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COUPLING OF WATERSHEDS AND COASTAL WATERS: SUBTERRANEOUS INJECTION OF NUTRIENT LOADS TO COASTAL ARABIAN SEA AND ITS LINKS TO MUDBANKS.

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Abstract: Southwest coastal waters of India (Arabian Sea) have a special environmental importance due to the formation of mud banks in southwest monsoon months. The present investigation in one of such mudbank regions indicated a possible subterranean flow from Vembanad Lake (Cochin Backwaters) that supplies primary nutrients to the adjacent coastal waters and precondition it for rich primary production during non-monsoon months. The activated trending faults in regions of submerged porous lime shell beds are probably coupling the adjacent watershed and the sea. Significance of this study is that subterranean flows could redefine the very concept of formation of mudbanks, which are presently recognized only as an oceanographic process. Unlike the existing theories, it is argued that formation of mudbanks are not entirely forced by coastal oceanographic processes; instead a remote forcing from the land involving a subterranean flow through the submerged coral beds, appears to be an initiative mechanism. The increased fresh water input through these passages stratifies the coastal waters by forming a surface lid of low saline waters, thereby diverting the incoming currents and wave energy to the bottom to disturb the bottom sediments. If the existence of the subterraneous channels linking Vembanad Lake to the adjacent coast is proved, it might even re-construct the historical evidence that the subterraneous flow plays a decisive role in the formation of mudbanks along this region. In view of the extreme sensitivity of Arabian Sea coastal zone to the introduction of nutrients into the Vembanad Lake, large variability in the coastal water quality can be expected on a variety of time scales. An increased delivery of fresh water and nutrients into the coastal zone can be expected during the southwest monsoon period, when the hydraulic level difference between the sea and lake is at the maximum. A sub aqueous injection of nutrients into the coastal waters through this region is possible even after the monsoon season. This assumption need further study to establish cause and affect mechanisms and quantify actual trends created by increased nutrient loading. The idea that land-use mosaic among sub-watersheds influence coastal processes such as mudbanks form an original work and this ostensible hypothesis may apply globally to any coastal regions hugged by wetlands and underlain with limestone deposits to develop into a region of mudbanks.

Key words: Mudbanks, Subterraneous nutrient injections, Arabian Sea

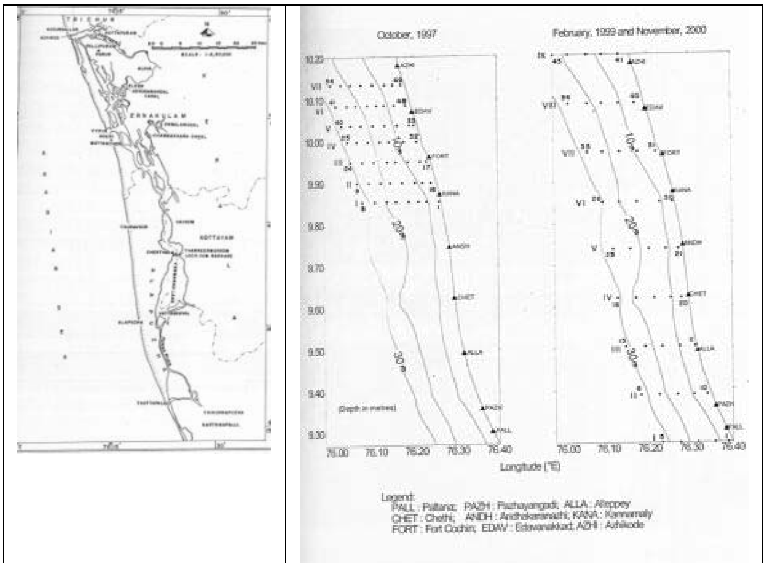
1. INTRODUCTION

The west coast of India is environmentally more sensitive than the east coast as it is bordering one of the most sensitive ecosystems, the Arabian Sea. The industrial establishments and human settlements along the west coast of India necessitate an evaluation of the type and quantum of inputs to the Arabian Sea as well as the regional assimilative capacities. If there is a possible threat to the well being of the living resources of EEZ of India, then the coastal waters of southwest coast of India, and in particular, Cochin region is the prime location prone to trigger it. The 16 major and several minor industries situated in the upstream region of the backwaters discharge nearly 0.105 Mm^3/d of effluents (Anon, 1996). The fertilizer consumption in Kuttanad region (the main agricultural field draining to Cochin backwater) alone is reported to be 20,239 t/y (Anon, 1998). The backwater receives organic wastes (~ 260t/d, Anon, 1998) and an annual dredge spoil from the harbor area to the tune of 10^7 m^3.

