# Table of Contents

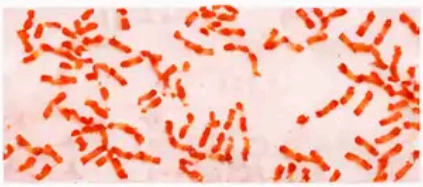
1. Introduction
2. Microbes in Household Products
3. Microbes in Industrial Products
4. Antibiotics
5. Chemicals, Enzymes and Other Bioactive Molecules
6. Microbes in Sewage Treatment
7. River Action Plan
8. Microbes in Production of Biogas
9. Microbes as Biocontrol Agents
10. Examples of Biological Control
11. Bioherbicides
12. Other Biocontrol Agents
13. Microbes as Biofertilisers
14. Importance of Biofertilisers

# Introduction

## Overview of Microorganisms

- Microorganisms (microbes) are organisms invisible to the naked eye, viewed under microscopes.
- They exist everywhere: soil, water, air, inside animals and plants, extreme environments like thermal vents, deep soil, snow layers, acidic sites.
- Microbes include bacteria, fungi, protozoa, microscopic plants, viruses, viroids, and prions.
- Bacteria are living microbes with varied shapes and movement structures; viruses are simpler infectious agents.
- Microbes like bacteria and fungi can be cultured on nutrient media to form visible colonies for study.

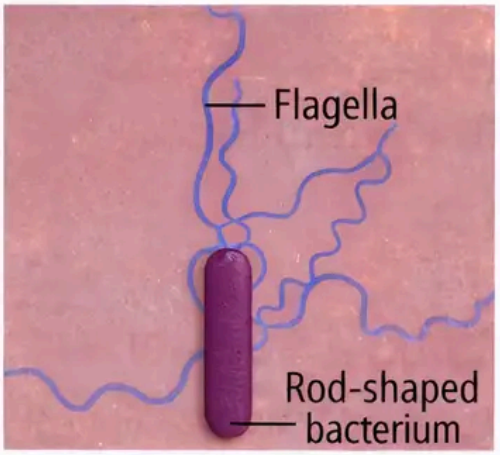
Prepzy



(a)

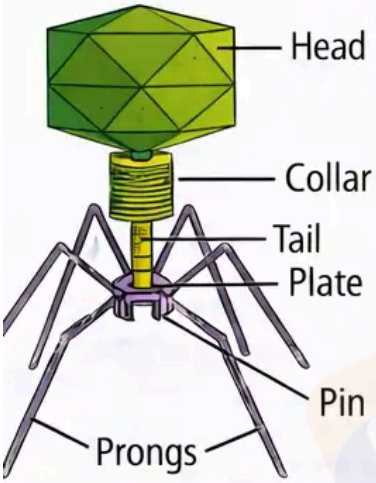


(b)

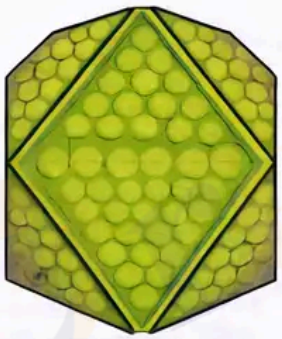



(c)

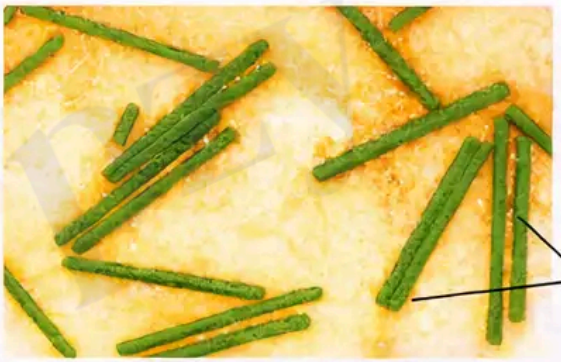
**Fig.:** Bacteria: (a) Rod-shaped, magnified 1500X; (b) Spherical-shaped, magnified 1500X; (c) A rod-shaped bacterium showing flagella, magnified 50,000X,




(a)

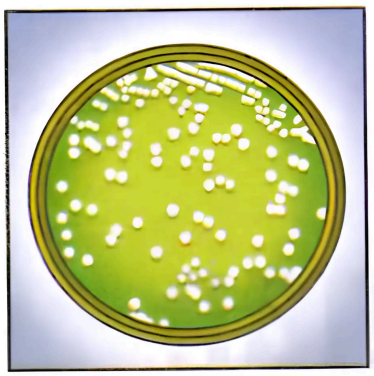


(b)

