[TOPIC 1] Microbes in Household Products, Industrial Products and Sewage Treatment

Microbes are the major components of biological systems on the earth. They are present everywhere, i.e. in soil, water, air, inside our bodies and those of other animals and plants. They can also be found deep inside the geysers (thermal vents with temperature around 100° C), deep in soil, under the layer of snow and in highly acidic environments.

Microbes are so minute that they cannot be seen by naked eyes. Various types of microbes are Protozoa, bacteria, fungi, virus, viroids and prions (proteinaceous infections agents).

1.1 Microbes in Household Products

The common products obtained by the use of microbes are curd, dough, toddy, cheese, etc.

Curd

Curd is formed by adding bacteria such as *Lactobacillus* and **Lactic Acid Bacteria** (LAB) in milk.

(*i*) A small amount of curd is added to the fresh milk as starter, which contains millions of LAB.

(*ii*) LAB at suitable temperature multiply and convert milk into curd, which also improves its nutritional quality by increasing vitamin-B_{12}.

(*iii*) During growth, LAB produce acids that coagulate and partially digest the milk proteins.

(*iv*) LAB also checks disease causing microbes in the stomach.

Dough

Dough is formed by the fermentation caused by bacteria.

(*i*) Dough used to make bread, is fermented using baker's yeast (*Saccharomyces cerevisiae*).

(*ii*) Carbon dioxide released during the process of fermentation gives the fluffy appearance to dough.

(*iii*) Dough is used to make foods like idli, dosa, in addition to different types of breads.

Toddy

Toddy is a traditional drink of Southern India. It is made by the fermentation of sap from palm trees by bacteria. It is a refreshing drink which can be used for producing vinegar, jaggery or palm sugar.

Cheese

Cheese is made by the partial degradation of milk using different microbes.

(*i*) **Swiss cheese** is made by a bacterium *Propionibacterium shermanii*. The large holes in this cheese are due to the production of large amount of CO_2 by the bacterium.

(*ii*) **Roquefort cheese** is made by the ripening with by fungi, *Penicillium roqueforti* to obtain a specific flavour. It is the best known cheese made from sheep's milk. **Camembert cheese** employs *Penicillium camemberti* for ripening.

Other Products

Microbes are also used to ferment fish, soybean and bamboo shoots to make food.

1.2 Microbes in Industrial Products

Microbes have immense importance in many industries. The main industrial products obtained from microbes are fermented beverages, antibiotics, organic acids, alcohol, enzymes and bioactive molecules, etc. Production of these products on industrial scale from raw material needs the microbes to grow in very large vessels called **fermentors**.

Fermented Beverages

Fermented beverages are wine, beer, whisky, brandy and rum.

(*i*) These are obtained by fermenting malted cereals and fruit juices with *Saccharomyces cerevisiae* or **brewer's yeast** to produce ethanol on commercial scale.

$$C_6H_{12}O_6 \longrightarrow 2C_2H_5OH + 2CO_2$$

(*ii*) Variety of alcoholic drink depends on the type of raw material used for fermentation and the type of processing (with or without distillation).

(*iii*) Wine and beer are produced without distillation.

(*iv*) Whisky, brandy and rum are produced by the distillation of the fermented broth.

Antibiotics
(Anti-against and *bio*-life)

Antibiotics are chemical substances, which are produced by some microbes and can kill or retard the growth of other (disease causing) microbes.

(*i*) **Penicillin** was the first antibiotic discovered by **Alexander Fleming**.

(*ii*) Fleming discovered penicillin while working on *Staphylococcus* bacteria. He observed a mould growing in one of his unwashed culture plates around which *Staphylococci* could not grow. He found that it was due to a chemical produced by the mould. He named it penicillin after the mould *Penicillium notatum*.

(*iii*) **Ernst Chain** and **Howard Florey** discovered full potential of this antibiotic.

(*iv*) Penicillin was extensively used to treat Americans wounded during World War II. Fleming, Chain and Florey were awarded Nobel Prize in 1945 for this discovery.

(*v*) Antibiotics are used to cure deadly diseases such as plague, whooping cough, diphtheria and leprosy.

Organic Acids

Organic acids are produced by the microbial metabolic action. Important ones are:

(*i*) Citric acid – *Aspergillus niger* (fungi)

(*ii*) Acetic acid – *Acetobacter aceti* (bacteria)

(*iii*) Butyric acid – *Clostridium butyricum* (bacteria)

(*iv*) Lactic acid – *Lactobacillus* (bacteria)

Enzyme

Enzymes used in various fields are also produced by microbes as given below:

(*i*) **Lipase** is used in detergent formulations and helps in removing oily stains from the laundry.

(*ii*) **Pectinases** and **proteases** are used for clarifying bottled juices. Because these enzymes digest the pectin fibres present in the fruit wall and juices, the bottled fruit juices bought from the market are clearer as compared to those made at home.

(*iii*) **Streptokinase** is produced by the bacterium *Streptococcus*. It is modified by genetic engineering and is used as a 'Clot buster' for removing clots from blood vessels of patients, who have undergone myocardial infarction leading to heart attack.

