RESEARCH NEWS

Arboreal alchemy

David E. Salt

"Hurt not the earth, neither the sea, nor the trees."
—Revelations 7:3

In a twist of fate, probably never envisioned by our forbears, we may soon be using trees to help us "heal the hurt" inflicted on the earth. By borrowing genes from bacteria, Rugh et al.[1] have been able to make yellow poplar perform a trick alchemists learned long ago: Turning cinnabar into quicksilver—or, in modern chemical parlance, reducing ionic mercury to volatile, elemental mercury. This trick raises the possibility that trees may soon be able to remove poisonous mercury from soil by blowing it into the atmosphere, in a process aptly named phytovolatilization (*phyto*, plant; *volatilization*, change to a vapor).

Since the earliest times, people have used plants in almost every aspect of their lives: To fill their bellies, clothe their bodies, paint their walls and pots, cure their ailments, and even stimulate their sex lives. With the advent of the industrial revolution, however, this reliance on plants as our basic raw material declined. At the same time, the continuing industrialization of our societies has resulted in the ever-increasing problem of pollution. The recent ground swell of interest in using plants to remediate some of these environmental problems[2] may help to reverse these trends.

Over millions of years, plants have evolved an exquisite root system that allows efficient acquisition of essential elements from soil. Researchers, regulators, and industrialists now hope to put this system to work, removing from soil inorganic pollutants (e.g., mercury[3], lead[4,5], and cadmium[6]) and providing a new, potentially low-cost, environmentally sound, remediation strategy.

Before fields of metal-accumulating plants are seen dotting the landscape, however, some basic hurdles need to be overcome. First, many pollutant metals are very insoluble in soil and therefore unavailable for plant uptake. Second, the pollutant metals of interest are usually toxic to plants and are restricted in movement to the shoot, reducing the accumulation of metals in the plants' harvestable above-ground parts. For their own purposes, so-called hyperaccumulator plants[7] have evolved solutions to all these problems. These wild plant species have developed an unusual adaptation to metal-rich soils. Instead of excluding metals, they accumulate them to very high concentrations. Unfortunately, there is a fly in the ointment: Most of these plants are also small and slow-growing, making them impractical for large-scale remediation.

IMAGE UNAVAILABLE FOR COPYRIGHT REASONS

Figure 1. Branching out: Genetic engineering has been used to create trees that detoxify contaminated sites. "Aquamarine" by Maxfield Parrish (American, 1917).

If we are to remove metals from a polluted soil in a reasonable time period—5 years for example—we need a rapidly growing plant that produces a lot of metal-accumulating biomass. In a series of two elegant papers Rugh et al.[1,3] have started to overcome the problems of metal transport—metal tolerance and plant size. By borrowing the *merA* gene from mercury-resistant bacteria, extensively modifying it for plant expression, and integrating it into the genome of yellow poplar, they have produced remarkably mercury-resistant plants. The *merA* gene encodes an enzyme, mercury reductase, that is capable of chemically reducing highly toxic ionic mercury (II) to elemental mercury, which is both much less toxic and volatile, thereby killing two birds with one stone.

By using the *merA* gene, they have been able to both increase the resistance of the plants to mercury and also increase the transport of mercury from the soil, in this case into the air. As is usual in the plant research community, this interesting idea was first tested in Thale Cress (*Arabidopsis thaliana*), a great model plant, but particularly impractical for clean-up applications due to its diminutive size. By moving *merA* into the larger yellow poplar, Rugh et al.[1] have taken a very important first step to producing a useful plant for removing mercury from soil. However, the question of the solubility of mercury in soil remains to be answered. As was the case with lead[4], it may turn out that although the plants are capable of volatilizing mercury, there may be no soluble mercury available in the soil for the plants to volatilize. This remains an open issue.

We can envisage a time when large areas of mercury-contaminated land may be covered with mercury-volatilizing plants, such as yellow poplar. The large leaf surface area presented by these plants would allow volatilization of large amounts of mercury. However, this raises another question: Would we simply be exchanging soil pollution for air pollution, or, is dilution into the atmosphere really the solution in this case? The answer to this question will continue to be debated long after this article is read. The regulators and ultimately the public will decide whether phytovolatilization is a safe and desirable method for restoring ecosystems polluted by toxic levels of mercury.

This being said, Rugh et al. have discovered a very rich vein of research opportunities. By demonstrating the practicality of using genetic material from metal-resistant bacteria, they will no doubt encourage others to dip into this rich resource. This will almost certainly speed the development of plants specifically designed for remediating metal-polluted environments, potentially solving (at least in part) the estimated $200 billion dollars worth of toxic and radioactive metal pollution produced in the United States alone[8].

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