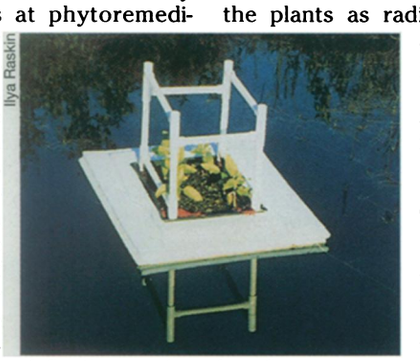
Botanical Cleanup Crews

Using plants to tackle polluted water and soil

By TINA ADLER

Rafts with sunflowers growing on them float on a small pond at the Chernobyl nuclear accident site in the Ukraine. No, it's not some touching monument to the 1986 disaster. The plants are helping to clean the pond; their roots dangle in the water to suck up the radionuclides cesium 137 and strontium 90.

This sunflower project is one of many international efforts at phytoremediation—the use of plants to absorb pollutants from air, water, and soil. In the United States, both government agencies and private companies, including Exxon Corp. and DuPont are testing a variety of plants to see if they can do some of the dirty work of cleaning up such pollutants as radioactive material, lead, selenium, and oil. Many plants, it turns out, have a taste for these stubborn contaminants.



Ilya Raskin

A floating garden of sunflowers absorbs radionuclides from a small pond on the Chernobyl site.

"To survive, plants have evolved sophisticated metabolic and sequestration mechanisms to detoxify a wide variety of chemical substrates," explains Scott Cunningham of DuPont Central Research and Development in Newark, Del. The plants are also loaded with microbes and fungi that help break down the chemicals. Cunningham spoke in May at a conference on phytoremediation held in Arlington, Va.

To many academic and industry researchers, including environmentalists, phytoremediation looks promising, although even bright-eyed sunflowers have yet to convince these observers that they are ready for the big time.

The Chernobyl sunflower project began in 1994. That summer, researchers from Phytotech, a phytoremediation company in Monmouth Junction, N.J., and their government and university colleagues installed the rafts. Together, they held 24 sunflowers and dotted a 75-square-meter pond located 1 kilometer from the Chernobyl reactor, says Burt Ensley, Phytotech's president.

The plants preferentially absorb cesium and strontium from a mixture of metals, he notes. The plants don't metabolize the radionuclides, but the cesium stays in the roots and most of the strontium moves to the shoots. The company disposes of the plants as radioactive waste after about 3 weeks on the pond.

The investigators started with too few flowers to clean the pond completely, Ensley acknowledges. This summer, they installed 50 to 60 sunflowers, which should clean the pond in a couple of weeks, he asserts. Ensley estimates that removing radioactive metals with sunflowers costs $2 to $6 per thousand gallons of water, much less than existing technologies.

However, to avoid recontaminating the pond, the ground nearby must be decontaminated at the same time. For 2 years, Phytotech scientists have been removing cesium and strontium from soil on one-quarter acre of the Chernobyl site by growing Indian mustard (*Brassica juncea*).

In the United States, almost all radioactive sites belong to the Department of Energy. Prior to the Chernobyl sunflower project, Phytotech researchers experimented with pumping contaminated groundwater into containers of sunflowers at a DOE uranium-processing plant in Ashtabula, Ohio. Within 24 hours, the plants reduced the concentration of uranium in the water from 350 parts per billion (ppb) to less than 5 ppb, which meets the legal limits for groundwater, Ensley says.

This summer, Phytotech and DOE researchers began a project using sunflowers to remove uranium from contaminated springs at the Oak Ridge (Tenn.) National Laboratory.

"I've heard of uranium contamination at DOE sites of 100 parts per million [ppm], and we couldn't clean that up. We could go up to 2,000 ppb," Ensley says.

Are DOE managers of tainted sites clamoring for Phytotech's help? Not quite, says Ensley. They have a bias against new technology and worry about its costs, he contends.

"What [Ensley] has is wonderful," but it's still just "gee-whiz science," asserts Rashalee Levine of DOE's Office of Technology Development in Germantown, Md. In general, phytoremediation performs very well on a small scale, she says, but she is waiting to see how it handles big jobs. Plants take a lot of space to cultivate and tend to work slowly, she notes. Also, "it remains to be seen how much it will cost."

Her office received a cut this fiscal year in its funding for phytoremediation projects. The agency is supporting research on the use of plants on six small sites contaminated with cadmium, zinc, cesium, strontium, uranium, or some combination of these.

Compared to the radionuclides, lead presents a particularly sticky problem for the environment and for phytoremediation researchers. It forms strong bonds with minerals and organic matter in the soil. Plants absorb only a little lead, and it doesn't move beyond the roots.

Scientists have recently circumvented this difficulty by watering the plants with a solution containing lead-chelating agents. These organic molecules wrap themselves around lead atoms and allow the lead to dissolve in water so plants can absorb it better. Phytotech has applied for a patent on the use of chelators for lead removal.

The company is using plants and chelator solutions to clean up a handful of sites contaminated with lead. Most recently, it began growing Indian mustard on a quarter-acre patch of a former battery recycling plant in Trenton, N.J. The soil has lead concentrations between 500 and 1,000 ppm, about twice

New Jersey's legal limit for lead in residential land.

The company disposes of lead-rich plants at hazardous-waste treatment facilities. Eventually, Ensley would like to give the plants to lead smelters, who could extract and reuse the metal. However, smelters won't take plants that have high concentrations of multiple chemicals, he notes.

