Phytoremediation

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Phytoremediation is a new application of biotechnology — an exploitation of specific plants to clean up the environment. Plants are used to treat or remove environmental contaminants from soil and other solids like dredge spoils, water, other liquids, and air.

Plants may be viewed as the original polluters. Our earth was hospitable to methanogenic bacteria before the evolution of photosynthesis by plants, producing oxygen that now is 20 percent of our atmosphere. Oxygen forced the methanogens into anaerobic regions of the world. Now we plan to use plants to help us clean up toxic soils. Scientists at the Ag Biotech Center at Rutgers University, such as Ilya Raskin, have explored methods of using plants to treat organic and inorganic contaminants in soils, and have discovered that plants provide very effective biological processes for cleaning up and removing contaminants from the environment.

I will focus on the use of plants to remove and concentrate heavy metals. Heavy metal contaminants in the soil and water in all developed countries are a large and important worldwide problem caused by manufacturing processes and other activities of commerce dating back to the 1700s. One may view a plant as a solar driven concentrator of chemicals like metals that took 360 million years to build, test, and optimize. The scientists at the Ag Biotech Center enhanced that process so it is more rapid and useful for clean up at contaminated sites.

What is the appeal of phytoremediation? First, it is an elegant method of treating contaminated sites relative to conventional treatment methods in which contaminated soil is transferred to a landfill (which means simply moving it

somewhere else), presumably for permanent storage, and then transferring uncontaminated soil to the original site. Plants leave the soil in place while removing the contamination. Phytoremediation is cost effective, while transfer of contaminated soils to a licensed hazardous waste site is expensive.

Even after 25 years of cleanup efforts and growing awareness of the dangers posed to the environment by contaminated sites, America still has a huge number of contaminated sites. The main reason for the slowness of the cleanup is the large expense of using conventional technology to clean up these sites. We must find more cost effective methods. The use of plants helps address the economic issue. This use offers owners a new method of remediating contaminated property at less cost, which presumably will accelerate the pace of remediation.

Phytoremediation is compatible with public concerns about technology. People have been concerned about biotechnology. They are frightened particularly about genetically engineered bacteria. They always will be. It is easy to frighten people about bacteria. For example, when you tell people how many bacteria there are in yogurt, it doesn't make them think better of the bacteria, it makes them quit eating yogurt. Plants are something that everyone can see; they are familiar and therefore comfortable with plants. Using plants to clean up a contaminated site is more acceptable to community members than the use of bacteria.

At the time of the Exxon Valdez oil spill, the state of Alaska decreed that no non-Alaskan micro-organisms could be used. This was the first microbial-immigration policy and it was useless. Bacteria travel on the wind, and in many other ways, and they didn't seek Alaskan regulators' permission before they entered Alaskan waters to eat the oil on the beach.

Phytoremediation is sophisticated scientifically. Technology must be developed so it can be safe, effective, and reliable.

Over the next five years the United States will spend $43 million to treat only sites contaminated with heavy metals and heavy metals mixed with organics. That's not what would be needed to clean up all the sites. We need low-cost approaches so that we can accelerate the pace of remediation.

Phytoextraction is the subset of phytoremediation in which plants remove contaminating toxic or radioactive metals from a site by root uptake and accumulation in the plant shoots.

I will describe the use of a plant — Indian Mustard — to remove lead from a toxic site. The plants are watered with agricultural chemicals that make the lead water soluble. The water containing lead is taken up by the roots and moved into the stems and leaves where it evaporates, leaving the concentrated lead in the plant. The harvested plants may be sent to a smelter where the metal is recycled — a hazardous waste is removed from the environment and recycled to commerce. This technology, developed by the Ag Biotech Center, is the subject of a technology transfer agreement between Rutgers University and Phytotech.

Brassica juncea (Indian Mustard) has the special property of metal accumulation that was discovered at the AgBiotech Center by screening plants for their metal uptake abilities. This metal uptake property is being expanded and enhanced by research including genetic engineering, mutagenesis, and selection at the Ag Biotech Center and at Phytotech. Most plants do not accumulate heavy metals in the stems or leaves and are not useful for phytoextraction. For most plants, some metal is taken up by the roots, but not much is transfered to the shoots and stems. Indian Mustard and Amaranthis accumulate cadmium, nickel, zinc, copper, lead, and chrome6, a widespread pollutant in New Jersey and a carcinogen.

To increase availability of lead, a biodegradable, short-lived chemical is added to the soil to cause the plants to take up the lead. An example is the metal chelator EDTA added to contaminated soil. There is a direct correlation between the amount of EDTA added and the metal uptake. We are also doing environmental impact rates and effect studies to evaluate the environmental impact, good and bad, of removing metal from the soil by growing the plants on site and adding chemicals to induce uptake and clean the site.

We are in the process of modeling, analyzing, and monitoring the impact of this approach to remediating contaminated sites. What do you do with the harvested plants following phytoextraction? We dry the plants, may incinerate them, may compost them, or may compact them by pressing followed by acid leaching and disposal, or recycling, of the heavy metal. The volume or mass of the plants that contain the extracted heavy metals is only about two percent of the volume or mass of contaminated soil. This is a 50-fold concentration.

Indian Mustard has many attractive characteristics for cleaning up toxic metal sites. It is inexpensive to grow and grows very rapidly to about five feet in about two months, producing 2-10 tons/hectare of dry weight with fairly rapid clean up of the site. We believe there are a significant number of contaminated heavy metal sites in the U.S. that could be remediated in about three years or less so that the Environmental Protection Agency or the state environmental agency would conclude that that site was safe for use. We have great hope that we will be able to use phytoremediation as an effective technology.

We have treated a site in the middle of an urban environment, Magic Marker, in Trenton, N.J. It was originally contaminated by a battery manufacturing and recycling facility located there since about 1950.

Other sites that we have examined in Trenton and other New Jersey towns were contaminated in the 1700s and 1800s by practices such as pottery making. Trenton was a big pottery making center at one time. Pottery glazes contained lead or cadmium and there is a large number of lead and cadmium contaminated sites in the city of Trenton.

The Magic Market site was blocked out, samples were taken to establish lead content, the site was plowed, and fertilizer was added. The soil on the site is dark, not because of humus, but due to the asphalt in the soil. The site was

once a parking lot. An irrigation system was installed and Indian Mustard was hydroseeded to evenly distribute the seeds without disturbing the soil.

We collaborated with the local residents. There was a Phytoremediation Day in Trenton. Through an organization called Isles Inc., we attended community meetings, told everybody that lived in the area (there are houses all around this site) what we were doing, and invited everyone to attend the first planting. The costs of those trials were paid by Phytotech, which had raised $6 million of venture capital and has 16 employees.

As indicated in my presentation, we are enthusiastic about the role of phytoremediation in the cleanup of toxic sites.