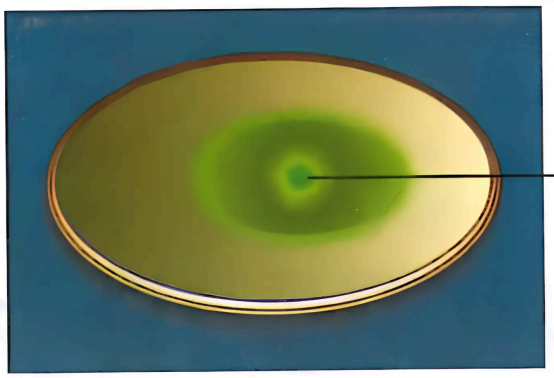



(c)

**ig.:** Viruses: (a) A bacteriophage: (b) Adenovirus which causes respiratory infections; (c) Rod-shaped Tobacco Mosaic Virus, magnified about 1,00,000—1,50,000X



(a)




(b)

**Fig.:** (a) Colonies of bacteria growing in a petri dish; (b) Fungal colony growing in a petri dish

### Memory Aids

- Microbes = tiny life forms everywhere, including extreme habitats.
- Bacteria = living cells; viruses = non-living infectious particles.
- Culture media help grow microbes visibly as colonies.

### Quick Checkpoints

- What environments do microbes inhabit?
- Which microbes are living cells and which are not?
- How are microbial colonies formed and observed?

## Microbes in Household Products

### Microbial Uses in Food

- Microbes or their products are used in daily foods: curd, cheese, bread, etc.
- Lactic acid bacteria (LAB) like *Lactobacillus* convert milk to curd by producing acids that coagulate and partially digest milk proteins.
- Curd is made by adding a small amount of starter (inoculum) containing LAB to fresh milk at suitable temperature.
- LAB increase vitamin B12 and inhibit harmful microbes in the gut.
- *Streptococcus thermophilus* and *Lactobacillus bulgaricus* make yogurt by curdling milk at 45°C for 4-6 hours.
- Buttermilk is made using *Lactobacillus bulgaricus* producing lactic acid and flavor compounds; butter is churned from soured cream.
- *Streptococcus cremoris* produces lactic acid rapidly; *Leuconostoc citrovorum* produces flavor compounds like diacetyl giving butter its aroma.
- Cheese is curd separated from whey; types depend on water content: soft (50-80%), semihard (45%), hard (<40%).
- Raw cheese is made by curdling milk with LAB.
- Unripened (cottage) cheese is made by inoculating skimmed milk with cultures and rennet enzyme; ripened cheese matures with bacteria/fungi for 1-16 months.
- Swiss cheese holes are from $CO_2$ by *Propionibacterium shermanii*; *Penicillium roqueforti* ripens Roquefort cheese; *Penicillium camemberti* ripens Camembert cheese.

- Dough for dosa, idli, and bread is fermented by bacteria and baker's yeast (*Saccharomyces cerevisiae*), producing $CO_2$ that puffs the dough.
- Traditional drinks like toddy are made by fermenting palm sap; microbes also ferment fish, soybean, bamboo shoots.
- Single cell protein (SCP) like *Spirulina*, yeast, *Fusarium graminearum* is microbial biomass used as food/feed, reducing pollution.
- Probiotics are live microbes taken orally to improve health by competing with pathogens and stimulating immunity; examples include *Lactobacilli* and *Streptococci*.

### Memory Aids

- LAB = key for dairy fermentation (curd, yogurt, butter).
- Cheese types depend on water and microbial ripening.
- Dough fermentation by yeast produces $CO_2$ for rising.
- Probiotics = friendly bacteria improving gut health.

### Quick Checkpoints

- Which bacteria are involved in curd and yogurt production?
- How is cheese classified based on water content?
- What role do microbes play in dough fermentation?
- What are probiotics and their benefits?

## Microbes in Industrial Products

### Fermented Beverages

- Yeast and some bacteria ferment carbohydrates into ethanol and carbon dioxide using enzyme Zymase.
- Equation: Glucose ($C_6H_{12}O_6$) → Ethanol ($C_2H_5OH$) + $CO_2$.
- Yeast species: *Saccharomyces cerevisiae* (brewer's yeast), *S. ellipsoideus* (wine yeast), *S. sake* (sake yeast), *S. pyriformis* (ginger beer yeast).
- Fermentation media vary: barley malt (beer), juniper berries malt (gin), rice (sake), cashew-apple (fenny), potato (vodka), corn/rye (whisky), molasses (rum), fruit juices (wine, brandy).

