

Microbes - An Introduction

Microbes = microscopic organisms only visible under a microscope. Include :

- ① Bacteria (prokaryotes) :
- ② Archaea (thermo / halophiles)
- ③ Fungi (yeasts, moulds)
- ④ Protozoa (amoebae, paramecium)
- ⑤ Microscopic algae (Chlamydomonas)
- ⑥ Viruses (not strictly cellular)
- ⑦ Viroids + Prions (sub-viral)

Where do Microbes Live?

Air, water, soil, gut, food, skin, hot springs, ice, deep sea, hospital surfaces - everywhere!

Beneficial vs Harmful

<5% of microbes cause disease.

Vast majority help us in food, medicine, agriculture, sewage, fuel, environment.

Indian Foods using Microbes

Curd, idli, dosa, dhokla, kheer, *paneer, butter, bread, ~~pickles~~ toddy, vinegar, soya sauce, kimchi.

Indian curd - Lactobacillus acidophilus.

Household Products (Curd, Bread, Cheese)

Curd = Fermented Milk

Lactic acid bacteria (LAB) - Lactobacillus

Ferment lactose (milk sugar) \rightarrow LACTIC ACID

\rightarrow coagulates milk proteins (casein) \rightarrow curd.

LAB also improves nutrition by producing :

Vit B12 + Vit K + beneficial for gut flora.

Idli, Dosa, Dhokla, Bhature, Naan

Fermented batter - bacteria + yeast.

CO₂ produced gives spongy / fluffy texture.

Bread

Yeast - *Saccharomyces cerevisiae*

Ferments sugar in dough \rightarrow CO₂ + Ethanol

CO₂ \rightarrow dough rises ; ethanol evaporates in baking.

Cheese

(a) Swiss cheese - *Propionibacterium shermanii*

produces CO₂ \rightarrow large 'eye' holes.

(b) Roquefort cheese - *Penicillium roqueforti*

\rightarrow blue veins, distinctive flavour.

Toddy + Alcoholic Beverages

Sap of palm fermented by yeast \rightarrow mild alcohol.

Industrial Products - Antibiotics

Antibiotics

Substances produced by some microbes that kill / retard growth of other (disease-causing) microbes.

First antibiotic - ~~Streptomycin~~ **PENICILLIN** by Alexander from *Penicillium notatum* on a Petri dish.

Mass produced by Ernst Chain + Howard Florey (Nobel 1945 with Fleming).

Common Antibiotics & Sources

Antibiotic	Microbial Source
Penicillin	<i>Penicillium notatum</i> / <i>chrysogenum</i>
Streptomycin	<i>Streptomyces griseus</i>
Tetracycline	<i>S. aureofaciens</i>
Chloramphenicol	<i>S. venezuelae</i>
Erythromycin	<i>S. erythreus</i>
Bacitracin	<i>Bacillus subtilis</i>
Cyclosporin-A	<i>Trichoderma polysporum</i> (immunosuppressant)
Statins	<i>Monascus purpureus</i> (cholesterol)

Antibiotic Resistance

Overuse / misuse → resistant strains evolve (MRSA, MDM-1)

Use antibiotics only as prescribed by doctor.

Other Fermentation Products

Product	Microbe	Use
Citric acid	<i>Aspergillus niger</i>	Food acidulant
Acetic acid	<i>Acetobacter aceti</i>	Vinegar
Butyric acid	<i>Clostridium butylicum</i>	Solvents, oils
Lactic acid	<i>Lactobacillus</i>	Preservative, plastics
Ethanol	<i>Saccharomyces cerevisiae</i>	Biofuel, drinks
Glycerol	Yeast	Cosmetics, explosives
Vit B12	<i>Pseudomonas denitrificans</i>	Supplement
Vit B2	<i>Eremothecium ashbyii</i>	Supplement
Single Cell Protein	<i>Spirulina, Methylophilus</i>	Food / Fodder
Streptokinase	<i>Streptococcus</i>	Clot buster (thrombolytic)

Bio-active Drugs

Statins → lower cholesterol (*Monascus*)

Cyclosporin-A → immunosuppressant for transplants

Streptokinase → dissolves clots in heart attack

Enzymes from Microbes

Lipase (oil stains), Pectinase (juice clarification),

Amylase + Protease (detergents), Renin (cheese),

Cellulase, Lipase, Pectinase - industrial uses.

