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Nutrient dynamics in the two lakes of Kerala, India

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Distribution and chemistry of major inorganic forms of nutrients along with physico-chemical parameters were investigated. Surface sediments and overlying waters of the Ashtamudi and Vembanad Lakes were taken for the study, which is situated in the southwest coast of India. High concentrations of dissolved nitrogen and phosphorus compounds carried by the river leads to oxygen depletion in the water column. A concurrent increase in the bottom waters along with decrease in dissolved oxygen was noticed. This support to nitrification process operating in the sediment-water interface of the Ashtamudi and Vembanad Lake. Estuarine sediments are clayey sand to silty sand both in Ashtamudi and Vembanad in January and May. Present study indicates that the sediment texture is the major controlling factor in the distribution of these nutrient forms. For water samples nitrite, inorganic phosphate was high in Vembanad in January and May compared to Ashtamudi. For sediments, enhanced level of inorganic phosphate and nitrite was found in Vembanad during January and May. It had been observed that the level of N and P is more in sediments. A comparative assessment of the Ashtamudi and Vembanad Lake reveals that the Vembanad wetland is more deteriorated compared to the Ashtamudi wetland system.

[**Key words:** Nutrients, Ashtamudi Lake, Vembanad Lake, Sediment, Texture]

Introduction

Estuaries host a complex mix of biogeochemical processes that can vary temporally and spatially within the system and often act as opposing or competing influences on nutrient distributions[1,2]. Phosphorus may be added to or removed from estuarine water columns via particle interaction[3-5] biological processes[6,7] or sediment flux[8-10]. In addition to biological removal and regeneration[11] nitrogen transformation through nitrification[12] and denitrification[13,14] makes nitrogen handing out within the estuaries more difficult to quantify than phosphorus. Freshwater flushing time may control the extent to which nutrient compositions are modified by internal processes by limiting the amount of time for nutrient uptake by phytoplankton, exchange with suspended particles, and interaction with the sediments. Input from agricultural and urban runoff and from sewage outfalls can elevate phosphorus and nitrogen concentrations in estuarine waters[15,16,17,5]. A comprehensive understanding of nutrient behaviour in aquatic ecosystem requires their study in both the water and sediment as sediment acts as a causative agent for many complex biogeochemical processes such as accumulation, regeneration of nutrients etc. Anoxic conditions result in higher nitrite concentration with low level of dissolved oxygen[18] Nitrite is considered as the intermediate in the regeneration process of nitrogen cycle.

Anthropogenic inputs frequently cause excessive eutrophication in the aquatic environment, especially where the circulation is restricted, such as in estuaries and coastal regions[5,19]. Several alterations in chemical characteristics and water quality in such water bodies occur as a result of varying river flows. These alterations can lead to various ecological consequences like changes in species composition, blooms of phytoplankton and decrease of oxygen concentrations.

Materials and Methods

Ashtamudi lake**,** located in the Kollam District, is the second largest estuarine system in Kerala with a water spread area of about 32 km^2. The lake is located between latitude 8°53′-9°2′N and longitude 76°31′–76°41′E. The main basin is approximately 13 km long and the width varies from a few 100 meters to about 3 km. It is a palm-shaped extensive water body with eight prominent arms, adjoining the Kollam town. The major river discharging is the Kallada River, originating from the Western Ghats have an annual discharge of 75×10^9 m^3

of water into this Lake. It is formed by the confluence of three rivers, viz., the Kulathupuzha, the Chendurni and the Kalthuruthy. The lake opens to the Arabian sea at Neendakara, southwest coast of India. Several major and minor drainage channels loaded with waste products from municipal and industrial (mainly fish processing units) sources join the lake at the southern end. Coconut husk retting for coir fiber manufacture is predominant at several locations in the eastern arms of the estuary. This lake is the deepest among all the estuaries of Kerala with a maximum depth of 6.4 m at the confluence zone. The area of the investigations and locations are given in Table 1 and Fig 1 and 2.

