Bioremediation: Cost-effective Alternative to Clean Environmental Messes

Enormous quantities of organic and inorganic compounds are released into the environment each year as a result of human activities. In some cases, these releases are deliberate and well regulated (e.g., industrial emissions) while in other cases they are accidental (e.g., chemical or oil spills). Many of these compounds are both toxic and persistent in terrestrial and aquatic environments. The contamination of soil, surface and groundwater is simply the result of the accumulation of these toxic compounds in excess of permissible levels.

Whether due to regulatory or legislative requirements, due to public pressure, due to insidious side effects on humans or due to enlightened corporate behaviour, there is growing realisation and movement to clean up such environmental messes. However, the cost of restoring the burgeoning global inventory of contaminated ecosystems to healthy and acceptable levels is virtually incalculable. As a result, the government, industry and the public have acutely felt the need for more cost-effective alternatives to traditional physical and chemical methods of remediation of these contaminated sites.

What is Bioremediation?

Bioremediation consists of using living organisms (usually bacteria, fungi, actinomycetes, cyanobacteria and to a lesser extent, plants) to reduce or eliminate toxic pollutants. These organisms may be naturally occurring or laboratory cultivated. These organisms either eat up the contaminants or assimilate within them all harmful compounds from the surrounding area, thereby, rendering the region virtually contaminant-free. Generally, the substances that are eaten up are organic compounds, while those, which are assimilated within the organism, are heavy metals. Bioremediation harnesses this natural process by promoting the growth and/or rapid multiplication of these organisms that can effectively degrade specific contaminants and convert them to non-toxic by-products. Importantly, bioremediation can also be used in conjunction with a wide range of traditional physical and chemical technologies to enhance their efficacy. Comments Dr Banwari Lal, the TERI researcher working on this project, "Bioremediation is an ecologically sound and state-of-the-art technique that employs natural biological processes to completely eliminate toxic contaminants".

There are two basic types of bioremediation:

Biostimulation provides nutrients and suitable physiological conditions for the growth of the indigenous microbial populations. This promotes increased metabolic activity, which then degrades the contaminants.

Bioaugmentation means introduction of specific blends of laboratory-cultivated microorganisms into a contaminated environment or into a bioreactor to initiate the bioremediation process.

The process of developing bioremediation techniques may involve the following steps:

Isolating and characterizing naturally-occurring microorganisms with bioremediation potential

Laboratory cultivation to develop viable populations

Studying the catabolic activity of these microorganisms in contaminated material through benchscale experiments

Monitoring and measuring the progress of bioremediation through chemical analysis and toxicity testing in chemically-contaminated media

Field applications of bioremediation techniques using either/both steps: (1) *in-situ* stimulation of microbial activity by the addition of microorganisms and nutrients and the optimization of environmental factors at the contaminated site itself (2) *ex-situ* restoration of contaminated material in specifically designated areas by land-farming and composting methods

Oilzapper: Cleans oil-contaminated sites and post-refining oil residues

Oil spills into the aquatic and terrestrial environments are a not so uncommon occurrence. The devastating effects on marine life from the Exxon Valdez spill in Alaska and the spills during the Gulf War due to destruction of oil reservoirs are well documented. However, oil spills occur in our harbours, inside or outside refinery premises, due to leakage from oil pipelines, due to accidents of oil tankers and due to mishandling of lubricant oil at storage depots and engine oil at auto workshops. These spills pose various kinds of environmental hazards such as:

Fire, as oil being lighter floats on water and is liable to catch fire Ground water pollution due to gradual percolation Threat to marine life Air pollution due to evaporation

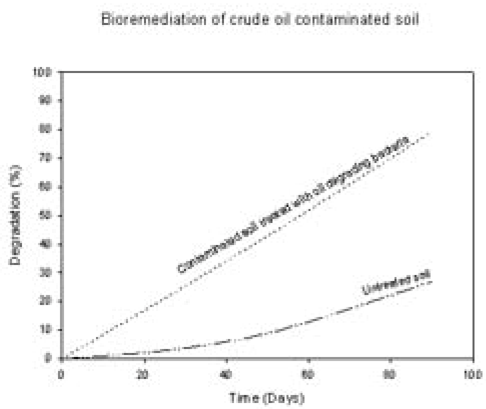
Another prominent source of contamination and risk is the oily sludge left behind after refining crude oil. This waste residue is at present dumped into specially constructed sludge pits - consisting of a leachate collection system and polymer lining system to prevent the percolation of contaminants into groundwater. However, these sludge pits face the drawbacks of being rather expensive to construct and maintain, and increasingly more and more land is required for this purpose, since once filled with sludge these pits cannot be used for further discharges.

Both the problems of oil spills and oily sludge can now be dealt with using TERI's Oilzapper - it is effective, low-cost, leaves behind no harmful side-effects or residues and easy to use. Developed by TERI researchers with active assistance from the Department of Biotechnology, Government of India and the Indian Oil Corporation, it consists of a combination of live culture of oil-degrading microbes mixed with specific carrier material. Packed in re-usable polybags for easy transport to various locations, it can be used in both marine and terrestrial environments.

When Oilzapper is applied over a contaminated site, then left to it, it speedily destroys the contaminants and restores the site. These innumerable strains of microbes under basic categories of bacteria degrade oil and oily sludge through digestion of harmful chemicals and compounds into simpler, less toxic or non-toxic substances. These, microorganisms, like all living organisms, need nutrients (such as nitrogen, phosphate, and trace metals), carbon and energy to survive. They break down a wide variety of organic (carbon-containing) compounds found in oil and oily sludge to obtain energy for their growth, transforming them into harmless substances consisting mainly of carbon dioxide, water and other non-toxic compounds.

Oilzapper: live cultures of oil-degrading bacteria, ready for use

The rate of degradation of contaminants using Oilzapper is manifold over degradation by naturally occurring bacteria. The graph below show this difference for a typical sample of oily sludge contaminated soil. More importantly, it achieves quick restoration of contaminated sites at a fraction of the cost involved using traditional physical and chemical remedies. Says Dr Lal, "I am extremely excited at the future prospects of bioremediation. While harmful effects due to oil spills would soon be a thing of the past, the opportunities for



Bioremediation

An ecologically sound, natural process; residues are usually harmless products

Instead of merely transferring contaminants from one environmental medium to another (e.g., from water to the air or to land) bioremediation completely eliminates the target chemicals

Bioremediation is far less expensive than other technologies that are often used to clean up hazardous waste

Bioremediation can often be accomplished where the problem is located ("*in-situ*"). This eliminates the need to transfer large quantities of contaminated waste off-site, and the potential threats to human health and the environment that can arise during such transportation.

(**Courtesty: article published in: www.teriin.org**)