REMEDIATION OF SOIL CONTAMINANTS

Traditionally, a variety of physicochemical methods have been used for soil remediation. However, these physicochemical strategies are often expensive and, many times, reduce the concentration of soil contaminants at the expense of damaging the integrity of the soil ecosystem. The main goal of any soil remediation technology must be not only to reduce the concentration of soil contaminants but to restore soil quality.

A variety of soil physicochemical and biological properties are often used as indicators of soil quality. It has also been proposed to assess the effectiveness of remediation methods in terms of the recovery of soil ecosystem services and/or attributes of ecological relevance, such as organization, stability, redundancy, etc.

As an alternative to physicochemical treatments, several biological methods of soil remediation, included within the terms bioremediation and phytoremediation, are currently receiving much attention, mainly owing to their lower cost and environmentally friendly character. Bioremediation, or the use of microorganisms (bacteria, fungi) to break down contaminants, takes advantage of the catabolic capacity of microorganisms to remove contaminants from soil. However, bioremediation is effective only with a limited range of contaminants and contaminant concentrations. In addition, bioremediation techniques might take too long to achieve the desired reduction in the concentration of soil contaminants.

The bioremediation of organic contaminants can be approached by three different strategies:

1. bioattenuation,

2. biostimulation, and

3. bioaugmentation.

Bioattenuation

relies on natural processes to maintain the growth and degrading activity of native microbial populations, so that contaminants are biodegraded without human intervention.

Biostimulation

refers to the adjustment of the environmental conditions (e.g., temperature, moisture, aeration, pH, redox potential) and the application of nutrients (e.g., nitrogen, phosphorus) and electron acceptors to contaminated soil, in order to enhance the growth of degrading microbial populations and, then, reduce the concentration of soil contaminants.

Bioaugmentation

has been defined as the inoculation into contaminated soils of microorganisms with the ability to degrade the target contaminants

Bioaugmentation can be divided into two different approaches:

(i) cell bioaugmentation, which relies on the survival and growth of the inoculated strains to perform the degradation of the target contaminants, and

(ii) genetic bioaugmentation, based on the spread of catabolic genes, located in mobile genetic elements (MGEs), into native microbial populations.

CELL BIOAUGMENTATION

Cell bioaugmentation is based on the survival and catabolic activity of inoculated microbial strains. The inoculation of bacteria with the necessary metabolic pathways for the degradation of the target contaminants can indeed accelerate the removal of such contaminants and, hence, reduce the time required for the intended bioremediation. Inoculated microbial strains must then compete for energy and resources (e.g., nutrients and electron acceptors) with the autochthonous microbial populations already present in the soil ecosystem. The major drawbacks for the successful application of cell bioaugmentation are the

(i) frequently very high mortality of the inoculated microbial strains, due to biotic or abiotic stresses, and

(ii) limited dispersal of such strains throughout the soil matrix

GENETIC (PLASMID-MEDIATED) BIOAUGMENTATION

Genes encoding the degradation of naturally occurring or xenobiotic organic compounds are often located on MGEs, such as plasmids, integrons and transposons. By acquiring these genes through mechanisms of horizontal gene transfer (HGT), recipient bacteria may achieve the capacity to degrade those organic contaminants. HGT allows the exchange of genetic information among bacteria from even distantly related taxonomic groups, thereby allowing bacteria to rapidly adapt to new environmental conditions. Although mutation events can certainly contribute to bacterial adaptation, mutation rates in bacterial populations are generally low. Besides, it is currently assumed that an increased rate of mutations would result in increased death owing to deleterious effects.

Genetic (plasmid-mediated) bioaugmentation is defined as a technology in which donor bacteria having self-transmissible catabolic plasmids are introduced into the soil matrix in order to enhance, by HGT, the potential and rate of contaminant degradation of existing bacterial populations.

Reference:

Garbisu C, Garaiyurrebaso O, Epelde L, Grohmann E and Alkorta I (2017) Plasmid-Mediated Bioaugmentation for the Bioremediation of Contaminated Soils. Front. Microbiol. 8:1966. doi: 10.3389/fmicb.2017

Bioremediation of Heavy Metals:

Heavy metals refer to metals with relatively high densities (more than 5gm/cm^3), atomic weights (greater than 50), and atomic numbers. They are often present in the earth as a normal component due to erosion process to rocks, naturally occurring decay of plant and animal waste matter, precipitation or atmospheric accumulation of airborne particles from volcanic eruption, and forest fire smoke.

Methods of Heavy Metal Remediation

In recent years, variable technologies and methods have been used in heavy metal remediation in contaminated environments such as soil and water. Such methods include physicochemical (in situ and ex situ bioremediation) and biological methods (in situ and ex situ bioremediation).

1. Physicochemical Methods.

Physicochemical methods include processes that work to remove heavy metals from any contaminated environment. They can be applied on the form of particulate of metals or metal-containing particles. This remediation can be conducted through physical and chemical processes such as ion exchange, precipitation, reverse osmosis, evaporative recovery, solvent extraction, filtration, chemical oxidation, chemical leaching, electro-kinetics, land filling, electrochemical treatment, electro-dialysis, ultrafiltration, solvent extraction, chemical precipitation, chemical reduction, and isolation (mechanical) separation of metals. However, these methods may show incomplete metal removal, they require high solvent and production of poisonous waste products. They also have an inherent negative environmental impact and are usually soil disturbing, besides that fact that they are labour intensive and expensive.

Limitations

methods are limited by their high costs, high energy requirements, low efficiency, unpredictable metal ion removal, and generation of toxic sludge.

2. **Biological Methods**

Biological remediation or biodegradation constitutes many types of methods involved in the removal or degradation of heavy metals through biological activity. These biological treatments may either include aerobic (presence of oxygen) or anaerobic (absence of oxygen) processes and can be used for heavy metal removal. Biodegradation is a process wherein the polluted environment is biologically degraded under certain conditions to levels below the concentration limits established by regulatory authorities