

COASTAL MICROBIAL PROCESSES

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Evidences show that in terms of total energy flow, processes in the ocean mediated by microorganisms are as important as those mediated by plankton and larger organisms. Since turnover of microbial biomass is much faster than the turnover of macroscopic biomass, it results in a much greater flux of energy and materials. Pomeroy (1974) suggested that nearly half of the ocean's total primary production is being processed by microbes. Assuming that a portion of the large reservoir of dissolved organic matter in the sea is an immediate byproduct of primary production (photosynthetic process), the heterotrophic growth of bacteria probably represents a major pathway, whereby this fraction of organic matter is converted into particulate matter and enters the food chain. Different estimates of bacterial production put the values between 0.7 and $1.4 \times 10^9 \text{ t C.Yr}^{-1}$, sometimes, the value being as high as $24 \times 10^9 \text{ t C Yr}^{-1}$. The bacterial carbon, especially in coastal waters, can vary between 4% and 25% of total plankton carbon biomass. The studies so far conducted indicate that the microbial processes are more important in coastal waters than in the open ocean.

Sediment Processes

Particle size fractionation and measurement of the rates of respiration give an idea about the relative importance of microorganisms in the water column. According to Pomeroy and Johannes (1966, '68) the respiration of microorganisms (mainly bacteria) accounted for over 90% of the total plankton respiration. DOM is converted to biomass, usable by large zooplankton. DOM can be converted to microbial biomass with an overall efficiency of about 97 - 99% .

Detritus, in various states of colonization by microbes, is transported laterally by currents but eventually settle down as sediments to the bottom. It includes living and recently dead plant fragments, colonized detrital particles, amorphous organic matter derived from DOM, planktonic bacteria and faecal pellets of planktonic and benthic animals, as a good source of food for invertebrates. According to Dale (1974), the biomass of bacteria in sediments was of the same order of magnitude as

that of animals (upto 30 g/m² dry weight). He also suggested that they might process a greater part of carbon entering the sediment.

The metabolism of the sediment organisms requires oxygen, but dissolved oxygen from the surface can penetrate only to a limited depth, varying from a few mm in the fine grained carbon rich sediments to many cm in a coarse sediment. The sediment becomes anaerobic and highly reducing, just below the oxidized layer. In the case of anaerobic decomposition, the bacteria use sulphate, nitrate or carbon-dioxide as hydrogen acceptors leading to the formation of H₂S, NH₃ or CH₄. Out of these processes, quantitatively the most important is sulphate reduction, since sulphate is abundant in sea water.

Hence the anaerobic zone is typically characterized by the production of H₂S which is precipitated as black ferrous sulphide. The reduction of iron from ferric to ferrous state leads to the liberation of adsorbed phosphates. This is an important mechanism in nutrient regeneration.

Sulphide is oxidized to elemental sulphur and sulphate, by white sulphur bacteria and purple photosynthetic bacteria. The proportion of carbon oxidation catalysed by sulphate reducing bacteria in the marine environment is nearly 53%. In deeper marine sediments, at a depth of 30-50 cm, significant amounts of methane are present indicating the use of CO₂ as a hydrogen acceptor. Beyond 50 cm depth the methane production increases and its concentration reaches upto 10 or 15 m.

Several species of marine animals including annelids, gastropods, sea-urchins, amphipods, mysids, prawns and fish, feed on deposits of detritus and ingest bacteria.

Micro organisms are also implicated in the process of biodeterioration, diseases of marine organisms and microbial pollution of seawater. In addition, these organisms are also known to produce a number of biologically active compounds such as antibiotics, anticancer compounds, plant growth hormones and vitamins.

Role in Biogeochemical cycles

The most important function of the micro organisms is their contribution to geochemical cycles of Carbon, Nitrogen, Sulphur and Phosphorus, by which the fertility of the sea is maintained.

Phosphate is known to limit plant productivity and bacterial decomposition of certain kinds of organic matter. Large quantities of phosphorus become bound in the bodies of organisms or their remains. The microbial transformations of phosphorus include:

- i) altering the solubility of inorganic compounds of phosphorus
- ii) mineralizing organic compounds with the release of orthophosphate
- iii) converting the inorganic phosphate into cell protoplasm
- iv) bringing about oxidation or reduction of inorganic phosphorus compounds. The bacteria capable of dissolving insoluble phosphates are commonly referred to as "Phosphate Solubilizing Bacteria" and this group had been studied extensively in India. All the samples collected from intertidal, interstitial, neritic and estuarine regions of PortoNovo coast showed 70-85.44% of bacterial population (Ayyakkannu and Chandramohan, 1970). In general, *Bacillus* sp. are the most common and active solubilizers. Phosphate solubilizing bacteria occurred in all samples irrespective of salinity variations (1 to 35 ppt) (Ayyakkannu and Chandramohan, 1971).

