"Realization of Hungarian-Romanian R&D Laboratory for the Development of Major Projects in Polluted Terrain Cleaning"
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BIOREMEDIATION – CHALLENGE OR NECESITY?

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Two countries, one goal, joint success!

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OUTLINE

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1. Bioremediation and Metabolism

Bioremediation involves chemical transformations mediated by microorganisms that satisfy nutritional requirements, satisfy energy requirements and detoxify the immediate environment.

Microorganisms are used for ***in-situ* microbial biodegradation or bioremediation** of domestic, agricultural and industrial wastes and subsurface pollution in soils, sediments and marine environments.

The ability of each microorganism to degrade toxic waste depends on the nature of each contaminant. Since most sites typically have multiple pollutant types, the most effective approach to microbial biodegradation is to use a mixture of bacterial species and strains, each specific to the biodegradation of one or more types of contaminants.

It is vital to monitor the composition of the indigenous and added bacteria in order to evaluate the activity level and to permit modifications of the nutrients and other conditions for optimizing the bioremediation process.

Interest in the **microbial biodegradation and bioremediation** of pollutants has intensified in recent years as humanity strives to find sustainable ways to clean up contaminated environments.

These bioremediation and biotransformation methods endeavour to harness the astonishing, naturally occurring ability of microbial xenobiotic metabolism to degrade, transform or accumulate a huge range of compounds including **hydrocarbons** (e.g. oil), **polychlorinated biphenyls** (PCBs), **polyaromatic hydrocarbons** (PAHs), **heterocyclic compounds** (such as pyridine or quinoline), **pharmaceutical substances**, **radionuclides** and **metals**.

Major methodological breakthroughs in recent years have enabled detailed genomic, metagenomic, proteomic, bioinformatic and other high-throughput analyses of environmentally relevant microorganisms providing unprecedented insights into key biodegradative pathways and the ability of organisms to adapt to changing environmental conditions.

Petroleum oil contains aromatic compounds that are toxic for most life forms. Episodic and chronic pollution of the environment by oil causes major ecological perturbations. Marine environments are especially vulnerable. In addition to pollution through human activities, about 250 million liters of petroleum enter the marine environment every year from natural seepages.

Despite its toxicity, a considerable fraction of petroleum oil entering marine systems is eliminated by the hydrocarbon-degrading activities of microbial communities, in particular by a remarkable recently discovered group of specialists, the so-called **hydrocarbonoclastic bacteria** (HCB).

Alcanivorax borkumensis was the first HCB to have its genome sequenced. In addition to hydrocarbons, crude oil often contains various heterocyclic compounds, such as pyridine, which appear to be degraded by similar, though separate mechanisms than hydrocarbons.

Bioremediation is also widely used in agriculture, for preparing soil and controlling livestock waste. It can effectively break down **chlorinated pesticides, dioxin and ammoniated hydrocarbons.**

Bioremediation can purify **ground water**, clean the **air,** prevent the off-gassing of Volatile Organic Chemicals (VOCs), and even accelerate the half life of **radioactive compounds**!

For this reason, it will likely be widely used in Japan as the country recovers from the devastating earthquake and subsequent nuclear meltdown.

Other examples of bioremediation include **bioventing, bioreactor, composting, bioaugmentation and biostimulation.**

Bioremediation may be used to break down **heavy metals** such as **arsenic, lead, and mercury.**

Microorganisms used to perform the function of bioremediation are known as **bioremediators**.

Not all contaminants, however, are easily treated by bioremediation using microorganisms. For example, heavy metals such as cadmium and lead are not readily absorbed or captured by microorganisms. The assimilation of metals such as mercury into the food chain may worsen matters.

Mycoremediation is a form of bioremediation in which fungi are used to decontaminate the area. Stimulating microbial and enzyme activity, mycelium reduces toxins in-situ.

Some fungi are hyperaccumulators, capable of absorbing and concentrating heavy metals in the mushroom fruit bodies. The term *mycoremediation* refers specifically to the use of fungal mycelia in bioremediation.

The key to mycoremediation is determining the right fungal species to target a specific pollutant. Certain strains have been reported to successfully degrade the nerve gases VX and sarin.