Sewage Treatment Plant

Sewage - municipal waste water (organic + pathogens).

Cannot be released directly into rivers.

STPs treat sewage - use microbes to break down organic

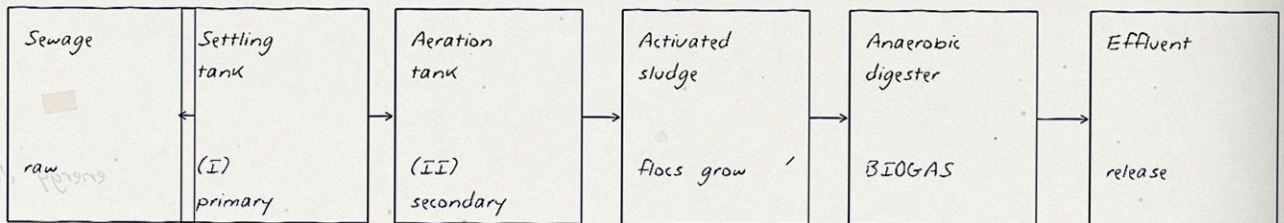


Fig. Activated sludge process

Two Stages

Primary - physical removal of solids by settling

Secondary - biological breakdown via :

(a) Aerobic flocs (bacteria + fungi) - consume BOD

(b) Anaerobic digester - methanogens produce CH_4 + CO_2

BOD Decrease

Effluent released ONLY after BOD falls significantly.

BOD & Activated Sludge

BOD - Biological Oxygen Demand

Amount of dissolved O₂ consumed by microbes in 5 days at 20 deg C while breaking down organic matter.

Units - mg O₂ / L of water

Higher BOD = more organic pollution.

Sample	BOD (mg/L)
Pure stream	1-2
Domestic sewage (raw)	100-400
Industrial waste	> 5000
Treated effluent	< 20 (safe to release)

Activated Sludge

Microbial flocs that develop in aeration tank.

Part of these flocs (10%) is used as IMOCULUM for next batch of sewage.

Rest goes to anaerobic digester.

Gout Action Plans

Ganga Action Plan (1985) - clean Ganga river.

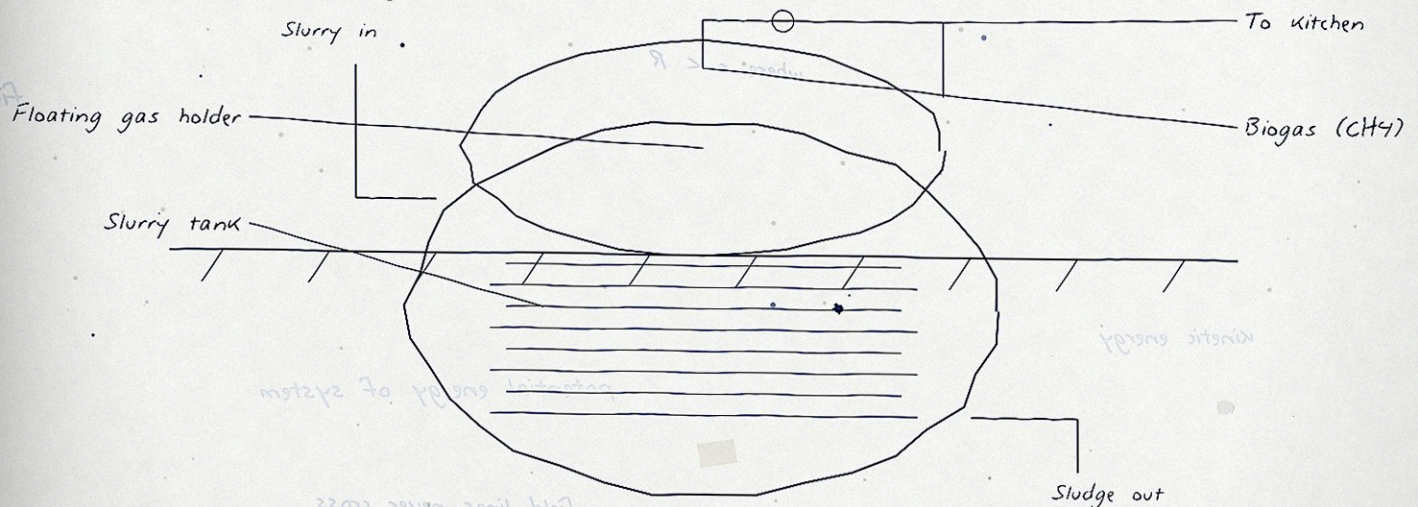
Yamuna Action Plan, Namami Gange (2014).

