Concept of phytoremediation

Sociology, Communication

In recent years it has become clear that some environmental chemicals can cause risks to the developing embryo and fetus. Evaluating the developmental toxicity of environmental chemicals is now a prominent publichealthconcern. The suspected association between TCE and congenital cardiac malformations warrants special attention because TCE is a common drinking water contaminant that is detected in water supplies throughout the U. S. and the world. There is a lot of concern about the clean up of toxic pollutants from theenvironment.

Traditional methods for cleaning up contaminated sites such as dig and haul, pump and treat, soil venting, air sparging and others are generally harmful to habitats. Some methods strip the soil of vital nutrients and microorganisms, so nothing can grow on the site, even if it has been decontaminated. Typically these mechanical methods are also very expensive. Most of the remediation technologies that are currently in use are very expensive, relatively inefficient and generate a lot of waste, to be disposed of.

Phytoremediation is a novel, efficient, environmentally friendly, low-costtechnology, which uses plants and trees to clean up soil and water contaminated with heavy metals and/or organic contaminants such as solvents, crude oil, polyaromatic hydrocarbons and other toxic compounds from contaminated environments. This technology is useful for soil and water remediation.

Phytoremediation uses one basic concept: the plant takes the pollutant through the roots. The pollutant can be stored in the plant (phytoextraction), volatized by the plant (phytovolatization), metabolized by the plant (phytodegradation), or any combination of the above.

Phytoextraction is the uptake and storage of pollutants in the plants stem or leaves. Some plants, called hyperaccumulators, draw pollutants through the roots. After the pollutants accumulate in the stem and leaves the plants are harvested. Then plants can be either burned or sold. Even if the plants cannot be used, incineration and disposal of the plants is still cheaper than traditional remediation methods. As a comparison, it is estimated a site containing 5000 tons of contaminated soil will produce only 20-30 tons of ash (Black, 1995). This method is particularly useful when remediating metals. Some metals are also being recycled from the ash.

Phytovolatization is the uptake and vaporization of pollutants by a plant. This mechanism takes a solid or liquid contaminant and transforms it to an airborne vapor. The vapor can either be the pure pollutant, or the plant can metabolize the pollutant before it is vaporized, as in the case of mercury, lead and selenium (Boyajian and Carriera, 1997; Black, 1995; Wantanbe, 1997).

Phytodegradation is plants metabolizing pollutants. After the contaminant has been drawn into the plant, it assimilates into plant tissue, where the plant then degrades the pollutant. This metabolization by plant-derived enzymes such as nitrosedictase, laccase, dehalogenase, and nitrilase assimilates into plant tissue, where the plant then degrades the pollutant. This metabolization by plant-derived enzymes such as nitroredictase, laccase, dehalogenase, and nitrilase, has yet to be fully documented, but has been demonstrated in field studies (Boyajian and Carriera, 1997). The daughter compounds can be either volatized or stored in the plant. If the daughter compounds are relatively benign, the plants can still be used in traditional applications.

The most effective current phytoremediation sites in practice combine these three mechanisms to clean up a site. For example, poplar trees can accumulate, degrade and volatize the pollutants in the remediation of organics.

Phytoremediation is more than just planting and letting the foliage grow; the site must be engineered to prevent erosion and flooding and maximize pollutant uptake. There are 3 main planting techniques for phytoremediation.

1. Growing plants on the land, like crops. This technique is most useful when the contaminant is within the plant root zone, typically 3 - 6 feet (Ecological Engineering, 1997), or the tree root zone, typically 10-15 feet.

2. Growing plants in water (aquaculture). Water from deeper aquifers can be pumped out of the ground and circulated through a “ reactor” of plants and then used in an application where it is returned to the earth (e. g. irrigation)

3. Growing trees on the land and constructing wells through which tree roots can grow. This method can remediate deeper aquifers in-situ. The wells provide an artery for tree roots to grow toward the water and form a root system in the capillary fringe.

The majority of current research in the phytoremediation field revolves around determining which plant works most efficiently in a given application. Not all plant species will metabolize, volatize, and/or accumulate pollutants in the same manner. The goal is to ascertain which plants are most effective at remediating a given pollutant. Research has yielded some general guidelines for groundwater phytoremediation plants. The plant must grow quickly and consume large quantities of water in a short time. A good plant would also be able to remediate more than one pollutant becausepollutionrarely occurs as a single compound. Poplars and cottonwoods are being studied extensively because they can used as much as 25 to 350 gallons of water per day, and they can remediate a wide variety of organic compounds, including LNAPL's.

Phytoremediation has been shown to work on metals and moderately hydrophobic compounds such as BTEX compounds, chlorinated solvents, ammunition wastes, and nitrogen compounds. Yellow poplars are generally favored by Environmental Scientists for use in phytoremediation at this time. They can grow up to 15 feet per year and absorb 25 gallons of water a day. They have an extensive root system, and are resistant to everything from gypsy moths to toxic wastes.