Wood-degrading fungi are particularly effective in breaking down aromatic pollutants (toxic components of petroleum), as well as chlorinated compounds (certain persistent pesticides)

Oyster mushrooms (Pleurotus ostreatus)

Phytoremediation describes the treatment of environmental problems (bioremediation) through the use of plants that mitigate the environmental problem without the need to excavate the contaminant material and dispose of it elsewhere.

Phytoremediation consists of mitigating pollutant concentrations in contaminated soils, water, or air, with plants able to contain, degrade, or eliminate metals, pesticides, solvents, explosives, crude oil and its derivatives, and various other contaminants from the media that contain them.

Phytoremediation may be applied wherever the soil or static water environment has become polluted or is suffering ongoing chronic pollution.

Examples where phytoremediation has been used successfully include the restoration of abandoned metal-mine workings, reducing the impact of sites where polychlorinated biphenyls have been dumped during manufacture and mitigation of on-going coal mine discharges.

Phytoremediation refers to the natural ability of certain plants called hyperaccumulators to bioaccumulate, degrade,or render harmless contaminants in soils, water, or air.

Contaminants such as metals (arsenic, cadmium, zinc, lead), pesticides, solvents, explosives, and crude oil and its derivatives, have been mitigated in phytoremediation projects worldwide. Many plants such as mustard plants, alpine pennycress and pigweed have proven to be successful at hyperaccumulating contaminants at toxic waste sites.

Phytoremediation is considered a clean, cost-effective and non-environmentally disruptive technology, as opposed to mechanical cleanup methods such as soil excavation or pumping polluted groundwater. Over the past 20 years, this technology has become increasingly popular and has been employed at sites with soils contaminated with lead, uranium, and arsenic.

2. Site Characterization

A contaminated site is a system generally consisting of four phases:

1) solid, which has an organic matter component and an inorganic mineral component composed of sand, silt, and clay,

2) oil (commonly referred to as nonaqueous phase liquid, or NAPL),

3) gas, and

4) aqueous (leachate or ground water).

These phases and compartments need to be characterized with regard to extent and distribution of contamination as well as potential exposure to human and environmental receptors.

Each phase affects bioavailability, i.e., interactions with microorganisms and exposure to human health and environmental receptors.

Each phase can be a site for biological reactions that results in the transformation of a parent chemical to CO_2 , H_2O, and other inorganic species through the process of mineralization, or transformation to intermediates that persist or that react with soil components to chemically bind to soil and therefore alter the bioavailability of the chemicals.

Evaluating the extent and distribution of contamination at a site will provide important information that can be used as a basis to select specific bioremediation technologies. t.

Distribution of contaminants at a site is determined by the physical and chemical properties of the contaminants and the properties of the site.

3. Intrinsic and Enhanced Bioremediation

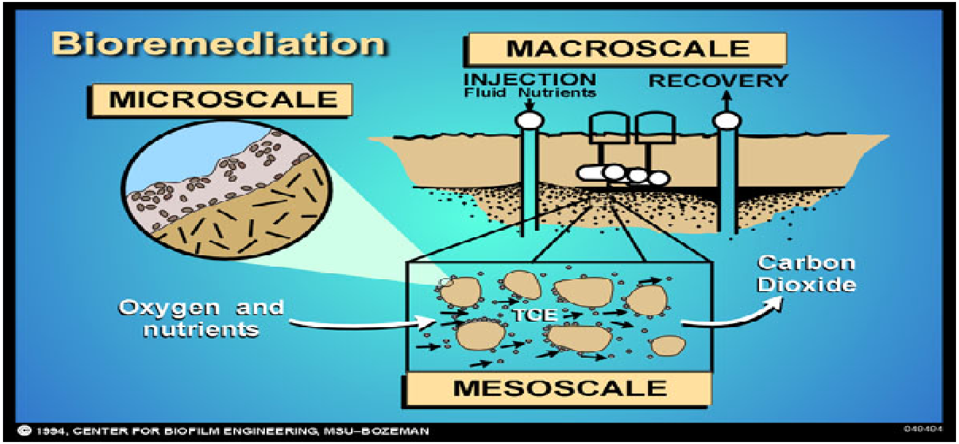
Biodegradation is the breakdown of carbon-based contaminants by microbial organisms into smaller compounds. The microbial organisms transform the contaminants through metabolic or enzymatic processes.

