

ECOLOGY OF INDIAN ESTUARIES: VIII. INORGANIC NUTRIENTS IN THE ASHTAMUDI ESTUARY

N. BALAKRISHNAN NAIR, K. DHARMARAJ, P.K. ABDUL AZIS,
M. ARUNACHALAM, K. KRISHNAKUMAR AND N.K. BALASUBRAMANIAN
Department of Aquatic Biology & Fisheries, University of Kerala, Trivandrum - 695 007.

ABSTRACT

Ashtamudi Backwater is the second largest estuarine system of the southwest coast of India. Surface and bottom waters from 52 stations covering the entire watershed from the lower reaches of the Kallada River to the mouth of estuary have been analysed. Data pertaining to temperature, salinity, transparency, pH, dissolved oxygen, phosphate-phosphorus, silicate-silicon, nitrate-nitrogen and nitrite-nitrogen are presented and discussed. Various sources of pollution, deposition and filling and their impact on the ecosystem are also discussed. All parameters exhibited wide spatial and zonal variations governed mainly by mixing, nature and intensity of water pollution and other human interferences. Results of the analyses are statistically compared. Phosphate-phosphorus and silicate-silicon are available throughout the watershed. Depletion of nitrate-nitrogen and nitrite-nitrogen has been observed in certain heavily polluted regions.

Key-words : Ecology, nutrients, estuary, Ashtamudi.

INTRODUCTION

Recent bibliographic and state of the art reports on the estuarine research in India indicate that detailed scientific studies have so far been made only in three of the many major estuarine systems (Anon., 1981, 1982). Ashtamudi, the second largest backwater system lying in southern Kerala (Fig. 1) is a hitherto little explored estuarine system of India. One of the very important fish landing centres on the west coast of India namely Neendakara is situated at the mouth of this estuary. The backwater supports rich and varied forms of fishery resources composed of several species of fin fishes, prawns, crabs, clams and oysters providing livelihood to nearly 17,000 fishermen. The Kallada river with a catchment basin of about 960 km² originating from the western ghats traverses for about 120 km before its confluence with the backwater. Of late the estuary has been exposed to severe pollution caused by industrial effluents, retting of coconut husks and sewage discharge. Annual cycles of hydrographical factors at four selected stations in the backwater have recently been reported (Nair, Abdul Azis, Dharmaraj, Arunachalam, Krishnakumar and Balasubramanian, 1983) and preliminary accounts pertaining mostly to the mouth region have been reported as parts of faunal studies (Dharmaraj and Nair, 1979, 1981; Divakaran, Murugan and Nair, 1981). The present paper discusses the distribution of nutrients in relation to environmental parameters.

MATERIALS AND METHODS

Observations were made during March 1981, covering the entire watershed of the estuary and lower reaches of the Kallada river where water is

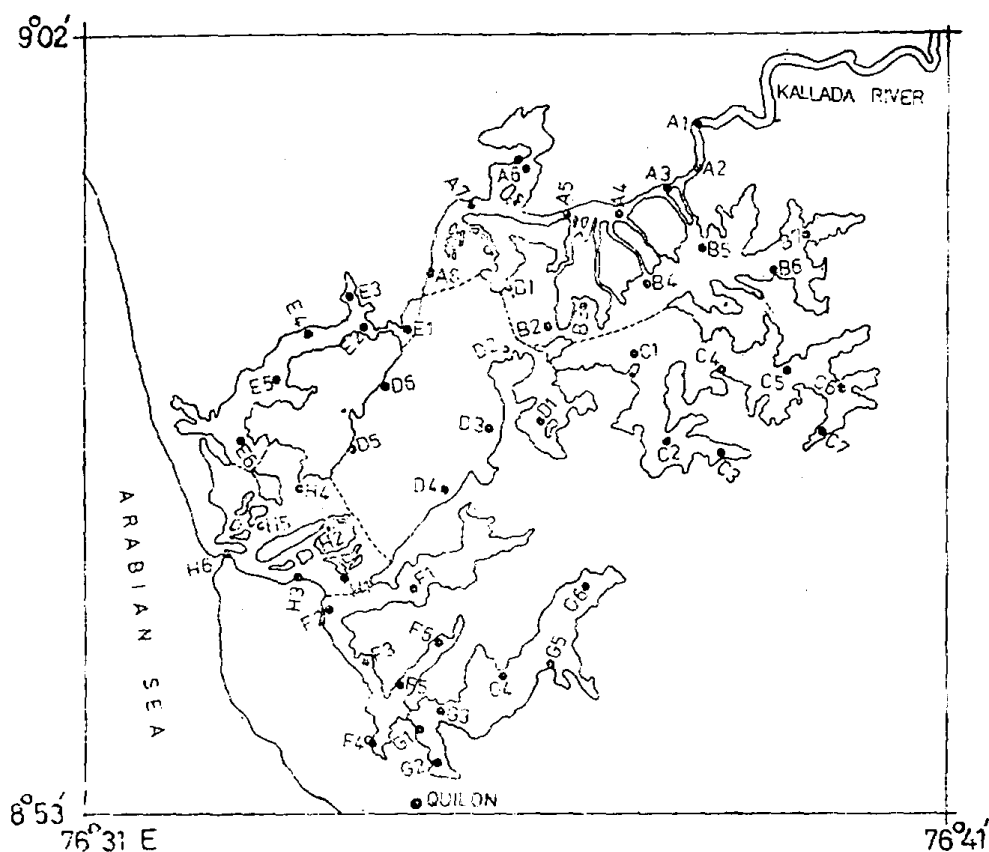


Fig. 1. Map of the Ashtamudi backwater showing the stations surveyed.

brackish. The watershed has been arbitrarily divided into eight zones on the basis of geographical positions and from each zone 6 to 8 stations were chosen. Altogether 52 stations were covered (Fig. 1). Samples from different stations within each zone were collected on the same day and the time lapse to cover the distance between stations was invariably minimised to avoid possible variations likely to result owing to tidal cycles and varying solar inclination. Whenever possible, samples were taken simultaneously from two to four stations.

