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POLLUTION-PROBLEMS IN MANGROVE ECOSYSTEM

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Introduction

Rigveda, one of India's and world's most ancient scriptures has generously sung hymns in praise of forests and air and water. In fact, Indian sages and poets through their literature have always appreciated the beneficiary role of environment.

Mangroves are woody plants species which grow along tropical and subtropical coasts, in a saline environment with typically anaerobic soils. The mangroves swamps are seriously endangered ecosystem in most areas, the immediate man-induced threat being over exploitation from clear cutting, land reclamation and pollution from hydrocarbons and metals.

Role of Mangroves in ecological set-up

Although mangroves are now recognized as shoreline stabilizers preventing coastal erosion due to wave and tidal action, the most favoured appreciation of mangrove ecosystem lies in its role as nursery and spawning grounds for commercially important fishes and crustaceans. Mangroves swamps are also of the best natural pollution buffers preventing industrial toxic waste and mine run-offs being carried by rivers into the sea. These last two roles counter each other and present a problematical situation, the solution of which requires profound understanding of various intricate processes taking place in the mangroves.

To a marine scientist, mangrove ecosystem represents a microcosm. Barring some of the particular processes like hot thermal vents, underwater volcanic eruptions or quite simply, the magnitude at which these and other phenomena occur, most of the fundamental bio-geo-chemical cycles that operate in open seas, take place here in mangroves. This may be compared with a kind of pilot plant where exists microcosmic marine environment on a controllable scale.

The intricately woven web of various life cycles of marine organisms from plankton to shrimps and small fish and their predators, are dependent upon and in turn influence various marine chemical processes. Mangroves are some of nature's sturdiest forests tolerating wide ranges in salinity, temperature, humidity, soil quality etc., supporting kind of marine life suitable under the prevailing conditions. The ecological balance nonetheless gets disturbed by factors mostly anthropogenic in character. Besides the effect of direct buffering action against mine run-offs and industrial waste carried by rivers and estuaries, it suffers the pollution effects of coastal oil spills and industrial waste discharged by pipelines far out into the sea but washed ashore by tides.

Oil spillage and Mangroves

In 1984, a barge carrying 250 barrels of Nigerian Crude oil sunk in River Niger Delta. The spill had occurred around mangrove swamps where baseline survey was already in progress. The impact of oil spillage could thus be monitored effectively. A complete elimination of littoral infauna, highly significant oyster mortality and 30% oiling of mangroves prop-roots and 32% oiling of seedlings resulting in partial defoliation and death of seedlings in 500 m² area has been reported (1).

Varied effects of oil spills on mangroves have been monitored. Whereas considerable damage to mangroves has been reported from oil pollution in Puerto Rico in 1973 and in Nigeria in 1980, the release of 245,442 barrels of crude oil in Colombia and Equador in 1976 did not seem to do much damage to mangroves (2). The diverse impact on mangroves are influenced by a number of factors including the initial toxicities of different types of oils and the degree of weathering and emulsification that has taken place between spillage and impact. The prevailing weather and seasonal conditions further influence the position, concentration and retention of oil deposited in mangrove areas. Geomorphology of mangrove areas has an effect on their sensitivity to oil and it may take a year or more for impacts to become noticeable in larger individuals. Oil affected mangroves may suffer from defoliation, blackening and curling of leaves, chlorosis, pneumatophore damage and in certain cases death of seedlings (3).

One cost effective and widely accepted method of fighting oil spillages in seas is to spray them with dispersants which breakdown oil in less toxic chemicals. But in the mangrove forests, this treatment is contra-indicated. It has been found that adding dispersants to oil spills in mangroves only compound the problems. In laboratory studies it has been found that Arabian Light Crude Oil (ALC) dispersed with Corexit 9527 was more toxic than the undispersed oil to *Avicennia germinans* and *Rhizophora mangle* species but dispersed Bunker C oil was less toxic than undispersed Bunker C on the same species (4). Lai et al in 1984 reported that the above ALC oil dispersed with Corexit 9527 was more toxic to samplings of *Avicennia intermedia* and samplings of the Genera *Rhizophora* and *Bruguiera* than oil alone. At lesser doses however the dispersant reduces the oils toxicity (5).

