The Aquatic Environment

The microbial population in a body of natural water is, to a large extent, determined by the physical and chemical conditions which prevail in that habitat. These include:

1. Temperature: the temperature of surface waters varies from the near 0oC in polar regions to 30 to 40oC in equatorial regions. More than 90% of the marine environment is below 5oC, a condition favourable for the growth of psychrophilic microorganisms. Microorganisms do occur in natural hot springs where temperatures as high as 75 to 80oC prevail. Lotic waters have a steady temperature throughout their mass due to constantly mixing by the water flow but lentic waters with weak or non-existent current has fluctuating temperature during the annual cycle.
2. Hydrostatic Pressure (HP): pressure affects activity of cells enzymatic systems. There are striking differences in the hydrostatic pressure of surface waters and of water in oceanic depths. HP affects chemical equilibrium which in turn, results in lowering the pH of seawater, resulting in a change in solubility of nutrients such as bicarbonate. HP also increases the boiling point of water, thereby maintaining water in its liquid state at high temperatures and pressures. HP increases with depth at the rate of 1atm per 10m. Barophilic microorganisms which cannot grow at normal atmospheric pressures have been isolated at depth between 1000 to 10000m. HP of the deep sea is an important factor in the occurrence and growth of marine microorganisms in the environment.
3. Light: most of aquatic life depends, directly or indirectly, upon the metabolic products of photosynthetic organisms. In most aquatic habitats, these primary producers are algae, and their growth is restricted to the upper layers of waters through which light can penetrate. The depth of the photic zones varies depending on such local conditions as latitude, season, and particularly the turbidity of the water. Generally, the photosynthetic activity is confined to the upper 50 to 125 m. carbon dioxide is available largely from HCO3-, although some gaseous CO2 is available. The amount of light penetrating different layers of water strictly depends on the position of the sun transparency, colour and depth of water. Most algae able to change and adapt their colouring to the light conditions but light is harmful to microorganisms without pigments.
4. Water Movement: Great importance to both temperature distribution and balance of chemical composition (gases, nutrients, pH). Movement of water caused by winds, suspended compounds, difference in the levels at the bottom (lotic waters) specific hydraulic engineering process, variations in density caused by different temperatures and contents of soluble compounds.
5. Salinity: the degree of salinity in natural waters ranges from near zero in freshwater to saturation in salt lakes. A distinctive characteristic of sea water is its high salt content, which is remarkably constant. The principal salts are chlorides, sulphates and carbonates of sodium, potassium, calcium and magnesium. The concentration of salts is usually less in shallow offshore regions and near river mouths. Most marine microorganisms are halophiles; they grow best at salt concentrations of 2.5 to 4.0 percent, whereas those from lakes and rivers are salt sensitive and do not grow at a salt concentration of more than 1 percent. Increase in salinity has an influence on the generation cycle of bacteria and fungi and on the morphological and physiological properties.
6. Turbidity: there is a marked variation in the clarity of surface waters. The suspended material responsible for the turbidity includes; (a) particles of mineral material which originate from land; (b) detritus predominantly particulate organic material such as cellulose, hemicellulose and chitin fragments and (c) suspended microorganisms. Turbidity of the waters influences the penetration of light, which in turn affects the photosynthetic zone. Particulate matter also serves as a substrate to which microorganisms adhere or as substrates that are metabolized. Many species of marine bacteria characteristically grow while attached to a solid surface and are called epibacteria or periphytes.
7. Non-organic substances: Besides free N2, many mineral compounds of this element such as nitrates, nitrites and ammonium salts occur in surface waters. Algae and heterotrophic bacteria most often use nitrates and ammonium salts. Maximum amounts of nitrogen tolerated by various algae species differ. Phosphorus is the limiting element for the development of algae. Algae may store phosphorus in their cells in amount exceeding their requirement. Accumulation of nitrates and phosphates in the deep waters of some large lakes and seas is as a result of heterotrophic microorganism activities. For nitrifying bacteria, NH4+and NO2- are the energy substrate while O2 combined in nitrates may be utilized by a number of denitrifying bacteria to oxidize the organic substances in anaerobic conditions.
8. Organic substances: they are either secreted by living cells or the products of their autolysis but the greatest amounts of organic compounds are introduce into the water by sewage, occurring in water in the form of solutions or suspended matter. They serve as food for heterotrophic bacteria and fungi. The development and metabolic changes of microorganisms are influenced more by the content of readily available compounds such as carbohydrates, organic acids, proteins and lipids rather than the amount of organic substances in general. When there is a lack of organic substances, bacteria do not reach their proper size and their cell division is slowed down.