Water samples were collected from the surface with a clean plastic bucket and from the bottom using an indigenous water sampler capable of opening and closing at the desired depth. Temperature was measured using an accurate mercury thermometer, transparency using a Secchi disc (20 cm diameter) and pH using an Elico digital pH meter (model L1-120). Chlorinity values were calculated from conductivity readings measured in an Elico conductivity bridge (model CM 82 T) calibrated with Eau de mer normale. Salinity was computed from chlorinity values. Reactive phosphate, silicate, nitrite and nitrate were determined following Kopp and KcKee (1979), Strickland and Parsons (1965), Grasshoff (1976) and Barnes (1959). Dissolved oxygen

content was determined by Winkler's method. Mean values of the different parameters for each zone were computed and t-test was performed to compare the nature of variations between zones and between surface and bottom waters in each zone.

Environment

Salient features of the eight zones are presented below.

The river zone (A) — Constitutes the lower reaches of Kallada river. Depth varies from 1.9 to 6.0 m and the basin is generally dominated by coarse sand fraction. Severe pollution results from paper mill effluents. Dense vegetation along the banks, retting of coconut husks towards the lower reaches and sand reclamation are major features of this zone.

The confluence zone (B) — Depth in this zone varies from 0.8 to 6.3 m. Influx of freshwater and paper mill effluents into the estuary occur at this point. Retting is prevalent along the shores. Stations B6 and B7 are not exactly at the confluence, nevertheless they are included owing to their proximity to this zone.

The Kanjirakode zone (C) — Interior most segment of the estuary and depth varies from 1.9 to 3.3 m. Major sources of pollution are retting activity and effluents from a starch, and aluminium and a ceramic factories. Water is turbid and colloidal at many stations especially near the starch factory. Water replenishment depends almost on tidal flushing alone.

The Ashtamudi zone (D) — Central portion of the estuary. Most of the stations are relatively less polluted and depth varies from 1.8 to 3.1 m. Water from zone A moves out into the sea through this zone.

The Chavara zone (E) — A sheltered arm of the backwater highly polluted due to retting of husks along the shores. Depth varies from 1.1 to 3.1 m.

The Thopilkadavu zone (F) — It is the major waterway for boats plying between Quilon and other localities. Depth varies from 2.2 to 3.5 m. Pollution from coconut husk retting and sewage disposal discernible.

The Kandachira zone (G) — One of the sheltered interior arms of the backwater. Highly polluted due to retting of coconut husk and sewage disposal. Depth varies from 1.6 to 2.9 m. Land reclamation by filling is prevalent in some sites at the upper reaches.

The marine zone (H) — Mouth region of the estuary. Neendakara fishing harbour is situated here. Influence of the sea is pronounced throughout the year more especially during the premonsoon when the present survey was carried out. Oil spillage from mechanised boats is a major source of pollution. Depth varies from 1.3 to 3.6 m and the zone is studded with several muddy banks and islands.

RESULTS AND DISCUSSION

Ashtamudi backwater receives the full benefits of the southwest monsoon and annually varying quantities of precipitation from the northeast monsoon. During the survey, salt water penetration was at its maximum reaching far upstream through the bottom into the Kallada river, there being very little drainage and comparatively poor freshwater influx from the river. This period (premonsoon) is considered as the most stable one with regard to hydrographical conditions (Dharmaraj and Nair, 1979). The impact of various sources of pollution is likely to be intense during the premonsoon period on account of poor freshwater replenishment. Besides, solar radiation reaching the water surface would also be maximum owing to clear sky conditions.

Depth, deposition and filling

Mean depth is maximum at the Thopilkadavu zone (F) and minimum at the marine zone (H) (Fig. 2). Comparatively shallower water at many localities of the marine zone is mostly due to the high rate of sedimentation probably resulting from uninterrupted filling at the upper reaches for land reclamation and intrusion of silt with tidal influx which is a serious problem altering the geomorphology of the basin of Ashtamudi backwater. In certain localities, rate of reclamation of land for coconut plantations is so high that in due course the area of the backwater would be reduced to a great extent. Accumulation of coconut pith resulting from coir processing along the shores causes not only the deposition of these organic wastes, but also their decomposition causing oxygen depletion and production of hydrogen sulphide to the detriment of benthic fauna such as clams, oysters and prawns (Azis, 1978; Azis and Nair, 1978). Only in two interzonal comparisons of depth, significant t values occur (Table I) indicating that variations are not much between zones.