- Baker's yeast: selected *S. cerevisiae* strains for baking (flavour, texture).
- Brewer's yeast: used for alcoholic drinks.
- Alcoholic beverages: beer and wine (undistilled), whisky, rum, gin, brandy, vodka, fenny (distilled, hard liquors).
- Fermentation methods:
    - Batch culture: closed system, no nutrient addition after start.
    - Continuous culture: nutrients added continuously, overflow harvested.
    - Fed batch culture: nutrients added gradually to extend growth.

$$C_6H_{12}O_6 \xrightarrow{\text{Zymase}} 2C_2H_5OH + 2CO_2$$

## Memory Aids

- “Batch = Closed, no change.”
- “Continuous = Constant feed and harvest.”
- “Fed batch = Nutrients added slowly.”
- “Saccharomyces = Yeast for beer and bread.”

## Quick Checkpoints

- What enzyme catalyzes fermentation?
- Which yeast species are used for wine and beer?
- Difference between baker's and brewer's yeast?
- Types of fermentation culture methods?

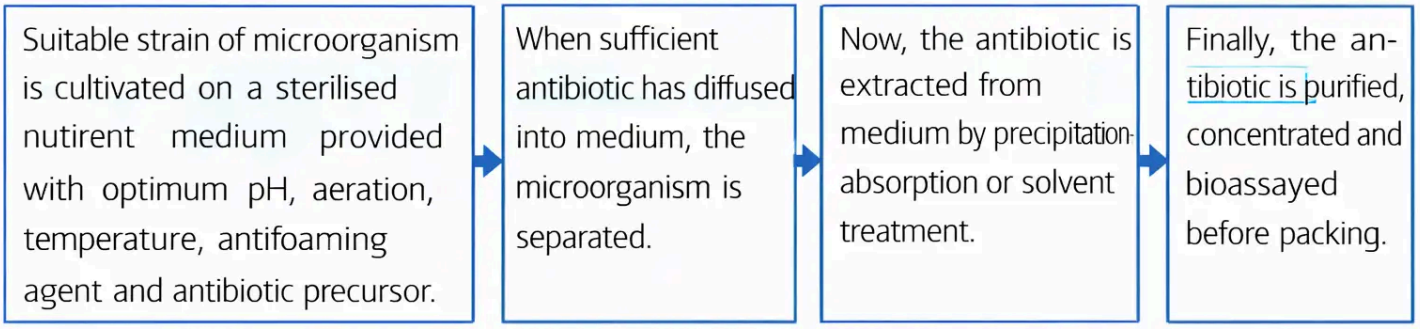
# Antibiotics

## Definition and Discovery

- Antibiotics: chemicals from microbes that kill or inhibit other microbes.
- “Anti” = against, “bio” = life; against disease-causing organisms but pro-life for humans.
- Penicillin: first antibiotic discovered by Alexander Fleming from *Penicillium notatum*.
- Commercial extraction by Ernst Chain and Howard Florey; Nobel Prize 1945.
- Used extensively in WWII for wounded soldiers.
- Other antibiotics followed for various infectious diseases.
- Effective against diseases like plague, whooping cough, leprosy, diphtheria.

## Production Process

- Microorganism grown in nutrient medium with controlled pH, temperature, air, anti-foaming agent, and precursors.
- After antibiotic production, microbes removed.
- Antibiotic extracted by precipitation, absorption, or solvent treatment.
- Purified, concentrated, tested, and packed.




## Characteristics of a Good Antibiotic

- Harmless to host, no side effects.
- Quick action.
- Destroys pathogens effectively.
- Harmless to normal gut microflora.
- Effective against all pathogen strains.

## Memory Aids

- “Penicillin from Penicillium.”
- “Good antibiotic: safe, fast, broad, and selective.”

## Quick Checkpoints

- Who discovered penicillin?

- What makes an antibiotic good?
- Steps in antibiotic production?
- Diseases treated by antibiotics?

## Chemicals, Enzymes and Other Bioactive Molecules

### Organic Acids

- Citric acid: produced by *Aspergillus niger* on carbohydrates; also by yeast *Candida lipolytica* under iron/manganese deficiency.
- Uses: medicines, dyeing, flavouring, food preservation.
- Acetic acid: from fermented alcohol by *Acetobacter aceti*; used in vinegar, pharmaceuticals, insecticides, plastics.
- Lactic acid: from fermentable carbs by *Lactobacillus bulgaricus* and *L. delbrueckii*.
- Butyric acid: from *Clostridium acetobutylicum*; found in rancid butter.
- First organic acid produced by microbes: lactic acid (Scheele, 1789).

### Enzymes

- Lipases from *Candida lipolytica* and *Geotrichum candidum*: remove oily stains in detergents.
- Pectinases from *Byssochlamys fulva*: used with proteases to clarify juices.
- Streptokinase from *Streptococcus*: clot buster enzyme, also called Tissue Plasminogen Activator (TPA).

### Bioactive Molecules

- Cyclosporin-A: from *Trichoderma polysporum*, an 11-membered cyclic oligopeptide; immunosuppressant in organ transplantation.
- Statin: from yeast *Monascus purpureus*; lowers blood cholesterol by inhibiting cholesterol synthesis enzyme.

