as to cause heavy mortality of the animals in the area. Fish shoal entering the polluted zone could not tolerate the cumulative effect of pollution, resulting in their sudden killing due to asphyxiation. It is suggested that treatment of waste be adopted to recycle and recover the ammonia and other pollutants from the effluent before it is let out into the estuary.

SEVERAL reports[1-6] on fish mortality due to pollution of river water by domestic and industrial wastes are available. In Kerala, Periyar river especially its lower reaches contributing to Cochin backwaters has been observed to be polluted to a considerable extent by the domestic and municipal sewage[7]. The variety of industrial wastes ranging from acid to ammonia and even to heavy metals like mercury, come from over dozen industries, which contribute to an Industrial Complex in Kalamassery (Udyogamandal) extending to a distance of nearly 5 km from Varapuzha to Alwaye along the upper reaches of the Cochin backwaters. Saline water is observed to extend to about 12 km upsteream from the Cochin barmouth especially during high tide of summer months. The factories are located on either side of the river (about 50 m wide) which provides water front and receives the effluents from the factories throughout the seasons.

While engaged in routine pollution monitoring studies, dead floating specimens of *Ambassis gymnocephalus* (Lac.) were observed (in the morning of 27 Feb. 1976) in scattered patches in and around the major outfall areas especially downstream from the chain of factories in Kalamassery Industrial Complex. Random samples from the floating specimens, samples of the effluent from the relevant factories, and water samples from the effluent discharging areas were examined for physical and chemical properties. In the present paper the incidence of fish mortality is presented and discussed in the light of the analysis made.

Five sampling stations were selected for the investigation (Fig. 1) from Varapuzha in the lower reaches of the effluent outfall to 1 km above the effluent confluence in the estuary. Station 1 located near Varapuzha is about 4 km downstream from the main effluent outfall and stations 2, 3 and 4 are located at varying distances from the respective discharge points. Station 5 is about 1 km upstream from the major effluent discharge point. Samples of the industrial effluent of 2 factories located closely on opposite sides of the river (points A and B, Fig. 1) were collected for chemical analysis from the main outfalls, immediately before it falls into the estuary. Water samples from the surface were collected with a plastic bucket while sampling was done with a Hytech water sampler from the bottom of each

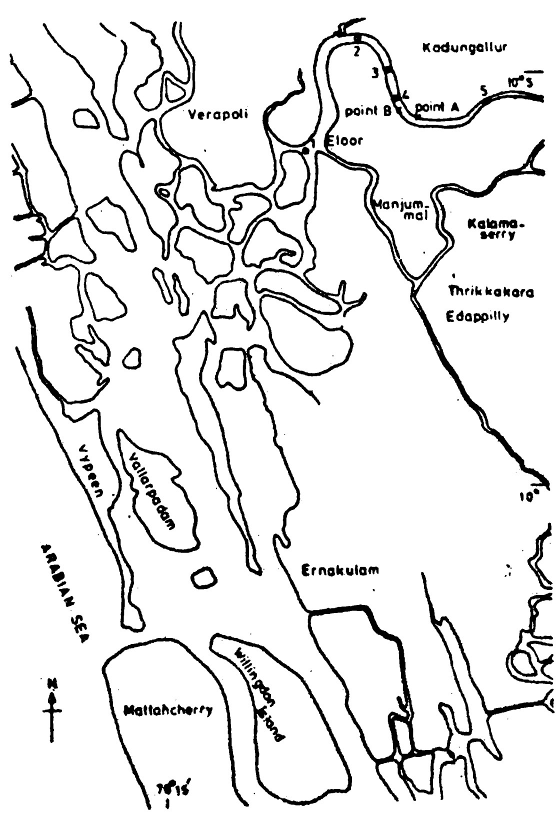

Fig. 1 — Location of stations in the study area

station according to their depths. Temperature, smell and colour of the effluent and the water were estimated in the field. *p*H values were measured using *p*H meter (Systronics). Ammonia[8] both in the effluent and in the estuarine water, suspended solids[9], and sulphate content[10] were also determined. Other estimations were done using standard methods[11]. For morphological and anatomical exminations 50 floating specimens of *A. gymnocephalus* were collected from in and around the stations 3 and 4 extending to an area of about 1 km.

Physico-chemical characteristics of the effluents from points A and B are given in the Table 1. Point A (Periyar Chemicals) receives effluent discharge at the rate of 12000 l/day while at point B (FACT) 50 to 60 million litres of effluent is discharged per day. It is evident from the data that the effluents had high temperature, suspended solids and sulphate. The appearance of the acidic waste from point A is dark reddish brown in colour with irritating smell whereas the effluent from point B is alkaline, pale yellow in colour with pungent smell of ammonia.

Hydrographic features of the estuarine water from the sampling stations 1 to 5 are shown in Table 2. The physico-chemical characteristics of the waters at stations 3 and 4 exhibit wide difference in temperature, suspended solids, *p*H, sulphate content, dissolved oxygen and ammonia. Salinity structure of the area under observation indicates that during high tide of premonsoon period, high saline water flows along the river bed with low saline water above, and extending upstream even beyond the areas of observation (Table 2).

TABLE 1 — CHARACTERISTICS OF EFFLUENT DISCHARGED INTO THE BACKWATERS AT POINTS A AND B

	Point A	Point B
Temperature (°C) of effluent	41·2	42·6
Colour of the effluent	Reddish brown	Pale yellow
Suspended solids (ppm)	2237	1765
*p*H	3·15	12·50
Sulphate content (ppm)	1257	3570
Ammonia-nitrogen (ppm)	0·82	432-560

Morphological observation of the dead specimens of *A. gymnocephalus* shows all the fishes with widely opened mouth, distended opercula and ruptured abdomen (Fig. 2A). Microscopic examination of the gills of the affected fish shows heavy damage to the gill filaments (Fig. 2B).

Mortality of the shoaling specimens of fish, *A. gymnocephalus*, observed in the present study in areas (stations 3 and 4) polluted by the large quantity (50 to 60 million litres per day) of ammoniacal effluents discharged mainly from Point B to a depth of 6 ft and the acidic effluents though much less in quantity (12000 litres per day) from point A (Periyar Chemicals) may be due to the

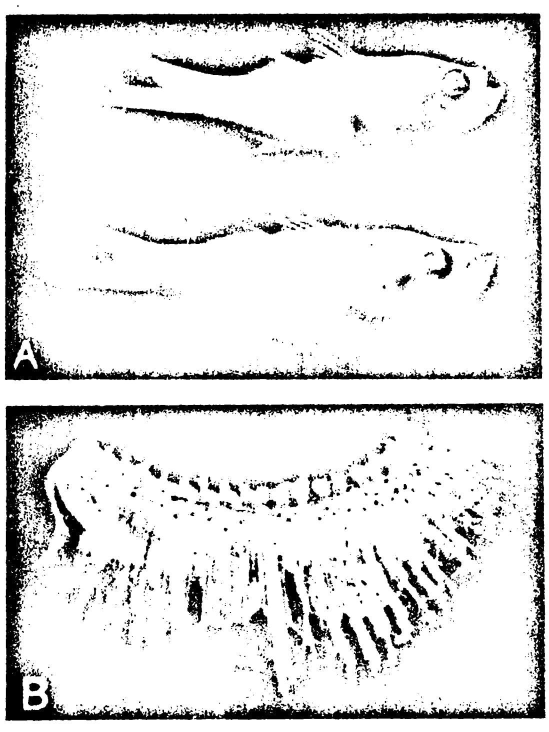

Fig. 2 — Unaffected and affected specimens of *A. gymnocephalus* (A) and damaged gill of affected fish (B)

TABLE 2 — HYDROGRAPHIC FEATURES AT SAMPLING STATIONS 1 TO 5

Surface parameters

Stn	Temp. (°C)	Sal. (‰)	O_2 (ml/litre)	*p*H	Suspended solids (ppm)	Sulphate (ppm)	Ammonia-nitrogen (ppm)
			SURFACE PARAMETERS				
1	31·2	8·68	5·74	8·55	9·5	186·8	0·3
2	31·6	4·65	4·67	7·80	85·0	417·3	27·0
3	32·6	4·09	2·32	11·7	447·2	3350·0	105·8
4	34·8	9·42	3·30	10·05	1225·5	1269·2	172·2
5	32·0	1·89	3·98	6·45	24·8	17·3	8·4
			BOTTOM PARAMETERS				
1	31·0	13·15	4·19	8·10	13·8	209·1	1·05
2	31·6	14·74	2·54	7·80	92·5	808·3	31·6
3	31·8	13·42	2·20	9·20	425·0	1914·5	102·9
4	33·6	14·51	2·21	9·20	1215·0	1298·0	170·16
5	32·0	9·78	2·54	7·25	26·7	853·6	10·9

severely altered environmental conditions which are evident from the physico-chemical features of the area (Table 2). The effluent carrying a heavy load of ammonia (432-560 ppm) pouring into the estuarine water from point B changes the hydrographic conditions to such an extent that fish life is impossible. High values of ammonia concentration in the effluents discharged at point B are reported[12]. The toxicity of dissolved ammonia to fish life has been studied by many workers[13,14]. The ammonia content at the present mortality zone far exceeds the lethal limit of 2·5 ppm. High *p*H of the surface and bottom waters of the area due to the discharge of alkaline effluent accelerates the toxicity of the environment by the synergistic action of ammonia and *p*H. As discussed elsewhere[14], the synergistic effect of ammonia at higher *p*H is observed to be harmful for the estuarine ecosystem of Cochin backwaters as well.

The critical condition of the zone of mortality is also due to the cumulative effect of various other factors. Due to the influence of high temperature of the effluent, temperature of surface and bottom waters of the mortality zone which extends to an area of about 500 m^2 is considerably increased, enhancing the chemical and biochemical processes of the environment which indirectly accelerates the pollution effect at the mortality zone. High turbidity of the waters, besides adversely affecting light penetration may also choke the gills of the fishes leading to mortality. However, the amount of suspended solids is found to decrease towards downstream due to settling and dilution by estuarine water, reaching minimum at station 1. Dissolved oxygen content of station 1 is satisfactory but a sudden fall is observed at the area of mortality.