Transparency

Mean Secchi disc values varied from 64 cm at zone G to 128 cm at zone D (Fig. 2). Water in zone G was highly turbid while at stations included in zones B and D were comparatively clear. Significant differences exist between transparencies in five interzonal comparisons (Table I) and are due to the low readings of zone G. The high light attenuation coefficients could be the result of dense plankton standing crop. The very low values at stations receiving large quantities of sewage and effluents may be on account of suspended matter and higher concentrations of dissolved organic matter present in the water. In shallow waters with muddy bottom, high turbidity may be caused by wind stirring up the bottom sediments (Kaliyamurthy, 1973). In the Ashtamudi estuary, frequent movements of trawlers and other boats and tidal currents significantly aid in increasing the suspended sediment load. Coconut husk retting along the shores leads to disposal of much dissolved organic matter, tanins, colloids and pith reducing the penetration of light.

Temperature

Mean air temperatures (Fig. 2) were between 30 and 31 °C at zones B to H excluding G. It was high at zone G and low at zone A. Mean surface

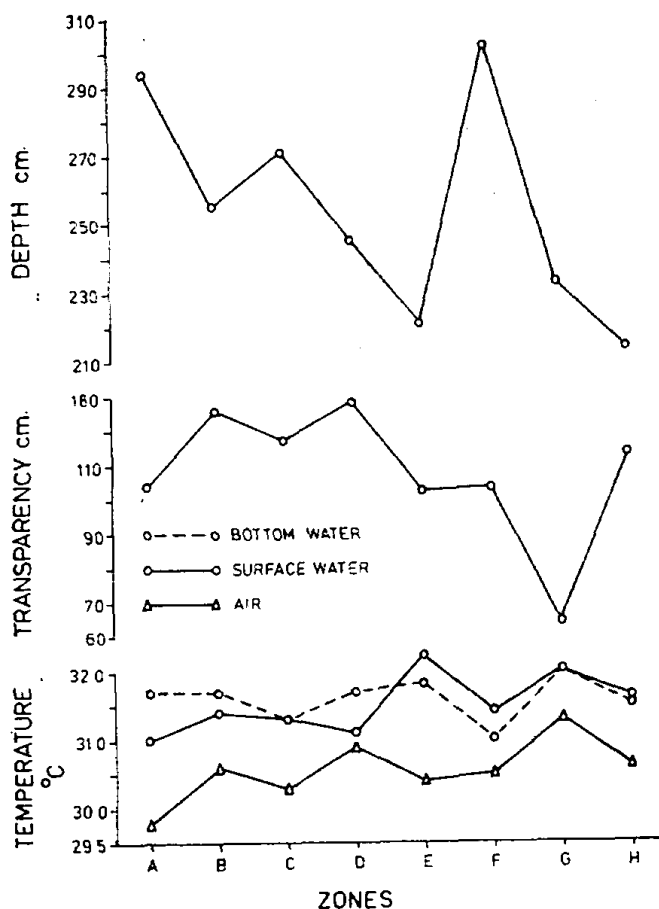


Fig. 2. Zonal mean height of the water column, Secchi disc transparency depth and temperature.

water temperature was maximum at zone E and minimum at zone A. The low surface water temperature of zone A could be attributed to the cooling effect of dense vegetation growing along the banks. Bottom water temperatures were slightly higher than those of the surface water at zones A to D probably due to certain biochemical reactions and convection of heat from the floor, and were slightly lower at zones E to H. Low bottom water temperature of the marine zone may be due to intrusion of dense and comparatively cooler seawater through bottom layers. Influx of freshwater through rivers and intrusion of seawater through the lower reaches have profound influence on the distribution of temperature in backwater systems (Pillai, Joseph and Nair, 1975) apart from local phenomena such as mixing of heated waste water, warming up of the water in semi enclosed bays, heat production during biochemical oxidation etc. Statistical interpretations (Table I) reveal that air temperature do not vary significantly between zones. Five interzonal comparisons resulted in significant *t* values at the surface and none of the bottom water temperature comparisons resulted in significant values. This indicates that temperature diffe-

rences are more pronounced at the surface. Temperature variations between the surface and bottom were also not significant at any of the zones (Table II).

pH

Surface water mean pH value was above 8 at zones H and D and the mean bottom water pH was above 8 only at zone H (Fig. 3). High pH of the marine zone was on account of the intrusion of highly saline seawater and low values of the river zone could be due to the influence of freshwater and effluents discharged from the Punalur paper mill. The zones receiving large quantities of ret liquor and sewage also contained waters of relatively low pH. However, at none of the stations, neutral or acidic conditions could be noticed. Irregularly alternating higher pH values occurred either in the surface or bottom. Fluctuations of dissolved oxygen content, carbon dioxide, salinity etc. also influence the pH in inland saline water bodies. Statistical analysis of the pH values (Table I) indicates that wide interzonal variations occur both in surface and bottom waters. No significant t value could be obtained while comparing the surface and bottom water pH values of the different zones (Table II). Sankaranarayanan and Qasim (1969) while discussing the pH of the Cochin backwater found a similar situation where pH of the entire water column varied simultaneously while a clear vertical stratification with regard to salinity and temperature was existing. Extensive buffering capacity of the seawater (Martin, 1970) allow only little pH changes to be pronounced normally while in enclosed portions biological activity can cause sizeable variations. pH values considerably vary with the time of the day also especially in highly productive waters where high values of pH occur during highly productive hours of the day.