### Memory Aids

- “Citric acid by Aspergillus, acetic by Acetobacter.”
- “Lipases clean oil, pectinases clear juice.”
- “Cyclosporin-A suppresses immunity.”
- “Statin lowers cholesterol.”

### Quick Checkpoints

- Which microbes produce citric and acetic acid?
- Uses of lipases and pectinases?
- Role of streptokinase?
- Function of cyclosporin-A and statin?

## Microbes in Sewage Treatment

### Process Overview

- Sewage contains human waste, organic matter, and pathogens.
- Must be treated before release to prevent water pollution and diseases.
- Treatment involves primary, secondary, and sometimes tertiary steps.

### Primary Treatment

- Removes floating and suspended solids by filtration and sedimentation.
- Coarse solids settle in grit chamber; finer solids settle in sedimentation tank.
- Settled solids form primary sludge; liquid above is effluent.
- Primary sludge is composted; effluent moves to secondary treatment.

### Secondary Treatment

- Biological process using microbes to degrade organic matter.
- Activated sludge system: aeration tanks mix effluent with air and microbes.

- Aerobic microbes form flocs—bacterial masses held by slime and fungal filaments.
- Microbes digest organics, reducing Biochemical Oxygen Demand (BOD) to 10-15% of raw sewage.
- Effluent passes to sedimentation tank; flocs settle as activated sludge.
- Part of activated sludge reused in aeration; rest sent to anaerobic sludge digester.
- Anaerobic microbes digest sludge, producing biogas ($CH_4$, $CO_2$, $H_2S$) usable as energy.

## Tertiary Treatment

- Removes nitrates and phosphates by precipitation.
- Expensive step producing water pure enough for drinking.

## Memory Aids

- Primary = Physical removal (filtration + sedimentation).
- Secondary = Biological digestion by activated sludge microbes.
- Tertiary = Chemical removal of nutrients (nitrates, phosphates).
- Activated sludge forms flocs = microbial mesh for organic breakdown.
- Biogas from anaerobic digestion = energy source.

## Quick Checkpoints

- What solids are removed in primary treatment?
- How do aerobic microbes reduce BOD?
- What is the role of activated sludge?
- Which gases form biogas in anaerobic digestion?
- What does tertiary treatment remove?

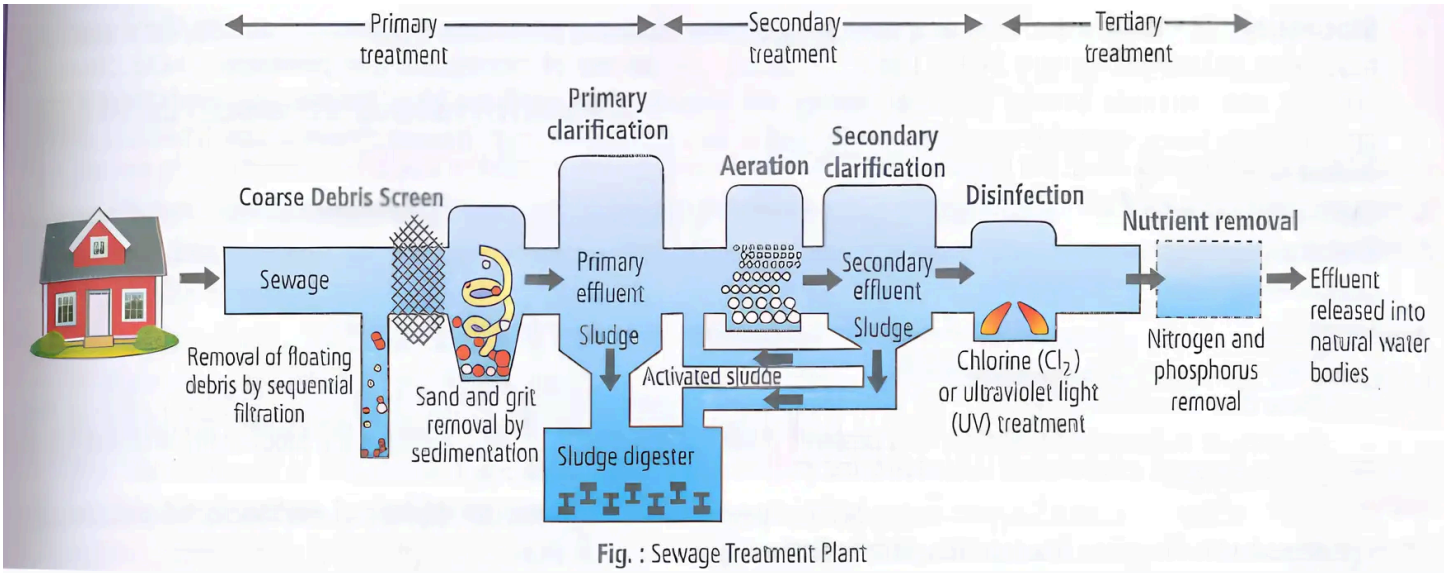



Fig. : Sewage Treatment Plant

# River Action Plan

## Background and Need

- Before 1985, most cities discharged untreated sewage into rivers.
- This caused river pollution and increased waterborne diseases.