Conventional understanding of coastal waters of southeastern Arabian Sea is that activation of mud banks by monsoon forcing triggers intense geochemical processes leading to high productivity (Sylas, E.G, 1984). Mud banks, as they appear only during monsoon and disappear with its retrieval, are unique in their formation and functions, and have turned out to be economically important for its rich biological resources. As far as the chemical features are concerned, the general picture so far emerged out is that except during the monsoon periods, the southwest coastal waters remained oligotrophic and surface chlorophyll *a* typically ranges from 0.1 to 5.3 mg/m^3, while primary productivity ranges from 100 to 360 $mgC.m^{-2}/d$. Recent studies as the one discussed here contradict these findings and show that even after the monsoon period, fresh injection of nutrients by hitherto unknown processes fertilize the coastal waters that are either permanent or quasi-permanent in nature. One of the major mudbank regions (between Alleppey and Pallana) of southwest coast of India was selected for observation that indicates episodic introduction of nutrients into the coastal waters during periods when mud banks are passive.

2. STUDY AREA

This study is based on a set of observation (February, 1999 and November, 2000) from 45 stations between 9.2 and 10.2° N and 76 to 76.4° E covering the coastal waters of Azhikode to Pallana up to 35 m depth (~ 2500 km^2) including Cochin and Alleppey (Fig.1 A, B). The study represents the periods when the mud banks are not activated and changes encountered with the fertility of coastal waters delineates new processes along the coast. Water samples collected from surface, mid-depth and near bottom were immediately analyzed for nutrients using UV-VIS spectrophotometer (HITACHI U-2000), chlorophyll a by UNESCO procedure).



A B

Fig. 1 Study area (A) and study region with location of stations and bathymetry (B)

3. RESULTS AND DISCUSSION

In February (pre-monsoon), the nitrogenous nutrients remained low except for the southern transects centered on Chethi and Alleppey. The phosphate concentrations did not show any spatial or vertical variation in the water column, but higher concentrations of ammonia, nitrate and silicate were observed at selected regions starting in the near shore regions and extending offshore (Fig.2 a-d). The Nitrate-N concentrations point towards a clear source between Chethi and Pazhayangadi, where it peaked up to > 8 µM and decreased towards offshore. A slight shift but with a similar trend was observed for ammonia-N with the source centered on Chethi (at about 15 m depth). It may be assumed that the ammonia released were either rapidly utilized by phytoplankton or oxidized within the system itself where the waters were saturated with dissolved oxygen. Distribution of silicate-Si was similar to that of nitrate (4 – 10 µM), higher than the corresponding values reported for the waters of Southeastern Arabian Sea (David et.al., 1994). The input of these nutrients supported high primary production up to 14 mg/m^3 of chlorophyll *a* (peak column production of 1529 $mg/cm^2/d$), approximately 3 times greater than the peak values reported so far from these waters (Qasim et.al., 1978). The peaks in chlorophyll *a* and ammonia showed a preference of ammonia among the nutrients for primary production. It is difficult to point out a definite source to these high nutrients during this period, as the fresh water discharge was at the minimum.

During November, homogenous mixed layer prevailed in the entire region. While the physical characteristics were more or less stable, there was considerable variability in the nutrients and in chlorophyll *a* concentration (Fig.3 a-d). A marked decrease in sub-surface dissolved oxygen (2.8 - 4.8 ml/l) was the characteristic feature of this period, which was concomitant with enriched nitrite (0.5 – 2.0 µM), phosphate (0.4 – 2.8 µM) and silicate (0.5 – 14 µM). The ammonia (1 – 7 µM) and nitrate (1 – 6 µM) were also elevated at some regions along southern transects. The enriched particulate organic carbon (> 3.5 mg/l) and Chlorophyll *a* (14.8 mg/m^3) were also the notable features of this period. The wide variations in the near shore – offshore chlorophyll *a* and particulate organic carbon (POC) concentrations were probably related to the availability of nutrients, intensity of coastal input, coastal currents, stability of the coastal waters and other coastal processes like upwelling, sinking etc. (Bhattathiri, et. al., 1977). It is likely that chlorophyll *a* values were proportionate to carbon production indicating a strong positive relationship binding it with nutrient related factors rather than seasonal or diurnal fluctuation. The elevated nitrite and phosphate levels around Cochin barmouth may be due to the coastal input through the backwaters, which receives substantial quantity of nutrients through various anthropogenic sources. Higher values of nitrite, POC and chlorophyll *a* towards the southern offshore waters off Pallana were conspicuous. The regions occupying high nitrite were also found to contain nitrate levels up to 6 µM and the low levels of ammonia ruled out the nitrification as a significant process responsible for nitrite accumulation. Instead, the remarkable co-existence of nitrite with nitrate strongly suggested that the nitrite production should mostly be due to assimilatory reduction. This was further substantiated by the high concentration of waters with Phosphate might be related to the regenerative activity of sediments and especially its contribution from mudbank region. It is to be noted here that even when the discharges from the Cochin backwaters with substantial amount of phosphorus to the coastal waters, the sediments of the shallow coastal region including the mudbank sediments are mainly regulating the adsorption-desorption of phosphate to the overlying waters.