Aquatic organisms: microorganisms include members of the plant kingdom, protozoa, bacteria and fungi.

Macrophytes are large aquatic plants and could be:

1. Rooted macrophytes- rooted in river bed or lake substrate and restricted to areas where flow is low enough to permit fine sediments to accumulate. They may have leaves entirely submerged, floating on the surface or emergent above the surface. In turbid water, little light penetrates and photosynthesis is restricted. Rooted macrophytes may extract nutrients from the well as absorbing them from the water as algae do.
2. Floating aquatic macrophytes- rootless plants that persist only in backwater areas where the flow slackens-otherwise they are carried downstream. Because their photosynthetic surfaces are above the water surface, these plants can grow in deep, turbid water and places where rooting sites are sparse.

Macrophyte abundance can fluctuate seasonally as a result of scouring of the bottom sediments and washout of plants during heavy rains. Aquatic macrophytes are important in many aquatic systems especially wetlands, slower moving water in streams and rivers and shallower areas of the lakes. They can provide habitat, refuge and spawning areas for insects and fish as well as surface for periphyton (algae) growth.

Energy is transferred to animals primarily when the dead plant tissue and associated decomposers are eaten. When floating plants are numerous, they form dense mats covering the water surface which blocks light penetration down the water column and prevent growth of other plants. The underlying water becomes deoxygenated in extreme cases.

Riparian Vegetation: plant growth that lines banks of rivers and other inland water bodies. These plants protect river banks from wave action and erosion, offer shelter, feeding and breeding areas for fish, birds and other organisms. Leaves and other organic matter from the riparian vegetation can provide significant quantities of organic matter to streams and rivers.

**Lakes and Ponds**

Lakes and ponds have a characteristic zonation and stratification. there is usually a fairly large littoral zone along the shore, which has considerable rooted vegetation and includes regions where light penetrates to the bottom. In open areas, limnetic zone is determined by the light compensation level (depth of effective light penetration). Photosynthetic activity decrease progressively in the deeper regions of the open water (profundal zone). The benthic zone is composed of soft mud or ooze at the bottom. Together with the profundal zone, the benthic zone is largely populated by heterotrophic organisms. When the benthic zone is composed primarily of organic materials, the majority of organisms will be anaerobic decomposers. The greatest variety of physiological types found in the limnetic and littoral zones, in addition they constitute the most productive regions. Productivity of course, is affected by the chemical nature of the basin and the nature of imported materials from streams and rivers.

Such stratification acts as a barrier to nutrient and oxygen exchange, especially in still water. In the summer, the top layers then to be warmer than the lower regions, but in the winter, ice, which is less dense, collects on the top: therefore, a reversal of temperature and mixing occurs in the spring and in the fall often resulting in massive growth of algae. Lakes or ponds enriched with nutrients, particularly nitrogen and phosphorus, a process referred to as eutrophication, are likely to support excessive algal growth.

**Streams**

Streams obtain a majority of nutrients from the flow of inorganic and organic materials from the terrestrial system or lakes or ponds. The microbial flora reflects the immediate conditions, including the effect of agricultural and industrial practices. The drastic environmental changes in stream and rivers created by rapidly expanding urbanization on the one hand and changes in farming practices on the other make it impossible to generalize upon typical of characteristic microbial flora