Table 1— The area of the investigations and locations

Stations	Ashtamudi Lake	Vembanad Lake
1	Fatima Island	Thevara
2	Kureepuzha Boat Jetty	Aroor
3	Chavara Thekumbagam	Anchuthurath
4	Dhalavapuram	Perumbalam
5	Neendakara	Marine Jetty
6	Sakthikulangara	Kumbalam

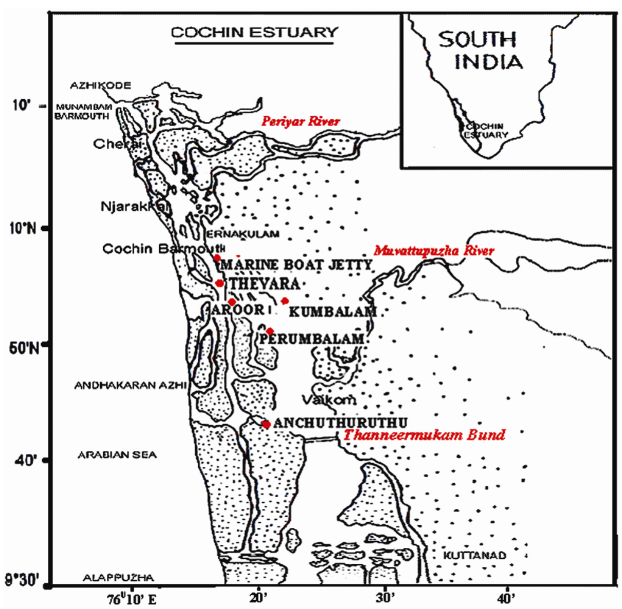


Fig. 1— Vembanad Lake (Cochin Backwaters)

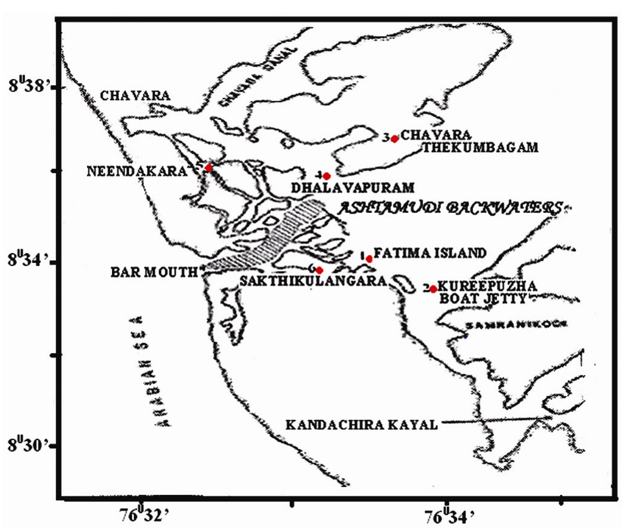


Fig. 2— Ashtamudi Lake

Vembanad Lake (Cochin backwaters) is the largest backwater estuarine system of Kerala. The lake has a length of 113 km and breadth varies from a few 100 meters to about 14.5 km and occupies an area of roughly 256 km^2 from about 9° 30′-10° 20′N and 76^o 13′-76° 50′E. Seven major rivers, five from south of Cochin and two from north, namely Chalakudi, Periyar, Muvattupuzha, Meenachil, Manimala, Achankovil and Pamba, flow into the lake. The lake opens in to the Arabian Sea through two permanent openings, the northern opening at Azhikode and another at Cochin and its depth varies between 1.5 and 6 m. The aquatic system is also delayering its quality by the introduction of a large variety of organic as well as inorganic substances including nutrients by the industries situated on its banks. The geochemistry of the sediments in the Cochin estuarine system and the adjoining aquatic environment have been influenced by both natural and anthropogenic pollution loads[20-25].

The present study consists the mobility of two major elements, N and P representative of nutrients in different phases of the lake environment - sediment, bottom water and surface water – . It also elucidates the chemical reactions involved in changing the physico-chemical regime of the system and to contrast the pollution and quality of Vembanad lake and Ashtamudi estuary for Environmental Impact Assessment.

