Role of microbes in environment: Positive and negative roles

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Environment

- Environment is defined as the circumstances or conditions that surround an organism or group of organisms.
- The environment includes abiotic factor such as climate, water, minerals, and sunlight as well as biotic factors such as organisms, their products, and effect in a given area.
- Microbes are omnipresent in the biosphere, and their presence invariably affects the environment in which they grow.
- The groups of similar species create population which results in a community.
- Microbial community means all microbial populations in a habitat.
- Microbial community may be terrestrial or aquatic.
- The atmosphere is an inhospitable climate for microbes because of stress due to dehydration. This results in a limited time frame for microbes to be active.
- The activities of complex communities of microbes affect biogeochemical transformations in natural, managed, and engineered ecosystem.

Microbes in soil

- Microbes play an important role in soil aggregate formation and soil stability that confer fertility and productivity to soil.
- The soil microbes participate in these processes through many ways, e.g., filamentous microbes assemble clay particles using extensive network of hyphae resulting into soil aggregates.
- Additionally, some microbes secrete exopolysaccharides or cause compaction of clay particles that promote soil aggregation.
- The surface soil is always rich in indigenous population of bacteria (including actinomycetes), fungi, algae, and protozoans.

Microbes in aquatic environment

- Aquatic microenvironments occupy more than 70 % of the earth's surface including mostly ocean but also others such as estuaries, harbors, river, lakes, wetlands, streams, springs, aquifers, etc.
- The microbiota, living in aquatic environment, are the primary producers (responsible for approximately half of all primary production on earth) and primary consumers as well.
- A large variety of microbial communities live in aquatic environments such as the planktonic, sediment, microbial mat, biofilm communities, etc.
- Planktons refer to photoautotrophic microbial community including both eukaryotes (algae) and prokaryotes (cyanobacteria) and heterotrophic community including bacteria (bacterioplankton) and protozoans (zooplankton).
- Phytoplanktons are the primary producers in the food web using their ability to fix CO_2 into organic matter through photosynthesis.
- Aquatic microenvironment is further classified into three microenvironments, occupied by microbes living in freshwater, brackish water, and marine water.

Important Impacts of Microbes on Ecosystems

- The effects of microbes on their environment can be beneficial or harmful or inapparent with regard to human measure or observation.
- The most significant effect of the microbes on earth is their ability to recycle the primary elements that make up all living systems, especially carbon, oxygen, and nitrogen (N).
- The process called CO_2 fixation, accounts for a very large portion of organic carbon available for synthesis of cell material.
- Decomposition or biodegradation results in the breakdown of complex organic materials to other forms of carbon that can be used by other organisms.
- Biological nitrogen fixation is a process found only in some bacteria which remove N_2 from the atmosphere and converts it to ammonia (NH_3), for use by the plants and animals.
- Nitrogen fixation also results in replenishment of soil nitrogen removed by agricultural processes.

Generate Oxygen in the Atmosphere

- **Oxygenic photosynthesis** occurs in plants, algae and cyanobacteria.
- It is the type of photosynthesis that results in the production of O_2 in the atmosphere.
- At least 50 percent of the O_2 on earth is produced by photosynthetic microorganisms (algae and cyanobacteria), and for at least a billion years before plants evolved, microbes were the only organisms producing O_2 on earth.
- O_2 is required by many types of organisms, including animals, in their respiratory processes.

Primary production

- **Primary production** involves photosynthetic organisms which take up CO_2 in the atmosphere and convert it to organic (cellular) material.
- The process is also called CO_2 fixation, and it accounts for a very large portion of organic carbon available for synthesis of cell material.
- Although terrestrial plants are obviously primary producers, planktonic algae and **cyanobacteria** account for nearly half of the primary production on the planet.
- These unicellular organisms which float in the ocean are the "grass of the sea", and they are the source of carbon from which marine life is derived.