**Estuaries**

An estuary is a semi-closed coastal body of water which has a free connection with the open sea, it is the coastal adjunct of the marine ecosystem and lacks constancy in many characteristics unlike the ocean waters. It is a complex system which receives inputs from a variety of sources. Temperature, salinity, turbidity, nutrient load and other conditions fluctuate over a gradient of time and space. The microbial flora of the estuary is subject to considerable fluctuation. Some species are indigenous to specific ecological niches of the estuary; others are transient, having been added from domestic, industrial, agricultural, or atmospheric sources. In areas receiving domestic pollution rich with organic nutrients, predominant bacteria include coliforms, faecal streptococci, and species of *Bacillus, Proteus, Clostridium, Sphaerotilus, Beggiatoa, Thiotrix, Thiobacillus* and many others. Virises of the enteric group are also likely to be found. In regions of the estuary that are nutritionally poor, one is likely to find the budding and/or the appendaged bacteria such as *Hyphomicrobium, Caulobacter* and *Gallionella*, in addition to pseudomonads. Soil bacteria e.g *Azotobacter, Nitrosomonas,* and *Nitrobacter* are also likely to be present.

**The Sea**

Microorganisms are found at all depths and at all latitudes in seawater. They occur in plankton and in the sediment of the ocean floor. The great volume of the open sea provides an environment with less variations in conditions than the other aquatic waters,

**Marine Plankton**

The phytoplankton population comprises numerous species of diatoms, cyanobacteria, dinoflagellates coccolithophores, silicoflagellates and chlamydomonads. This group of microorganisms is chiefly responsible for the conversion of radiant energy to chemical energy-energy stores in chemical substances that accumulate in the sea. Planktonic algae under certain environmental conditions, may grow into enormous populations with resultant discoloration of the water- a condition referred to as **bloom**. The bacterial population throughout the photosynthetic zone is closely related to the distribution of phytoplankton. The beneficial effect of the plankton may be attributed to both the organic substances they elaborate and the solid surfaces provided for bacterial aggregation. Bacterial population differ widely with prevailing conditions. Most marine bacteria, however, are halotolerant or slightly to moderately halophilic. Among the psychrophilic forms are certain luminous bacteria which can produce light in the presence of oxygen. These bacteria may exist in symbiotic association with certain species of marine animals. In general, aquatic bacteria tend to be Gram negative; it is thought that the Gram negative envelope provides a structure better suited to support life in nutritionally dilute aquatic environment than the Gram positive cell wall. Important hydrolytic enzymes retained in the periplasmic space, rather than being excreted and lost to the aquatic environment as would be the case for Gram positive bacteria. In addition, lipopolysaccharide (LPS) of the outer membrane affords Gram negative bacteria protection from certain toxic materials. Species of the following genera are commonly found in freshwater: *Pseudomonas, Flavobacterium, Aeromonas,* and *Alcaligenes*. Common to marine and estuarine waters are *Vibrio, Acinetobacter, Pseudomonas, Flavobacterium, Alteromonas* and *Staphylococcus.* Bacteria in the surface region of the marine environment are often pigmented, a characteristics which may afford protection from the lethal portion of solar radiation. Mold spores and mycelium fragments are present in seawater throughout the photosynthetic zone. Species of *Deuteromycetes, Phycomycetes* and *Myxomycetes* have been isolated from marine environment.

Protozoa e.g species of *Foraminifera and Radiolaria* as well as many flagellated and ciliated species are present in large numbers in the region inhabited by the phytoplanktons which they feed on. At night, the animals (zooplanktons) graze on phytoplankton at the surface, and during the day they sink below the photic zone.

The microbial population is sparse near the surface of the sea because the intensity of iluumination is inhibitory. Beneath the region of photic activity there exist another region inhabited during the day by vertical migrating zooplankton. The bacterial population is distributed more or less uniformly throughout and below these layers, feeding on descending organic material and other nutrients,

**The Benthic Population**

Offshore sediments are inhabited by bacteria and protozoa. Large numbers are present at the mud-water interface; the bacterial population may range from a few hundred to millions per millilitre. The counts in sediments are as high as108 bacteria per gram.