## Government Initiatives

- Ministry of Environment and Forests started sewage treatment plant development.
- National River Conservation Authority oversees projects like Ganga Action Plan, Yamuna Action Plan, Sutlej Action Plan, Gomti Action Plan.
- Goal: Protect major Indian rivers from sewage pollution.

## Memory Aids

- GAP = Ganga Action Plan for river cleaning.
- Action plans target major rivers to reduce pollution.
- STPs reduce waterborne diseases by treating sewage.

### Quick Checkpoints

- Why was sewage treatment rare before 1985?
- What is the purpose of river action plans?
- Name some major river action plans in India.

## Microbes in Production of Biogas

### Biogas Composition and Microbial Role

- Biogas is methane-rich fuel produced by bacterial degradation of biological matter under anaerobic conditions.
- Composition: 50-70% methane (CH□94), 30-40% carbon dioxide (CO□92), 1-5% hydrogen (H□2), traces of oxygen (O□2), nitrogen (N□2), and hydrogen sulfide (H□2S).
- Methanogens are anaerobic bacteria that produce methane by breaking down cellulosic material; examples include *Methanobacterium* and *Methanococcus*.
- These bacteria are found in anaerobic sludge during sewage treatment and in the rumen of cattle.
- In the rumen, methanogens help digest cellulose, aiding cattle nutrition.
- Cattle dung (gobar) is rich in methanogens and used as raw material for biogas production (gobar gas).
- Slurry (cattle dung + water) is digested anaerobically at 34-48□0C, producing methane and carbon dioxide.
- Gas pressure builds up in the biogas plant, lifting the floating cover as biogas is produced.