A. gymnocephalus is an estuarine shoaling migratory fish which spawns in the coastal waters[15]. The fishes might have accidentally entered the polluted zone upstream during feeding movements. The zone of incidence, due to intense pollution, acts as a death trap for the fishes shoaling upstream in the Periyar waters. High concentration of ammonia in the mortality zone may be one of the possible reasons for the death of the fishes. It would seem that ammonia acts as a true internal poison, entering the body by way of gills for its toxicity seems to be strictly correlated with the permeability of gills for the toxic molecules[16]. It has been said that the sticklebacks die suddenly with widely opened mouth, and perches die with the gill covers raised revealing a higly congested condition of the respiratory organs[17]. A more or less similar situation is noticed in the present incidence.

Due to the very high alkalinity of the environment, the gill lamellae (Fig. 2B) have been heavily corroded and this has adversely affected the respiration process of the fish resulting in asphyxiation. Also the corroded gills could not help the fish to utilise the limited oxygen content available in the environment. It may also be mentioned that the opercular cavity of the dead fish was completely choked by the suspended solids from the highly turbid water causing death.

During the present investigation ammonia (NH_3-N) is found to be the major pollutant discharged from the largest factory (FACT) in the Kalamassery Industrial Complex of Cochin backwaters. Specimens of *A. gymnocephalus* were observed dead and floating at the effluent discharging site of this factory. The ammonia concentration in the effluent discharged (432-560 ppm) is well above the tolerable limit (2·5 ppm) of ammonia concentration for aquatic biota. It is suggested that treatment of the wastes to recycle and recover the ammonia or to remove ammonia from the effluent before it is let out into the waters, may be practised. Pollution effect seems to be very much reduced far below the Industrial Complex area mainly due to dilution which in due course may not be an effetive counteraction to the present pollution.

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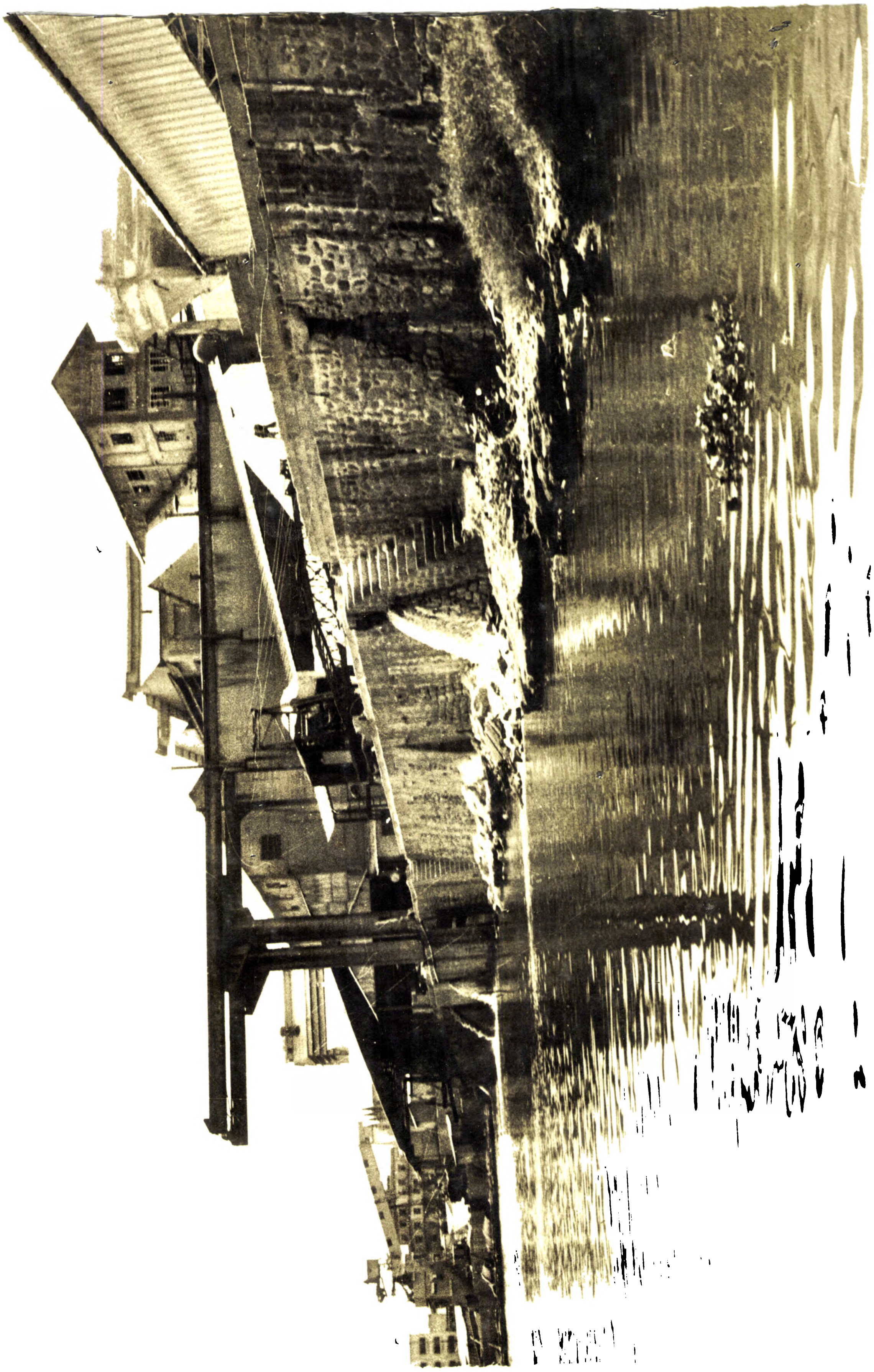


EFFECT OF POLLUTION FROM INDUSTRIAL EFFLUENT DISCHARGE IN COCHIN BACKWATERS.

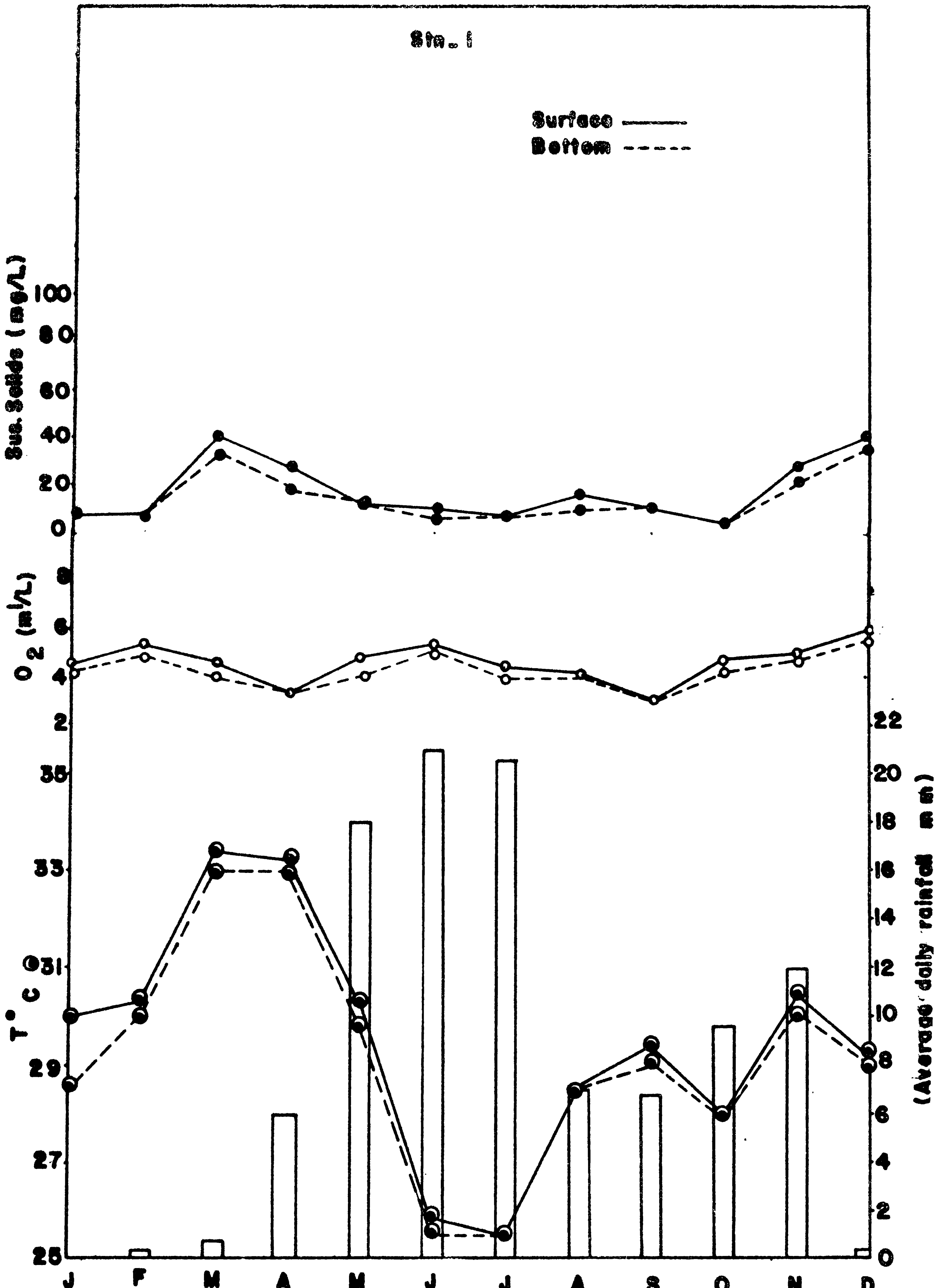
As a part of monitoring pollution in Cochin backwaters studies were carried out from 4 fixed locations (Fig.1) for an year from December 1976 to November 1977 in Cochin backwaters with special reference to the influence of effluent discharge from the chain of industrial establishments located on the bank of the Periyar river (Unnithan et al., 1977) in the upper reaches of the estuary. Data on temperature, chlorinity, dissolved oxygen, suspended solids, organic carbon, organic nitrogen, C/N ratio and heavy metals are presented and discussed below. Variations in the different parameters during the period of observation are shown in Figs. 13-16. In presenting, the results the year is divided into 3 seasons: premonsoon January-May, monsoon June-October and postmonsoon November-December.