Recycle nutrients stored in organic matter to an inorganic form

- Decomposition releases the mineral nutrients (e.g., N, P, K (potassium)) bound up in dead organic matter in an inorganic form that is available for primary producers to use.
- Without this recycling of inorganic nutrients, primary productivity on the globe would stop.
- On land, most of the decomposition (also called "mineralization") of dead organic matter occurs at the soil surface, and the rate of decomposition is a function of moisture and temperature (too little or too much of either reduces the rate of decomposition).
- Fungi are the most important decomposers of structural plant compounds (cellulose and lignin – but note that lignin is not broken down when oxygen is absent).
- In water, the decomposition of organic matter is mostly oxic in streams and in the ocean and anoxic in the bottoms of lakes or in swamps.

Fix nitrogen from the Atmosphere into a Useable Form

- The only organisms capable of removing N_2 gas from the atmosphere and "fixing" it into a useable nitrogen form, ammonia and ammonium, (NH_3, NH_4), are bacteria.
- The specific bacteria that can perform N fixation are scattered throughout the groups including the cyanobacteria.
- Nitrogen fixation also results in replenishment of soil nitrogen removed by agricultural processes.
- Some bacteria fix nitrogen in symbiotic associations in plants. Other Nitrogen-fixing bacteria are free-living in soil and aquatic habitats.

Contribution of Microbes in Recycling Wastes and Detoxification

- Bacteria and fungi are able to biodegrade/ detoxify substances; thereby, microbial processes are extensively used for bioremediation.
- Biostimulation and bioaugmentation processes promote the rate of degradation of organic and inorganic pollutants.
- Heterotrophic microbes such as *Pseudomonas*, *Sphingomonas*, and *Mycobacterium* are known to be involved in oil degradation.
- Microbes (bacteria and fungi) are able to degrade a range of biodegradable pesticides such as atrazine, which is degraded by a bacterium, e.g., *Arthrobacter nicotinovorans*, and related derivatives such as simazine, propazine, and cyanazine.
- The microbial ability to withstand metal toxicity and their physiological adaptation to metal stress has an important significance.
- Nowadays, the microbial ability to transform heavy metals is being extensively used as a tool for bioremediation.

Cloud condensation by microalgae

- The distinctive seaside smell, for exampe is caused by dimethyl sufide (DMS) released into the atmosphere by microalgae.
- DMS reacts in the atmosphere to form natural sulfate aerosols which function as nuclei for condensation of water vapor into clouds.
- Annual DMS release form ocean is estimated about 75×10^9 metric tons.

Harmful effects

Contribution to greenhouse gases

- Another important impact of decomposition besides generating inorganic nutrients is to produce CO_2 and CH_4 (green house gases) that is released to the atmosphere.
- Methanogens produce methane in natural and artificial anaerobic environments (sediments, water-saturated soils such as rice paddies, wasterwater facilities, biogas facilities and anthropogenic methane production associated with fossil fuels.
- Agriculture is the largest emitter of the potent greenhouse gas nitrous oxide (N_2O), which is released by microbial oxidation and reduction of nitrogen.

Microbes Cause Food Spoilage and Decomposition

- Microbes are the agents of food spoilage and decomposition of clothing and sheltering materials.
- The factors that allow microbes to accomplish biodegradation and carbon cycling are at work on everything organic, which includes:
  - foods and grains stored in granaries,
  - supermarket or refrigerator,
  - natural structural materials
  - textiles used for our shelters and clothing.
- Nothing lasts forever, and the microbial decomposition of everything organic will occur in time.
- Fungi and bacteria are the major microbial agents of decomposition in aerobic environments.
- Bacteria take over in environments that lack oxygen.

Microbes Cause Infectious Disease

- A microbe which is capable of causing infectious disease in an animal or plant is called a pathogen.
- Water purification, immunization (vaccination), and modern antibiotic therapy (all developments in the field of bacteriology) have dramatically reduced the morbidity and the mortality of infectious disease during the Twentieth Century, at least in the developed world where these are acceptable cultural practices.
- However, many new microbial pathogens have been recognized in the past 30 years and many "old" bacterial pathogens, such as *Staphylococcus aureus* and *Mycobacterium tuberculosis*, have emerged with new forms of virulence and new patterns of resistance to antimicrobial agents.
- Microbes are also the cause of many diseases in plants, which, if crop plants or forest resources, may have important economic or social consequences.

Questions

- What is environment? How the presence of microorganism effect the environment?
- Write short note on:
  - Beneficial effects of microbes on environment
  - Harmful effect of microbes on environment