## Biogas Plant and Process

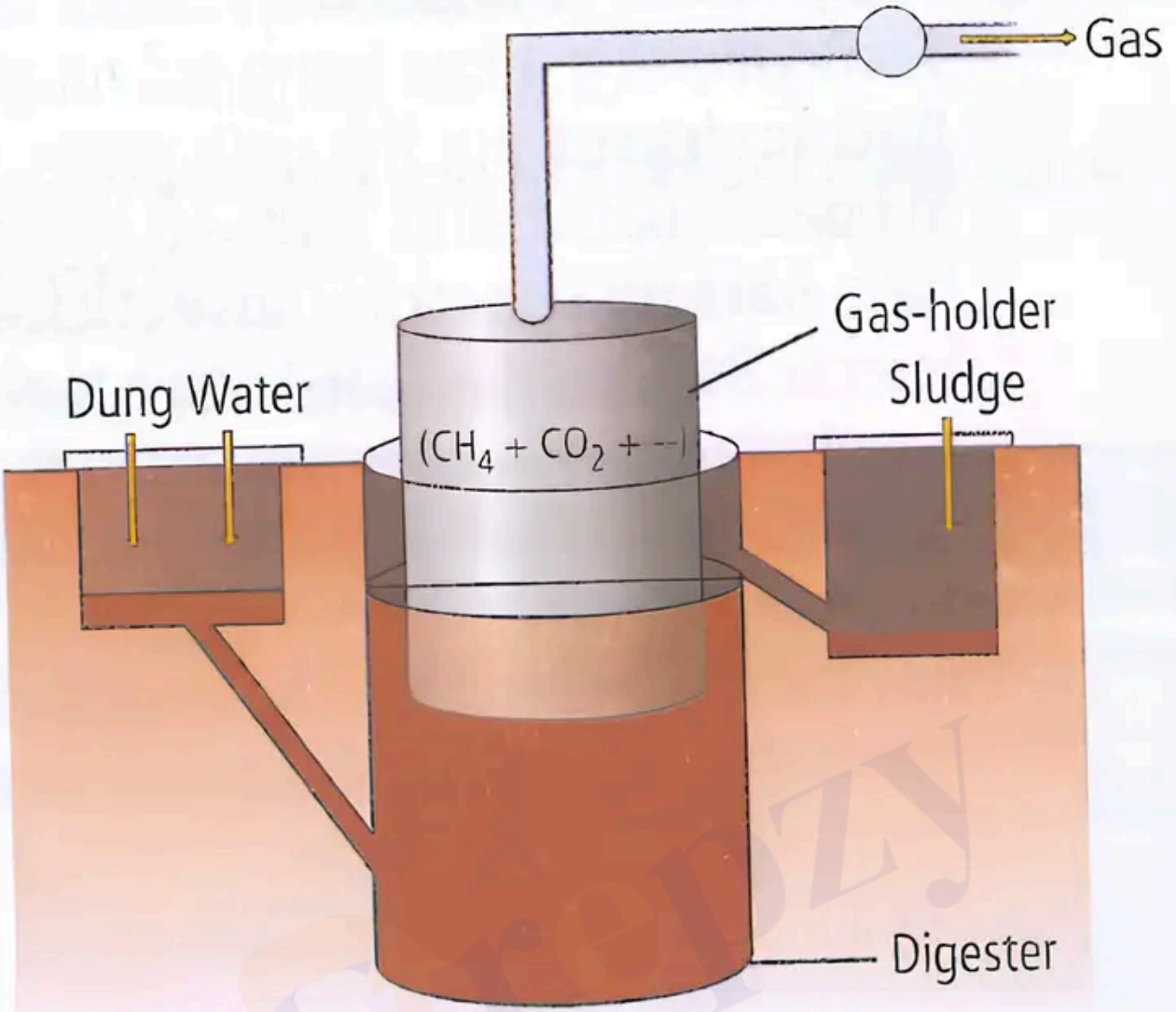
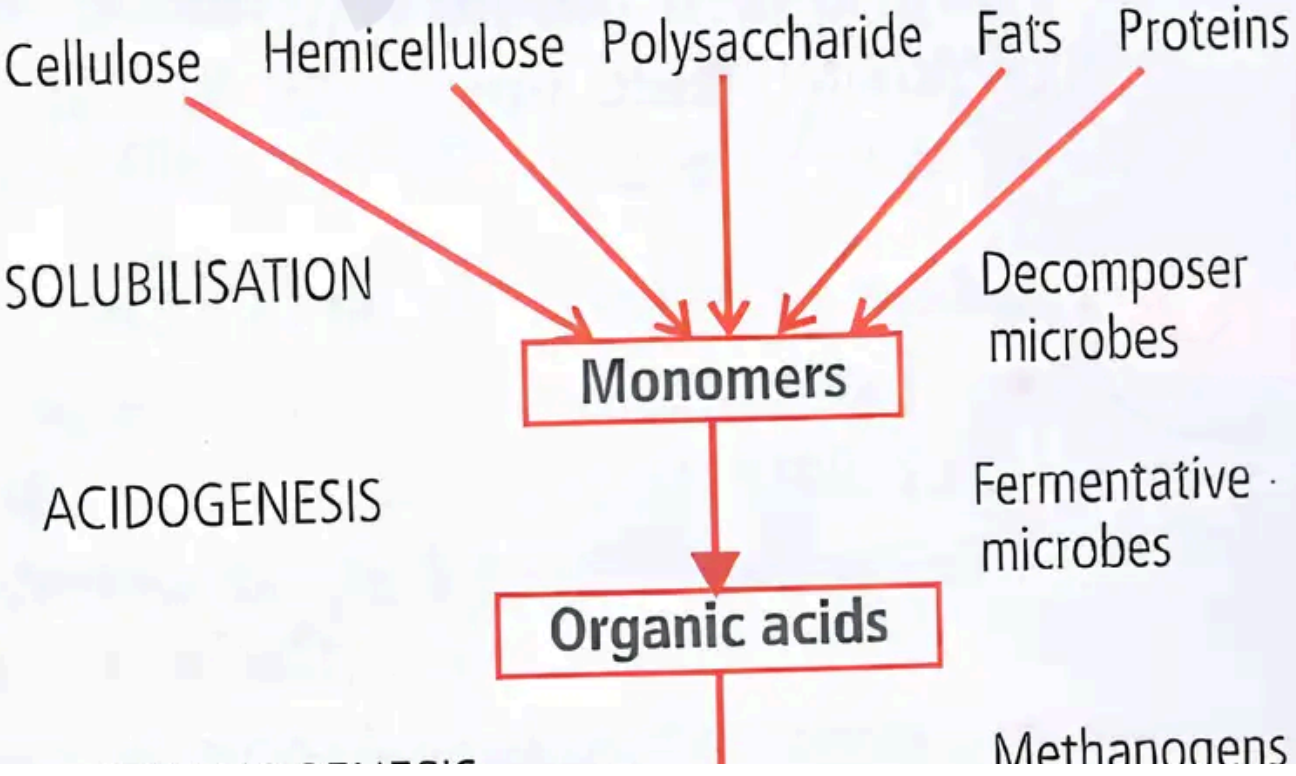