MoEFCC monitors STPs across India.

Biogas Plant (Gobar Gas)

Biogas - CH_4 (75%) + CO_2 + H_2 + H_2S
Produced by methanogens (anaerobic bacteria)

Eg. Methanobacterium ; thrives on cow dung +
sludge from STP digesters.



Built by

IARI (Indian Agricultural Research Institute)

KVIC (Khadi + Village Industries Commission)

Uses

Biocontrol Agents

Use of biological methods (microbes / animals) instead of toxic chemicals to control pests + weeds.
Eco-friendly, no chemical residue.

Agent

Bacillus thuringiensis (Bt)
Trichoderma sp.
Baculoviruses (NPV)
Ladybird beetle
Dragonfly
Gambusia fish
Cactus moth

Target

Butterfly caterpillar, cotton bollworm
Fungal pathogens in plant roots
Insects + arthropods - very specific
Aphids
Mosquito larvae
Mosquito larvae (anti-malaria)
Prickly pear control

Bt - Spray Form

Bt spores + toxin crystals dried + powdered.

Sprayed on crops; insects eat \rightarrow toxin activates in their alkaline gut \rightarrow ~~survives~~ dies of gut perforation.

Safe for humans + other animals (acidic stomach).

Organic Farming

No chemicals; uses biofertilisers + biocontrol + crop rotation + composting.

Sikkim - 1st 100% organic state in India (2016).

Biofertilisers

Microbes that enrich soil nutrient content, improving fertility **WITHOUT** chemicals.

N₂-Fixing Bacteria

- ① Symbiotic - Rhizobium (in legume root nodules)
- ② Free-living - Azotobacter, Azospirillum, Beijerinckia
- ③ Cyanobacteria - Anabaena, Nostoc, Oscillatoria
Eg. rice paddies become enriched naturally.

- ④ Frankia (actinomycete, in non-legume Casuarina roots)
- ⑤ Azolla-Anabaena (water fern + symbiont; rice)

Mycorrhiza - Fungal Partners

Symbiotic association between fungi (Glomus) and plant roots. Two types :

ECTO-mycorrhiza - outside the root cells

ENDO-mycorrhiza (VAM) - inside* root cells

Fungi help plant absorb P, N, water, resist drought.

Plant supplies sugars to fungi.

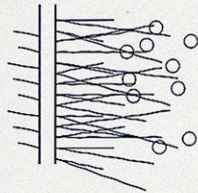
Other Biofertilisers

Bacillus polymyxa - K solubiliser

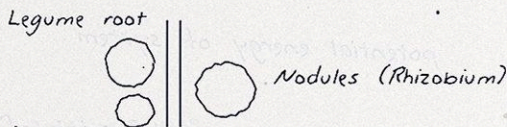
Pseudomonas - PGPR (plant growth promoting rhizobacteria)

Compost from earthworms + microbes (vermicompost).

Root Nodule + Mycorrhiza Diagram



Mycorrhizal Root + hyphae



Module Formation

Rhizobium enters root via infection thread.

Forms nodule \rightarrow bacteria turn into BACTEROIDS.

Bacteroids fix atmospheric N_2 \rightarrow NH_3 \rightarrow NH_4^+ .

Leghaemoglobin - pink protein, scavenges O_2 .

Nitrogenase enzyme - ~~aerobic~~ strictly anaerobic..

Benefits

Single Cell Protein (SCP)

Edible PROTEIN biomass produced from microbes.

Used as food / animal feed supplement.

Alternative protein source amid food shortages.

Producing Organisms *

Spirulina (cyanobacterium)

Chlorella (algae)

Saccharomyces cerevisiae

Methylophilus methylotrophus

Fusarium graminearum

Candida utilis

Easy growth on waste H₂O

Used since 1950s

Brewer's yeast

Methylotrophic bacteria

Mycoprotein - Quorn

Torula yeast

Advantages

(a) High protein content (60-80% dry weight)

(b) Grows quickly (doubling 1-3 hrs)

(c) Uses cheap substrates (CO₂, methanol, waste)

(d) Rich in essential aa + vitamins

(e) Small land footprint

Computation *

Methylophilus - high productivity ; 250 g

produces ~~250 kg~~ 25 tonnes protein in 24 hrs vs cow 200

from 250 kg body weight!

