FACTFILE: GCE ENVIRONMENTAL TECHNOLOGY

BIOREMEDIATION

Bioremediation

Learning outcomes

Students should be able to:

- explain bioremediation as a method of using micro-organisms to treat contaminated land, for example a brownfield site with waste oil, heavy metals, chlorinated pesticides, polychlorinated biphenyls (PCB) and diesel oil;
- identify of a range of named micro-organisms and the pollutants they treat:
  - Pseudomonas putida to treat organic solvents;
  - Pseudomonas aeruginosa to treat oil; and
  - Dehalococcoides ethenogenes to treat halogenated hydrocarbons;
- discuss the economic and environmental benefits of using bioremediation technology compared to traditional treatment methods;
- outline the role of, and the issues arising from, using genetic engineering to modify micro-organisms used in bioremediation to further enhance the scope of the technology; and
- explain the use of in situ bioreactor systems to treat small to medium scale amounts of contaminated soil.

Course Content

This process uses micro-organisms, primarily bacteria, to decontaminate soil / land of man made pollutants.

There is an ever growing list of contaminants that can be treated and of bacteria capable of bioremediation.

Contaminants which can be treated include:

- Waste oil
- Heavy metals
- Chlorinated pesticides
- Polychlorinated Biphenyls (PCBs)
- Diesel oil.

Pupil Activity

Identify 6 possible locations that could benefit from bioremediation and for each site suggest the likely contaminants. Refer to the sites http://water.usgs.gov/wid/html/bioremed.html and http://www.ecenvironmental.ca/Bioremediation/tabid/1237/Default.aspx for examples.

There is a range of organisms which can be used in the bioremediation process such as;

- **Pseudomonas putida** – a rod shaped bacterium which is found in most soil and water habitats where there is oxygen. This is used to treat organic solvents such as toluene and styrene.
- **Pseudomonas aeruginosa** – can be used to degrade aromatic hydrocarbons such as methylbenzenes, the by-products of petroleum industries which are the by-products of petroleum industries and are commonly used as solvents for enamels and paints as well as in the production of drugs and chemicals.
- **Dehalococcoides ethenogenes** – this a very thick cell wall and a single membrane layer and is the only known bacteria that can fully degrade PCE (Tetrachloroethylene) to ethene.

Economic benefits of using bioremediation

In using bioremediation techniques costs can be reduced drastically in terms of time, resources and economic costs. Reasons for this include:

- clean up times can be reduced significantly sometimes from months and years to days and weeks;
- contaminants can be reduced effectively to near zero;
- contaminants are not being recycled into some other form or into the atmosphere;
- the clean up of the site is done on the site itself and without disturbing the surrounding environment; and
- the process requires less labour costs than traditional techniques.

Genetic engineering and bioremediation

There are instances where naturally occurring micro-organisms cannot be used to remove certain contaminants. This has resulted in the increased use of genetic engineering techniques being employed to produce micro-organisms which can be used to remove a range of contaminants.

Scientists are designing or deploying microbes to purge sites of contaminants such as PCBs, oil, radioactive waste, petrol and mercury and new bioremediation research findings appear regularly.

An example of this is modified E. coli bacteria (a common laboratory bacteria) with genes which allow the micro-organisms to not only survive in mercury but to remove it from waste sites. These particular genes produce proteins called metallothionein and polyphosphate kinase which allow the bacterial cells to develop a resistance to mercury and to accumulate large amounts of the heavy metal within the organism, thereby isolating it. Mercury is a very toxic material for which no natural organisms can be used for bioremedial purposes.

However, this takes bioremediation into the debate surrounding genetic engineering and its side effects. Micro-organisms which have been genetically modified and introduced into the environment could have a negative and potentially dangerous impact on other organisms or mutate themselves into other potentially dangerous organisms through gene transfer.

Pupil Activity

Produce a presentation on the debate surrounding genetic engineering. Focus your presentation on the issues relating to genetic engineering of micro-organisms for use in bioremediation.

In situ bioremediation

Bioremediation can be carried out in situ, i.e. where the soil is treated on site where it sits. Or it can be taken off site, treated, and then re-turned known as ex situ treatment. In either case the soil material can be treated with micro-organisms that will break down the contamination material.