**Fig.:** A typical biogas plant



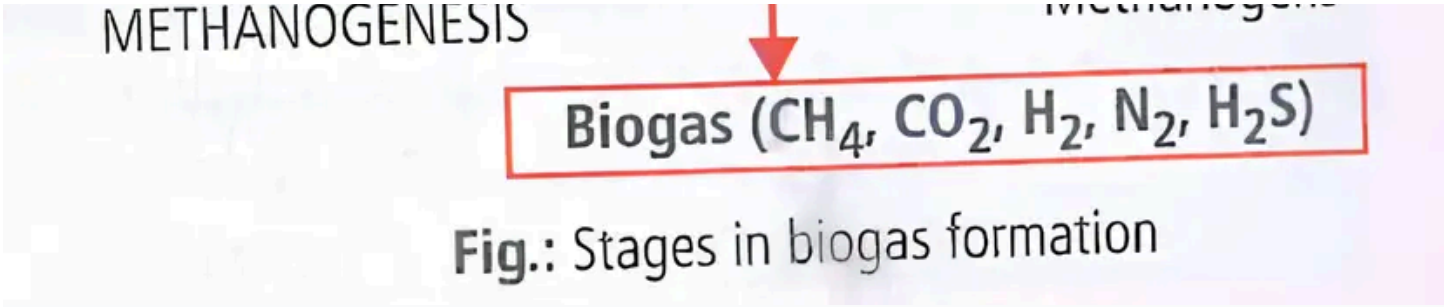



**Fig.:** Stages in biogas formation

- Organic materials (cellulose, hemicellulose, polysaccharides, fats, proteins) enter the digester.
- Solubilisation: decomposer microbes break complex materials into simpler monomers.
- Acidogenesis: fermentative microbes convert monomers into organic acids.
- Methanogenesis: methanogens convert organic acids into biogas (mainly CH□94, CO□92, H□2, N□2, H□2S).
- Biogas is collected in the gas-holder for fuel use; remaining sludge is used as fertilizer.
- Biogas plant outlets supply gas for cooking and lighting; spent slurry is used as manure.
- Biogas is eco-friendly and pollution-free energy.
- Technology developed in India by Indian Agricultural Research Institute (IARI) and Khadi and Village Industries Commission (KVIC).

## Memory Aids

- Methanogens = methane producers in anaerobic conditions.
- Gobar gas = biogas from cattle dung (gobar).
- Biogas stages: Solubilisation → Acidogenesis → Methanogenesis.
- Temperature 34-48□0C ideal for anaerobic digestion.

## Quick Checkpoints

- What microbes produce methane in biogas plants?
- Which substrates do methanogens act upon?
- What gases mainly compose biogas?
- Describe the stages of biogas formation.
- How is cattle dung used in biogas production?
- What is the role of the biogas plant's floating cover?
- Which Indian institutes contributed to biogas technology?

# Microbes as Biocontrol Agents

## Biocontrol Overview

- Biocontrol uses biological methods to manage pests and plant diseases.
- Chemical pesticides are toxic, harmful to humans, animals, and pollute soil and water.
- Biological control reduces chemical pesticide use, lowering environmental pollution.
- Biopesticides include bioherbicides and bioinsecticides, derived from living organisms.
- Biocontrol maintains pest populations at manageable levels, preserving beneficial insects and ecosystem stability.
- Biocontrol agents are non-persistent, non-toxic, and biodegradable.
- It follows a holistic approach to pest management.

## Memory Aids

- Biocontrol = Biological + Control of pests without chemicals.
- Bioinsecticides = Living organisms targeting insect pests.
- Bioherbicides = Living organisms controlling weeds.
- Non-toxic + biodegradable = Environment-friendly.

## Quick Checkpoints

- What are biopesticides?
- How does biocontrol maintain ecosystem stability?
- Why is biocontrol preferred over chemical pesticides?

# Examples of Biological Control

## Bioinsecticides and Agents

- Bioinsecticides include viruses, bacteria, and fungi that control insect pests.
- **Lady bird beetle** (*Coccinella*) controls aphids.
- **Dragonflies** (*Sympetrum*) control mosquitoes; called mosquito hawk.
- *Trichoderma* fungus controls several plant pathogens.

- **Baculoviruses** (e.g., Nucleopolyhedrovirus) infect and kill specific insect pests without harming non-target species.
- *Bacillus thuringiensis* produces insecticidal protein toxin **thurioside** and **cry protein** that kill insect larvae.
- Bt toxin gene introduced in cotton and tobacco for insect resistance.
- **Fungi-based bioinsecticides** like *Beauveria bassiana* control insect populations without affecting warm-blooded animals.

### Memory Aids

- Lady bird beetle = Aphid control.
- Dragonfly = Mosquito hawk.
- Bacillus thuringiensis = Bt toxin for insect larvae.
- Baculoviruses = Species-specific insect killers.
- Trichoderma = Soil fungus biocontrol.