Salinity

Salinity of the surface water exhibited decreasing trend from the marine end towards the confluence and the river zones. But, this is complicated by the numerous semi enclosed creeks and small bays where water exchange is relatively little. Mean surface salinity was minimum in the river zone and maximum in the marine zone. Surface salinity was low in zones B and G also and the other zones exhibited mean surface salinity above 20‰ (Fig. 3). Variations of surface salinity between stations were high at the Chavara and the river zones. Mixing of freshwater from the river and seawater intruding through the marine zones determine the surface salinity only in zones which have direct access to these two different water masses while in partially isolated and semi enclosed regions relatively low saline conditions prevail even during this period as a result of local drainage from man made canals and terrestrial wet lands lying in the vicinity. Mean bottom water salinity also was maximum at the marine zone and minimum at the river zone. Invariably bottom water was saline than surface water and the differences were highly pronounced at zone A. A tongue of high saline bottom water intrudes far upstream in to the Kallada river up to the region called Uppukuttu. Tidal ebb and flow strongly influence the salinity distribution in the Ashtamudi backwater. Statistical analysis of the salinity data (Table I) shows that wide interzonal diffe-

rences exist in the surface water and relatively it is less pronounced in the bottom. While comparing the surface and bottom salinities of the different zones (Table II) significant t values were obtained only for zones A and G which indicate that the differences are high in these two zones.

Dissolved oxygen

Mean dissolved oxygen of the surface water varied from 3.30 ml/l at zone E to 5.46 ml/l at zone B (Fig. 3). Values above 5 ml/l were obtained for zones D and H also and, two zones (E and G) contained low dissolved oxygen the mean of which falling below 3 ml/l. The low surface values were probably owing to heavy pollution resulting from sewage disposal and intense coconut husk retting activity. Mean values of bottom water dissolved oxygen were invariably lower than those of the surface at all the zones, ranging from 3.16 ml/l at zone E to 5.20 ml/l at zone B (Fig. 3). High rate of primary production by phytoplankton and benthic macro algae may be accounted for the higher concentrations of dissolved oxygen recorded at zones B and H

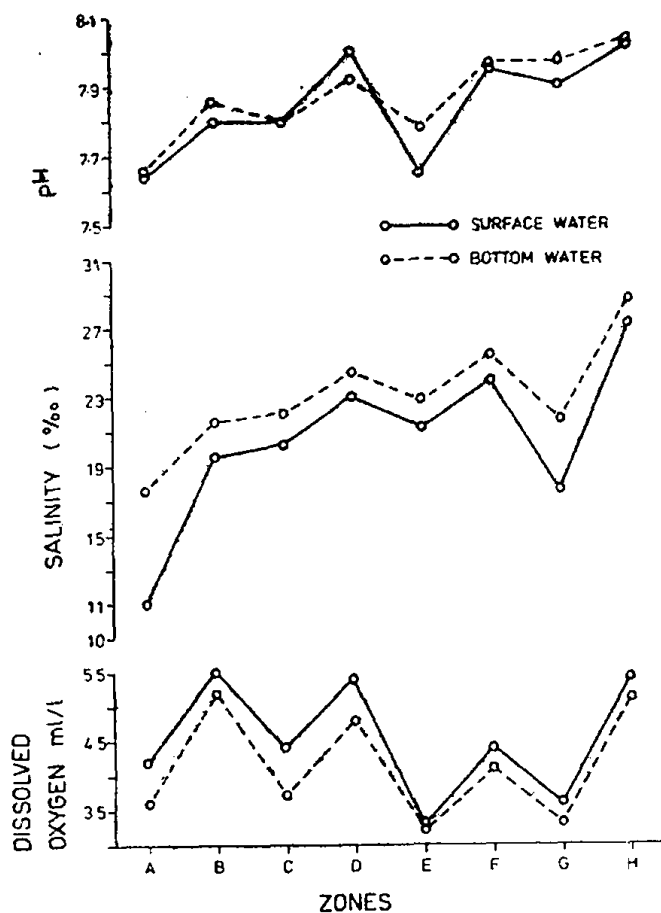


Fig. 3. Mean values of salinity, pH and dissolved oxygen content at the different zones.

which could also be augmented by wave action enhancing the rate of solubilisation of atmospheric oxygen. Photosynthetic production of oxygen in estuarine waters alone averages at a rate of 1000 g/m²/yr, a value about four times the globally averaged river input of oxygen into estuaries (Burton, 1979). At stations where dissolved oxygen could not be detected, replenishment of dissolved oxygen may be too low to meet the oxidative demands and consequently suboxic or anoxic conditions could be established with changes in redox potential. Significant t values obtained in seven interzonal comparisons of the surface water and six of the bottom water dissolved oxygen (Table I) reveal that variations are considerable both in the surface and bottom. Comparisons of the surface and bottom oxity conditions reveal that there is no statistically significant difference (Table II).