Sampling and analysis

Surface and bottom water samples were collected from six stations of Ashtamudi and Vembanad Lake (Figs 1 and 2) during the first week of January and May 2008. Surface water samples were collected by clean bucket and bottom water by a Niskin sampler. Sediment samples were obtained by a Van Veen Grab sampler (0.042 m^2). After the collection the samples were preserved at 4^{o}C till analysis. The pH of the water samples was determined using a portable pH meter. Salinity was calculated by Mohr-Knudsen titration technique. Dissolved Oxygen (DO) was determined by the modified Winkler method[11]. Nutrient samples were refrigerated. Before analysis, sediments were dried and homogenized. The concentrations of N and P in the samples were determined[8]. Phosphate was estimated spectrophotometrically using Ascorbic acid and Mixed reagent at 880 nm. Nitrite were estimated as described by Strickland and Parsons (1960) using Sulphanilamide and NED and was measured at 543 nm. Texture analysis of the sediments was based on Stoke's Law by using the method of Krumbein and Pettijohn[26].

Results and Discussion

pH, DO, Salinity

The values of various Hydrographical Parameters for surface and bottom waters are summarized in Table 2. Generally pH of the bottom water was slightly higher (7.7-8.1) than that of the surface water (7.3-8.0) in January and lower in May. All the stations recorded high values for dissolved oxygen. In Ashtamudi Lake the values were found to be in the range 3.93-5.53 mg/l and 1.9-6.3 mg/l in surface and bottom waters during January and May. In Vembanad Lake it was found to be 2.02-4.89 mg/l and 3.69-4.84 mg/l in surface and bottom waters during January and May. The distribution of dissolved oxygen is found to be greatly related to salinity and has an inverse relation with it. The DO content of bottom water was lower than that of surface water in both months. Lowest DO values were reported for both surface and bottom at stations 5 and 6 in Vembanad. The lower DO values in the estuarine sites may be attributed to the low solubility of oxygen in saline waters and supports with the earlier studies conducted by Sankaranarayanan and Panampunnayil, 1979[2]. Surface salinity values were found to be lower than that of bottom in most of the Stations indicating the prevalence of density stratification within the estuary. The influx of high saline water and low discharge of fresh water by rivers caused high salinity during May especially in Ashtamudi. The differences in the surface and bottom salinity can also be due to the out flowing riverine water giving a two layered structure[27]. Similar results were reported by Nasnolkar *et al.*, 1996[28].

Sediment characteristics

The granulometric fractionation of sediments showed drastic differences in the admixture of sand, silt and clay fractions. Such difference in texture type is mainly due to the transport of sediments from one place to another and reversal exchange with the tidal currents[2]. Sedimentary characteristics are listed in Table 3.

In both Ashtamudi and Vembanad all through the study period, sediment texture was mainly clayey sand to silty sand. In the Vembanad, textural pattern is highly complicated owing to the fluctuation in the physico-chemical conditions prevailing in the system. The granulometric composition of the sediments is sandy, except at a few locations where silt dominates. The texture of the sediments has a significant role in the physico-chemical processes as well as in the species diversity of the depositional environment[29].

Nitrogen

The concentrations of NO_2-N, for surface and bottom waters are shown in Table 4. The