### Quick Checkpoints

- Name a bioinsecticide fungus.
- What is the role of Bacillus thuringiensis?
- How do baculoviruses affect pests?

## Bioherbicides

### Weed Control Using Living Organisms

- Bioherbicides are living organisms that control weeds.
- First bioherbicide (1981) was a mycoherbicide from *Phytophthora palmivora* controlling milk weed vines.
- Cochineal insect (*Cactoblastis cactorum*) controls cactus overgrowth in India and Australia.
- Fungal spore products like **Devine** and **Collego** control weeds.
- Transgenic crops with herbicide resistance genes allow herbicide use without crop damage.

### Memory Aids

- Devine and Collego = Fungal bioherbicides.
- Cactoblastis cactorum = Cactus control insect.
- Mycoherbicide = Fungus-based herbicide.

### Quick Checkpoints

- What is a bioherbicide?
- Name an insect used for weed control.
- How do transgenic plants help in weed management?

## Other Biocontrol Agents

### Integrated Pest Management (IPM)

- IPM reduces agro-chemical pollution and improves crop productivity.
- Methods include pest starvation, cultural controls, crop rotation, and sanitation.
- Minimize synthetic pesticide use; promote biological control methods.
- Mixed cropping with target weeds attracts pests away from main crops.

### Memory Aids

- IPM = Combine multiple pest control methods.
- Starvation + cultural controls = Pest reduction.
- Mixed cropping = Pest diversion.

### Quick Checkpoints

- What are key methods in IPM?
- How does mixed cropping help pest management?
- Why minimize synthetic pesticide use in IPM?

# Microbes as Biofertilisers

## Sources and Roles

- Chemical fertilisers cause pollution; organic farming is preferred.
- Biofertilisers are organisms that enrich soil nutrients, especially nitrogen and phosphorus.
- Main biofertiliser sources: **bacteria**, **fungi**, and **cyanobacteria**.
- *Rhizobium* forms root nodules in legumes, fixing atmospheric nitrogen into usable forms.
- Free-living nitrogen-fixing bacteria: *Azospirillum*, *Azotobacter*.
- **Fungi** form mycorrhiza with plant roots, mainly *Glomus* species, aiding phosphorus absorption and enhancing growth and stress tolerance.
- **Cyanobacteria** (e.g., *Anabaena*, *Nostoc*, *Oscillatoria*) fix nitrogen and add organic matter, improving soil fertility.
- Biofertilisers are commercially available and reduce chemical fertiliser use.

**Table : Various biofertilisers and their nutrition/association with examples**

| | Biofertiliser | Nutrition/Association | Examples |
|---|---|---|---|
| (i) | Free-living nitrogen fixing bacteria | (a) Saprotrophic<br>(b) Photoautotrophic | *Azotobacter, Clostridium, Rhodospirillum, Chromatium* |
| (ii) | Free-living nitrogen fixing cyanobacteria | Photosynthetic | *Anabaena, Nostoc, Aulosira* |
| (iii) | Symbiotic nitrogen fixing bacteria | Mutual association with plants | *Rhizobium* |
| (iv) | Symbiotic nitrogen fixing cyanobacteria | Mutual association with many plants | *Anabaena* |
| (v) | Mycorrhiza | Symbiotic association of fungus with roots of higher plants. | *Glomus* |

## Memory Aids

- Biofertilisers = Bacteria + Fungi + Cyanobacteria.
- *Rhizobium* = Root nodules + Nitrogen fixation.
- Mycorrhiza = Fungi + Roots + Phosphorus uptake.
- Cyanobacteria = Nitrogen fixers + Photosynthetic microbes.
- Free-living nitrogen fixers = *Azotobacter*, *Azospirillum*.

### Quick Checkpoints

- What are biofertilisers and their main sources?
- How does *Rhizobium* benefit leguminous plants?
- Role of mycorrhiza in plant nutrition?
- Examples of free-living nitrogen-fixing bacteria?
- Why are cyanobacteria important in paddy fields?

## Importance of Biofertilisers

### Benefits

- Increase plant yield by 15-35%.
- Effective under semi-arid conditions.
- Improve soil texture and fertility.
- Suppress soil pathogens.
- Non-polluting and eco-friendly.
- Produce vitamins and growth-promoting biochemicals.

### Memory Aids

- Biofertilisers boost yield and soil health.
- Eco-friendly alternative to chemical fertilisers.
- Enhance plant resistance and growth.

### Quick Checkpoints

- How do biofertilisers improve plant yield?
- What soil conditions do biofertilisers tolerate?
- How do biofertilisers affect soil pathogens?
- What additional substances do biofertilisers produce?