Microbes in Manufacturing

Beverages

Wine, beer, whisky, rum - *Saccharomyces cerevisiae*

Distillation gives high-alcohol drinks (whisky, vodka).

Brewing - cereals fermented; barley + hops → beer.

Vinegar

Acetobacter aceti converts ethanol → acetic acid (CH_3COOH).

Pickles + Sauces

Lactobacillus + other LAB fermentation.

Eg. kimchi, sauerkraut, soya sauce, gondhoraj pickle.

Enzymes from Microbes

Lipase	Detergents, oil stains
Pectinase	Juice clarification, fibre
Protease	Detergents, meat tenderiser, cheese
Amylase	Bread; starch digestion
Cellulase	Paper + textile
Streptokinase	Anti-clotting agent (<i>Streptococcus</i>)
Renin	Cheese making (replaces calf rennet)

Microbial Mining

Bioremediation

Use of microbes / plants to clean pollutants from soil, water, air.

Oil Spills

Pseudomonas putida - superbug to degrade hydrocarbons.

Ananda Chakrabarty (Indian American) - 1st patented GMO ; used to clean Exxon Valdez oil spill (1989).

Heavy Metal Removal

Some microbes (*Thiobacillus*, sulfate-reducing bacteria) remove arsenic, mercury, lead from polluted water.

Phytoremediation

Plants absorb pollutants from soil \rightarrow ATP / biomass.

Eg. Sunflower removes uranium ; Brassica - Cd, Pb.

Composting

Aerobic decomposition of organic waste by fungi + bacteria \rightarrow nutrient-rich compost.

Vermicomposting (*Eisenia fetida*) - earthworm based.

Bio-degradation of Plastic

Ideonella sakaiensis - bacterium that ~~eats~~ digests PET pla.

Wax moth larvae - digest polyethylene.

Microbes in Energy

Bioethanol

Sacch. cerevisiae ferments sugar / starch \rightarrow ethanol (C_2H_5OH).

Used as biofuel (E10, E85 blends).

India - sugar industry + Mission Bioethanol 20%.

Biogas Recap

Methanogens - e.g. *Methanobacterium*

Anaerobic digestion of cow dung / sludge \rightarrow CH_4 .

Used for cooking, lighting, electricity in villages.

Biodiesel

Made from vegetable oils (*Jatropha*, soybean)

OR microbial oils - *Yarrowia lipolytica*, microalgae.

Microbial Fuel Cells

Bacteria oxidise organic matter \rightarrow electrons captured as electricity. Used in remote sensors.

Hydrogen from Algae

Chlamydomonas reinhardtii produces H_2 in low S.

Potential clean fuel.

Renewable energy through microbes - bright future!

Drinking Water Treatment

Steps

- ① Screening (remove large debris)
- ② Sedimentation (particles settle)
- ③ Coagulation + flocculation (alum)
- ④ Filtration (sand + activated charcoal)
- ⑤ Disinfection (chlorination, UV, ozone)

Chlorination

Cl_2 reacts with H_2O ^{*} $\rightarrow \text{HOCl} + \text{Cl}^-$

Hypochlorous acid kills bacteria + viruses.

Effective + cheap, but ~~can~~ can form THM by-products.

Indicator Organisms

E. coli (coliform) \rightarrow presence indicates fecal contamination.

MPN (Most Probable Number) test for E. coli.

WHO Standards

Zero coliform / 100 ml - drinking water safe.

Turbidity < 1 NTU, pH 6.5-8.5.

Boiling at Home

100 deg C for ≥ 1 min kills most pathogens.

Iodine + Chlorine Tablets

Microbial Diversity

Where Microbes Live (Extremes)

- Halophiles - high salt (Dead Sea, Sambhar)
- Thermophiles - hot springs (60-110 deg C)
- Psychrophiles - arctic / antarctic ice (-15 deg C)
- Acidophiles - pH < 3 (sulfuric acid pools)
- Alkaliphiles - pH > 9 (soda lakes)
- Barophiles - ocean depths (high pressure)
- Radioresistant - Deinococcus (5 kGy gamma?)