Temperature:

At all stations temperature at the bottom and surface varied with seasons and showed good relation to the onset, intensity and duration of monsoons. Annual ranges in temperature for surface and bottom were 25.50 - 33.20 and 25.5 - 33.1 at Station I, 25.5 - 34.1 and 25.2 - 33.6 at Station II, 26.3 - 33.0 and 26.1 - 32.1 at Station III and 26.0 - 33.1 and 25.0 - 31.2 at Station IV. Variations in surface and bottom temperatures were not very pronounced at Stations I,II and III being shallow stations (Figs. 13-16), but some degree of thermal stratification could be noticed in the premonsoon (January-May). Station III showed some stratification during early monsoon also. Strong gradients were observed towards the end of monsoon (August/September, Fig.16) at Station IV, due to the presence of upwelled water in the sub-surface layers (Sankaranarayanan et al.,1969, Ramamritham et al., 1963). Annual ranges in temperature were slightly higher at Stations I,II and III owing to their shallow nature and the absence of strong tidal influence, which facilitates water exchange and nullifies localised t thermal excursions. Station II in general showed higher temperature except during the monsoons when the river was in spate.

Chlorinity:

Stations I and II had fresh water regime round the year. Chlorinity was generally low at both the stations. Higher chlorinity wasnoticed at Station II in February which was lowered in March and again raised by April; was low in May and continued to be low throughout the period of observation (Fig.14). It was also noticed that Station II had higher levels of chlorinity as compared to Station I (Figs. 13 and 14) during the pre- and post-monsoon months (November-May) when the river discharge was low. The higher levels and high values during February (1.4 at surface and 2.45 at bottom) and April (1.35 at the surface and 0.52 at the bottom) may be attributed to the release of chlorides through the effluents. The analytical data of Jayapalan et al. (1976) show wide variations in the chloride content over their period of observation (1968-1971). They have also reported chloride content for the effluents, which were subject to considerable flustuations. Stations III and IV were subjected to seasonal variations in chlorinity. Range of variations at Station III was ~ 0 to 8.97 at the surface and ~ 0 to 9.18 at the bottom. Annual ranges of variation and the nature of salinity regime for Station IV (Barmouth) are well documented. The present values agree fairly well with reported



Stn. I
Surface
Bottom
Sus. Solids (mg/L)
100
80
60
40
20
0
O_2 (ml/L)
8
6
4
2
35
33
31
29
27
25
T° C
22
20
18
16
14
12
10
8
6
4
2
0
(Average daily rainfall mm)
J
F
M
A
M
J
J
A
S
O
N
D

Fig.12.

figures. Chlorinity values for all stations showed an inverse relation with rainfall, this like temperature came down drastically with the onset of the monsoons. The higher values observed towards the end of monsoon at Station IV at the bottom may be attributed to the presence of upwelled water (Ramamritham et al., 1963) (Fig.16). Some degree of stratification was noticed at Station III during January to May (Fig.15). It may be due to the premonsoonal showers and the incursion of saline water in November/December in the postmonsoon season.

pH:

The pH values ranged from 6.0 - 7.0 at Station I and 5.5 to 8.0 at Station II, 6.0 - 7.5 at Station III and 6.5 - 7.5 at Station IV. The pH values were similar at Stations I,II and III during the monsoons. Station II showed wider ranges of fluctuation and these did not conform to any pattern. The fluctuations were not noticeable during the monsoons. The erratic nature of fluctuations in pH values in the non-monsoon months may be due to the localised influence of effluent plumes prior to adequate dilution.

Dissolved Oxygen:

Dissolved oxygen values were higher during the

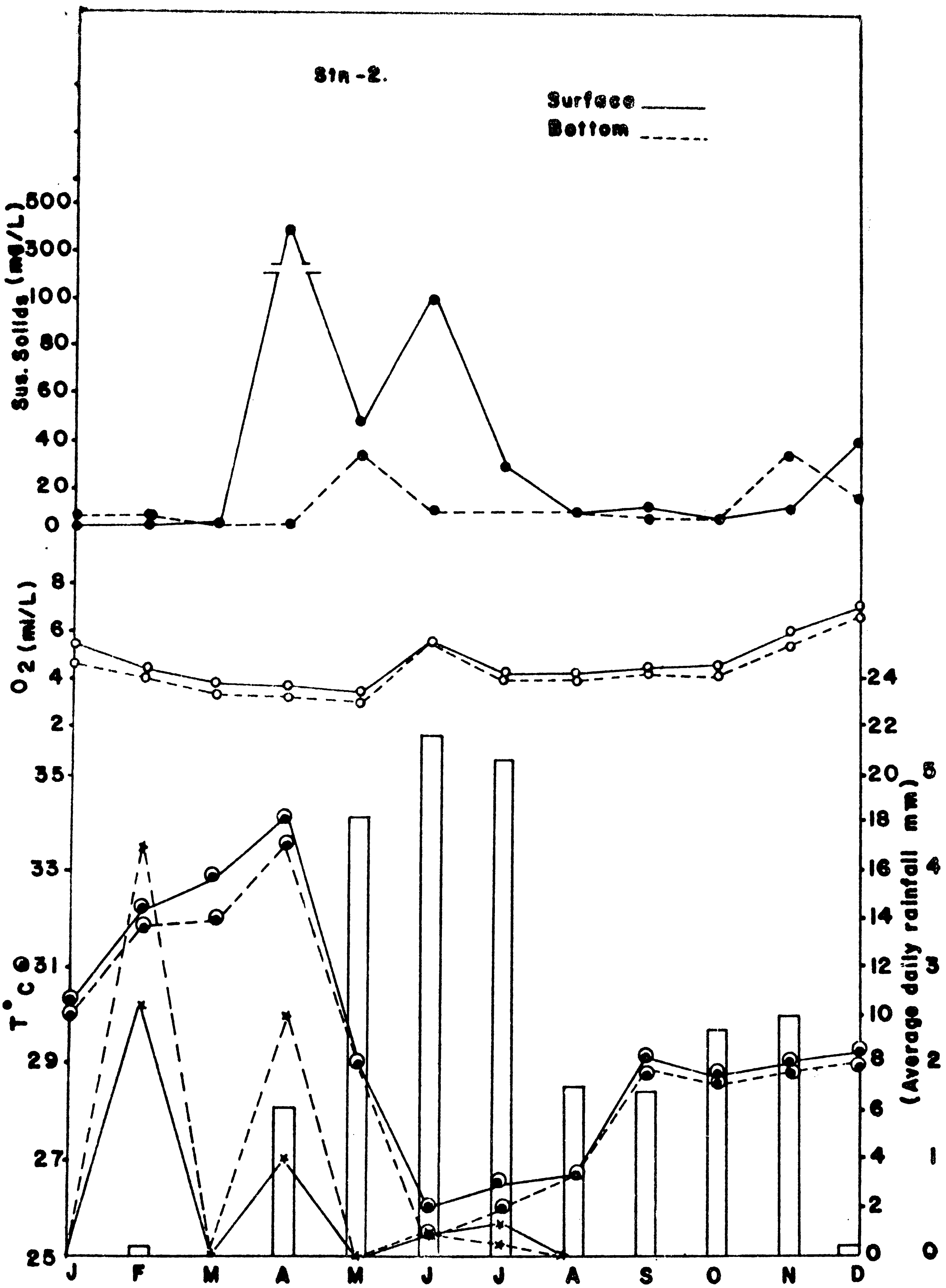

Stn - 2.
Surface
Bottom
Sus. Solids (mg/L)
500
300
100
80
60
40
20
0
O2 (ml/L)
8
6
4
2
35
33
31
29
27
25
T°C
24
22
20
18
16
14
12
10
8
6
4
2
0
5
4
3
2
1
0
(Average daily rainfall mm)
J
F
M
A
M
J
J
A
S
O
N
D

Fig. 14

monsoons at all stations, and were low during the pre-monsoon months. Surface values in general remained higher (Figs.13-16). There was no indication of an oxygen gradient, except at Station IV during the monsoon months. This gradient which disappeared with the re-establishment of marine conditions has been reported previously. The absence of a gradient at Stations I-III may be explained as due to their shallow nature. The annual ranges in values for oxygen were 3.0 - 5.5 ml/L (Station III) and 2.0 - 4.2 ml/L (Station IV). There was no indication of any serious depletion of oxygen at any of the stations. Station II, the effluent discharge area always had well oxygenated condition.