Among the bacteria involved in the nitrogen cycle, only the free living nitrogen fixing bacteria received attention in the past. The quantitative distribution of *Azotobacter* spp. in sediments of marine, estuarine and mangrove regions of PortoNovo was studied by Lakshmanaperumalswamy *et al* (1975). Selected isolates were tested under laboratory conditions for their ability to fix nitrogen and it was found that all the isolates preferred a salinity of 30 ppt for optimum growth and maximum nitrogen fixation; even though several other species were capable of fixing nitrogen they were not looked into.

Silica forms an essential part of the skeleton in many silico-flagellates, diatoms, radiolarians and sponges. Since these organisms constantly remove silica from natural waters, its availability depends on the solubilization process brought about by the microorganisms. The occurrence and distribution of such silicate solubilizing bacteria have also been reported in the Vellar estuary and adjoining areas (Purushothaman *et al*, 1974)

Strains of *Pseudomonas* were found to be the main silicate solubilizers which tolerated wide fluctuations in salinity. The physiological properties of these bacteria showed that under laboratory conditions, 2-ketogluconic acid was the main solubilizing agent (Purushothaman *et al*, 1975).

From the geobiological point of view, the contribution of bacteria to sulfur cycle in the sea is second in importance to their essential role in the formation and transformation of carbon and nitrogen compounds. A number of reports are available on the occurrence and distribution of *Thiobacillus*, a group of chemolithotrophic sulfur oxidizing bacteria, in the marine environment. Several strains of this group were isolated from marine and estuarine sediments of PortoNovo and their physiology was studied (Dhevandran *et al.*, 1975). Another group of sulphur bacteria which received considerable attention is the sulphate reducing bacteria. The sulphur reducing bacteria are strictly anaerobic, recovered in plenty from anaerobic marine water masses and organic rich coastal sediments.

Though lot of information is available on their nature and activity from other lands, very little is known about them in India. Studies on sulphate reducing bacteria have been restricted to beach sediments and mangrove swamps (Lokabharathi and Chandramohan, 1985; Saxena *et al.*, 1987). Physiological tests conducted with 99 srb isolates showed that they are not only lactate and acetate utilizers but also propionate oxidizers. As over 50% of the isolates showed autotrophic growth with formate, it is suggested that these organisms can survive under nutrient limitation conditions. *Desulfo-vibrio* (20%) and *Desulfo tomaculum* (29%) are the most common genera.

One of the most abundant polymers in the marine environment is chitin, whose biodegradation contributes significantly to nitrogen and carbon budgets of coastal waters. There is only one systematic study on the occurrence, distribution and activity of chitinoclastic bacteria which was conducted in the Vembanad lake, south-west coast of India by Ivy (1982). The most common chitinoclastic genera are, *Vibrio*, *Aeromonas*, *Alcaligenes*, *Pseudomonas*, *Bacillus* and members of Enterobacteriaceae. *Vibrio* was found to be the most predominant genus (86%in sediments, 72% in water, 71% in prawns and 65% in fishes). Laboratory studies indicate that factors like temperature , pH and salinity influenced chitinase production.

Role in Fish Spoilage and Diseases

Much work has been done on microbiology of tropical fishes mainly because of its importance in spoilage. The role of bacteria in fish spoilage has been very well studied by various workers in different parts of the world. Several detailed investigations have also been carried out in India (Moorjani, 1976; Chandrasekaran, 1985).

The gut microflora of three estuarine fishes (*Ambassis commersoni*, *Chanos chanos* and *Liza parsia*) and one marine fish (*Rastrelliger kanagurta*) collected near Porto Novo coast was studied in detail (Mary *et al*, 1975; Fatima *et al*, 1980). The results of these studies indicate the significant role played by gut microflora in fish spoilage and nutrition. A similar study has also been conducted on the prawn *Penaeus indicus* (Palaniappan, 1983).

One of the most important commercial fishes in the Vembanad lake is the "Pearl Spot" (*Etroplus suratensis*). A fin rot disease of this was reported by Brightsingh (1981). Species of *Pseudomonas*, *Vibrio* and *Aeromonas* have been isolated from infected fins but no single organism could be identified as an etiologic agent.

In another survey conducted near Porto Novo coast, several species of fish with fin rot diseases were recorded (Lakshmanaperumalsamy, *et al*, 1984). Approximately 46,000 marine and 22,000 estuarine fishes were examined in this survey. Fin rot was recorded in 17 species of marine fish and bone tumour in a cat fish (*Tachysurus* sp.). Fin necrosis accompanied by external haemorrhage, ulceration and loss of scales were the symptoms. Species of cat fish (*Tachysurus spp.*) grunter (*Pomadasyd* sp.) queen fish (*Chorinemus* sp.) and pikes (*Sphyraena* sp.) were found to be mostly affected by fin rot with a peak recorded in April. More than 80% of the tumour bearing fish had fin necrosis. Unfortunately none of the above studies could be continued further. From the information collected, however, it is evident that fin rot disease seems to be the most common marine fish disease possibly caused by bacteria in Indian waters.

