Bioremediation

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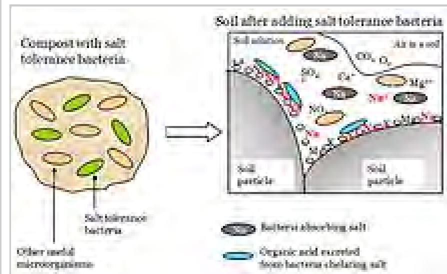

Mechanism of salt removal from tsunami affected soil by bioremediation

Bioremediation is a waste management technique that involves the use of organisms to remove or neutralize pollutants from a contaminated site.[1] According to the United States EPA, bioremediation is a “treatment that uses naturally occurring organisms to break down hazardous substances into less toxic or non toxic substances”. Technologies can be generally classified as *in situ* or *ex situ*. *In situ* bioremediation involves treating the contaminated material at the site, while *ex situ* involves the removal of the contaminated material to be treated elsewhere. Some examples of bioremediation related technologies are phytoremediation, bioventing, bioleaching, landfarming, bioreactor, composting, bioaugmentation, rhizofiltration, and biostimulation.

Bioremediation may occur on its own (natural attenuation or intrinsic bioremediation) or may only effectively occur through the addition of fertilizers, oxygen, etc.,that help in enhancing the growth of the pollution-eating microbes within the medium (biostimulation). For example, the US Army Corps of Engineers demonstrated that windrowing and aeration of petroleum-contaminated soils enhanced bioremediation using the technique of landfarming.[2] Depleted soil nitrogen status may encourage biodegradation of some nitrogenous organic chemicals,[3] and soil materials with a high capacity to adsorb pollutants may slow down biodegradation owing to limited bioavailability of the chemicals to microbes.[4] Recent advancements have also proven successful via the addition of matched microbe strains to the medium to enhance the resident microbe population's ability to break down contaminants. Microorganisms used to perform the function of bioremediation are known as **bioremediators**.

However, not all contaminants are easily treated by bioremediation using microorganisms. For example, heavy metals such as cadmium and lead are not readily absorbed or captured by microorganisms. A recent experiment, however, suggests that fish bones have some success absorbing lead from contaminated soil.[5][6] Bone char has been shown to bioremediate small amounts of cadmium, copper, and zinc.[7] A recent experiment, suggests that the removals of pollutants (nitrate, silicate, chromium and sulphide) from tannery wastewater were studied in batch experiments using marine microalgae.[8] The assimilation of metals such as mercury into the food chain may worsen matters. Phytoremediation is useful in these circumstances because natural plants or transgenic plants are able to bioaccumulate these toxins in their above-ground parts, which are then harvested for removal.[9] The heavy metals in the harvested biomass may be further concentrated by incineration or even recycled for industrial use. Some damaged artifacts at museums contain microbes which could be specified as bio remediating agents.[10] In contrast to this situation, other contaminants, such as aromatic hydrocarbons as are common in petroleum, are relatively simple targets for microbial degradation, and some soils may even have some capacity to autoremediate, as it were, owing to the presence of autochthonous microbial communities capable of degrading these compounds.[11]

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.[12]

Contents

Genetic engineering approaches

The use of genetic engineering to create organisms specifically designed for bioremediation has great potential.[13] The bacterium *Deinococcus radiodurans* (the most radioresistant organism known) has been modified to consume and digest toluene and ionic mercury from highly radioactive nuclear waste.[14] Releasing genetically augmented organisms into the environment may be problematic as tracking them can be difficult; bioluminescence genes from other species may be inserted to make this easier.[15] :135

Mycoremediation

Mycoremediation is a form of bioremediation in which fungi are used to decontaminate the area.

One of the primary roles of fungi in the ecosystem is decomposition, which is performed by the mycelium. The mycelium secretes extracellular enzymes and acids that break down lignin and cellulose, the two main building blocks of plant fiber. These are organic compounds composed of long chains of carbon and hydrogen, structurally similar to many organic pollutants. 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.

In one conducted experiment, a plot of soil contaminated with diesel oil was inoculated with mycelia of oyster mushrooms; traditional bioremediation techniques (bacteria) were used on control plots. After four weeks, more than 95% of many of the PAH (polycyclic aromatic hydrocarbons) had been reduced to non-toxic components in the mycelial-inoculated plots. It appears that the natural microbial community participates with the fungi to break down contaminants, eventually into carbon dioxide and water. Wood-degrading fungi are particularly effective in breaking down aromatic pollutants (toxic components of petroleum), as well as chlorinated compounds (certain persistent pesticides; Battelle, 2000).