Nutrients: Reactive phosphate

In the surface water, mean phosphate content fluctuated between 3.40 and 6.02 $\mu\text{g.at/l}$ respectively at zones H and A (Fig. 4). Generally phosphate content decreased from the river end towards the lower reaches of the backwater (Fig. 4), but in heavily polluted creeks and stations higher values were recorded. In 16 interzonal comparisons significant t values occur (Table I) which indicate that phosphate content varies very widely in the surface water of the Ashtamudi backwater. Mean reactive phosphate content of the bottom water varied from 3.81 to 6.22 $\mu\text{g.at/l}$ respectively at zones H and C. Except at zone A, phosphate content was relatively high in the bottom than the surface. The reverse recorded at zone A was probably owing to the high rate of phosphate input with freshwater. Release of inorganic phosphate to the bottom water during the degradation of organic matter and sediment water during the degradation of organic matter and sediment water exchange of the nutrient seem to maintain higher concentrations in the bottom where the influx of freshwater is negligible. Statistically significant t values occur in 11 interzonal comparisons of the reactive phosphate content of the bottom water (Table I). Therefore, interzonal variations, although are considerable, are relatively lesser than at the surface. In three zones t values comparing the surface and bottom values are significant (Table II) and in these zones vertical stratifications are highly pronounced.

Silicate-silicon

Mean values of silicate content varied between 15.47 and 42.56 $\mu\text{g.at/l}$ respectively at zones C and A in the surface water. Mean concentration at the marine zone also was low (Fig. 4). A negative relationship in the distribution of silicate and salinity was discernible. Maximum concentration of this nutrient encountered at the river zone was due to heavy influx through freshwater draining from wide catchment area of the Kallada river. Non-biological removal of silicate seems to be considerably induced by pollution apart from salinity. This would have been the cause for the low silicate contents encountered in zones situated away from the marine end. Statistical interpretations

Table I. t-values comparing the physicochemical parameters and nutrient levels at different zones of the Ashtamudi backwater. (SW — surface water, — bottom water, * — significant at 5% level, § — significant at 1% level)

Sl. No.	Between zones	DF	Depth	Secchi disc transparency	Temperature		pH value		Salinity		Dissolved oxygen	
					Air	SW	BW	SW	BW	SW	BW	SW
1	A & B	13	0.4473	0.9012	1.0418	0.7014	0.0734	2.8406*	3.9715§	1.7453	2.6517*	4.2194§
2	A & C	13	0.4206	0.5181	0.5970	0.6066	0.6652	1.7095	2.1478	1.8414	0.3325	0.2046
3	A & D	12	0.8643	1.0847	1.3060	0.2525	0.0672	6.8184§	4.5674§	2.9346*	2.3623*	1.7988
4	A & E	12	1.2193	0.1083	0.7599	2.6099*	0.2347	0.1591	2.3614	3.4343§	1.2039	0.5333
5	A & F	12	0.1576	0.1469	0.6751	0.6984	1.2614	4.8090§	5.8196§	4.4924§	0.4211	1.4740
6	A & G	12	1.0609	4.7760§	1.8520	2.2080*	0.1651	3.7687§	5.3610§	2.5988*	0.5755	0.4053
7	A & H	12	1.2889	0.4893	0.8465	1.1390	0.3122	5.6356§	7.8236§	4.8661§	2.3253*	4.5019§
8	B & C	12	0.2019	0.2586	0.6002	0.1581	0.6602	0.0000	0.9329	0.4049	1.4536	1.9093
9	B & D	11	0.1239	0.0742	0.4285	0.5107	0.0043	3.5986§	1.2099	2.8213*	0.0626	0.5664
10	B & E	11	0.3915	0.7125	0.4714	1.6871	0.1446	1.7692	1.7083	0.5585	2.7456*	2.3199*
11	B & F	11	0.5611	0.8496	0.1035	0.0080	1.1788	2.1356	2.4502*	3.6055§	2.3315*	2.2824*
12	B & G	11	0.2573	2.2612*	1.2126	1.2610	0.2096	1.0137	2.1637	0.8248	1.7278	2.2504*
13	B & H	11	0.4599	0.4063	0.0511	0.3557	0.3461	2.9471*	4.6486§	0.0886	0.1019	0.1600
14	C & D	11	0.8694	0.3308	1.0442	0.4207	0.6496	2.0207	1.6949	4.9553§	1.2906	1.0404
15	C & E	11	1.3932	0.4381	0.2353	2.2378*	0.7990	1.2223	0.2577	0.3976	1.1702	0.5019
16	C & F	11	0.9996	0.5064	0.2690	0.1543	0.5423	1.3256	2.5371*	2.3056*	0.0370	0.4763
17	C & G	11	1.2305	1.9013	1.8294	1.7911	0.4153	0.6036	2.3859*	2.6538	0.6680	0.4106
18	C & H	11	1.4324	0.1205	0.4134	0.5944	0.3825	1.8874	3.8083§	1.1501	0.6680	0.4106
19	D & E	10	0.6660	0.8053	1.0752	3.2675§	0.1481	4.2448§	2.6288*	4.4574§	1.2650	1.7491
20	D & F	10	1.9227	1.0318	0.3489	0.5469	0.1693	0.9631	0.9573	0.8755	2.4768*	1.4189
21	D & G	10	0.3913	2.5703*	0.8291	3.0081*	0.2012	2.3509*	0.8579	1.1079	2.0121	0.8329
22	D & H	10	0.7606	0.5034	0.4442	1.1110	0.3426	0.0000	0.5640§	2.1876	1.5567	1.3465
23	E & F	10	2.2308*	0.0451	0.1467	1.8463	1.3271	3.1602*	2.5686*	4.7588§	0.0358	0.4565
24	E & G	10	0.3422	1.6808	2.0877	1.0451	0.3440	2.3794	4.0275§	1.5027	1.3473	1.0180
25	E & H	10	0.1491	0.3791	0.2744	1.6748	0.5119	3.5021	1.9545	0.6458	0.2545	0.0888
26	F & G	10	2.2728*	9.7191§	0.8035	1.5215	0.9201	3.7701§	6.6653§	3.3564§	2.4544*	2.1458
27	F & H	10	2.1632	0.5240	0.0319	0.3838	1.0316	1.1115	0.0001	3.3094§	0.6885	0.9251
28	G & H	10	0.4720	2.5284*	1.0888	1.1702	0.1002	1.9243	1.6865	4.5338§	1.9747	2.3054*
									8.3874§	6.0123§	1.5396	2.0817

Table I — Continued.