**ADDENDUM**

**Natural methods of wastewater treatment**

1. **Purification of soil**: This consists of irrigating a field with sewage. Biogenic substances contained in sewage lead to an average of 20% yield increase. After spreading, the sewage seeps into the soil and the contents of impurities are absorbed by the soil particles. After some time, the absorbed organic compounds and microorganisms create a microscopic film around the soil particles and the surface soil layer works like a biological filter. The final products of the mineralization process taking place in this layer acts as fertilizer for the soil. Limited amount of sewage can be purified by this method otherwise, the field becomes excessively loaded with sewage which triggers oxygen free processes that are accompanied by the formation of toxic substances and odour release causing the plant growth to stop. Sewage must be cleared of helminth eggs prior to irrigation. During infiltration in soil, sewage gets purified and then carried over a receiving body of water by a drainage system.
2. **Soil filter**: This consists of spreading waste upon the surface of soil that leads to its biological purification using non-culturable fields. The field is divided into drying beds and flooded with waste (thickness 5-10 cm) every 0-5 days. Purified waste is drained by a drainage system installed in the ground. After some time, the soil filters lose the ability to purify and have to be periodically excluded from operation in order to regenerate.
3. **Hydrobotanic purification**: This consists of utilization of self purifying processes that take place in waterlogged ecosystems (wetland system). Purification as a result of the cooperation of soil microorganisms and boggy (permanently moist/damp but not waterlogged) plants. Microorganisms decompose the organic compounds contained in the sewage, turning them into non-organic compounds creating a plant biomass. The adsorption of impurities by the particles of soil is improved due to the very small mineral particles (silt) present in the substrate.

This type of treatment unit utilizes wetland vegetable (common reed, reed-mace, basket willow) that has a high requirement for food, thus, it absorbs large quantities of mineral salts. As a result, the vegetation desalts the sewage and does not lead to eutrophication of water reservoirs.

Types of hydrobotanic purification plants include:

1. **Soil-plant filters**: Filter types with horizontal, vertical or combined flow, mainly sandy with rooted boggy vegetation e.g common reed, reed mace.
2. **Shallow reservoirs with rooted vegetation**: include water reservoirs or ducts of deptyh between 10-50 cm. they are occupied by boggy vegetation e.g common reed, reed-mace.
3. **Seated reservoirs with floating vegetation**: ponds of depth between 1-2m, with seeled bottoms and side walls and floating vegetation e.g duck weed- *Lemna minor.*

**Nutrients removal**

Nitrogen and Phosphorus in wastewater should be properly treated or reused thereby reducing their containment effects in aquatic ecosystem. Nutrients (N and P) enrichment or eutrophication can profoundly alter the structure and function of aquatic ecosystem potentially endangering human health, biodiversity and ecosystem sustainability.

Microalgae used for treatment of wastewater due to their capacity to assimilate nutrients including both N and P.

Advantages: Probability of recycling assimilated N and P into algae biomass as fertilizer. Low operational cost. Reduction of lifr-cycle freshwater usage by as much as 90%. Lack of competition with existing food production on land. Microalgae treatment of wastewater does not generate pollution. An example of microalgae used is *Chlorella*.

Chemical method of removal of

**Nitrogen**

Ammonia stripping at high pH (lime, CaO)

NH4-+OH- → NH3↑ +H2O

**Phosphorus**

Precipitation by metal ions

Ca(OH)2 + HPO42-→ Ca(OH)(PO4)3

Al2(SO4)3+PO43- →AlPO4+SO42-

**Biological phosphorus removal**

1. Assimilation: C,N,P,S etc uptake for the synthesis of new cells
2. Dissimilation: C,N,S oxidized/reduced to provide energy- oxic, anoxic, anaerobic.
3. Nitrification: Heterotrophic bacteria breakdown organics, generate NH3, CO2 and water.
4. Autotrophic bacteria utilize inorganic compounds and CO2 as carbon source.

Nitrification- 2 steps

Oxidation of NH3→NO2- Nitrite

*Nitrosomonas*

Nitrite oxidation to nitrate

NO2- → NO3-

*Nitrobacter*

Denitrification requires anoxic conditions to encourage the appropriate biological communities to form and this is facilitated by a wide diversity of bacteria.

Phosphorus can be removed by a process called enhanced biological phosphorus removal. Here, specific bacteria called polyphosphate accumulating organisms (PAQs)are selectively enriched and accumulate large quantities of phosphorus within their cells. When the biomass enriched in this bacteria is separated from the treated water, these biosolids have a high fertilizer value,