Researchers at DuPont spend about $1 million a year on phytoremediation research. Using chelator solutions, they report that they can make almost any plant in a greenhouse setting absorb a significant amount of lead, even crops such as corn and peas, which don't normally extract metals from soil. They find that the best plants for lead removal grow big and fast, absorb a lot of water, and tolerate slightly poor soil.

Cunningham reports that ethylenediaminetetraacetic (EDTA) salt is one of the most promising chelators. Manufacturers use EDTA salt and closely related compounds as food preservatives.

DuPont's team has yet to test chelators in the field, but it may begin doing so next summer, Cunningham says. It first needs to make sure that the chelator solutions don't free more lead from the soil than the plants can absorb, because the excess could seep into the groundwater. The DuPont scientists haven't yet decided on the best chelators and plants to employ.

One of the most common groundwater pollutants is trichloroethylene (TCE), once used in abundance for dry cleaning and as a degreasing agent but now banned. Washington alone has about 10,000 sites contaminated with TCE, according to the state's Department of Ecology.

Fortunately, poplar trees appear to have a fondness for TCE. Moreover, their roots can reach depths of 40 to 50 feet, making them particularly well suited for cleaning groundwater.

With funding from the manufacturing company Occidental Chemical, Milton T. Gordon of the University of Washington in Seattle and his colleagues last year began growing 18 poplars in large, sealed containers into which they pump water containing TCE concentrations of 50 to 70 ppm. The trees are removing 95 percent of the chemical. Most contaminated groundwater has TCE concentrations below 25 ppm.


Lee Newman

Poplars growing in trichloroethylene-contaminated water in Fife, Wash.

The Washington team plans to investigate how much of the chemical entering the trees stays in the roots, stems, and leaves. The TCE that the trees transpire into the air degrades quickly, as sunlight breaks down the chemical. When the trees have exhausted their capacity to take up TCE, they may be burned or pulped, which would probably render the chemical harmless, Gordon says.

Soil in parts of the western United States has a natural abundance of selenium, an important nutrient for animals and humans that in high doses is toxic. Drainage water from agricultural fields often becomes rich in selenium. Growers then send the water to their evaporation ponds, where the selenium reaches even higher concentrations, which are deadly to wildlife.

Plants, however, "are very effective at removing selenium from contaminated soils," asserts Norman Terry of the University of California, Berkeley. They not only absorb the chemical, they also turn some of it into the less toxic dimethyl selenide gas. Selenate, the common form of selenium in soil, is about 600 times more toxic than dimethyl selenide gas.

In June, Terry and his colleagues completed construction of 10 experimental quarter-acre wetlands in Corcoran, Calif. They want to see if these wetlands reduce selenium concentrations in agricultural runoff to less than 2 ppb before it reaches the evaporation ponds. Grasses, such as cattails, bulrushes, and *Spatina*, grow in the wetlands.

The researchers are also investigating how much of the selenium in wetlands stays in sediments and plant tissues rather than being volatilized and dispersing into the atmosphere. Plants with large amounts of selenium could sicken birds and insects that eat them, the scientists fear. Studies from the late 1980s suggested that plants volatilize about 30 percent of the selenium entering a wetland. Terry's recent laboratory studies, however, show that volatilization rates differ from plant to plant and depend on the concentration of selenium in the soil.

Terry expects to have more information on volatilization later this summer, after analyzing data on the selenium stored in plants in a 90-acre wetland in Point Richmond, Calif., that Chevron Corp. built in 1988. The company originally constructed the wetland, which features cattails and bulrushes, for its beauty. Now, the wetland is removing 70 to 75 percent of the selenium from the 10 million liters of wastewater that the company pumps through it every day, says Terry.

In central California, at least two farmers are using Indian mustard and tall fescue to extract selenium from irrigation water, reports Gary S. Bañuelos of the U.S. Department of Agriculture's Agricultural Research Service in Fresno, Calif. He advises the farmers on the phytoremediation technology.


Steve Downey

Indian mustard grows on a farm in Five Points, Calif., to extract selenium from irrigation water.

More farmers will probably become interested in this green technology, because a new law in California requires them to greatly reduce selenium concentrations in drainage water, Bañuelos says.

To address the broader problem of oil contamination, Exxon and other companies (SN: 8/5/95, p. 84) find that plants stimulate bacteria that break down hydrocarbons. However, researchers must then contend with herbicides that companies sometimes use on contaminated spots to prevent fires, says Evelyn Drake of Exxon in Annandale, N.J.

This is just one of the many barriers to the widespread use of phytoremediation. Investigators must still find or develop plants that are superior hazardous waste handlers. For years, breeders have cultivated commercial plants primarily to produce a large yield.

Soil poisoned long ago will prove particularly difficult for plants to tackle because the chemicals have become firmly entrenched, says Cunningham.

"Technical and economic success will probably first come in treating water and airborne contaminants," he contends. "Soils are more difficult and more complex."

Unexpected costs continue to plague the phytoremediaton industry. For example, Cunningham says he needed legal advice just to determine how to meet environmental regulations for decontaminating a tractor used in a phytoremediation project.

Environmentalists, often critical of big businesses' low-cost cleanup schemes, are giving cautious support to phytoremediation.

"The methods can be used in certain circumstances," asserts Robert W. Hastings, a Sierra Club spokesperson at Southeastern Louisiana University in Hammond. "Though it certainly won't be a cure-all. We need to cut down on the production of contaminants up front. But where we do have cleanup problems, phytoremediation does have potential." □