Sl. No.	Between zones	DF	Phosphate		Silicate		Nitrite		Nitrate	
			SW	BW	SW	BW	SW	BW	SW	BW
1	A & B	13	2.0315	1.3307	7.5310§	11.3842§	3.6524§	1.0786	5.0139§	2.0894
2	A & C	13	2.2184*	1.3591	9.6595§	12.7405§	5.1667§	3.3618§	5.6539§	3.0013§
3	A & D	12	4.6657§	0.5092	8.4994§	13.7168§	7.0407§	3.8853§	5.2544§	2.5266*
4	A & E	12	1.8451	1.5378	2.5425*	1.0603	0.2173	1.5895	2.4136*	0.8258
5	A & F	12	5.4072§	2.1929*	7.3715§	10.8424§	5.2723§	3.9199§	3.4265§	1.4441
6	A & G	12	2.3737*	0.9200	5.9273§	10.0578§	5.9029§	5.5572§	6.1785§	3.3364§
7	A & H	12	5.8180§	3.1277§	8.6524§	11.0945§	8.0728§	3.6313§	5.3109§	2.4311*
8	B & C	12	0.4410	0.3714	1.9624	1.5575	2.1651*	2.4053*	2.0548	1.3070
9	B & D	11	2.8010*	1.5996	1.3963	2.0121	3.1230§	2.7403*	1.0070	0.6819
10	B & E	11	0.2007	0.1818	6.2356§	5.5349§	3.0520*	0.4188	2.8334*	1.8814
11	B & F	11	3.7063§	3.3528§	0.3843	0.6157	1.5912	2.8102*	0.8626	1.0878
12	B & G	11	0.5961	0.4108	3.0029*	2.3402*	2.3815*	4.3448§	2.5296*	1.7079
13	B & H	11	4.1587§	3.9467§	1.5296	1.4997	3.5985§	2.5272*	1.8487	0.3861
14	C & D	11	1.6698	1.4976	6.4648	0.3537	0.2646	0.3918	1.1581	0.7928
15	C & E	11	0.5038	0.2312	10.0784§	6.3660§	4.3736§	2.1547	3.6971§	2.8436*
16	C & F	11	2.5004*	2.5887*	3.1698*	2.2027*	0.8414	0.2136	2.3549*	2.2534*
17	C & G	11	0.1196	0.6416	8.0904§	4.0329§	0.1149	0.4064	0.1766	1.0977
18	C & H	11	2.7339*	3.2659§	0.3417	0.1899	0.3242	0.4207	0.1327	1.0939
19	D & E	10	3.4791§	1.7726	8.4371§	6.3659§	6.0999§	2.8024*	3.3484§	2.7726*
20	D & F	10	1.8146	1.3416	2.2480*	2.9423*	1.4511	0.2416	1.5455	2.0080
21	D & G	10	1.6852	1.2585	6.0680§	5.4015§	0.4638	1.4690	1.4816	1.0058
22	D & H	10	2.6967*	2.2483*	0.1225	0.0891	0.0603	0.0602	0.9802	0.4236
23	E & F	10	4.2929§	3.7107§	6.9623§	4.9646§	4.5111§	2.8092*	1.3766	1.3661
24	E & G	10	0.7810	0.6124	5.0419§	4.3007§	5.0575§	5.2655§	4.3503§	4.1783§
25	E & H	10	5.0013§	4.0720§	8.7818	5.7611	7.0988§	2.4795*	3.4758§	3.2436§
26	F & G	10	2.5526*	3.1385*	3.8196§	1.8324	0.8585	1.0111	2.7340*	3.4557§
27	F & H	10	0.1832	1.3729	2.4823*	2.0036	1.7332	0.2805	2.1449	2.2645*
28	G & H	10	2.8531*	3.6320§	6.6200§	3.4614§	0.5758	1.3648	0.3887	1.6324

Table II. t-values comparing the variations of physicochemical parameters and nutrients between surface and bottom waters. (§ — significant at 1% level and * — significant at 5% level)

S.No.	Zone	DF	Physicochemical parameters and nutrients							
			Temperature	pH value	Salinity	Oxygen	Phosphate	Silicate	Nitrate	Nitrite
1	A	14	1.3901	0.4712	2.1671*	1.6558	1.2547	4.2482§	1.3181	0.3750
2	B	12	0.5485	1.0789	1.3372	0.5429	2.1520	1.8826	1.6700	0.2991
3	C	12	0.1178	0.0000	1.0054	0.7766	2.0936	1.4122	0.2631	0.2818
4	D	10	1.2084	1.7581	1.4541	0.8008	2.9241*	2.0402	1.4161	0.1809
5	E	10	0.9841	1.6170	0.7476	0.1173	2.2619*	1.9215	1.5811	0.4734
6	F	10	0.5473	0.2546	2.0779	0.6871	3.0896*	2.6018*	0.2099	0.8296
7	G	10	0.9273	1.5370	2.2917*	0.2670	2.1653	7.3484§	0.3721	0.4200
8	H	10	0.1178	0.2615	1.5091	0.5687	0.8507	1.5101	1.5368	1.5891