Bioactive Molecules

Bioactive molecules produced by microbes are:

(*i*) **Cyclosporin-A** is produced by the fungus *Trichoderma polysporum*. It is used as immuno- suppressive agent in organ-transplant patients. It acts by inhibiting the activation of T-cells.

(*ii*) **Statins** is produced by the yeast *Monascus purpureus* and are used as blood cholesterol lowering agents. It acts by competitively inhibiting the enzyme responsible for the synthesis of cholesterol, e.g. pravastatin, simvastatin, etc.

1.3 Microbes in Sewage Treatment

Sewage is the municipal wastewater containing mainly human excreta. It contains large quantity of organic matter and pathogenic microbes. Therefore, before discharging into natural bodies, sewage needs to be made less polluting and this process employs the use of microbes. Sewage treatment is carried out in Sewage Treatment Plants (STPs) in following steps:

Primary Treatment of Sewage

(*i*) This step involves the physical removal of large and small particles from sewage through filtration and sedimentation.

(*ii*) Floating debris is removed by sequential filtration by passing through wire mesh screens.

(*iii*) After this, the grit (soil and small pebbles) is removed by sedimentation in settling tanks. The sediment is called **primary sludge** and the supernatant formed is called primary **effluent**.

(*iv*) The primary effluent is then taken for secondary treatment.

Secondary Treatment (Biological Treatment)

(*i*) Primary effluent is passed into large aeration tanks with constant mechanical agitation and air supply.

(*ii*) This allows vigorous growth of useful aerobic microbes into **flocs** (masses of bacteria associated with fungal filaments to form mesh-like structures).

(*iii*) These microbes consume major part of organic matter in the effluent, while growing. This reduces the **Biochemical Oxygen Demand** (BOD) of the effluent.

(*iv*) When BOD of the sewage gets reduced, the effluent is passed into **settling tank**.

(*v*) The bacterial flocs are allowed to settle in the tank and the sediment is called **activated sludge**.

(*vi*) A small amount of activated sludge is pumped back into the aeration tank to serve as the inoculum.

(*vii*) The remaining major part of the sludge is pumped into large tanks called **anaerobic sludge digesters**.

(*viii*) In sludge digesters, other kinds of bacteria, which grow anaerobically, digest the bacteria and the fungi in the sludge. During this process, bacteria produce a mixture of gases, such as methane, hydrogen sulphide and the carbon dioxide, which form **biogas** (can be used as source of energy as it is inflammable).

(*ix*) The effluent from secondary treatment is generally released into natural water bodies like rivers and streams.

Biochemical Oxygen Demand (BOD)

Biochemical Oxygen Demand (BOD) refers to the amount of the oxygen that would be consumed if all the organic matter in one litre of water is oxidised by bacteria.

(*i*) BOD measures the rate of uptake of oxygen by the microbes in a sample of water. Indirectly, it measures the organic matter present in the water.

(*ii*) More BOD of water indicates more polluting potential.

River Action Plans

(*i*) Due to the increasing urbanisation, sewage is being produced in larger quantities. So, the untreated sewage is often discharged directly into the rivers leading to their pollution and increase in water borne diseases.

(*ii*) The Ministry of Environment and Forests has initiated **Ganga Action Plan and Yamuna Action Plan** to save the major rivers of our country from pollution.

Under these plans, building of a large number of sewage treatment plants is proposed, so that only treated sewage can be discharged in the rivers.

[TOPIC 2] Microbes in Production of Biogas as Biocontrol Agents and Biofertilisers

2.1 Microbes in Production of Biogas

(*i*) **Biogas** is a mixture of gases (mainly methane) produced by the microbial activity and may be used as a fuel.

(*ii*) Certain bacteria, which grow anaerobically on cellulosic material produce large amount of methane along with CO_2 and H_2. These bacteria are called methanogens (one of the common bacterium is *Methanobacterium*).

(*iii*) **Methanogens** are commonly found in the anaerobic sludge during sewage treatment and are also present in the rumen (a part of stomach) of cattle.

(*iv*) In rumen, methanogens help in the breakdown of cellulose anaerobically thereby releasing CO_2 and H_2. This process plays an important role in the nutrition of cattle. The excreta of cattle called **gobar**, is rich in these bacteria. Therefore, cow dung can also be used to produce biogas, commonly called **gobar gas**.

Biogas Production

(*i*) The biogas plant consists of a concrete tank (10-15 feet deep) in which bio-wastes are collected and a slurry of dung is fed.

(*ii*) A floating cover is placed over the slurry, which keeps on rising as the gas is produced in the tank due to microbial activity.

(*iii*) The plant has an outlet, which is connected to a pipe to supply biogas to nearby houses.

(*iv*) The spent slurry is removed through another outlet and may be used as fertiliser.

(*v*) In rural areas, cattle dung is available in plenty. So, biogas plants are built more in these areas to produce biogas for cooking and lighting.

(*vi*) This technology of biogas production was developed in India due to the efforts of **Indian Agricultural Research Institute** (IARI) and **Khadi** and **Village Industries Commission** (KVIC).