Table 2— Concentration of various hydrographical parameters

S-surface B-bottom	*p*H				DO (mg/l)				Salinity (psu)				Temperature (^oC)			
	Ashtamudi		Vembanad		Ashtamudi		Vembanad		Ashtamudi		Vembanad		Ashtamudi		Vembanad	
Stations	Jan	May	Jan	May	Jan	May	Jan	May	Jan	May	Jan	May	Jan	May	Jan	May
S1	7.6	7.9	7.7	8.5	5.10	2.90	2.45	4.61	30.62	35.17	33.18	12.2	29	32	29	32
S2	7.3	8.1	7.7	8.3	5.46	3.87	3.17	4.84	35.65	24.98	27.13	12.1	30	32	30	33
S3	7.5	7.9	7.2	8.3	4.95	5.33	4.46	4.49	29.81	34.82	11.33	6.8	30.5	32	31	33
S4	7.7	8.3	7.1	8.2	4.37	6.3	4.89	4.84	27.06	36.68	14.38	4.5	30.5	32.5	31	33
S5	7.8	8.1	7.7	8.3	5.53	3.87	2.02	4.03	30.50	35.04	26.08	16.0	30.5	32	31	32
S6	8	7.9	7.7	8.1	4.66	3.87	2.30	4.84	28.09	22.94	28.18	8.1	29.7	32	30	32
B1	7.9	7.9	7.9	8.1	4.81	4.2	2.59	4.26	30.75	36.45	28.84	15.3	28.9	32	28.9	32
B2	7.8	8.1	7.8	7.9	5.24	3.5	2.45	3.69	31.04	25.62	27.69	20.0	29	32	29	33
B3	7.7	7.9	7.3	8	4.37	3.7	3.60	4.49	36.91	35.24	14.03	7.8	26	31.5	30.5	33
B4	7.9	7.9	7.2	7.8	3.93	1.9	4.46	4.84	30.09	36.30	13.19	7.4	26.5	32	30.5	33
B5	7.9	7.8	7.7	8.2	5.39	3.2	2.16	3.69	30.84	35.55	22.12	18.0	27.5	32	30.5	32
B6	8.1	7.9	7.8	7.8	4.37	4.3	2.59	4.03	30.21	24.82	28.13	12.9	27	32	29.7	32

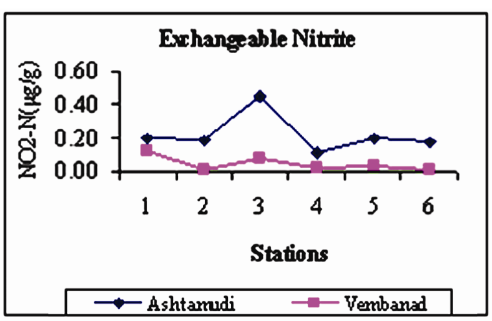
Table 3— Sedimentary characteristics:

Lakes	Month	Texture (%)	Stations 1	2	3	4	5	6
		Sand	93.2	43.75	92.11	5.03	98.98	97.33
	January	Silt	0.8574	27.77	1.81	43.71	0.5194	0.041
		Clay	5.93	28.46	6.06	51.25	0.5006	2.26
Ashtamudi		Sand	57.51	4.23	81.11	49.27	96.8	69.17
	May	Silt	28.58	57.77	11.9	37.5	0.54	22.84
		Clay	13.91	38	6.99	13.24	2.66	7.99
		Sand	2.07	82.47	83.71	91.05	10.8	0.7972
	January	Silt	48.66	5.19	4.18	2.28	51.3	48.7
Vembanad		Clay	49.26	12.33	12.09	6.66	37.84	50.45
		Sand	39.97	1.835	93.32	91.56	3.903	69.44
	May	Silt	32.09	57.58	0.84	1.89	75.39	14.5
		Clay	27.94	40.58	5.84	6.33	20.7	16.06

Table 4— Concentration of various nutrients in water samples

S-surface
B-bottom

	Nitrite (µmol/l)				Phosphate (µmol/l)			
	Ashtamudi		Vembanad		Ashtamudi		Vembanad	
Stations	January	May	January	May	January	May	January	May
S1	0	0.346	0.581	14.07	0	0.312	1.352	1.566
S2	0.002	0.89	0.452	16.24	0	0.208	0.624	1.81
S3	0	0.198	0.861	5.884	0.138	0.468	0.104	0.489
S4	0.001	0.099	0.301	1.416	0.276	2.444	0.084	0.783
S5	0.012	0.297	0.431	16.94	0.046	4.161	1.352	3.181
S6	0	0.198	0.431	15.23	0	1.716	0.312	1.908
B1	0.018	0	0.689	7.006	0.322	0.676	1.404	1.859
B2	0	0.173	0.689	2.574	1.794	2.184	0.312	1.957
B3	0.002	0.371	0.172	2.06	0.322	0.884	0	0.783
B4	0.002	0.42	0.344	1.379	0.552	3.225	3.537	0.734
B5	0	0.297	0.818	5.057	0.138	1.404	0	4.991
B6	0	0.346	0.194	1.103	0	0.936	6.657	2.202