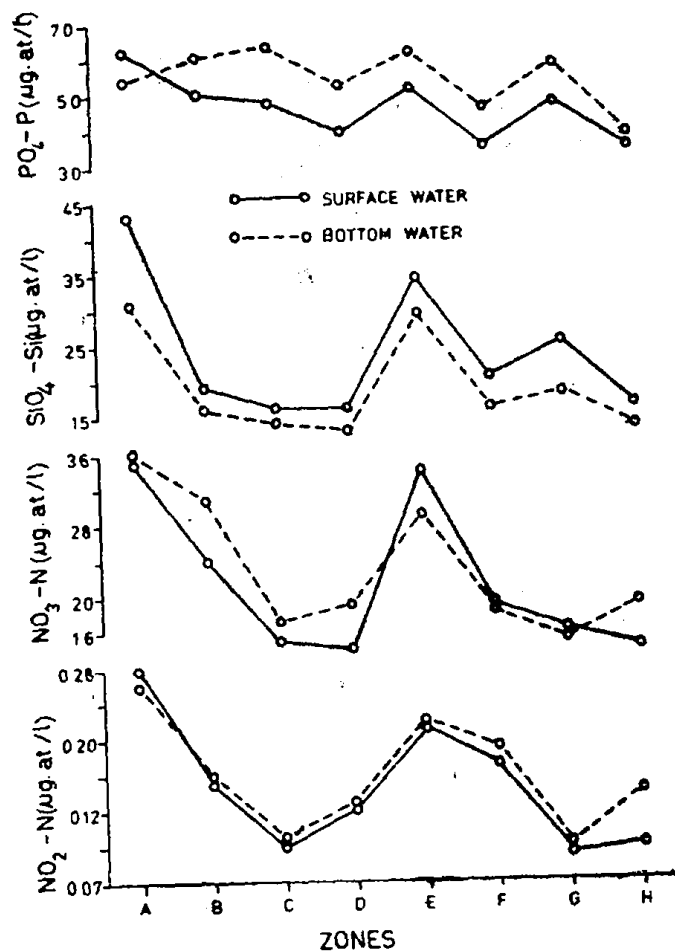


Fig. 4. Zonal mean concentrations of inorganic nutrients in the backwater.

(Table I) suggest that interzonal variations of the silicate content of the surface water are widely pronounced with significant *t* values in as many as 21 comparisons. In the bottom, mean silicate content varied from 13.17 to 31.20 $\mu\text{g. at/l}$ respectively at zones D and A. Mean silicate content at the marine zone was slightly higher than at zone D, however, the lowest value recorded was at a station in the marine zone. Invariably silicate content was lower at the bottom than at the surface. Statistical analysis (Table I) reveals very wide interzonal variations with as many as 18 significant *t* values out of the total 28 comparisons. Between the surface and bottom, wide variations with significant *t* values occur at zones A, G and F (Table II). Low silicate content of the bottom water and the roughly increasing trend discernible from the marine end towards the river end indicate the role of river water in maintaining higher concentrations of silicate.

Nitrate-nitrogen

In general, nitrate availability was very low all along the estuary during

the survey. It was below detectable limit in the bottom waters at heavily polluted stations (5 & 7) of zone C and in one station (7) even in the surface. Zonal mean concentration (Fig. 4) was minimum at zone D (1.40 $\mu\text{g.at/l}$) and maximum at zone A (3.50 $\mu\text{g.at/l}$). The pattern of nitrate-nitrogen distribution is very peculiar in this backwater because higher values prevailed at zone E which is severely polluted with ret liquor while in other polluted zones the concentration was very low. 16 comparisons yield statistically significant t values between zones with regard to the surface water nitrate content indicating that spatial variations are wide (Table I). The low nitrate content of polluted regions would be due to low rate of replenishment during the degradation of organic matter and also possibly due to nitrate reduction. Influence of nitrate rich freshwater could explain for the higher values recorded at the river and the confluence zones. At the bottom also, nitrate content was comparatively high at zones A and B where mean values above 3 $\mu\text{g.at/l}$ were encountered. At zones F and G mean concentration was relatively lower in the bottom water than at the surface. On account of the poor availability of nitrate, the fertility of the estuary may be affected, however, the availability of other forms of nitrogenous nutrients such as ammonia and urea also need to be investigated before drawing any conclusion. Statistical interpretations indicate that nitrate content varies widely between zones at the bottom also (Table I). Surface-bottom comparisons (Table II) do not result in any significant t value indicating little difference between the two layers.