Biodegradation processes vary greatly, but frequently the final product of the degradation is carbon dioxide or methane.

Biodegradation is a key processes in the natural attenuation of contaminants at hazardous waste sites. Bacteria can metabolize hydrocarbons and other contaminants, converting them to less toxic products. Some live deep underground, some live in the absence of oxygen. Specific organisms are injected into the groundwater, and in some cases, special nutrient are injected with the microbes.

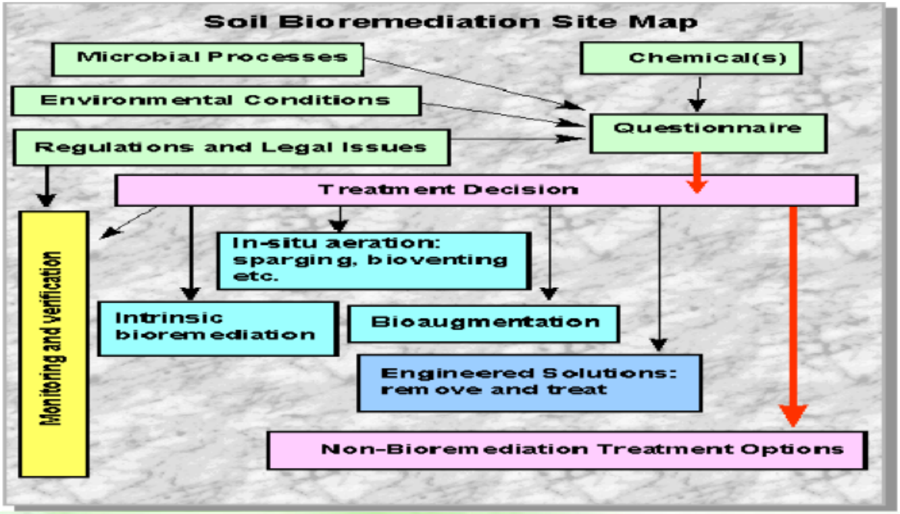
The method is especially useful for remediation of hydrocarbons in groundwater. Natural bioremediation occurs when naturally occurring bacteria living in the aquifer degrade toxic contaminants into less toxic compounds.

Natural bioremediation is most effective in aquifers where bacteria are plentiful, and where contaminant levels are low. Enhanced bioremediation involves stimulating natural bacteria by injecting nutrients and/or carbon compounds needed by the bacteria into the aquifer.



Nutrients and carbon compounds are injected into an aquifer (macroscale sub-image) to stimulate naturally occurring bacteria living in biofilms on sediment particles (microscale sub-image). The bacteria break down contaminants such as trichloroethylene TCE into non-toxic compounds such as carbon dioxide (mesoscale sub-image).

The choice of whether to use bioremediation is a complex one based on site analysis, characterization and the local conditions plus a knowledge of the chemistry and physical properties of the contaminant(s) in the field. The process may be summarized in a Procedure Map that assumes bioremediation is a preferred option because of low costs and then examines whether it should be used:



Conclusions

Due to human activities, organic pollutants (including oil) are spilled to the environment where they threaten public health, often as contaminants of soil or groundwater.

The elimination of a wide range of pollutants and wastes from the environment requires increasing our understanding of the relative importance of different pathways and regulatory networks to carbon flux in particular environments and for particular compounds, and they will certainly accelerate the development of bioremediation technologies and biotransformation processes.

There are numerous advantages to bioremediation.

First and foremost, it is ecologically sound. It is one of the most environmentally responsible ways to treat contamination.

Secondly, it allows you to treat areas that are difficult to reach, including underground and deep in the ocean. It is also less expensive than traditional cleanup techniques which often require excavation, incineration and mechanisms for pumping.

Lastly, it is safer than traditional techniques and does not place humans in harm’s way.

Thanks for your attention!