

## **Mudbanks off South West coast of India - Role of Subterraneous Flow**

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### **Abstract**

*The mudbanks along the south west coast of India is a unique geological phenomenon during the SW monsoons. The quiescence offered is on account of the increased viscosity of sea water due to the mud being in a colloidal suspension over a very loose and non-rigid clay bottom. A favorable combination of several factors like rainfall, sea water temperature, salinity and some other unknown factors - lead to the mudbank formation and decide its extent and duration. The recent findings of subterraneous discharges through the porous narrow sedimentary lime shell strip between the wetlands and Arabian Sea, forming pockets of low saline nutrient rich patches points the influence of such flows in the formation of mudbanks. A band of N/P > 15 funneling out from coastal region provided an indication of 'external source' of nitrogenous compounds. The long-term (decadal) trend of chlorophyll showed a "greening" of the near-shore waters. If the existence of subterraneous channels is proved, it might even re-construct the historical evidence that the subterraneous flow plays a decisive role in mudbank formation. The idea that land-use mosaic among sub-watersheds influences the coastal processes such as mudbanks may apply globally to any coastal regions hugged by wetlands and underlain with porous deposits and points towards the possibility of developing mudbanks like phenomena in such regions.*

### **1. Introduction**

The Mudbanks (Chakara) off Alleppy (Southwest India) is a unique geological phenomenon serving very much as a natural harbor and is defined as transient accumulations of dense fine-sediment suspensions, which form sub-circular/elliptical depositional areas having dimensions from 2-5 km alongshore and 1.5 to 4 km offshore, occur yearly along certain stretches of the west coast of southern tip of India. Mudbanks nearly always occur shortly after the arrival of the southwest monsoon in late May/June. The remarkable characteristic of them is that they did not lead to any silting of the coast on which ships could have run aground. They protect both the incoming and outgoing ships during the heavy downpours and stormy winds of the South West monsoon. When active, they are noted for their wave damping effects that a 1.8 m high wave outside the mud bank is reduced to 0.5 m in the mud bank, within a distance of 1.1 km. This reduction can be 100% in a fully developed mud bank. The quiescence offered is on account of the increase in viscosity of the sea water due to the mud being in a colloidal suspension over a very loose and non-rigid clay bottom. The mud bank also provides protection to the coastal zone, by way of allowing accretion.

The mudbank formation occurs within a week or so after the onset of the southwest monsoon. The occurrence is sporadic and erratic. This varies from year to year, in extent and duration. In some years they are not formed at all. They were also mobile, moving from place to place for long distances along the coast. A suitable combination of several factors like rainfall intensity and duration, temperature, salinity and some other unknown factors lead to its formation, its extent and duration of continuance. Apart from the beneficial to fishing

industry, the mudbanks have a role on the shore stability as mudbank accretes the coast behind. The present challenges are to predict mudbank formation, its artificial generation, precautions against down coast erosion, integrated management of mud bank areas taking into account the phenomena, coastal protection, socio-economics and infrastructure developments. 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 phytoplankton productivity. Recent studies as the one discussed here contradict these findings and show that even after the monsoon period, fresh injections 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 (Alleppy) of southwest coast of India was selected for observation that had indicated the introduction of nutrients into the coastal waters during periods when mud banks are passive.

## **2. Methods and materials**

During the hydrographic observations, sea water samples were collected from the coastal area (Fig.1g) using Niskin bottles from the surface, mid-depth (where the depth > 5m) and near bottom and were kept packed in iceboxes and brought to the shore laboratory. Nutrients were analyzed calorimetrically [1] and chlorophyll a by UNESCO procedure within 6 hours of collection.

## **3. Results and discussion**

The quality of coastal waters is coupled closely to the drainage of uplands. Primary attention has been given to river hydrography, but recent evidence shows that other transport mechanisms, particularly the discharge of groundwater, are important in areas covered by unconsolidated sediment or lime shell beds. Human activities on coastal watersheds seem to provide the major sources of nutrients to shallow coastal ecosystems. The human population along the coastal belt with more than 70 % of households (287 households/km<sup>2</sup>) without proper sanitation facilities had increased the use of septic tanks and the nutrient inputs to ground waters, particularly in the regions with limestone beds. The ground water quality of the region had shown that nitrate in sediment extract up to 12 µM, ammonia (in water) 8µM, urea (in water) 14 µM, urea (sediment extract) 15 µM [2].

