ECONOMIC IMPORTANCE OF MARINE MICRO ORGANISMS

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Bacteria and allied micro-organisms are of direct economic concern to man in many ways besides causing diseases and bringing about the decomposition of marine animals and commercial algae. There are many problems in the general economy of the ocean, the solution of which requires the aid of the microbiologist. The micro-organisms belong to a wide range of groups and include bacteria, blue-green algae (Cyanophyceae), diatoms (Bacillariaceae) and possibly yeasts (Ascomycetes) and protozoa and early stages of brown seaweeds (Phaeophyta). When micro-organisms from these groups are present, they are often found as discrete colonies of a single species. If we consider the fact that 72% of earth's surface is covered with mostly salt water and that micro-organisms populate the surface regions as well as the bottom sediments, we can visualise the sea as the largest natural environment inhabited by microbes.

The role of micro-organisms in the carbon, nitrogen, sulphur and phosphorus cycles in the sea as well as general circulation of organic compounds by processes analogous to those in the soil is usually taken for granted. By virtue of their effects upon plant nutrients, the micro-organisms with which microbiologists are concerned influence the productivity of the sea. The distribution of oxygen and carbondioxide in water is influenced by microbial activity. Micro-organisms are the principal dynamic agencies which influence hydrogen ion concentration and oxydation-reduction potential of natural bodies of water and of the underlying bottom deposits. There are several ways in which microbial activities affect the diagnosis of sedimentary materials including protopetroleum. Many marine microbes associated with aquatic plants and animals are parasitic while others are beneficial in many ways.

Microbiology thus occupies a logical and prominent position as an integral marine science. Marine microbiologists are confronted by several practical problems which are outlined below.

The role of micro-organisms in the spoilage of fish and other marine products

Proteolytic bacteria are primarily responsible for the spoilage of fish, shell fish, crab meat and other marine

food products. Marine fish are more susceptible than fresh water fish. Possibly marine bacteria may be more actively proteolytic at low temperatures than corresponding fresh water flora.

Fish and other marine food products soon show signs of spoilage if not properly refrigerated. The consistency and colour of the muscle tissue are altered by bacterial activity and an odour of ammonia, indol, Trimethylamine, or other protein decomposition products are manifested. Quantitative tests for ammonia, indol, trimethylamine, histamine, tyrosine and other protein decomposition products have been proposed by various workers as a means of detecting the early stages of fish spoilage. The spoilage of fish may be retarded or prevented by refrigeration. Proteolytic activities of bacteria are minimized by refrigeration at subzero temperatures. Some of the bacteria were actively proteolytic at −3°C. Fish having 1,000,000 or more bacteria per gram were not considered to be marketable. Bacteria often affect the marketability of fish by causing discolouration. *Diplococcus gadidarum* caused reddenning of cod and allied fishes. *Micrococcus litoralis* caused the reddenning in salted codfish. *Micrococcus morrhauae*, *Sarcina morrhauae* and *Bacteriam halobium rubrum* were found associated with dry cod. 30 species of halophilic bacteria including two species of *Serratia* was found to be associated with the reddening of salted fish. A *Pink yeast*, *Torula wemeri*, along with *Micrococcus* and *Bacterium zoptii* were isolated from reddened codfish.

The greenish yellow discolouration of halibut was attributed primarily to *Pseudomonas fluorescens*. It may also be due to the presence of *Flavobacterium marinum*, *Flavobacterium fucatum* and *Achnomobacter pellucidam*. Bedford (1933a) attributed the discolouration and subsequent souring of halibut to the activity of various pink, orange and yellow marine bacteria in addition to the fresh water *Pseudomonos fluorescens*. All of the bacteria were active at 0°C and some developed at 5°C.