Role in Pollution

Microbiological aspects of pollution studies in coastal waters assume importance from the view point of coastal zone management. In recent years, fish and shellfish from coastal areas have been implicated as important transmitters of food borne diseases. Further, elevated levels of human pathogens in coastal waters adversely affect recreational activities. Hence, it is mandatory to monitor and estimate qualitatively and quantitatively the distribution of human pathogens in coastal waters. Several reports on the distribution of human pathogens and indicator bacteria in water, sediment, plankton and faunal samples along the Indian coast, are available.

The seasonal incidence of *Escherichia coli* in environmental samples (water, plankton and sediment) during 1981-'82 and in sea foods during 1982-'83 was monitored, at Vellar estuary region of Portonovo (Natarajan and Ramesh, 1987). High *E. coli* counts in water ($1.7 \times 10^3/100\text{ml}$), plankton ($3.6 \times 10^4/\text{g}$) and sediments ($7.0 \times 10^3/\text{g}$) were recorded during monsoon and postmonsoon periods while low population was found in summer.

The existence of *Salmonella* in non-human sources like fresh water, estuaries and the sea water has been authentically shown. The incidence of three new serotypes of *Salmonella* viz. *S. irumu*, *S. panama* and *S. lexington* was recorded for the first time in India in the environmental samples of Pitchavaram mangroves and Vellar estuary (Ramamurthy *et al.*, 1985).

Another bacterium of health significance in the marine environment which received considerable attention is the halophilic *Vibrio parahaemolyticus*. This bacterium is an etiologic agent in the sea food borne gastroenteritis. A detailed and systematic survey conducted at Parangipettai revealed the ubiquitous presence of *V. parahaemolyticus* in water, sediment, flora and fauna (Martin, 1981). Unlike the other organisms, this bacterium forms a part of the native flora in the marine environment.

Vibrio fischeri and *V. harvey* dominated the species composition of luminous bacteria. *Photobacterium leiognathi* was only a major component in water. A few strains of *P. phosphoreum* were also recovered from deeper waters (Jayabalan, 1980; Ramesh, 1986).

Biomass and heterotrophism

During the last few years attempts have been made to understand the microbial biomass and heterotrophic activity in coral reef lagoons of Lakshadweep islands in the Arabian sea. Based on the number of *Corallochtrium limacisporum* (thraustochytrid), total viable bacteria (saprophytic numbers), chlorophyll and total ATP of the lagoon waters, the contribution of thraustochytrid to microbial biomass was calculated (Raghukumar *et al.*, 1987). *C. limacisporum* and total viable bacteria, together, contributed only 0.844 to 6.02% ATP and 0.822 to 4.97% organic carbon to the biomass. About 90% of the microbial biomass in the lagoons appeared to come from organisms other than thraustochytrid pleateable population of bacteria and phytoplankton.

In another study, the heterotrophic potentials of the microbial populations in lagoon waters and adjoining open ocean were estimated, employing C^{14} labelled sugars and aminoacid (Chandramohan and Ramaiah, 1987). The respiration studies indicated that nearly 50 to 80% of the assimilated carbon was respired indicating a very high rate of mineralization in this ecosystem. In another study, the population of urea-hydrolyzing bacteria was estimated in Kavarati atoll (Chandramohan, Unpublished). Photosynthetic sulphur bacteria, *Chromatium violascens* (purple) and *Prothecochloris aestuarii* (green) were found to occur in the lagoon of Agathi atoll (Lakshadweep) (Lokabharathi and Chandramohan, 1986). The contribution of photosynthetic bacteria to primary production in some micro-environments can be as high as 85%. These bacteria are important not only as food for secondary producers but also in the removal of toxic sulphide through anaerobic photo-oxidation in the process of CO_2 assimilation.

Role as epiphytes

Very little information is available on epiphytic bacterial flora of seaweeds in Indian estuaries. In one study, heterotrophic bacterial population, associated with seaweeds (*Enteromorpha* sp., *Chaetomorpha* sp. and *Hypnea* sp.) and water of Vellar estuary, were estimated (Lakshmanaperumalsamy and Purushothaman, 1982). Total heterotrophic bacteria associated with seaweeds were found to be more abundant than in water samples. *Bacillus*, *Corynebacterium*, *Vibrio*, *Alcaligenes* and *Pseudomonas* were the genera commonly encountered. The bacteria present on the surface of *Enteromorpha intestinalis* cells and in sea water were found to produce the growth hormone, Indole acetic acid (IAA) in media supplemented with 1-tryptophan (Chandramohan, 1971).

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