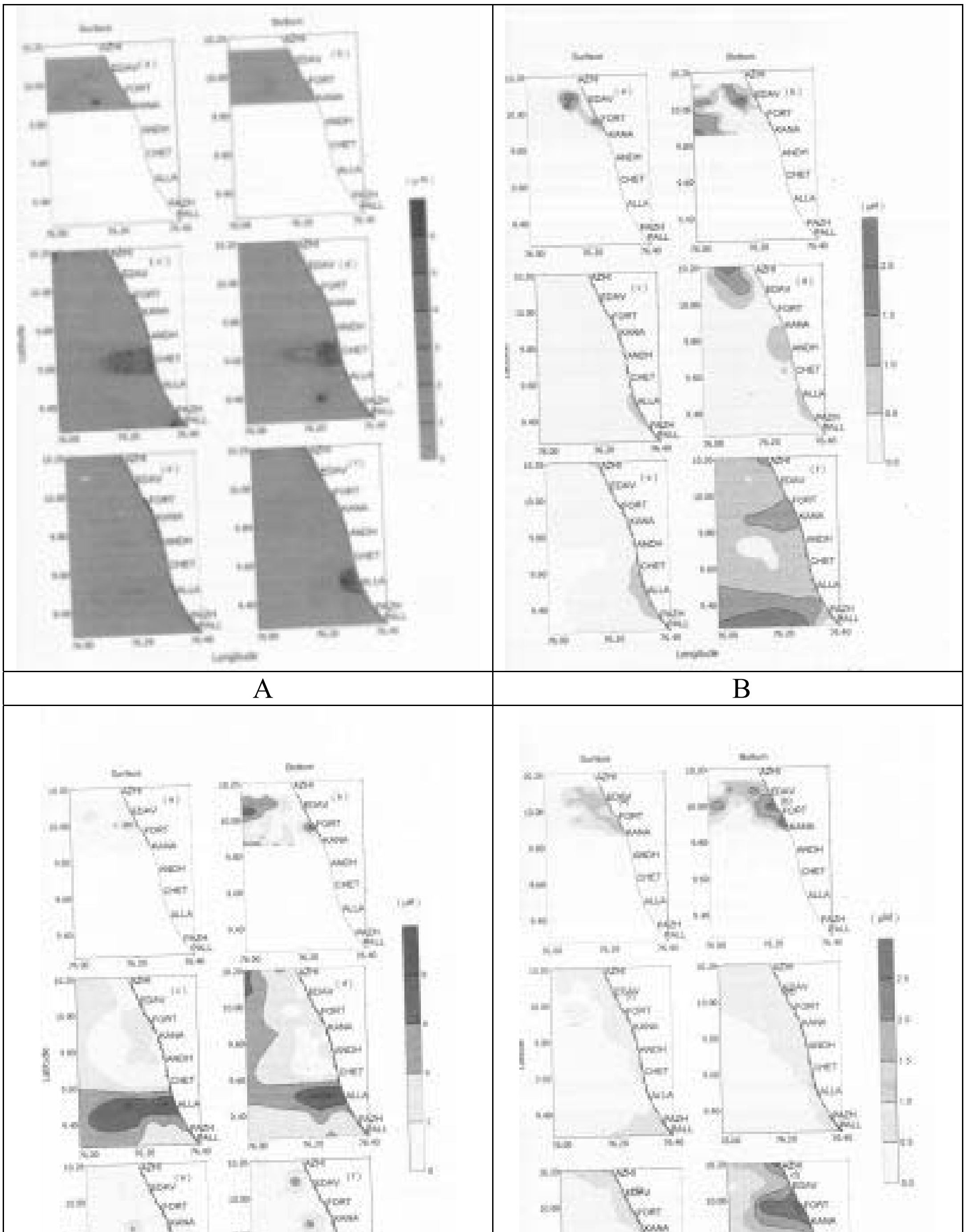


Fig. 2 Distribution of ammonia-N (A), nitrite-N (B), nitrate-N (C) phosphate-P (D) at the surface and bottom during October (a,b), February (c,d) & November (e,f)