Spoilage of fish and fish eggs by yeasts and molds

The importance of yeasts and molds in modifying the marine environment is strictly secondary to that of ubiquitous and more versatile bacteria. As the causative agents of diseases of marine plants and animals, fungi may be extremely important. Sparrow (1936) described a fungus, *Petersenia* sp. which parasitises rotifer eggs. Malformed sardine eggs collected and preserved by the California Fish and Game Commission were found to be filled with fungi. The preliminary observation of those eggs suggest the possibility of fungus infections, accounting for extensive failure of sardine crops. The brown alga, *Macrocystis pyrifera*, which is of considerable economic importance, may be subject to epidemics of fungus infections. Similarly other commercially valuable marine algae may be affected by parasitic or saprophytic fungi problem which invites attention.

Spoilage of Oysters

The spoilage of oysters takes place in 3 stages. According to Eliot (1926) there is a period of rapid increase in acidity due to the bacterial fermentation of glycogen followed by a period of abundant gas production. Proteolytic bacteria subsequently complete the disintegration of the oyster tissue. Oysters, clams and mussels are often eaten raw or in a partially cooked condition. Numerous cases of typhoid fever and Asiatic cholera have been traced to the ingestion of these contaminated shell fish. Though normally free from dangerous bacteria in clean water, oysters that have grown in polluted water are undesirable as articles of human food, regardless of whether or not they contain specific organisms of disease because there are recorded evidences of the survival of typhoid bacilli in oysters from 9 to 42 days and of *Escherichia coli* from 7 to 17 days.

Large numbers of saprophytic bacteria are ordinarily associated with oysters. These are considered of little sanitary significance except that they promote the decomposition of shellfish. Decomposition of oysters at the start is due to the members of *Serratia*, *Pseudomonas*, *Proteus*, *Clostridium*, *Bacillus* *Aerobacter* etc. Later in the course of spoilage *Streptrocci*, *Lactobacilli* and *yeast* find more suitable conditions for growth when oysters become very sour and putrid. Yeasts are really a problem to the oyster industry. *Pink yeast* and *Torula yeast* are primarily responsible for spoilage of oysters.

Spoilage of clams

3 days have been accepted as the safe period of storage for clams. Clams followed the same pattern of increasing acidification as oysters. *Bacillus* and *Pseudomonas* were the common organisms causing spoilage.

Micro-organism's role in decomposition

Decomposers are indispensable in a marine environment. Ellenberg (1971) considers the group *decomposers* which live on dead organic material especially fungi and bacteria as the *3rd group of secondary producers*. Without continuous decomposition and mineralization of dead organic material, vast quantities of undecomposed remains would pile up in the sea. This *'natural garbage'* would ultimately make it impossible for other phytoplankton to get along with less nutrient materials. As a consequence productivity of the seas under natural conditions, nearly constantly quite high, would fall off considerably. Primary producers and decomposers are therefore essential components of every independent ecosystem.

Decomposition of Cellulose by Bacteria

Decomposition of Cellulose, Hemicellulose, Chitins, Pectin and Alginic acid are due to the respective bacteria concerned with the decomposition of the above things.

The deterioration of fish-nets was found to be due to cellulose digesting bacteria. Decomposition of cellulose can proceed under either aerobic or anaerobic conditions. Both linen and cotton lines, seines and nets were attacked. The value of fiber seines, net traps, and lines used by commercial fisherman in Kerala was about Rs. 2000/-. Such equipment lasts an average of less than 2 years and it's durability is being affected by cellulose-decomposing bacteria. The durability of the net seines and lines can be extended by applying *copper resinate* and other preservatives. The tendency of certain preservatives, to decrease the flexibility, impart undesirable colours or otherwise, adversely affect the properties of the fiber equipment complicating the problem.

Manila ropes and cotton nets were found by Atkins and Warren (1941) to be destroyed after 14 months of alternate wetting and drying as in ordinary use. Preliminary treatment of *copper napthenate* was found to prolong the useful life of the rope by 40%. According to several theories of petroleum formation, cellulose may also be converted into higher hydrocarbons like petroleum. Theoretically, cellulose could be reduced by either hydrogen or hydrogen sulphide to hydrocarbons. This is to be investigated.