Mangroves and metal pollution

The mangrove sediments, besides influencing its pollution response to oil-spills, also play a tremendous role in the bio-geo-chemical cycles in the eco-system. This in its turn regulates another kind of pollution: the toxic wastes discharged by industries and mines into the sea. Inherent physical and chemical properties of mangrove muds confer an extraordinary capacity to accumulate materials discharged to the nearshore marine environment. The sheltered, slack water environment of tidal swamps allows deposition of finest clays, silt and detrital particles which provide optimum surfaces for trace metal transport. The characteristic root system of *Avicennia* for example, comprises of radiating aerenchymatous roots supporting a dense grid of vertical pneumatophores projecting approx. 20 cms above the mud surface. This natural arrangement effectively traps suspended clay and silt particles settle out. This material is bound and stabilized by a tangled mat of root hairs growing

horizontally just below the mud surface, thus perpetuating the fine grained, organic rich mangrove substrate.

Previous studies of trace metals in natural waters have established the strong enrichment of metals in suspended matter and the importance of this material as a transport medium. Consequently, even if metals are discharged to the nearshore zone, sheltered environments of deposition such as mangroves are more likely to accumulate this particle-borne load.

Analysis of intertidal sediments from Barker Inlet indicates that the proportion of clay/silt (<63 μm size) increase towards the margins of the inlet (the high water level), that mangrove muds contain more than 85% particles in this size class, and that, irrespective of proximity to the various sources, trace metal concentration is higher in these sediments (6). The mangrove system, however, not only provides a physical trap for fine particulates and their transported load of trace metals, but also a chemical trap for precipitation of metals from solution.

Sediment/water interactions on tidal mudflats may also result in the release of metals from the sediment surface. The chemical environment in a shallow water system is subject to diurnal fluctuations, particularly during extended periods of slack water. Generally, highest levels of Eh and pH are recorded near mid-day and reducing conditions prevail in sheltered waters before dawn. Analysis of dissolved metals in 50 samples of tidal waters from Barker Inlet showed that, Fe^{++} and Mn^{++} in dissolved ionic state increased significantly just before dawn, and Cu^{++} appeared to increase in the oxidizing conditions during mid-day (6). These observations are supported by the work of Lu & Chen (7), who controlled the redox potential of sea water overlying metal-enriched sediments in laboratory tanks and demonstrated increases in dissolved Fe and Mn and decreases in Cd, Cu, Ni, Pb and Zn, under reducing conditions. The parameters used to model reducing conditions in that study i.e. zero dissolved oxygen and 15-30 mg.l^{-1} total dissolved sulphides, are frequently encountered at dawn in waters overlying mangrove muds.

Metals deposited in the sediments undergo changes brought about by, either natural biogeochemical reactions that take place inevitably in sediments, or anthropogenic ones, i.e., man made effects which includes addition of organic/inorganic substances to the sediments through dumping and exposing anoxic sediments to oxidation by aeration through dredging. Microbial degradation of the high content of organic matter in mangrove muds generally removes all oxygen from sediments below the surface layer, creating ideal conditions for bacterial sulphate reduction (8). When photosynthetic oxygen production ceases during the night, H_2S diffuses upward through the mud and escapes to shallow water covering the sediments (9). Metals dissolved in this water as free ions or metal humate complexes, are then deposited as sulphites (10). Stratification of zinc and copper associated with bacterial sulphate reduction in sediments enriched with organic matter has been demonstrated by Hallberg et al (11). On mangrove mudflats, sediments with high rate of sulphide production and corresponding high potential for precipitation of metal sulphides are often readily identified by pink, green and blue green mat of photosynthetic bacteria on the surface. Photosynthesis by diatoms etc. also contribute to the precipitation of metal carbonate and hydroxides from water covering tidal mudflat. The rapid removal of carbon-

dioxide from shallow water during the day can raise pH by one of two units facilitating carbonate precipitation. Iron and manganese hydroxide also found under oxidizing conditions will simultaneously remove other metals from the water-body by adsorption and precipitation (6).