Indian Examples

- Tattapani (HP), Manikaran (HP) hot springs
- Lonar lake (Maharashtra) - alkaline
- Sambhar lake (Rajasthan) - hypersaline

Microbes in Space

Some bacteria survive in space vacuum + cosmic rays.
Used in panspermia hypothesis research.

Microbiome

Trillions of microbes living. IN us (mostly gut).
Roles - digestion, immunity, mood, vitamins.
Imbalance (dysbiosis) -> obesity, colitis, autism.

Probiotics

Microbial Pollution

Air Pollution

Spore-forming bacteria + fungi suspended in air.

Cause Resp. infections, allergies, sick-building syndrome.

Hospitals (HAI) - ~~safest~~ high microbial load → Pseudomonas

Water Pollution

Fecal contamination - E. coli, Vibrio, Salmonella.

Causes - cholera, typhoid, diarrhoea, jaundice.

Food Spoilage Microbes

Aspergillus flavus
Clostridium botulinum
Salmonella
Listeria
E. coli O157:H7

Aflatoxin in maize / nuts
Botulism (canned food)
Food poisoning
Cheese, deli meats
Severe diarrhoea, kidney

Food Preservation

Refrigeration, drying, salting, pickling, smoking,
canning (heat), pasteurisation (63 deg C, 30 min)
or 72 deg C, 15 sec) - milk safety.

UHT - 135 deg C, 1-2 sec.

Genetic Modification of Microbes

Microbes engineered for various uses.

Examples

E. coli + human insulin gene

E. coli + somatostatin

Yeast + Hep-B surface gene

E. coli + clotting factors

Pseudomonas + oil-degrading genes

Bacillus thuringiensis + cry gene

Humulin (Eli Lilly)

Growth hormone

Hepatitis-B vaccine

Haemophilia treatment

Cleanup of spills

Bt cotton, brinjal

Patenting & Bio-piracy

*Chakrabarty's Pseudomonas - 1st patented life form (1981).

Patents on basmati, turmeric, neem - contested by India.

Cas9 + CRISPR in Microbes

Naturally found in bacteria as defence against viruses.

Now used for precise gene editing in all organisms.

Risks

(a) Escape of GM microbes into environment

(b) Unforeseen ecological effects

(c) Patent / ownership concerns

(d) Bioterrorism potential

Microbe Glossary

Microbe	- microscopic organism
Prokaryote	- no nucleus (bacteria, archaea)
Yeast	- unicellular fungus
Mould	- filamentous fungus
Spore	- reproductive / resting cell
Methanogen	- produces CH ₄ anaerobically
LAB	- lactic acid bacteria (Lactobacillus)
Sporopollenin	- tough exine material
BOD	- biological oxygen demand (mg/L)
COD	- chemical oxygen demand
Floc	- microbial clump in sludge
Inoculum	- starter culture
Sterile	- free of microbes
Pathogen	- disease causer
Probiotic	- beneficial live microbe
Prebiotic	- food for probiotics
Symbiont	- partner in symbiosis
Antibiotic	- kills bacteria
Hybridoma	- fused antibody-producing cell
Bioremediation	- microbial cleanup

Recap & Key Microbes

Lactobacillus
Sacch. cerevisiae
Propionibacterium shermanii
Penicillium roqueforti
Penicillium notatum/chrysogenum
Streptomyces griseus
Aspergillus niger
Acetobacter aceti
Clostridium butylicum
Trichoderma polysporum
Monascus purpureus
Methanobacterium
Rhizobium
Azotobacter
Anabaena, Nostoc
Glomus (mycorrhiza)
Bacillus thuringiensis (Bt)
Trichoderma
Baculovirus (NPV)
Spirulina

Curd, idli, yoghurt
Bread, alcohol, biofuel
Swiss cheese
Roquefort cheese
Penicillin
Streptomycin
Citric acid
Vinegar
Butyric acid
Cyclosporin
Statins
Biogas
N₂ fixation in legumes
Free-living N₂ fixer
Cyano N₂ fixer
P uptake
Bollworm biocontrol
Anti-fungal biocontrol
Insect biocontrol
SCP (food)