Large quantities of cork are used as floats with fish-nets, fish-lines, life preservers etc. Although relatively resistant to bacterial attack, cork is decomposed by marine micro-organisms which slowly destroy its buoyancy by rupturing the cell walls of the cork. Eventually pieces of cork continuously or periodically exposed to sea water break into pieces. Cork is lignocellulose suberin complex filled with air-spaces which are responsible for its buoyancy. Hemicellulose also forms a part of cork tissue.

Decomposition of cellulose by fungi

Marine fungi are mostly isolated from wood or rope which had been submerged in the sea. The fungi penetrate and ramify the cell walls of wood and cordage fibers inducing decay by enzymatic hydrolysis of the cellulose and other cell wall constituents. The fungi readily utilise cellulose pectin and starch under experimental conditions. Barghoorn (1942) reports that the fungi cause deterioration of both hard and soft woods as well as cordage fibers under marine conditions.

Decomposition of Hemi cellulose

Hemicellulose (Pentosans-arabans xylans, araboxylans, methyl pentosans and Hexosans) form a part of the plant tissue. Decomposition of Hemicellulose proceeds most intensively under aerobic conditions. Different groups of micro-organisms like fungi, actinomycetes and bacteria induce decomposition.

Lignin decomposition

Lignin is a complex carbohydrate like substance which constitute part of woody structure of plants. Lignin is slowly oxidized by certain bacteria like *Micromonospra* in muds. Lignin decomposing micro-organisms as well as those which attack cellulose are instrumental in the destruction of timbers, wooden pilings, ropes, fish nets or other cellulose or lignin containing structures.

Decomposition of Lignin by fungi

Marine fungi attack lignin and are dominantly responsible for the deterioration of hemp, jute and sisal cordage as well as pilings and other wooden structures in the sea. According to Imshenetsky and Kokurina (1941) micro-organisms cause the destruction of jute covering on ships.

Chitin decomposition

Exoskeletons of invertebrate animals such as crustacea, certain mollusca, coelenterata and protozoa have chitin as their chief component. If chitins were not decomposed, it would become a serious drain upon carbon and nitrogen in the cycles of these elements. From the lesions of live lobsters having a shell disease. Hess (1937) found chitinoclastic bacteria. Chitin is attacked more slowly than other types of organic matter. It is decomposed less readily anaerobically than aerobically. Johnson (1932) found chitinoclastic bacteria growing on crabs packed in ice.

Pectin decomposition

Clostridium pectinivorum, C. felsineum, C. haumanni, C. roseun, C. carallinum, C. saturnisubrum and *C. auranti butyricin* are bacteria capable of breaking down pectins. They are widely distributed in water masses and are significant in the recycling of matter. They are important economically because of their involvement in the setting of bast-fibrous plants such as flax. Pectin are broken down under natural conditions by anaerobic bacteria, aerobic bacteria and fungi.

Decomposition of alginic acid

The decomposition of alginic acid occuring abundantly in marine algae was found by Waksman *et. al.* (1934) to be caused by certain specific bacteria. Three new marine species which decompose alginic acid are, *Bacterium alginicum, Bacterium alginivarum* and *Bacterium fucicola*.

The decomposition of Ambergis

Ambergis is a solid, fatty substance produced by spermwhale. Fresh ambergis has a solid sweet odour and is used as an ingredient in perfumes but, that found floating in the sea has a disagreeable odour. Foul odour is due to the decomposing action of bacteria. From concretions of ambergis a bacteria has been isolated namely *Spirillum recti phyreteris*.

