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Microbial Degradation of the Non-Degradable (Xenobiotic) Compounds in the Environment

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A compound that is foreign in nature to biological systems is known as xenobiotic compound. Xenobiotics are chemical found but not produced in organisms or the environment. Some naturally occurring chemicals (endobiotics) become xenobiotics when present in the environment at excessive concentrations. A xenobiotic is a chemical substance found within an organism that is not naturally produced or expected to be present within the organism. It can also cover substances that are present in much higher concentrations than are usual. Natural compounds can also become xenobiotics if they are taken up by another organism, such as the uptake of natural human hormones by fish found downstream of sewage treatment plant outfalls, or the chemical defenses produced by some organisms as protection against predators (Mansuy, 2013). Microbial degradation in mitigating xenobiotic pollution most such compounds cannot be readily degraded, and have harmful effects on human beings and the natural ecosystem.

Types of Xenobiotic Compounds

1. Pesticides
2. Pharmaceuticals
3. Industrial chemicals
4. Hydrocarbons
5. Food additives
6. Drugs
7. Antioxidants

Fundamentals of microbial degradation

Microbial diversity: Microbial degradation involves a wide range of microorganisms , including **bacteria** , **fungi** , and even some **archaea** , each with unique capabilitiesto break down various organic compounds .

Enzymatic activity : Microbes produce specialized enzymes that catalyze the degradation of complex organic molecules into simpler compounds. These enzymes play a crucial role in the breakdown of substrates.

Substrate Specificity : Microbes exhibit substrate specificity, meaning they are specialized in degrading particular types of organic materials. Different microbes are responsible for breaking down carbohydrates, lipids, proteins, and other organic compounds.

Metabolic pathways : Microbial degradation often involves intricate metabolic pathways where the initial substrate is progressively transformed into intermediates and ultimately into simpler end products . These pathways are highly regulated.

Environmental factors : Various environmental factors , such as temperature , pH , oxygen, availability, and nutrient levels, significantly influence microbial degradation. These conditions impact their degradation capabilities.

These principles underline the complex process of microbial degradation, which plays a crucial role in recycling organic matter and maintaining ecological balance.

Although the body is able to remove xenobiotics by reducing it to a less toxic form through xenobiotic metabolism then excreting it, it is also possible for it to be converted into a more toxic form in some cases. This process is referred to as bioactivation and can result in structural and functional changes to the microbiota (Park et al., 2011).

Exposure to xenobiotics can disrupt the microbiome community structure, either by increasing or decreasing the size of certain bacterial populations depending on the substance. Functional changes that result vary depending on the substance and can include increased expression in genes involved in stress response and antibiotic resistance, changes in the levels of metabolites produced, etc (Lu Kun et al., 2015).

What are the advantages and disadvantages of microbial degradation ?

ADVANTAGES	DISADVANTAGES
Relatively low cost	Longer remediation times
Easily implemented and maintained	Climate dependent
Severalmechanisms for removal	Effects to food web might be unknown
Environmentally friendly	Ultimately contaminant fates might be unknown

Wastewater treatment plants are often not effective enough at removing xenobiotics from wastewater, causing xenobiotics to enter public sewers and into the food chain, directly affecting humans (Karthigadevi *et al*., 2021) and contributing toward polluting water bodies with micropollutants (Gabet-Giraud *et al*., 2010

Biodegradation pathways of xenobiotic compounds

1. Aerobic biodegradations -

Xenobiotic compound + O_2 → CO_2 + H_2O + Biomass + residue

2 . Anerobic biodegradations -

Xenobiotic compound → CO_2 + CH_4 +H_2O+biomass+ residue

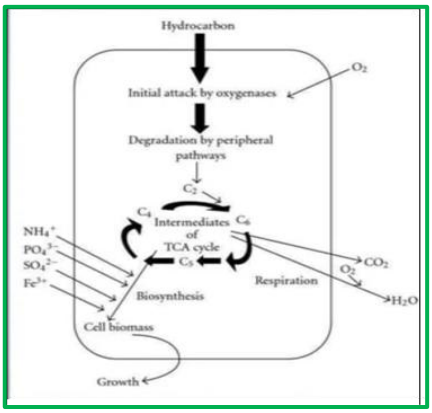
Aerobic and anaerobic xenobiotics degradations Bacteria	
Aerobic bacteria	**Anaerobic bacteria**
Pseudomonas	*Pelatomaculum*
Gordonia	*Desulphovibrio*
Bacillus	*Methanospirillum*
Moraxella	
Micrococcus	