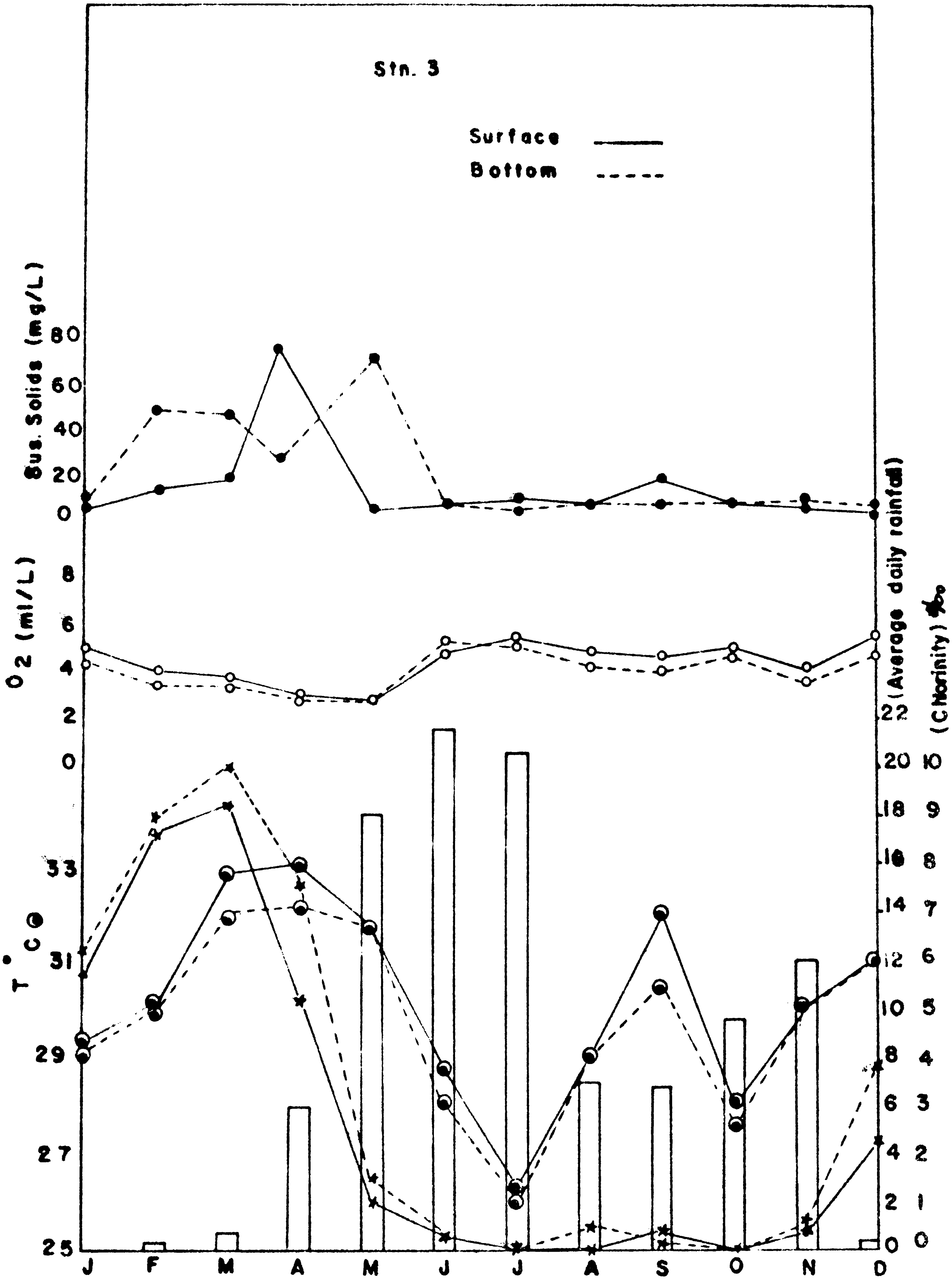
Suspended solids:

The pattern of distribution of the suspended solids were different in the four stations (Figs.13-16). Station I had lower quantities of suspended solids (range 4 - 40 mg/L) as compared to Stations II,III and IV (ranges 4 - 408 mg/L for Station II,III - 75 mg/L for Station III, and 4 - 260 mg/L for Station IV). Station I had higher values in the premonsoon, which came down during the monsoon and remained higher during postmonsoon. Station II showed wide fluctuations in suspended load, the surface values being generally higher and subject to wider variations (Fig.14). These variations, more pronounced during the non-monsoon months may be due to periodic release of greater amounts of suspended matter along with the effluents and aerial fall out. Station III had higher values during the premonsoon months which came down in the monsoon months. The higher values in pre-monsoon may partly be due to the local disturbances caused by a small time fishery of the estuarine clam <u>Villorita cyprinoides</u>. Stations I, II and III had comparable values during the monsoon season indicating the influence of high river discharge. At Station IV the suspended solids showed higher values, with very high values during the monsoons (Fig.16). Gopinathan and Qasim (1971) have attributed the higher level of suspended solidsto resuspension of sediment material by fresh water runoff and strong tidal action.

<u>Chemical Oxygen Demand (COD)</u>:

Table 12 givesthe average values and ranges of COD for the four stations. In calculating the average values and ranges figures too close to the calculated chloride-interference have been discarded as unreliable. The COD values were low and quite comparable at Stations I,II and III during the monsoon. Values at Station IV though diminished were higher compared to the other stations. The higher average values at Station IV were due to high values (1216 mg/L at surface and 2237 mg/L at the bottom) in June. The values for the rest of the monsoon season were considerably lower at Station IV. The high values in June may be due to the added load of organic matter brought down with the land drainage following the first monsoonal showers. Premonsoon values were higher at all stations indicating a build up of organic load at all the four stations. Station II had fairly high values during this season, but showed considerable range of variations (Table 12) indicating fluctuating COD load. The oxygen assets of the receiving waters at this station, however, did not show any serious oxygen depletion (Fig.13). Station III had consistently higher values throughout the period of observation, probably due to domestic sewage and other particulate waste discharged into the harbour area. Previous work (Unnithan et al.,1975 and Vijayan et al., 1976) have also shown appreciable degree of organic pollution in the harbour area.

It is to be stressed that the COD by dichromate reflex method has the disadvantage of high background noise due to chloride interference in saline waters.



Stn. 3
Surface
Bottom
Sus. Solids (mg/L)
80
60
40
20
0
O2 (ml/L)
8
6
4
2
0
T° C
33
31
29
27
25
(Average daily rainfall)
(Chlorinity) ‰
22
20
18
16
14
12
10
8
6
4
2
0
10
9
8
7
6
5
4
3
2
1
0
J
F
M
A
M
J
J
A
S
O
N
D

Fig.15

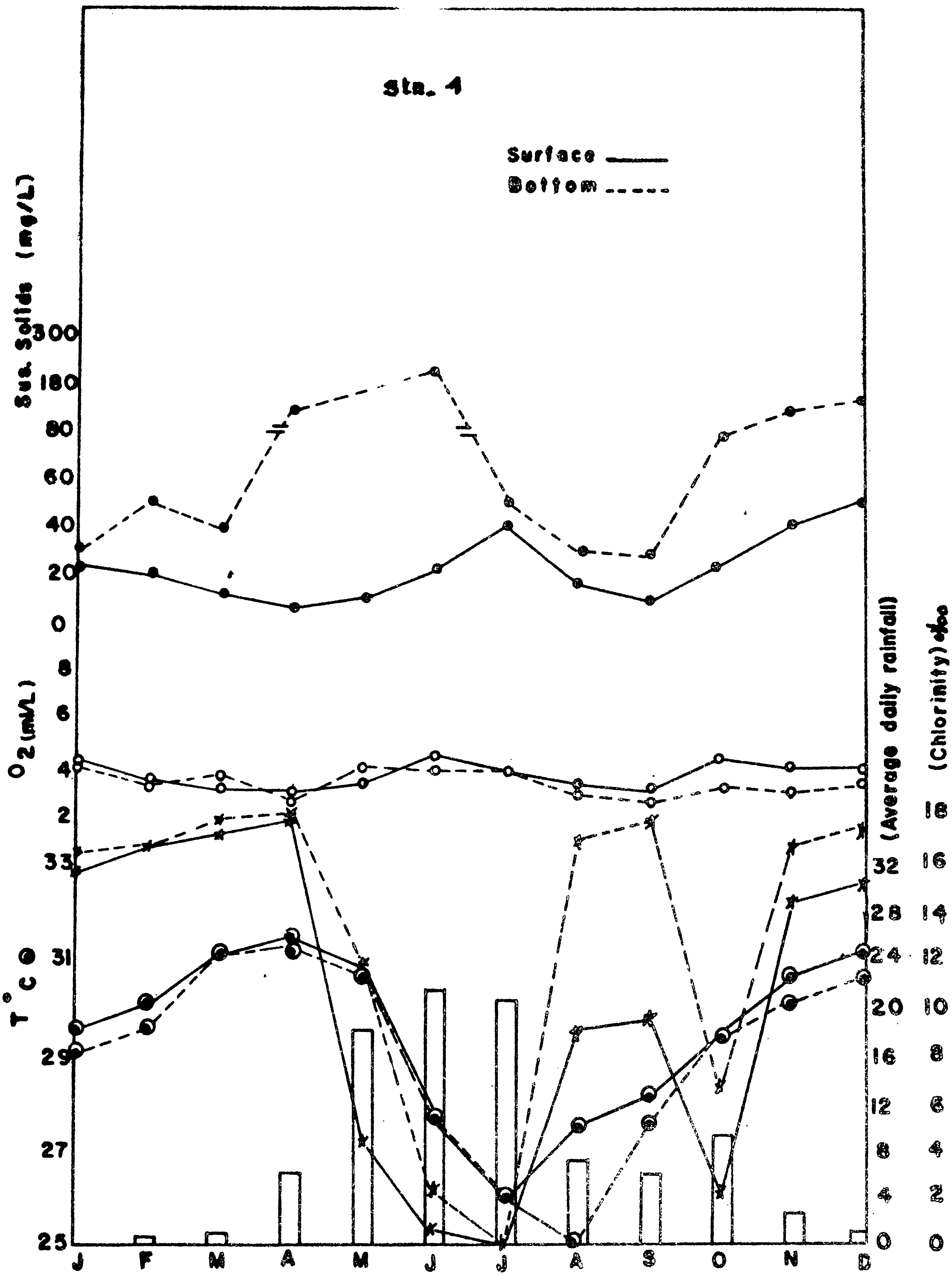
The oxidisability of chlorides in dissimilar systems containing organic and non-organic matter are reported to be different. The present data hence may be treated as an index of the order of magnitude of organic load at the different stations.

Some char$_a$cteristicsof the effluents discharged at Station II are listed in Table 13. They all had higher than ambient temperature, varying pH and alkalinity, and ranged from well oxygenated to very low (< 0.05 ml/L) in oxygen content. The oxygen demand was generally low except in one instance where the dichromate COD was 4400 mg/L (Table 13). This effluent came from an organic chemical factory. Suspended solids were generally high and foam and oil slicks could be noticed on many occasionsat the discharge area. Ammonia levels varied from 0.12 - 3.0 ppm which on two instances surpassed the accepted lethal value of 2.5 ppm. Jayapalan et al. (1976) have also reported high ammonia values for some effluents from the same area. The BOD_5 values were quite variable probably due to the relative toxic effects on the bacterial flora. Only one effluent had appreciable BOD_5 value (Table 12), and two showed oxygen depletion lesser than the seed sample. Values for BOD_5 though in most cases well above those for natural waters, the highest value recorded was only 1/6 - 1/10th of that for domestic sewage.

Data on the oxygen demanding characteristics of the effluents and the different stations worked out does not reveal appreciable organic loads at Stations I and II and the effluents, with one exception (Tables 12 and 13). Although Station II experienced sporadic high oxygen demand during the premonsoon it failed to show significant influence on the oxygen assets of the station. Station IV however, showed consistently higher oxygen demand (Table 12). Comparison of these two areas and analytical data on the effluents suggest that the pollution load at Station II is not principally organic and that the organic load does not seriously deplete the oxygen.