Oxidation of hydrocarbons

a) *Oxidation of petroleum hydrocarbons*

According to ZoBell (1934a) bacterial species of *Nocardia, Actinomyices, Pseudomonas, Micromonspora* and *Mycrobacterium* are geological agents which oxidize various kinds of petroleum hydrocarbons. There are many ways in which bacteria may be instrumental in the formation and accumulation of petroleum hydrocarbons. Petroleum consists primarily of hydrocarbons which are believed to have been formed in the sea probably from the reduction of organic matter in anaerobic bottom deposits.

b) *Oxidation of oil, wax etc.*

Species of *Actinomyces, Micromonospora, Mycrobacterium, Pseudomonas* and other genera attack aliphatic, aromatic napthenic and olefinic hydrocarbons in the presence of free oxygen. These species are widely distributed in sea water and marine mud. *Desulphovibrio* species of marine origin attack waxes and heavy oils with the formation of lighter hydrocarbons. Micromonospora species rapidly oxidize paraffin wax paraffin oil, toluene, napthelene, benzene, phenol etc.

c) *Oxidation of Rubber*

Rubber is an unsaturated hydrocarbon having the chemical formula (C_5H_8) Unsaturated hydrocarbons are readily susceptible to bacterial oxidation. Rubber is regarded as a biologically inert material but even highly purified rubber is attacked by marine bacteria including species of *Actinomycetes, Micrococcus, Nocardia Pseudomonas* and *bacillus*. Hydrocarbon oxidizing bacteria play an important role in the carbon cycle in the sea. The decomposition of rubber is of little consequence in the carbon cycle but it is a grave problem of economic importance.

Fouling

For a long time economical considerations have made *fouling* a matter for study in many countries. Investigations made throughout have provided a sound knowledge of fouling organisms, the annual settltng cycles of the main species, trophic relationship, resistance to toxic substances and other ecological aspects. In nautical parlance *fouling* is the attachment and growth of a heterogenous assemblage of plants and animals on ship's bottom, piles and other submerged structures. By increasing the resistance of ships in water. fouling organisms diminish the speed of the vessel, increase fuel consumption and cause wear and tear of the machinery. Fouling organisms necessitate the dry-docking of vessels at frequent intervals. The fouling problem is of gravest concern to the Navy particularly when operating far from home bases. Algae, diatoms, hydriods, barnacles, oysters, bryozoans, and serpulids are the most abundant organisms observed in submerged surfaces. On badly fouled surfaces bacteria may constitute as much as 8 or 9% by volume of the total cumulation. Bacteria play an important role in the fouling of submerged surfaces. This they may do in a variety of ways as:

a) by affording the planktonic larval stages of fouling organisms a foot hold or otherwise mechanically facilitating their attachment.

b) by discoloring glazed or bright surfaces.

c) by serving as a source of food (Barnacles, mussels, tunicates and other fouling organisms are nourished by bacteria).

d) by promoting the deposition of calcareous cements of sessile organisms.

e) by increasing the concentration of plant nutrients including carbondioxide and amonia which result from the bacterial decomposition of organic matter.

Biocontrol of fouling organisms

Fouling in vessels can be successfully dealt with at present by passing electric current. In a number of cases this method cannot be applied and special paints which contain antifouling compounds with various toxic substances are used. According to Wisely (1964) on painted surfaces of the ships, barnacles showed post-attachment mortality. Bryoyoans and tubeworm larvae showed pre-attachment mortality. Mollusc larvae are repelled long before they become attached.

The progress of marine microbiology in explaining the presence of many chemical compounds and biogenic substances like petroleum in the sea is still very insufficient. The obvious part played by microorganisms prompts geochemists to expect an explanation from microbiology. Only very generalised data have so far accumulated concerning the so-called geological activity of microorganisms such as oxidation of petroleum hydrocarbons, oil etc. The improvement of old methods and the working out of new methods for the quantitative study of biochemical activity of microorganism under natural conditions of their environments is the most important task of microbiology to be handled yet. At this time of energy crisis it is necessary to intensify marine microbiological and geological investigations in order to satisfy the energy demands of the country.

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