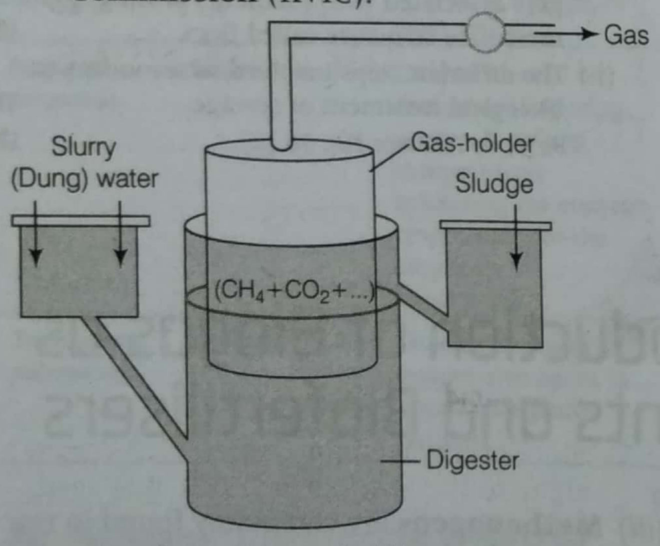

Figure 10.1 A typical biogas plant

2.2 Microbes as Biocontrol Agents

(*i*) **Biocontrol** refers to the use of biological methods for controlling the plant diseases and pests.

(*ii*) The insecticides and pesticides are although useful for field output, but toxic and extremely harmful to humans and animals as they are polluting our environment, crop plants etc.

(*iii*) Biocontrol agriculture relies on the natural control of pests, i.e. natural predation rather than introduced chemicals.

(*iv*) A key belief of the organic farmer is that biodiversity furthers health. They believe in holistic approach that seeks to develop an understanding of the webs of interaction between the myriad of organisms that constitutes the field fauna and flora.

They hold the view that the eradication of the creatures that are often described as pests is undesirable because without them, the beneficial predatory and parasitic insects would not survive.

(*v*) Some approaches for biological farming are:

(a) Familiarity with various life forms inhabiting the field.

(b) Understanding of their life cycles, patterns of feeding and preferred habitat of predators and pests.

(c) Greatly reduced dependency on toxic chemicals and pesticides by the use of biocontrol measures.

(*vi*) Examples of biocontrol agents include:

(a) The ladybird and dragonflies are useful to get rid of aphids and mosquitoes, respectively.

(b) The bacteria, *Bacillus thuringiensis* (*Bt*) is used to control butterfly catterpillars as follows:

- Dried spores of *Bt* are mixed with water and sprayed onto vulnerable plants such as brassicas and fruit trees, where they are eaten by the insect larvae.
- In the gut of the larvae, the toxin is released and the larvae get killed.
- The bacterial disease will kill the catterpillars, but leave other insects unharmed.
- *B. thuringiensis* toxin genes are introduced into plants by genetic engineering. Such, plants are resistant to the attack by insect pests, e.g. *Bt* cotton.

(c) The fungus, *Trichoderma* is used for the treatment of plant disease.
These are free-living fungi that are very common in the root ecosystems.

(d) Baculoviruses are pathogens that attack insects and other arthropods.
- Majority of baculoviruses which are used as biocontrol agents belong to the genus *Nucleopolyhedrovirus*.
- These are species specific, narrow spectrum insecticides.
- They do not harm plants, mammals, birds, fish and other non-target insects.
- Baculoviruses are beneficial in **Intergrated Pest Management** (IPM) programme, in which beneficial insects are conserved.

2.3 Microbes as Biofertilisers

Microbes as biofertilisers enrich the nutrient (nitrogen, phosphorus, etc.) quality of the soil. The main sources of biofertilisers are bacteria, fungi and cyanobacteria.

(*i*) **Bacteria as biofertiliser**

(a) The nodules on the roots of leguminous plants are formed by the symbiotic association of *Rhizobium* bacteria.

(b) These bacteria fix atmospheric nitrogen into organic forms, which is used by the plants as nutrient.

(c) Other bacteria, such as *Azospirillum* and *Azotobacter*, fix atmospheric nitrogen while free-living in the soil. They enrich the nitrogen content of the soil.

(*ii*) **Fungi as biofertilisers**

(a) Fungi form symbiotic association with plants (mycorrhiza).

(b) The fungal symbiont absorbs phosphorus from the soil and passes it to the plant.

(c) Many members of the fungus genus *Glomus* form mycorrhiza.

(d) Mycorrhiza shows the following benefits:
- Resistance to root borne pathogens.
- Tolerance to salinity and drought.

- Overall increase in plant growth and development.

(*iii*) **Cyanobacteria as biofertilisers**

(a) Cyanobacteria are autotrophic microbes, many of them fix atmospheric nitrogen.

(b) Examples of cyanobacteria are *Anabaena, Nostoc, Oscillatoria*, etc.

(c) Blue-green algae also add organic matter to the soil and increase its fertility.

Use of Biofertilisers

A number of biofertilisers are available commercially in the market. Farmers use them in fields to replenish soil nutrients and to reduce dependence on the chemical fertilisers. Also these biofertilisers do not allow the pathogens to flourish and these are non-polluting.