Rewarding Learning

A2 LEVEL

Environmental Technology

Phytoremediation

For first teaching from September 2014

For first award in Summer 2015

environmental technology

Sustainability and Future Development

FACT FILE

environmental technology

Phytoremediation

Specification Content

Students should be able to:

- describe how plants can be used to decontaminate industrial pollution of soil and remove:
  - copper;
  - cadmium;
  - strontium;
  - rubidium;
  - arsenic; and
  - antimony.

- discuss the advantages and limitations of using alpine pennygrass and Indian mustard in the commercial decontamination of soil contaminated with the following metal ions:
  - cadmium;
  - zinc;
  - copper;
  - lead;
  - gold; and
  - uranium.

Course Content

Industrial processes make use of a wide range of chemicals many of which are toxic to humans. Land can become contaminated with these as a result of accident or neglect.

Phytoremediation is a process whereby contaminated land is decontaminated using plants that extract the metals from the soil and retain the metal in their tissues. It is also an ecologically friendly, solar-energy driven clean-up technology, based on the concept of using nature to cleanse nature.

The list of plants capable of the process is lengthening. Two examples are Alpine Pennygrass and Indian Mustard.

Alpine Pennygrass, shown on the right, naturally accumulates high levels of metals such as copper, cadmium and zinc from the environment in which they are grown. It is described as a hyperaccumulator since the levels that it can collect and still remain healthy would be toxic to most plant species. Alpine pennygrass can also be used to extract traces of arsenic from soil.

The use of plants in this application also helps prevent wind, rain, and groundwater from carrying pollution away from sites to other areas since the plants stabilise the soil and the contaminants are less likely to be carried off.

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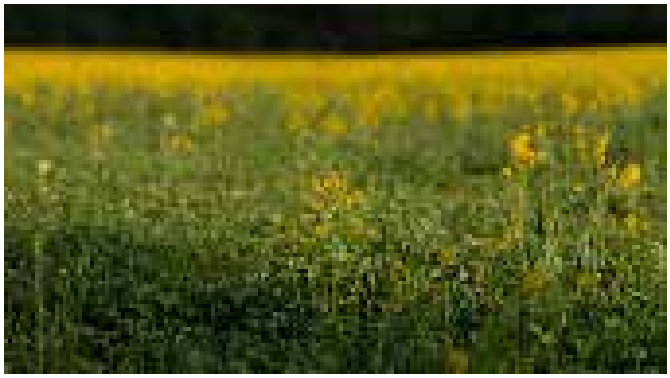
Phytoremediation works best at sites with low to medium amounts of pollution. Plants remove harmful chemicals from the ground when their roots take in water and nutrients from polluted soil. Once inside the plant, heavy metal ions can be stored in the roots, stems, or leaves. When the plants have grown and absorbed the metal pollutants they are harvested and disposed of safely.



Indian mustard is used in phytoremediation to remove heavy metals, such as lead from the soil in hazardous waste sites because it has a higher tolerance for these substances and stores the heavy metals in its cells. Some

areas close to population centres can be susceptible to lead pollution from wind carried particles of lead based paint which have been chipped off buildings. The plant can be harvested and disposed of in the normal way. As with other phytoremediation techniques this method is easier and less expensive than traditional methods of removing heavy metals. It also prevents erosion of soil from the sites preventing further contamination. Indian mustard can also be used to extract gold and copper.

The image below shows a cabbage plantation growing close to a zinc smelter in Silesia, Poland. As a result of smelt activities lead concentration was highly increased in the soil and picked up by a number of crops in the surrounding areas.

The cabbage would hyperaccumulate the lead which could then be removed and extracted or safely disposed of. The smelting plant had shut down, so after a few seasons of cabbage growing the lead levels dropped sufficiently to allow food crop production to resume on the land.

The uptake of contaminants in plants occurs primarily through the root. The root system provides an enormous surface area that absorbs and accumulates the water and nutrients essential for growth, as well as other non-essential contaminants. Deep-lying contaminated ground water can also be treated by pumping the water out of the ground and using plants to treat the contamination.

Plant roots also cause changes at the soil-root interface as they secrete inorganic and organic compounds (root exudates) in the area around the roots (rhizosphere). These root exudates affect the number and activity of the micro-organisms, the aggregation and stability of the soil particles around the root, and the availability of the contaminants. Root exudates can increase the availability of the contaminants in the rhizosphere of the plant through changes in soil characteristics, release of organic substances, changes in chemical composition, and/or increase in plant-assisted microbial activity.

With selective breeding and genetic modification of the plants, their natural ability to hyperaccumulate can be enhanced even further or, the hyperaccumulation ability of some plants may be transferred into other plants that would be better suited to specific locations. Therefore it is possible to 'tailor' a plant to a specific pollutant and location.

Phytoremediation is an alternative or complimentary technology that can be used along with or, in some cases in place of mechanical conventional clean-up technologies that often require high capital inputs and are labour and energy intensive.

Limitations to phytoremediation in soil include;

- The depth of the treatment zone is determined by plants used in phytoremediation. In most cases, is limited to shallow soils.
- It involves the same mass transfer limitations as other biotreatments, i.e., with the soil in-situ and no mechanical mixing the rate of transfer or contaminants to plant root can be slow.
- It may be seasonal, depending on location;
- It can transfer contamination across media, e.g., from soil to air, but only for the volatile pollutants. This is not likely to be an issue for metal ion decontamination.
- It is not effective for strongly absorbed (e.g., PCBs) and weakly absorbed contaminants. Metal ions are no affected as much by this as they are less strongly absorbed onto soil particles.
- The toxicity and bioavailability of biodegradation products is not always known.
- Products may be mobilized into ground water or bioaccumulated in animals if the accumulating plants are not harvested after growth.

Pupil Activity

1. Use the link http://www.ndsu.edu/pubweb/famulari_research/index.php to investigate the range of plants which can be used to extract contaminants.

2. Write a short report evaluating the use of plants such as Alpine Pennygrass in the decontamination of brown field sites.

Sustainability and Future Development

COUNCIL FOR THE **CURRICULUM EXAMINATIONS** AND **ASSESSMENT**
29 Clarendon Road, Clarendon Dock, Belfast BT1 3BG
✆ +44 (0)28 9026 1200 🖷 +44 (0)28 9026 1234 ☎ +44 (0)28 9024 2063 ✉ info@ccea.org.uk 🌐 www.ccea.org.uk

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