Levels of metal present in the run-off waters in particulates form, arising from natural erosion, or mineralization are of importance especially from the point of view of Goan mangrove ecosystems. Metals in an inorganic matrix such as minetailings appear to vary in the solubility from one area to another. A comparison of the leaching of metals from two mines, one zinc-lead mine on the west central coast of Greenland and another copper mine on the west coast of Vancouver island shows a great difference between the two. Very little of copper in tailings from the later mine appears to leach into the sea water of Rupert Inlet where the tailings are discharged or is bioaccumulated by the marine organisms. On the other hand, lead appears to have entered in substantial concentration in coastal of Greenland and has been bioaccumulated by such organisms as mussels. This apparent contradiction only indicates that all the factors involved in the rate of leaching of metals from minerals are not fully understood(14).

Bio availability and pollution in mangroves

To have an impact on aquatic organisms, metals must be in a form that is biologically available to them. Only in this form the metals inflict a toxic action on the organisms and/or are bioaccumulated by them. The biologically available form of metal is usually a dissolved ionic form, but not all ionic forms pose the same biological hazard. Metals in the pure form are normally only available to marine organisms if they become oxidized and their oxidation products are soluble in sea water.

Metals in particulate form both suspended in the water and the sediments, are seldom available directly to aquatic organisms. Such metals may be either fixed in an organic medium e.g. contaminated plankton, or inorganic matrix e.g. mine tailings. The only exception to their biological unavailability is when the particulate metals are ingested by marine organisms and become solubilized in the acidic juices of their guts.

Certain metals particularly cadmium, have been shown to combine with metal binding proteins to cope with the additional metal ingested. This process explains, in part, the apparent 'acclimation' of certain organisms to moderately high levels of metals in their environment. While this detoxification process apparently protects, in some degree, the organism ingesting a given metal, it does not protect predators, including man, from an excessive intake of the metal.

Different species have different rates of bioaccumulation and the sites of major concentration may differ from one species to another. Cadmium concentrates in the hepatopancreas of American lobster *Homarus americanus* (12). The liver and kidneys are usually the sites of major concentrations of metals in fish, although mercury tends to be present in relatively high concentration in the muscle of fish. Because certain metals e.g. Zn and Fe are essential elements in the nutrition of most animals, some marine organisms have developed a capability of controlling their intake. Conclusions drawn

solely from this capability can confound any relationship that one may try to develop between the concentrations of a metal in the water or sediments and in the tissues of the exposed organisms.

Mangrove ecosystem and pollution due to war

In one major example of this kind (13), it is estimated that the environmental assault on South Viet Nam from 1961 to 1971 constituted in the form of spraying the herbicides and bombings, approximately 40 million liters of Agent Orange, 20 million liters of Agent White and 8 million liters of Agent Blue on crop lands, forests and wooden areas, of which mangroves were a very large part. Of these, Agent Orange contains highly toxic, both to man and nature, organic chemical called 'dioxin'. The result of this onslaught was near total devastation of plant life including mangroves. It is estimated that approx. 124, 000 hectares of mangroves, comprising 46 species, were eliminated in this period.

Mangroves provided Vietnamese with fruits to eat when their rice supplies ran out. Leaves fed the domestic animals and fertilize the paddies. Mangrove flowers attracted bees, providing the locals with honey and wax. Ecologically speaking, broad leaves of Rhizophora are an important link in the food chain fish and shell fish.

After the war, the massive mangrove ecosystem recovery programmes undertaken did not succeed properly till fish and forestry resources departments were unified. Further, a mangrove research centre is planned to give impetus to the green revolution in Viet Nam. But, in spite of all efforts on war footings, authorities predict a complete recovery only by A.D. 2020.

SUMMARY

Mangroves are a very intricate ecosystem which balances fundamental, chemical and biological cycles. The management of this environment against pollution should be done on scientific basis.

Three major influences on trace metals, fine particulates, organic matter and sulphide production, are inherent characteristics of mangrove muds and confer an enhanced capacity for metal accumulation. Where tidal movement is reduced, wide diurnal oscillations in pH and redox potential are observed in shallow waters covering tidal mudflats. Oxidizing conditions at midday could favour the precipitation of carbonate, oxide and hydroxide phases, while reducing environment measured before dawn would facilitate the precipitation of sulphides. Extreme variations in Eh and pH could also alter the concentrations of dissolved metals and increase their availability to marine organisms.

Because mangrove forests are vital to the maintenance of fish populations, their potential as a sink and a source of pollutants should be taken into account, when locations for waste water discharges are proposed.

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