As far as the chemical features of the coastal region 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 ranged from 0.1 to 5.3 mg.m<sup>-3</sup>, while primary productivity ranged from 100 to 360 mgC.m<sup>-2</sup>.d<sup>-1</sup>. The present study in the post- monsoon season had revealed highest value of 14 mg/m<sup>3</sup> for chlorophyll-a, approximately 3 times greater than the peak values reported so far from these waters. A band of N/P > 15 funneling out from coastal region provided an indication of 'external source' of nitrogenous compounds into the coastal waters (Fig 1b-f). The long-term (decadal) trend of chlorophyll had shown a "greening" of the near-shore waters. The present investigation represents the period when the mudbanks were not activated and the results showed a fertilization of the coastal water by injection of nutrients by hitherto unknown processes. The high nitrate-N, ammonia concentrations, enriched particulate organic carbon (> 3.5 mg/l) and Chlorophyll-a (14.8 mg/m<sup>3</sup>) at localized coastal regions had indicated clear near shore nutrient sources. It is difficult to point out a definite source for the high nutrient values as the fresh water discharge

was at its minimum. These sources of nutrients deserve identification as it was traced in a region far away from any river mouth and the injection of nutrients was observed during non-monsoon months, when mudbanks were passive.

The productivity boosting in southwest coastal Arabian Sea can be partially attributed to the possibility of nutrient rich ground water discharges to the coastal sea across the narrow strip of porous lime shell bed separating the Vemabadu Lake and the sea. The necessary forcing for the ground water flow is gained when the fresh water level in Vembanadu Lake and the sea level reaching a critical value. With regard to the hydraulic mechanism, it would appear that apart from the trending faults and water level variations in the lake, existence of several passages depending on the thickness of the lime shell bed also contribute to the sub aqueous flow. It is likely that the subterranean flows during the present observations were very weak (ooze), it can be expected to be much larger during the southwest monsoon period, when the sea level is at its annual minimum and the water level of the lake, approximately 5 feet above than normal due to the increased river discharges. A head of 5 ft. of water exerting a pressure of 2 lb/sq.inch may be insufficient to push suspended solids [2], but is good enough to erode frictional resistance and force ground water flow into the coastal region [3]. It is ultimately this flow of brackish water through these passages that stratifies the water column (Fig 1a) and diverts the converging waves to unsettle the sediment. The increased fresh water input through these passages stratifies the coastal waters by forming a surface lid of low saline water, thereby diverting the incoming currents and wave energy to the bottom to disturb the bottom sediments. This can be the starting mechanism of mudbank formation.

The periodicity and intensity of groundwater flows depend on the water level of the Vembanadu Lake, which depends on monsoon variability and frequency of floods. If the sufficient critical fresh ground water flow required to induce stratification in the coastal waters is available, the nutrient rich flow can also induce high primary productivity. The possibility of heavy rains and flash floods linked with cyclones is high with the ongoing climate variability, such critical conditions can occur during non-monsoon seasons and mudbank formations can shift to similar locations.

#### **4. Conclusions**

The causative factors discussed are indicative of existence of a subterranean flow connecting Vembanadu Lake to the adjacent coastal waters through the submerged porous lime shell beds. Continuous nutrient entry through such process is bound to upset coastal water productivity pattern. The brackish ground water fluxes seems to stratify the coastal region and to induce the mudbank formation. The significance of this study is that subterranean flows could redefine the very concept of formation of *mudbanks*, which is presently recognized only as an oceanographic process. The formation of mudbank is not entirely forced by coastal processes; instead a remote forcing from the land involving a climate controlled subterranean flow through the submerged lime shell beds appears to be an initiative mechanism. If the existence of the subterraneous channels linking Vembanadu 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. This assumption need further study to establish cause and effect mechanisms and quantify actual trends created by increased nutrient and brackish water loading.

## 5. References

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