Nitrite-nitrogen

Level of nitrite-nitrogen also was very poor almost throughout the backwater. Nitrite concentrations were below detection limits at certain stations of zones B, C, D, G and H. At zones A, E and F, atleast trace quantities of nitrite could be recorded. Mean concentration of nitrite was maximum at the river zone both in surface and bottom water (Fig. 4). At all the zones excepting A, nitrite content was relatively high in the bottom water than at the surface. The reverse, probably due to the influx of freshwater the influence of which is more in the surface, occurred at zone A. Minimum mean values occurred at zone G both in the case of surface and bottom waters (Fig. 4). Nitrite being an intermediate product produced both during nitrification and denitrification processes, its unstable nature would have been the major factor responsible for the low and varying values encountered during the survey. Higher values encountered at the marine and nearby zones in the bottom water suggest possibilities of rapid nitrite uptake in the surface and rapid regeneration at the bottom. This could be also due to intrusion of seawater probably containing higher concentration of nitrite-nitrogen. Sewage input and organic pollution seem to reduce the availability of nitrite. Statistical analysis of the data indicates significant t values in 15 interzonal comparisons of the surface water nitrite content (Table I). At the bottom 11 comparisons have significant differences suggesting that spatial variations are wide in the surface water. No significant t value could be obtained in the surface-bottom comparisons of

nitrite-nitrogen (Table II). High rate of biochemical oxygen demand prevails in the vicinity of regions with high organic load (Mackay and Leatherland, 1976). This could be attributed as one of the factors responsible for the nearly total depletion of nitrite at polluted stations of the Ashtamudi estuary.

ACKNOWLEDGEMENTS

This work was carried out with funds provided by the University Grants Commission, New Delhi for the implementation of the sponsored project "Studies on the coastal ecosystems of Kerala in relation to fisheries" (No. F. 22-9/7 (SR-II) dated 2.1.1979) and the financial assistance is gratefully acknowledged.

REFERENCES

- Abdul Azis, P.K., 1978. *Ecology of the Retting Grounds in the Backwater System of Kerala*. Ph.D. Thesis, University of Kerala, 773 pp.
- Abdul Azis, P.K. and N.B. Nair, 1978. The nature of pollution in the retting zones of the backwaters of Kerala. *Aquatic Biology*, 3: 41-62.
- Anonymous, 1981. *Estuarine Research in India — a bibliographic study*. National Institute of Oceanography, Goa, India, 43 pp.
- Anonymous, 1982. *Estuarine Research in India — State of the art report*. National Institute of Oceanography, Goa, India, 75 pp.
- Barnes, H., 1959. *Apparatus and Methods of Oceanography, Part I*. George Allen and Unwin Limited, London, 341 pp.
- Burten, J.D., 1979. An overview of the chemistry of estuaries. In: *Tidal Power and Estuary Management*, edited by R.J. Severn, D. Dineley and L.E. Mawker, Scientehnica, Bristol, p. 245-256.
- Dharmaraj, K. and N.B. Nair, 1979. Studies on the ecology of wood boring sphaeromatids in a tropical estuary. *Aquatic Biology*, 4: 49-71.
- Dharmaraj, K. and N.B. Nair, 1981. *The nature of distribution of inorganic nutrients in the Ashtamudi backwater in relation to environmental factors*. All India Seminar on the Status of Environmental Studies in India, Centre for Earth Sciences Studies, Trivandrum, 26-28 March 1981 (Abstract), p. 27-28.
- Divakaran, O., T. Murugan and N.B. Nair, 1981. Distribution and seasonal variation of the benthic fauna of the Ashtamudi lake, southwest coast of India. *Mahasagar—Bulletin of the National Institute of Oceanography*, 14: 167-172.
- Grasshoff, K. (Ed.), 1976. *Methods of Seawater Analysis*. Verlag Chemie, Weinheim, New York, 317 pp.
- Kaliamurthy, M., 1973. Observations on the transparency of the waters of the Pulicat lake with particular reference to plankton production. *Hydrobiologia* 41: 3-11.
- Kopp, J.F. and G.D. McKee, 1979. *Methods for Chemical Analysis of Water and Wastes*. U.S. Environmental Protection Agency, Cincinnati, Report No. EPA-600/4-79-020, 460 pp.
- Mackay, D.W. and T.M. Leatherland, 1976. Chemical processes in an estuary receiving major inputs of industrial and domestic wastes. In: *Estuarine*

- Chemistry*, edited by J.D. Burton and P.S. Liss, Academic Press, London, p. 185-218.
- Martin, D.F., 1970. *Marine Chemistry, 2. Theory and Applications*. Marcel Dekkar Inc, New York, 451 pp.
- Nair, N.B., P.K. Abdul Azis, K. Dharmaraj, M. Arunachalam, K. Krishnakumar and N.K. Balasubramaniam, 1983. Ecology of Indian estuaries, Part I -- Physicochemical features of water and sediment nutrients of the Ashtamudi estuary. *Indian Journal of Marine Sciences*, **12**: 143-150.
- Pillai, V.K., K.J. Joseph and A.K.K. Nair, 1975. The plankton production in Vembanad lake and adjacent waters in relation to the environmental parameters. *Bulletin of the Department of Marine Sciences*, University of Cochin, **7**: 137-150.
- Sankaranarayanan, V.N. and S.Z. Qasim, 1969. Nutrients of the Cochin back-water in relation to environmental characteristics. *Marine Biology*, **2**: 236-347.
- Strickland, J.D.H. and T.R. Parsons, 1965. A manual of seawater analysis. *Bulletin of the Fisheries Research Board of Canada*, **125**: 1-203.