The in situ method is preferable since no expensive excavation or transport of vast quantities of soil is needed, which in itself would be polluting due to the fossil fuel emissions from the excavation equipment for example.
http://www.icsinc.tv/content/services/bioremediation_bioventing.shtml

There are various other physical, biological or chemical treatments that can also be added to speed up the bioremediation process. These include:

Bioventing

Here the bioremediation process is boosted by pumping air into the saturated zone in the soil where the contaminant is most concentrated. The air assists the natural aerobic respiration process of the bacteria, thereby speeding the process up. Low soil temperatures and waterlogged soil will hinder the process since both these conditions will limit the rate of bacterial respiration, making the aeration less beneficial.

Land Farming

Land farming is a bioremediation technology, which usually incorporates liners and other methods on the ground on to which the contaminated soil is spread in order to control leaching of contaminants. Contaminated soil or sludge is applied into lined beds and periodically turned over or tilled to aerate the waste.

Soil conditions are often controlled to optimize the rate of contaminant degradation. Conditions normally controlled include;

- Moisture content must be maintained (usually by irrigation or spraying),
- Natural aeration (by tilling the soil with a predetermined frequency, the soil is mixed and aerated),
- pH (buffered near neutral pH by adding crushed limestone or agricultural lime),
- Other amendments (e.g., Soil bulking agents, nutrients, etc.).

Contaminated soil is usually treated in piles (lifts) that are up to 18 inches thick. When the desired level of treatment is achieved, the lift is removed and a new lift is constructed. It may be desirable to only remove the top of the remediated lift, and then construct the new lift by adding more contaminated media to the remaining material and mixing. This serves to inoculate the freshly added material with an actively degrading microbial culture, and can reduce treatment times.

Bioreactor Systems

For this method the contaminated soil is transferred on site into a bioreactor vessel. In this vessel the soil will be inoculated with the bacteria, the temperature, pH, aeration and stirring conditions can then be controlled to give the optimum rate of bacterial activity. When finished the soil can be tipped back onto the site. By having the bioreactor in-situ transport costs are avoided however some excavation costs will be incurred since the soil must be dug up and loaded into the bioreactor.

Composting

Compost bioremediation refers to the use of a biological system of micro-organisms in a mature, cured compost to break down contaminants in water or soil. The contaminants are digested, metabolized, and transformed into humus and inert by-products, such as carbon dioxide, water, and salts. Compost bioremediation has proven effective in degrading or altering many types of contaminants, such as chlorinated and non-chlorinated hydrocarbons, wood-preserving chemicals, solvents, heavy metals, pesticides, petroleum products, and explosives.

Compost used in bioremediation is referred to as “tailored” or “designed”compost in that it is specially made to treat specific contaminants at specific sites.

The ultimate goal in any remediation project is to return the site to its pre-contamination condition, which often includes revegetation to stabilize the treated soil. In addition to reducing contaminant levels, compost advances this goal by facilitating plant growth. In this role, compost provides soil conditioning and also provides nutrients to a wide variety of vegetation.

Bioaugmentation

Bioaugmentation is a process where selected, standardized bacteria (microbes) are added to an area that has been contaminated with an unwanted substance. These bacteria breakdown the contaminants.

Scientific advances have enabled us to isolate and mass-produce standardized pro-biotic bacteria and fungi into industrial concentrated inocula. These selected formulations, of multiple strains of bacteria, can be targeted to address specific contaminants. Scientific studies for microbial products have been conducted and demonstrate the efficacy of microbe mixtures, known as Colony Forming Units, for the safe remediation of numerous contaminants.

These standardized high CFU count probiotic formulations allows the bioaugmentation process to remediate pollutants and a rate which far exceeds that of natural indigenous microbes and exceeds present bioventing technology rates. Some of the bacterial strains used may have been genetically engineering also to enhance their bioremediation ability above that of the non augmented form.

Biostimulation

Biostimulation is a form of in situ bioremediation which has been enhanced by injection of nutrients and other supplementary components such as surfactants and emulsifiers to the native microbial population to induce the bacterial population to grow at a hastened rate. Since the population is now more numerous then the breakdown of the contaminant will speed up.