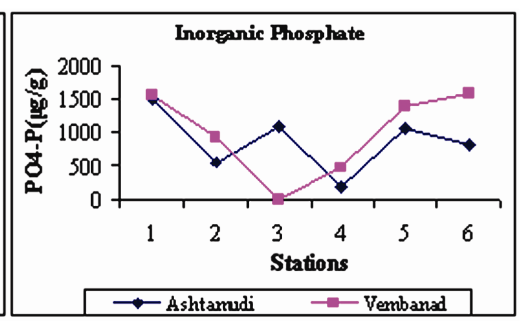


Fig 1: (G) Graphical Representation of nutrients for sediment samples in January

concentrations of NO_2-N, in the surface and bottom waters were very low in both the lakes during January compared to May. NO_2-N concentration was high in Vembanad compared to Ashtamudi during the investigation periods. It is well known that NO_2-N will be released during oxidation of NH_3 [30-33]. This is produced as a result of the digenetic decomposition of organic matter rich in estuarine sediments[33,31, 27] and brought to the sediment-water interface during sediment compaction[34-36]. In sediment samples, exchangeable nitrite was found to be higher for Ashtamudi compared to Vembanad in January. The higher values may be due to the nitrification, which is the main source of nitrite in sediments.

Phosphorus

Compared to May both lakes showed low values during January (Table 3). Vembanad has

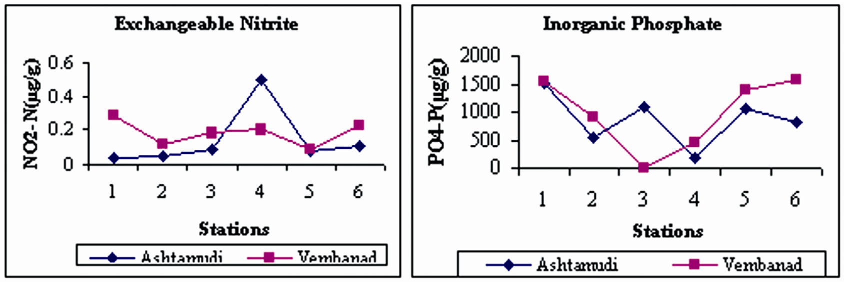


Fig 2: (G) Graphical Representation of nutrients for sediment samples in May

comparatively high concentration than Ashtamudi Lake. Inorganic phosphate was comparatively low in Ashtamudi (Figs 1 (G), 2(G)). Highest values were shown by station 1 and 5 of Vembanad and station 4 of Ashtamudi during January. In May, station 1 of both Vembanad and Ashtamudi showed highest values. Phosphate was more with silty sediments. The distribution of inorganic phosphorus shows significantly higher levels in the estuarine area affected by urban sewage and/or coconut husk retting activities. The increase in phosphorus may be due to rainfall and land runoff and other external disaster occurrence[37-38] and supports this justification. Probably sediments brought down into the estuary by the river form a source of phosphorus and are settled at the bottom.

Conclusion

Present study elucidates the natural process of Nitrogen Cycle, consisting biological uptake and regeneration apart from freshwater flushing time, that prevails in the two lakes. Higher nutrient concentrations were associated with lower oxygen content and higher salinities. The system was delicately poised, as continuous release of pollutants including nutrients into these estuaries. This would affect fish and shellfish production, The nutrient supply can initiate eutrophication in the Lake system. The distribution patterns of nutrients in these lakes are controlled by many factors like estuarine dynamics, effluent discharges from urban, agricultural and industrial sources, coconut husk retting, post-depositional diagenesis, fish processing units etc. Sediment texture is the major controlling factor for the adsorption and desorption of the chemical components. A relative appraisal of the Ashtamudi and Vembanad Lake reveals that the Vembanad is more affected due to urbanization and elevation in population, practice of domestic waste disposal, industrial discharge, enormous use of agrochemicals, enhancement of antibiotics in aquaculture.

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