Source of Xenobiotics

Chemical and pharmaceutical industrial - Produce a wide array of xenobiotics and synthetic polymerase**.** Pulp and paper bleaching - Natural and man made chlorinated organic compound in environment**.**

Mining-Which release heavy metals into biochemical cycle Fossil fuels - Coal and petroleum.

Intensive Agriculture that releases massive amount of fertilizer, pesticides and herbicides .

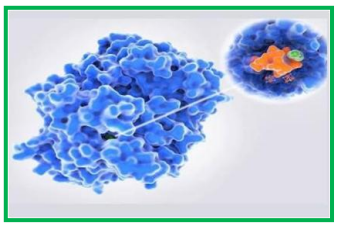


Mode of Action

Microbial Degradation of Xenobiotic Compounds

Microorganisms has the capability of degrading all naturally occurring compounds. This known as the principle of microbial infallibility. Microorganisms play a major role in degradation of xenobiotics . Most of the microorganisms, particularly bacteria are known for detoxifying abilities .

Microbial Enzymes involved in biodegration of petroleum hydrocarbons and pesticides



Microbial Oxidoreductases: Oxidoreductases detoxify toxic xenobiotics like phenolic or anilinic components,either by polymerization, copolymerization.

Microbial Oxygenases: Oxygenases classified under the oxidoreductase group of enzymes . Oxidation reaction is the major enzymatic reaction of aerobic biodegradation is catalyzed by oxygenases .

Phosphotriesterases: PTEs are microbial isolated enzyme which hydrolyze and detoxify organophosphatepesticides (OPs).

Factors Influencing Pesticides Degradation

The Environment

- pH , temperature and salinity
- Nutrient availability
- Light quality and intensity
- Available water
- Binding to surfaces

The molecule

- Solubility in water
- Chemical structure , molecule weight
- Concentrations and solubility

Application of Microbial Degradation of Xenobiotics

1. **Bioremediation** : Microbial degradation is used to clean up polluted environments by breaking down hazardous xenobiotics , such as oil spills and chemical waste .
2. **Wastewater Treatment :** Microbes are employed to treat industrial and municipal wastewater , removing pollutants and xenobiotics from the water .
3. **Pharamaceutical Industry :** Microbes are used to biodegrade pharamaceutical by products and contaminants , reducing environmental pollution .
4. **Agriculture :** Microbes can break down pesticides and herbicides , reducing their persistence in soil and preventing harm to ecosystems .
5. **Biofuel Production :** Microbes are used to break down lignocellulosic biomass into biofuels , such as bioethanol , from plant materials .
6. **Food Industry :** Beneficial microbes can metabolize food contaminants , improving food safety and shelf life .
7. **Oil Spill Cleanup :** Certain oil-degrading microbes can be used to mitigate the environmental impact of oil spills in marine ecosystems .
8. **Biodegradable Plastics :** Microbes can degrade xenobiotic plastics , promoting the development of environmentally friendly biodegradable material .
9. **Dioxin Degradation :** Microbes have studied for their ability to break down persistent organic pollutants like dioxins and furans .

10. **Bioremediation of Mining Sites :** Microbial consortia are applied to remediate sites contaminated with heavy metals , like arsenic and lead , often as a result of mining activities .

Degradation of Pesticides

- The pesticides belong to category of chemicals that are used worldwide as **herbicides, insecticides , fungicides , rodenticides ,** and **plant growth regulators** in order to control weeds, pests and diseases in crops as well as for health care of humans and animals .
- The use of pesticides for pest control has been widely used in Agriculture. However, the indiscriminate use of pesticides has inflicted serious harm and problems to humans as well as to the biodiversity (de Oliveira et al., 2020).

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