The N/P ratio for these coastal waters was below 15 during November, possibly due to the disproportionate release of P from mudbank sediment. However, a band of N/P > 15 funneling out from Alleppey region was indicative of an 'external source' of nitrogenous compounds into the coastal waters. Submarine discharges of groundwater with high N:P ratios (> 15) have been reported to cause P-limitation in coastal waters (Lapointe et.al., 1992). Since nitrogen and phosphorus are independent of primary production in near shore waters of this region (Balachandran, K. K, 2001), NH_4 and NO_3 remain elevated in the water column at a greater distance from land compared to PO_4. A comparison of long-term (decadal) trend in the chlorophyll data of this region showed "greening" of near shore waters (Devassy, V. P, 1983). This suggests that phytoplankton standing crops had increased historically, possibly in response to watershed nutrient inputs. These sources of nutrients deserve identification as it was traced to a region, far away from any river mouths.

Both the observations in general indicated the presence of a nutrient source between Chethi and Pallana. Though this region represents mud banks, the release of nitrogenous compounds cannot be accounted as due to a release from sediments. Further, the injection of nutrients was in non-monsoon months when mud banks were passive. The possible explanation for this is the influence of Vembanad Lake on the coastal waters. Developmental activities in Vembanad Lake over the past century have included urbanization, reclamation, drainage of wetlands and agriculture. One of the recent estimate shows that in spite of receiving 42.4 $x10^3$ $mol.d^{-1}$ of inorganic phosphate and 37.6 x 10^3 $mol.d^{-1}$ of inorganic nitrate from Periyar side of the estuary, the export to the coastal waters is only 28.2 $x10^3$ $mol.d^{-1}$ of inorganic phosphate and 24 $x10^3$ $mol.d^{-1}$ of inorganic nitrate (Hema Naik, 2000). Thus, the estuary acts as a sink for the nutrients, flushing out only a portion of the pollution load that it receives. A comparison of the environmental parameters collected presently with the earlier data can indicate the estuarine system behavior over the years. The phosphate and nitrates were present in very low levels up to mid 70s', the levels increased during 80s' and 90s'. During 1965, the surface phosphate and nitrate were 0.75 and 2.0 μM, which has increased to 2.9 and 6 μM respectively by 2000 even though, between the years it show still higher levels. The trend also shows a build up of nitrogen and phosphorus fractions after 1975 and from 1980 onwards, the concentrations remained high. During 1980-81, the study region had nitrate and phosphate levels up to 40 and 12 μM with its upstream peaks of 108 μM and 186μM (Saraladevi, 1986). The present study recorded phosphate levels from 5 to 40μM for the same region. Sheeba (2000) also had reported nutrient enrichment in this system and recorded nitrate up to 451μM and phosphate up to 33 μM at the bar mouth alone

Increased human population along the coastal belt has also resulted in concomitant increases in widespread use of septic tanks and nutrient inputs to coastal waters, particularly from regions occupying limestone beds. It has been found that domestic wastewater from septic tanks provide more nitrogen than that due to precipitation or use of fertilizers. The situation is exacerbated in the present study region, as more than 70 % of households in these coastal belt and adjacent areas of Vembanad Lake do not have proper sanitation facilities, leading to direct defecation either into lake or to small pits. Moreover, agriculture combined water management practices in Kuttanad, have greatly increased nutrient loading (approx. 20,000 tones fertilizer/yr.[31]) that also threatens water quality relationships of the entire Vembanad Lake system. Significant amounts of nutrients from fertilizer applied in Kuttanad agricultural fields (approx. 94 kg/ha) leach out into waterways, groundwater and coastal bays Lizen Mathews (2000).

4. CONCLUSIONS

In view of the extreme sensitivity of this coastal zone to the episodic introduction of nutrients into the Vembanad Lake, large variability in the coastal water quality may be expected on a variety of time scales. If the existence of the subterraneous channels linking Vembanad Lake to the adjacent coast is proved, it might even re-construct the historical evidence that the subterraneous flow plays a decisive role in the formation of mud banks along this region. An increased delivery of fresh water and nutrients into the coastal zone can be expected during the southwest monsoon period, when the hydraulic level difference between the sea and lake is maximum. A sub aqueous injection of nutrients into the coastal waters through this region is possible even after the monsoon season. This assumption need further study to establish cause and effect mechanisms and quantify actual trends created by increased nutrient loading.

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