Two species of the Ecuadorian fungus Pestalotiopsis are capable of consuming Polyurethane in aerobic and anaerobic conditions such as found at the bottom of landfills.[16]

Mycofiltration is a similar process, using fungal mycelia to filter toxic waste and microorganisms from water in soil.

Advantages

There are a number of cost/efficiency advantages to bioremediation, which can be employed in areas that are inaccessible without excavation.[17] For example, hydrocarbon spills (specifically, petrol spills) or certain chlorinated solvents may contaminate groundwater, and introducing the appropriate electron acceptor or electron donor amendment, as appropriate, may significantly reduce contaminant concentrations after a long time allowing for acclimation. This is typically much less expensive than excavation followed by disposal elsewhere, incineration or other *ex situ* treatment strategies, and reduces or eliminates the need for "pump and treat", a practice common at sites where hydrocarbons have contaminated clean groundwater. Using archaea for bioremediation of hydrocarbons also has the advantage of breaking down contaminants at the molecular level, as opposed to simply chemically dispersing the contaminant.[18]

Monitoring bioremediation

The process of bioremediation can be monitored indirectly by measuring the *Oxidation Reduction Potential* or redox in soil and groundwater, together with pH, temperature, oxygen content, electron acceptor/donor concentrations, and concentration of breakdown products (e.g. carbon dioxide). This table shows the (decreasing) biological breakdown rate as function of the redox potential.

Process	**Reaction**	**Redox potential (E_h in mV)**
aerobic	$O_2 + 4e^- + 4H^+ \rightarrow 2H_2O$	600 ~ 400
anaerobic		
denitrification	$2NO_3^- + 10e^- + 12H^+ \rightarrow N_2 + 6H_2O$	500 ~ 200
manganese IV reduction	$MnO_2 + 2e^- + 4H^+ \rightarrow Mn^{2+} + 2H_2O$	400 ~ 200
iron III reduction	$Fe(OH)_3 + e^- + 3H^+ \rightarrow Fe^{2+} + 3H_2O$	300 ~ 100
sulfate reduction	$SO_4^{2-} + 8e^- + 10H^+ \rightarrow H_2S + 4H_2O$	0 ~ −150
fermentation	$2CH_2O \rightarrow CO_2 + CH_4$	−150 ~ −220

This, by itself and at a single site, gives little information about the process of remediation.

1. It is necessary to sample enough points on and around the contaminated site to be able to determine contours of equal redox potential. Contouring is usually done using specialised software, e.g. using Kriging interpolation.
2. If all the measurements of redox potential show that electron acceptors have been used up, it is in effect an indicator for total microbial activity. Chemical analysis is also required to determine when the levels of

contaminants and their breakdown products have been reduced to below regulatory limits.
3. Chemical analysis should also be carried out for assessing transformations in inorganic contaminants (e.g. heavy metals, radionuclides). Unlike organic pollutants, inorganic pollutants cannot be degraded[19] and remediation processes can both increase and decrease their solubility and bio-availability. An increase in heavy metal mobility can occur, even in reductive conditions, during *in-situ* bioremediation.[20]

See also

- Biodegradation
- Bioleaching
- Biosurfactant
- Dutch standards
- Folkewall
- List of environment topics
- Living machines
- Green wall
- Mega Borg Oil Spill
- Microbial biodegradation
- Mycoremediation
- Phytoremediation
- *Pseudomonas putida* (used for degrading oil)
- US Microbics
- Xenocatabolism

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External links

- **Phytoremediation Website** hosted by the Missouri Botanical Garden (http://www.mobot.org/jwcross/phytoremediation)
- Toxic cadmium ions removal by isolated fungal strain from e-waste recycling facility (http://www.appliedbioresearch.com/data/index.php?option=com_content&view=article&id=57&Itemid=58) (Kumar et al., 2012)
- Removal of Cu2+ Ions from Aqueous Solutions Using Copper Resistant Bacteria (http://www.nepjol.info/index.php/ON/article/view/5733/4721%20) (Rajeshkumar and Kartic 2011)

Categories: Bioremediation | Biotechnology | Environmental soil science | Environmental engineering | Environmental terminology | Conservation projects | Ecological restoration | Soil contamination