Observations on the qualitative aspects of benthic life showed that Stations I, III and IV supported benthic life, but not Station II. Station I had two species of mussels, Lamellidens marginalis and Batissa sp. throughout the year. The estuarine clam Villorita cyprinoides of of different size groups were present at Station III at all times, indicating a thriving population. It also supports a "small time fishery" in this area. In the higher saline periods (premonsoon) gammarid amphipods were common at Station III. Station IV had a fairly diverse benthic life. The higher organic load at this station failed to show any deleterious effects on aquatic life.

An examination of the discharge area from a biological point of view would indicate that the stresses at Station II are varied and intermittent (Tables 12 and 13). The present investigation and available information (Jayapalan et al., 1976, Unnithan et al., 1977) show the presence of high ammonia a potent toxin in the effluents and at times in the water. Higher loads of suspended material, higher temperature and variable pH along with the occasional high chloride and COD levels especially in the dry months seem to make this environment hazardous. A gradient of stress which diminishes away from Station II towards both upstream and downstream is apparent.



Sta. 4
Surface
Bottom
Sus. Solids (mg/L)
300
180
80
60
40
20
0
8
6
O_2 (ml/L)
4
2
33
T°C
31
29
27
25
(Average daily rainfall)
(Chlorinity) ‰
32
28
24
20
16
12
8
4
0
18
16
14
12
10
8
6
4
2
0
J
F
M
A
M
J
J
A
S
O
N
D

Fig.16

Table 12: COD mg/L

Stations		Premonsoon Range	Premonsoon Average	Monsoon Range	Monsoon Average	Postmonsoon Range	Postmonsoon Average
I	S	20-65	35	5-15	12	28-40	34
	B	15-62	37	8-15	13	5-36	21
II	S	93-322	200	15-25	20	16-27	23
	B	25-307	203	10-22	18	20-29	25
III	S	78-192	110	27-70	30	33-43	38
	B	15-1043	367	30-60	30	15-107	61
	S	197-3797	1882	184-1217	653	300-1020	560
	B	312-2795	1706	192-2237	447	380-970	675

Table 13: CHARACTERISTICS OF THE EFFLUENTS

Source of Effluent	Temp. (°C)	Chlorinity (%.)	pH	Dissolved Oxygen (ml/L)	Alkalinity ($mgCaCo_3/L$)	Suspended solids (Mg/L)	Permanganate consumed (mg/L)	COD (Dichromate (mg/L)	BOD_5 (mg/L)	Ammonia (ppm)	Colour of effluent
Periyar Chemicals	33.9	0.20	8	1.8	117.0	264.0	51.3	4400	51.3	0.12	Orange
Catalysts and Chem. India Ltd.	43.9	0.31	6	1.4	16.40	184.0	7.67	20	14.3	2.76	Brown
Cominco Binani Zinc Smelters(1)	35.5	0.30	2	<.05	195.84	8.00	11.93	30	1.3	0.154	Colourless
Bleach " (2)	32.2	0.05	2	4.5	157.70	16.0	6.67	10	-	1.10	"
Indian Rare Earths Ltd.	36.0	0.05	6	4.2	10.80	15.0	12.67	20	6.3	1.86	"
FACT	30.20	0.05	6	4.4	16.30	12.5	14.0	30	5.3	>3.0	Light grey
TCC	31.00	0.15	7	4.3	16.40	50.0	14.67	190	-	0.175	Colourless
Water Sample Upstream	29.5	0.05	6.5	6.90	18.	8.00	5.3	20	9.0	0.03	-

Fig.16: Station 4: Temperature, Oxygen, Suspended solids, Rainfall data and Chlorinity.

ORGANIC CARBON, ORGANIC NITROGEN AND C/N RATIO

The colour and texture of the sediments varied with stations and seasons, the changes being more marked at stations 1 and 2. The finer sediments (Silt and Clay) were higher during pre and post monsoon seasons except at station '2' which had higher values in the monsoon season (Table 14). The higher values for finer sediments at station 2 are attributed to the initial accumulation of the sediments at the end of the monsoon season (August-September) after the monsoonal flushing (June-July). The content of finer particles in the sediment showed good relation to organic carbon in these samples also. The inter relationships of these two factors are discussed at some detail in an earlier Chapter. The annual ranges of organic carbon and nitrogen in percentages were 0.3 - 2.4 and 0.02 - 0.28 at station 1, 0.7 - 4.1 and 0.06 - 0.37 at station 2, 0.9 - 2.7 and 0.09 - 0.23 at station 3 and 1.3 - 2.1 and 0.05 - 0.19 at station 4. The averages for seasons of organic carbon and nitrogen and their ranges as well as the C/N ratios and finer sediments percentages for the different stations are given in (Table 14). The peak values for C & N for stations 1,2 and 3 were recorded in the monsoon season while at station 4 they occurred in the premonsoon. Higher values for C/N ratio at stations 2,3 and 4 were found on the monsoon season while it occurred in the premonsoon season at station 1. The annual variation in C/N ratios were largest at station 2 while at the other stations fluctuations were not very wide. The large fluctuations at station 2 probably indicates intermittent high organic loads, presumably from the effluents. A comparison of the organic carbon, nitrogen and C/N ratios at station 4 and the retting grounds is presented in table 15. The values given are pooled values for stations 1,2 and 3 of retting grounds (polluted). While carbon nitrogen were higher at the retting grounds, the C/N ratios were consistently higher at the barmouth, probably indicating the cumulative influence of the organic loads from domestic wastes and other sources which eventually find their way to the barmouth.

Table 14: AVERAGE FOR SEASONS

	Season	Carbon %	Nitrogen µg/g	C/N ratio	Silt + Clay %
Station 1	Postmonsoon	2.2 (2.0 - 2.4)	1.9 (0.2 - 2.3)	12.5	64
	Premonsoon	1.9 (0.6 - 2.4)	1.3 (0.7 - 1.9)	13.9	49
	Monsoon	2.1 (0.3 - 3.1)	2.0 (0.9 - 2.8)	9.8	35
Station 2	Postmonsoon	0.7 (0.6 - 0.8)	0.6	11.1	46
	Premonsoon	0.9 (0.3 - 2.8)	2.4 (0.5 - 4.7)	6.6	59
	Monsoon	4.10 (1.0 - 9.3)	2.4 (1.4 - 3.7)	19.1	80
Station 3	Postmonsoon	1.3 (1.0 - 1.5)	1.7 (1.4 - 1.9)	7.8	20
	Premonsoon	1.4 (0.9 - 2.0)	1.6 (0.9 - 1.9)	10.0	27
	Monsoon	1.6 (1.0 - 2.7	1.6 (0.9 - 2.3)	12.5	15
Station 4	Postmonsoon	2.7 -	1.9 -	14.3	51
	Premonsoon	1.8 (1.3 - 2.2)	1.5 (0.5 - 1.7)	18.5	75
	Monsoon	2.0 (1.5 - 3.1)	1.3 (0.7 - 1.9)	18.6	31

Table 15: COMPARISON OF SEDIMENTS AT TWO SITES OF VARYING LEVELS OF ORGANIC POLLUTION (AVERAGES FOR SEASONS)

	Season	Carbon %	Nitrogen %	C/N ratio
Retting grounds Stations 1,2 & 3	Postmonsoon	3.65	0.34	10.7
	Premonsoon	6.88	0.39	17.9
	Monsoon	2.89	0.31	9.3
Retting ground clean station	Postmonsoon	1.90	0.36	5.3
	Premonsoon	2.96	0.59	5.0
	Monsoon	1.14	0.20	5.7
Barmouth	Postmonsoon	2.7	0.19	14.3
	Premonsoon	1.8	0.15	18.5
	Monsoon	2.0	0.13	18.6

TRACE METALS

Increasing interest is being shown in the fate of trace metals in estuarine and coastal environments. Shelton (1971), Mackay *et al* (1972) and Halcrow *et al* (1973) have studied the accumulation of these metals in the bottom deposits as a result of disposal of solid and liquid wastes. In India some studies on concentration of heavy metals in marine organisms especially in molluscs are available. Sastry and Bhatt (1965) and Bhatt *et al* (1968) have worked on some of the metal concentrations in oysters from Bombay region. Zingde *et al* (1976) have reported the concentrations of metals in *Crassostrea cucullata* and *Crassostrea gryphoides* from the Goa region. Sankaranarayanan *et al* (1978) have studied the concentrations of some heavy metals in the oyster *Crassostrea madrasensis* from Cochin backwaters.