Partial listing of current remediation possibilities.

Plant Chemicals Clean-up numbers

Pondweed TNT & RDX 0. 016-0. 019 mg of TNT L per day

Poplar Trees Atrazine 91% of the Atrazine taken up in 10 days

Poplars Nitrates from fertilizers From 150 mg/L to 3 mg L in under 3yrs.

Mustard Greens Lead 45% of the excess was removed

Pennycress Zinc & Cadmium 108 lb./acre per year & 1. 7 lb./acre per yr.

Halophytes Salts reduced the salt levels in the soils by65%

Advantages and Disadvantages to Phytoremediation:

Advantages: (www. rtdf. org/genlatst. htm)

1. Aesthetically pleasing and publicly accepted.

3. Works with metals and slightly hydrophobic compounds, including many organics.

4. Can stimulate bioremediation in the soil closely associated with the plant root. Plants can stimulate microorganisms through the release of nutrients and the transport of oxygen to their roots.

5. Relatively inexpensive - phytoremediation can cost as little as $10 - $100 per cubic yard whereas metal washing can cost $30 - $300 per cubic yard.

6. Even if the plants are contaminated and unusable, the resulting ash is approximately 20-30 tons per 5000 tons soil (Black, 1997).

7. Having ground cover on property reduces exposure risk to the community (i. e. lead).

8. Planting vegetation on a site also reduces erosion by wind and water.

9. Can leave usable topsoil intact with minimal environmental disturbance.

10. Generates recyclable metal rich plant residue.

11. Eliminates secondary air or water-borne wastes.

1. Can take many growing seasons to clean up a site.

2. Plants have short roots. They can clean up soil or groundwater near the surface in-situ, typically 3 - 6 feet (Ecological Engineering, 1997), but cannot remediate deep aquifers without further design work.

3. Trees have longer roots and can clean up slightly deeper contamination than plants, typically 10-15 feet, but cannot remediate deep aquifers without further design work .

4. Trees roots grow in the capillary fringe, but do not extend deep in to the aquifer. This makes remediating DNAPL's in situ with plants and trees not recommended.

5. Plants that absorb toxic materials may contaminant thefoodchain.

6. Volatization of compounds may transform a groundwater pollution problem to anair pollutionproblem.

7. Returning the water to the earth after aquaculture must be permitted.

8. Less efficient for hydrophobic contaminants, which bind tightly to soil.

1) At the Naval Air Station Joint Reserve Base Fort Worth, phytoremediation is being used to clean up trichloroethylene (TCE) from a shallow, thin aerobic

aquifer. Cottonwoods are being used, and after 1 year, the trees are beginning to show signs of taking the TCE out of the aquifer. (Betts, 1997)

2) At the Iowa Army Ammunitions Plant, phytoremediation is being used as a polishing treatment for explosive-contaminated soil and groundwater. The demonstration, which ended in March, 1997, used native aquatic plant and hybrid poplars to remediate the site where an estimated 1-5% of the original pollutants still remain. A full-scale project is estimated to reduce the contamination by an order of magnitude (Betts, 1997).

3) After investigating using phytoremediation on a site contaminated with hydrocarbons, the Alabama Department of Environmental Management granted a site. The site involved about 1500 cubic yards of soil, and began with approximately 70% of the baseline samples containing over 100 PPM of total petroleum hydrocarbon (TPH). After 1 year of vegetative cover, approximately 83% of the samples contained less than 10-PPM TPH.

4) Phytoremediation was used at the decommissioned Detroit Forge plant to clean up approximately 5, 800 cubic yards of lead-impacted soil. Two plantings were completed, the first using sunflowers and the second mustard plants. Following treatment, analysis indicated soil lead concentrations were below the target clean-up criteria. The project resulted in an estimated saving of $1, 100, 000 over hazardous waste disposal.

5) Water, soil, and trees transpired gases were monitored to track the fate of TCE. About 2-4% of the TCE remained in the effluent as compared to 68% in a non-vegetated control group. The field trial demonstrated that over 95% of

TCE were removed by planting trees and letting them grow. Additional studies showed that the trees did not release TCE into the air, as no measurable TCE was present in the air immediately surrounding the leaves (captured in small leaf bags and analyzed) or in the general atmosphere (using a laser technology that can see TCE in the air in the tree canopy).

Phytoremediation is an aesthetically pleasing, solar-energy driven, and passive technique that can be used at sites with low to moderate levels of contamination. Phytoremediation is more than just planting and letting the foliage grow; the site must be engineered to prevent erosion and flooding and maximize pollutant uptake. Currently, the majority of research is concentrated on determining the best plant for the job, quantifying the mechanisms by which the plants convert pollutants, and determining which contaminants are amenable to phytoremediation. Polluted sites are being studied, and phytoremediation looks promising for a variety of contaminants.