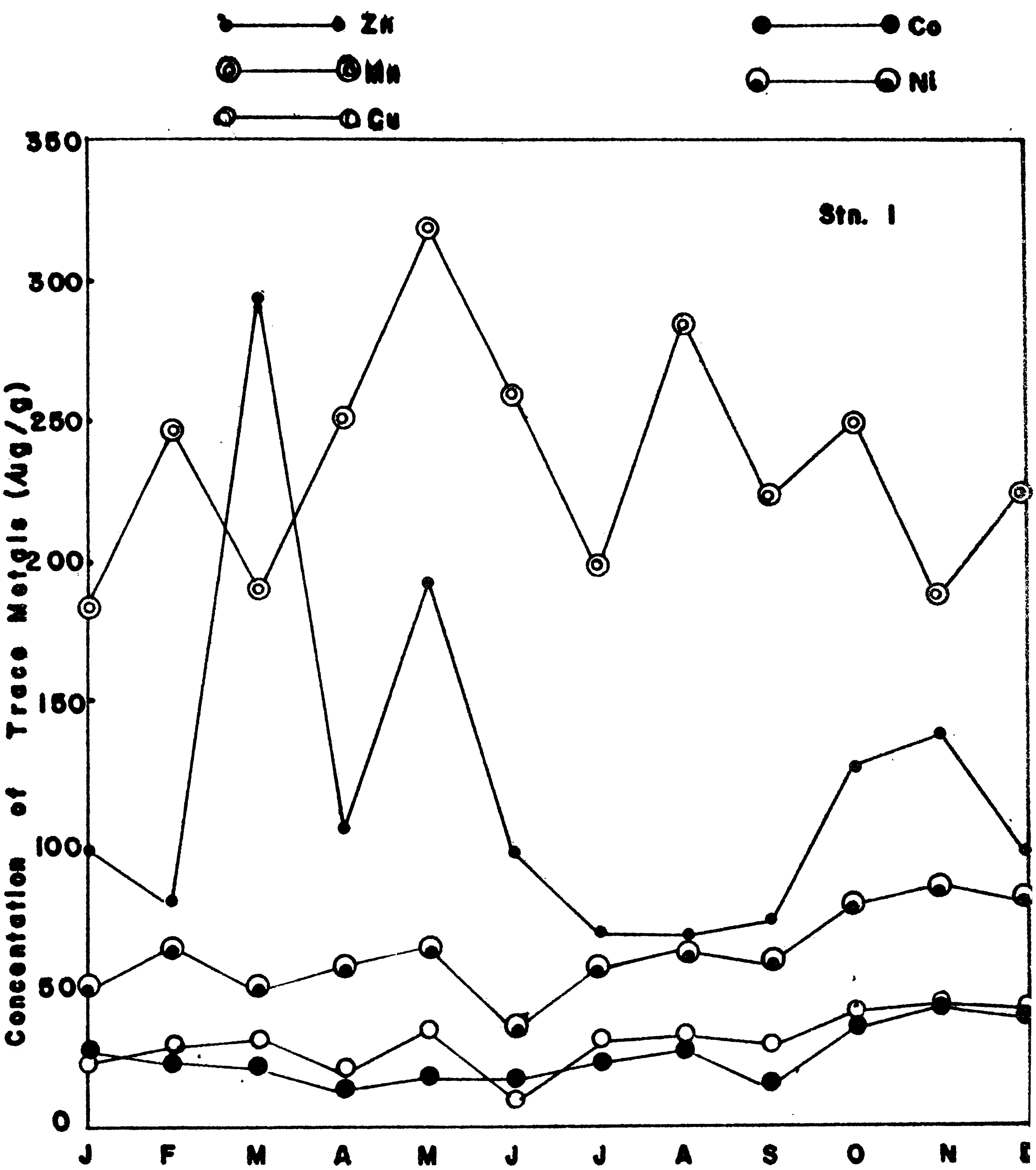
The purposes of analysing metals in sediments and bivalves are:

(1) Many pollutants particularly metals and halogenated hydrocarbons are readily absorbed into suspended particulate material which settles on the bottom and gets

locked up in the bottom sediments. (2) The bottom sediment acts as the main source of food for most of them (3) The filter feeding habit of molluscs places them on a low trophic level and their unusual ability to abstract and concentrate pollutants especially metals, pesticides etc. on an almost continuous basis makes them unusually suitable as biological monitors of aquatic environment (Butler et al 1972). (4) Bivalves which are mostly edible, concentrate the pollutants to levels at which they are hazardous to human health. So the study of concentration of these metals is useful to safeguard against these hazards.

In the present study the concentration of copper, cobalt, nickel, manganese and zinc in the sediment and in three species of bivalves, viz. *Batissa sp.*, *Villorita cyprinoides* and *Modiolus striatulus* were estimated.

Figures 17-20 give the seasonal variations of the metals in sediments at the four stations. The metal concentrations in sediments showed good relationship with the abundance of the finer fractions (silt & clay) in the sediments which is fairly



Zn
Mn
Cu
Co
Ni
Stn. 1
Concentation of Trace Metals (µg/g)
350
300
250
200
150
100
50
0
J
F
M
A
M
J
J
A
S
O
N
D

Fig.17

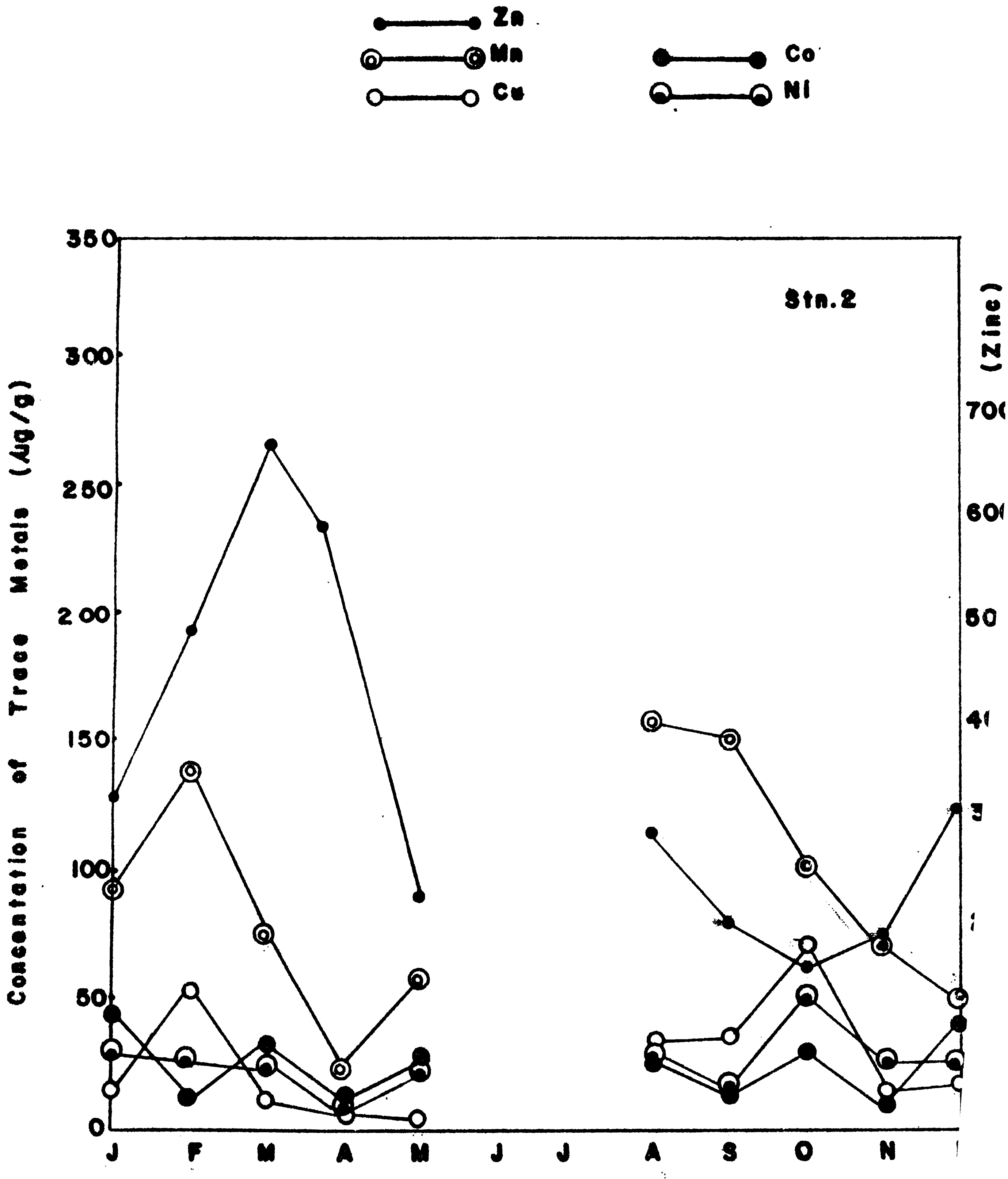
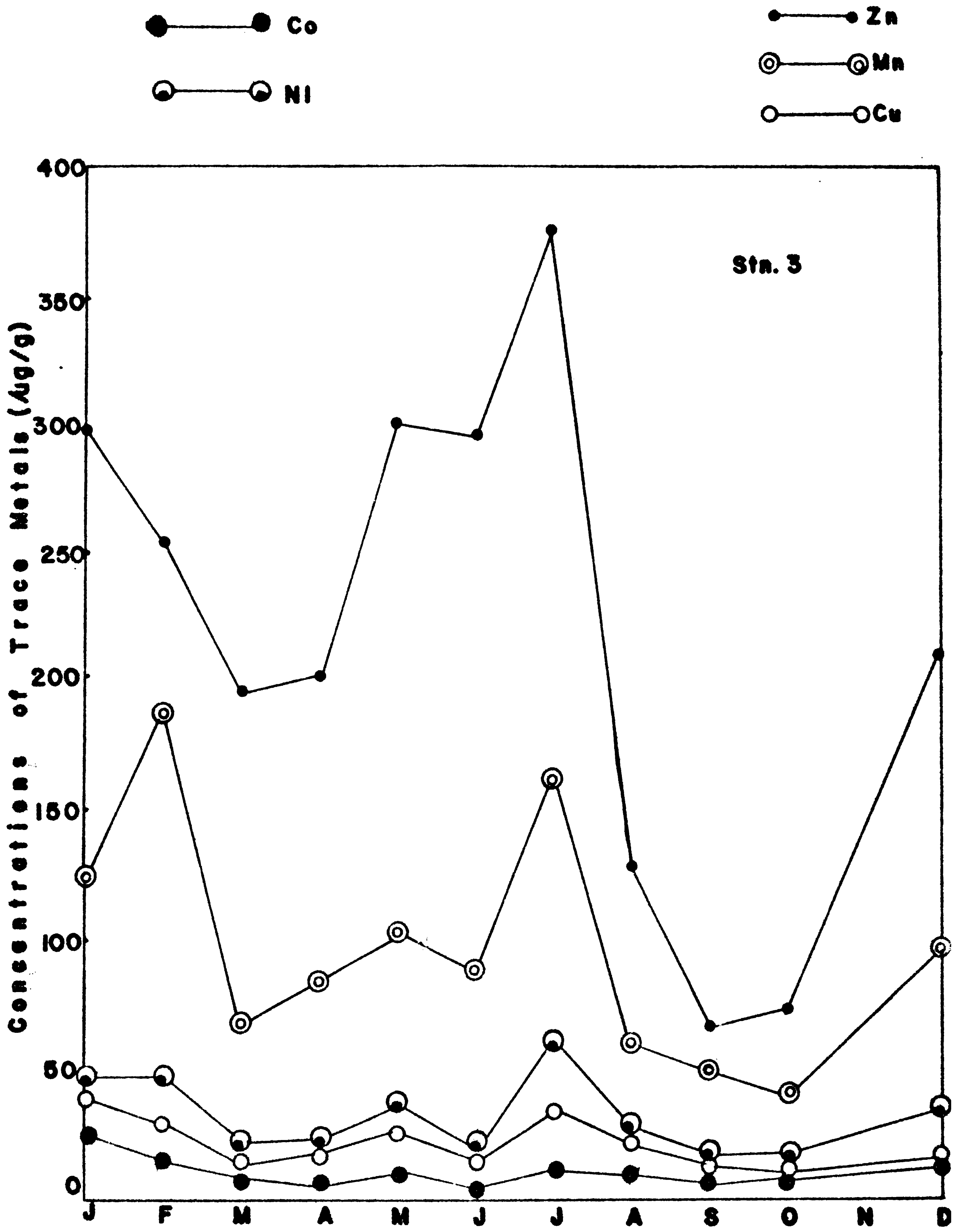

Zn
Mn
Cu
Co
Ni
Stn.2
Concentation of Trace Metals (µg/g)
(Zinc)
350
300
250
200
150
100
50
0
700
600
50
40
J
F
M
A
M
J
J
A
S
O
N

Fig. 18

well established (Loring & Nota 1968, Murty et al 1978 and Loring, 1976). In all the metals studied, some degree of seasonal variations were quite evident. The background concentrations which can be taken as those at Stations I were also subject to seasonal variations. The inputs at this station, being away from the influence of the industrial belt are mainly from weathering in the drainage area with some contribution from the agricultural activities on the river bank. The concentrations of zinc and copper were appreciably high in station 2 which is the main effluent discharging point./ The source of high zinc concentrations in this area will be from the zinc processing plant of Cominco Binani, one of the major factories of the Industrial Complex./ It may also be mentioned that the silt and clay component were quite substantial in this station during the late monsoon season (August-September, See table 14). The study of the hydrography and faunal pattern of this station indicated that this area is seriously affected by the discharge of the industrial effluents. Besides, this region was found to be devoid of fauna. Copper acts synergistically with zinc (Perkins, 1974) producing toxic effects to

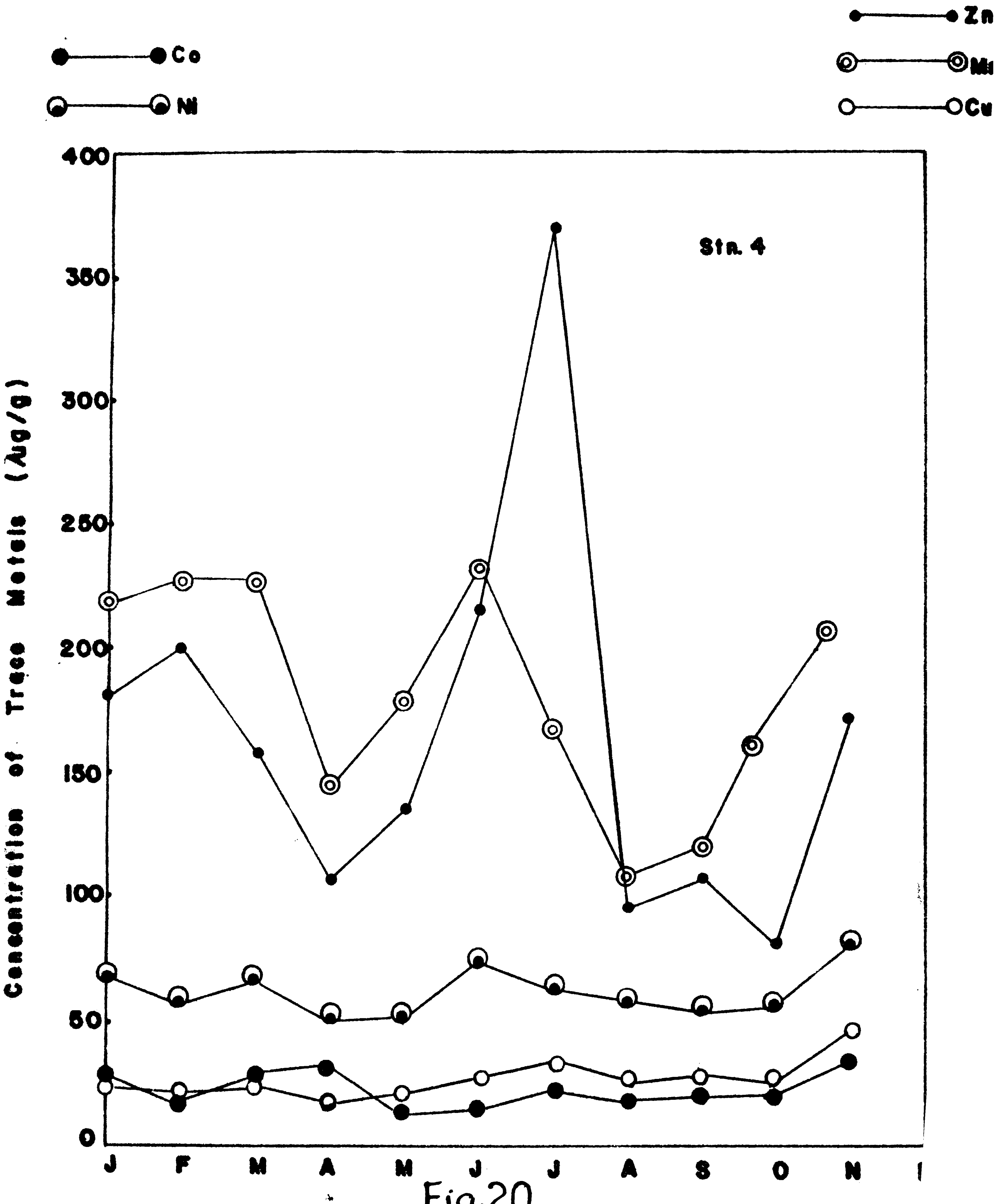
Fig.19: Seasonal variation of metals in sediments in Station 3.



Co
Ni
Zn
Mn
Cu
Stn. 3
Concentrations of Trace Metals (µg/g)
400
350
300
250
200
150
100
50
0
J
F
M
A
M
J
J
A
S
O
N
D

Fig. 19

Fig.20: Seasonal variation of metals in sediments in Station 4.


Zn
Co
Mn
Ni
Cu
Stn. 4
Concentration of Trace Metals (µg/g)
400
350
300
250
200
150
100
50
0
J F M A M J J A S O N
Fig.20

fauna, that are greater than expected from each substance separately. This may be one of the reasons for the absence of biota in station 2. The higher levels of almost all metals at station 3 during pre-monsoon season (Fig.19) probably is due to the down stream transport. Station '4' which is the final exit point of the estuarine waters to the sea had high levels of all metals during the post and early premonsoon seasons (Fig.20). Superimposed on the effects of the products of weathering these probably are substantial contributions from the industrial sources and domestic wastes that find their way to this station. The studies indicate considerable anthropogenic influence on the trace metal concentration of this estuarine system from industrial effluents and sewage disposal.

Seasonal difference in the concentration of metals noticed depends upon the (1) time and frequency of the discharge of effluents and its quantity (2) Concentration of metals in the effluent discharged and dilution provided by receiving waters. (3) Probability and time taken for the metals to be adsorbed by the sediment etc.

Table (16) gives the seasonal average for the metal concentration studied in the three species of bivalves viz. Batissa sp., Villorita cyprinoides and Modiolus striatulus. In Batissa sp. the highest mean values for manganese, nickel and zinc were recorded during monsoon. Concentration of copper was observed to be high during post monsoon in Batissa sp. and Modiolus striatulus. In all the three species of bivalves, the concentrations of cobalt was high during premonsoon. The range of concentration of all the metals studied in three species are given in Table 17. The accumulation of manganese, cobalt, zinc and nickel was high in Batissa sp. while the highest concentrations of copper was recorded in Villorita cyprinoides (Table 16). Accumulation of the metals was found to be low in Modiolus striatulus.

In the case of three species of bivalves studied the accumulating capacity was high in Batissa sp. and low in Modiolus striatulus. This may be due to the difference in the size and specificity. In the present observation, Batissa sp. and Villorita cyprinoides collected respectively from station 1 and 3 just upstream and downstream of the main discharging site (station 2), showed high tolerance to metallic pollution. Toxic levels of metals in bivalves, though not immediately lethal to them, but being toxic to their consumers, pose a health problem to human being. The current state of food standards regulation in Tasmania (Public Health Food and Drugs Standards Regulation ., 1971) specify allowable maxima for the quantities of zinc, cadmium and copper which the food may contain; zinc 40 ppm; cadmium 4.5 ppm; copper 30 ppm. No maxima is specified for manganese.

The results in the present study (Table 16) show that all species contain level of zinc above the permitted maxima. In this context health standard regulation seems inevitable.

Table 16: AVERAGE FOR SEASONS

	Copper (µg/g)	Manganese (µg/g)	Cobalt (µg/g)	Nickel (µg/g)	Zinc (µg/g)
Post monsoon					
Batissa sp.	12.60	145.76	6.45	5.12	210.55
Villorita cyprinoides	14.25	34.05	2.73	2.98	261.52
Modiolus striatulus	19.91	38.43	2.10	1.72	167.44
Premonsoon					
Batissa sp.	10.02	[illegible]5.41	9.06	7.59	477.20
Villorita cyprinoides	9.16	32.27	3.35	4.43	195.03
Modiolus striatulus	9.81	63.56	5.75	13.40	83.82
Monsoon					
Batissa sp.	10.29	528.27	8.70	10.29	968.75
Villorita cyprinoides	19.70	8.00	2.84	19.70	294.38
Modiolus striatulus	13.40	23.26	4.46	12.84	132.22

Table 17: RANGE OF VALUES FOR DIFFERENT METALS IN THE THREE SPECIES OF BIVALVES

	Copper (µg/g)	Manganese (µg/g)	Cobalt (µg/g)	Nickel (µg/g)	Zinc (µg/g)
Batissa sp.	6.19 - 18.89	50.10 - 818.55	6.46 - 11.24	4.08 - 18.03	209.66 - 1265.05
Villorita cyprinoides	6.92 - 23.12	5.30 - 79.85	1.18 - 7.17	1.94 - 8.00	143.51 - 548.40
Modiolus striatulus	5.44 - 19.91	23.26 - 101.69	2.10 - 10.21	1.72 - 13.28	7.29 - 167.44

CHAPTER V

POLLUTION IN COCHIN BACKWATERS FROM DIFFERENT SOURCES

A comparison of the three areas studied, in Cochin backwaters, viz. the sewage polluted localities around Willingdon Island, retting grounds of Vaduthala and the industrial effluent discharging site of Eloor (Udyogamandal) give an account of the nature and extent of pollution in the backwaters to a remarkable extent. Though the type of pollution is the same i.e. organic pollution in the former two places, the nature and composition of pollutants are different. Pollution around Willingdon Island is mainly from the town sewage and land drainage. Sewage is a mixture of pollutants and may be defined as a cloudy fluid arising out of domestic and industrial sources containing minerals and organic matter either in solution or having particles of solid matter floating or in suspension or in colloid or pseudocolloidal form in dispersed state (Jhingran, 1976). In Vaduthala pollution was mainly from decomposition of coconut husk, due to the process of retting brought about by the pectinolytic activity of microorganisms especially bacteria and fungi liberating large quantities of organic substances like pectin, pentosan, fat and tannin into the medium. Polyphenols also get constantly leached out. In both the areas the net effect was depletion of oxygen due to the decomposition of organic matter and the production of sulphide.

In the sewage polluted area the tidal effect was observed to be considerable, due to the nearness to the barmouth when compared with the retting yard. The anoxic conditions initiated by the decomposing sewage are apparently confined to the limited area for a shortwhile, seasonaly. Moreover, due to tidal mixing the water never becomes depleted of oxygen permanently (Vijayan et al 1976). But in the retting grounds the continuous practice of retting has converted that section of the backwaters (about 2000 sq. ms.) into a foul smelling stagnant body of water. Though this is only a small area compared to the vast lake, with several such retting grounds observed in various localities in the backwaters, pollution lead is on the increase. Also, the location of the retting grounds far away from the barmouth as pockets of the backwater system precludes the possibility of effective tidal flushing and adds to the pollution concentration in the estuary. A recovery period was observed only during monsoon when a part of accumulated products of retting is flushed out of the area by floods. Worst effect of pollution in both cases were noticed during premonsoon due to accelerated decomposition of organic matter at higher temperatures.

In both cases the pollution was found to be adversely affecting the benthic fauna studied so as to bring about the reduced abundance and difference in the distribution of species according to their level of tolerance to polluted conditions.

In the benthic study emphasis was given to the selection of an indicator species. Prionospio polybranchiata (Spionidae) which is a selective deposit feeder, is proposed as an indicator species of pollution in the sewage polluted area while in the retting grounds, Paraheteromastus tenuis (Capitellidae) a nonselective suspension feeder is selected as an indicator of pollution. Spionidae and Capitellidae are reported as pollution indicators elsewhere. It may be that the difference in the local abiotic factors of the two water bodies vary considerably so as to choose their own indicator species.

The difference in the type of food available, nature of shelter preferred etc. may also be factors governing the percentage survival of these two species from the different families observed in the two polluted areas. The two indicator species distinguish the two areas of organic pollution from different sources in the backwaters. Pollution from industrial effluent discharge in Eloor and nearby places in the backwaters gives a different picture especially due to the difference in the source of effluent. Temperature, chlorinity, COD, pH, suspended solids, organic carbon/nitrogen and metals of the water sediments and animals, have been variously affected. The biota especially of Eloor, the main effluent discharge site, has been affected the worst. The type of pollution is mainly inorganic.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Cochin backwaters, the largest estuary in the State of Kerala, receives the city sewage of over five lakhs population, effluents from the largest number of factories in the state and accommodates many coconut husk retting grounds.

In the backwaters, areas around Willingdon Island, Vaduthala - 5 km upstream from the barmouth and Kalamassery Industrial Complex (Udyogamandal) about 10 km up from barmouth were selected for intensive investigation on the effects of sewage pollution, pollution due to retting of coconut husk and pollution from industrial effluent discharge, respectively. The hydrography, bottom and macrobenthos of the areas were studied during the year 1974-75 with 168 observations, 1975-76 with 48 observations from 4 fixed stations and 1976-77 with 48 observations from 4 stations around Willingdon Island, Vaduthala retting grounds and Kalamassery to Barmouth, respectively. A comparative study is also made with the results on organic pollution investigation around Willingdon Island, the retting grounds and pollution due to industrial effluent discharge so as to assess the extent of pollution in Cochin backwaters from the different sources.

Sewage pollution around Willingdon Island has considerable effect on the hydrography of the backwaters (Vijayan, Remani and Unnithan, 1976). Effect of the sewage on the bottom fauna is observed to be mostly indirect and dependent on the concentration and rate of decomposition of sewage. Pollution effect leads to the formation of a spectrum of benthic animal species which range from those that prefer pollution, indifferent to pollution and avoid pollution. Polychaetes are the most pollution tolerant group of benthic animals and Prionospio polybranchiata is proposed as an indicator species. Composition of the bottom is also observed to be effective in determining the benthic fauna.

Retting of coconut husk is observed to have varying effect on the hydrographic features of Cochin backwaters. Pollution does not seem significantly effective on temperature and salinity while oxygen depletion, sulphide production and high BOD_5 values indicative of high organic content and bacterial activity are observed to be the most affected due to pollution from retting of coconut husk. The values of BOD_5 reaches to 513.76 mg/l, sulphide 4.97 mg/l and oxygen < 0.05 ml/l in polluted stations especially during premonsoon. Worst effects of pollution is noticed during premonsoon. A recovery period is observed during monsoon due to flushing of organic content by rain water. In the healthy station aerated conditions prevailed throughout the year.

The sediment of polluted stations are black in colour, malodorous due to production of sulphide and composed of fine silt clay particles rich in organic content in contrast to coarser sediment with less organic matter in the 'clean' station. High concentrations of organic carbon is observed in polluted station, average value ranging from 1.56 - 9.4% when compared to healthy station with low organic content ranging from an average of 1.14 - 2.96%. Organic nitrogen content ranges from an average of 0.231 to 0.53% in stations 1-3. Here it is observed that the organic nitrogen content is low with respect to organic carbon when compared to the clean station where the organic nitrogen value ranged from 0.193 - 0.588%. The C/N ratio is high in stations 1-3. Mean values range from 6.4 to 19.5, whereas in healthy station the average value ranged from 5.0 to 5.9.

Polychaetes, crustaceans and molluscs constitute the major groups of animals distributed in few of the stations. An enormous increase in all varieties of animals is noticed in the clean station as compared to the other three stations. This reduction in the distribution of animal population may be considered as one of the main pollution effects. Least abundance of animals is noticed in stations 1-3 during premonsoon when compared to postmonsoon and monsoon. This can be attributed to the worst effect of pollution due to accelerated decomposition of coconut husk at higher temperatures and salinity.

In the benthic study the main factors considered are ranges of environmental parameters within which the benthic animal species occur, frequency of their occurrence and type of the substratum. Observations show that ecological groups of organisms may be distinguished on the basis of their reactions to pollution. Accordingly in the present study the benthic animals are separated into three groups, (a) species which favour pollution with their maximum occurrence in polluted areas, (b) indifferent species which show an incomplete affinity to polluted habitat though they are not totally absent in the polluted areas and (c) species which avoid pollution, which are more or less absent from polluted areas.

In the present study it is observed that pollution effect is mostly indirect even though direct effects exists to a limited extent. Direct effects due to pollution in the retting grounds centres round an avoidance reaction by local fishes rather than pronounced lethal effects. Regarding indirect effects, the pollution load directly affects the substratum contributing to a basic change in its character which indirectly affects the composition, distribution and abundance of benthic faunaof the area. Another indirect effect noticed is that the area is characterised by high dominance of certain species which are apparently resistant to the stress conditions of pollution.

In the retting grounds the polychaete Paraheteromastus tenuis (capitellidae) limivorous in feeding habit is proposed as an indicator species with a high population density in polluted stations.

Effect of industrial pollution on the hydrography, organic carbon/nitrogen, metals and biota of the estuary especially the Eloor stretch of backwaters showed considerable pollution effect such as the depletion of biota, fish mortality, presence of high ammonia as pollutant toxin, etc., though the gradient of stress mainly due to inorganic sources seemed to reduce towards up and down streams. It is also observed that all species studied contain level of zinc above the permitted maxima.

A comparative study of the three polluted areas of Cochin backwaters i.e. sewage polluted locality around Willingdon Island, the retting grounds of Vaduthala and the industrial effluent discharging site of Udyogamandal show that pollution is considerable in the backwaters. Though the type of pollution is the same in former two areas (organic pollution) the nature and source of pollutants are different. In both the areas the net effect is depletion of oxygen due to the decomposition of organic matter and the production of sulphide. In the sewage polluted area, due to tidal influence, the anoxic conditions are confined to the limited area for a shortwhile. In the retting yard the tidal influence is not considerable and has converted this section of back-waters into a foul smelling stagnant body of water. In both cases pollution is found to be adversely effective on the benthic fauna so as to bring about the reduced abundance and difference in the distribution of species according to their level of tolerance to polluted conditions. Another noticeable fact is that Prionospio polybranchiata (Spionidae) which is a selective deposit feeder is proposed as an indicator species of pollution in the sewage polluted areas while in the retting grounds Parheteromastus tenuis (Capitellidae) is selected as an indicator of pollution. It may be that the difference in the local abiotic factors of the two water bodies vary considerably so as to choose their own indicator species at least in the macroenvironment. In the industrial effluent discharging area of Udyogamandal the pollution is mainly from inorganic source and the chain of factories are solely responsible.

It is suggested that waste treatment, recovery or reuse of unused waste should be practised as remedial measures for pollution effect. Waste materials like pith and fibres may be used for filling purposes for

for low lying lands or may be used as raw material for the manufacture of straw boards and similar usable by-products. The retting should be done only in limited area of backwaters which are sufficiently isolated from the main stream. Also the backwaters should be allowed to mix with the retting waters only when there is good flushing so that the sulphide will be distributed without getting accumulated. By-products technology should be practised so that the final effluent discharged into the backwaters from the factories is devoid of acid, ammonia and similar constituents immediately harmful to the biota of the estuary.

CHAPTER VII

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