MONEY DOESN'T GROW ON TREES, BUT SOME METALS DO

Cars, jewelry, coins, batteries and stainless steel cookware all contain nickel. Global demand for the metal is driving industry to probe ore deposits for increasingly smaller concentrations of difficult-to-extract nickel, while researchers are looking for ways to obtain more of the metal from sub-economic ores.

Now, there's another way. It can be grown. Phytomining — raising crop plants that accumulate heavy metals, such as nickel, in their leaves — may offer an economic means of extracting residual metal from mine waste.

Over the past 60 years, nickel production has grown more than eightfold. Sulfide ores, containing on average between 10 and 26 percent nickel, have been the major source of the metal. They comprise only 30 percent of the world's nickel resources, but account for roughly 60 percent of current nickel production.

The other 70 percent of the world's nickel resources are tied up in weathered soils rich in iron and magnesium. These deposits, called laterites, exist mainly in tropical zones, in countries such as Australia, Indonesia, the Philippines and the French island of New Caledonia in the Pacific.

As global demand for nickel increases about 4 percent annually, mining companies are turning toward ultramafic laterites, also known as serpentine soils, which contain nickel in far smaller concentrations — 0.5 to 1.5 percent — than sulfide ores.

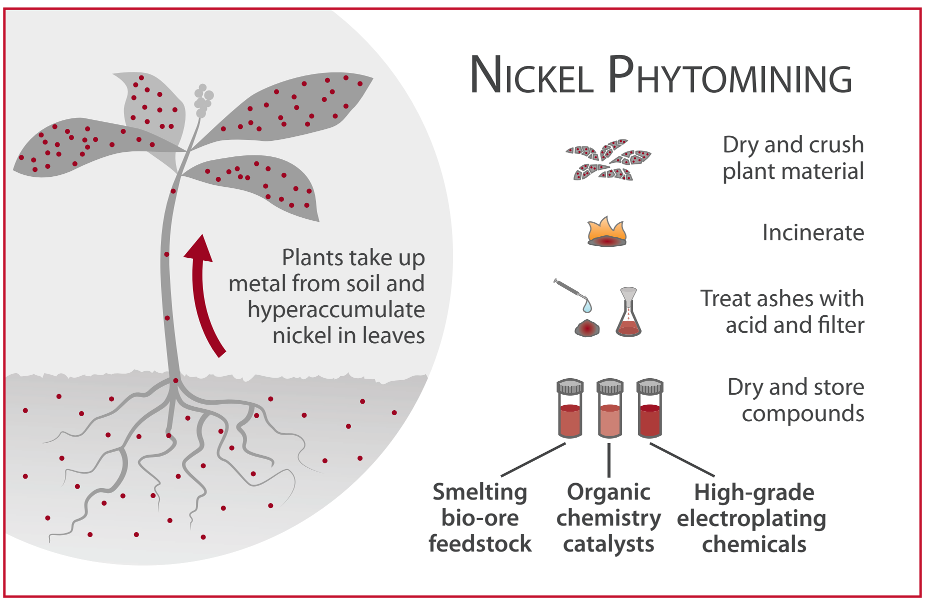
Traditional laterite strip mines, which remove the top layer of soil to access subsurface soils that are higher in nickel, require about a 1 percent nickel concentration to make the mine economically viable. Traditional mining can be inefficient, leaving much of the metal behind in the soil, according to Rufus Chaney, an agronomist at the U.S. Department of Agriculture in Maryland.

Plants, Chaney says, can do better.

While researching plants that could grow on the polluted soils of old industrial and mine sites in the 1970s and 1980s, Chaney and colleagues uncovered a rare group that can take up and store as much as 100 times more nickel in their shoots than ordinary plants grown on nickel-containing soil. Dubbed hyperaccumulators, these plants can concentrate high levels of nickel — up to 20 percent in the ash once incinerated — from soil containing as little as 0.1 percent nickel, far lower than would be useful for traditional mining.

"Using hyperaccumulators to extract nickel from soil is a relatively straightforward idea that requires just sunlight and fertilizer," says Chaney, who helped develop methods for growing and retrieving nickel from one fast-growing species of flowering plant native to southeastern Europe, called *Alyssum,* in the early 2000s.

The plant *Alyssum murale* accumulates heavy metals, which makes it toxic to animals. Efforts are under way to use such plants to clean contaminated soils and to mine metals.



When laterite soils are mined for nickel, high heat, high pressure and strong acids must be applied to extract nickel, leaving a toxic slurry. Phytomining is cleaner than strip mining, and the nickel product is more pure.

No one is sure why some plants evolved the ability to take up nickel at such high levels. Some experts suggest that the metal may give the plants some protection against fungal diseases and insects. In the process, hyperaccumulators do the work of separating out the nickel from the other elements, creating a product that is desirable for both the nickel smelting and chemical industries.

While the technology to cultivate nickel hyperaccumulators on an agricultural scale has existed for nearly a decade, it has yet to be utilized. Viridian LLC, a U.S.-based environmental services company, holds patents on the technology, but the company isn't using it. Those patents expire in 2015, at which point the technology is up for grabs.

Antony Van der Ent, a doctoral candidate in biogeochemistry at the University

Bottom: Kathleen Cantner, AGI; top: courtesy of Ken French, Oregon Dept. of Agriculture

SEA-ICE ALGAE A BIG PART OF ARCTIC CARBON BUDGET, ECOLOGY

Like a slimy shag carpet, meter-long strands of green algae hang from beneath much of the Arctic's floating sea ice, according to an international team of researchers. During a research cruise aboard the icebreaker R/V Polarstern last summer, when sea-ice extent and thickness fell to historic lows, the group found *Melosira arctica* dangling from the sea ice at seven of eight sites they visited in the Arctic Ocean north of Europe and Asia.

Algae growing under sea ice have been observed before, but its contribution to primary biological production in the Arctic and its role in Arctic ecology have been largely unclear. Led by Antje Boetius of the Alfred Wegener Institute for Polar and Marine Research in Germany, the team reported in Science that the amount of algae observed could account for nearly half of the total primary production in the area studied. They also found that, when the sea ice melted, large amounts of the algae sank several kilometers through the water column, eventually forming mats covering up to 10 percent of the seafloor. Once there, the algae attracted ocean-bottom grazers, such as sea cucumbers, and also fed increased microbial activity relative to uncovered areas.

Comparing their seafloor observations to previous work, the researchers wrote that the contribution of algae appears to have been especially prolific last summer, possibly due to higher transmission of growth-stimulating sunlight through the thinned ice. The observations have important implications for the Arctic's carbon budget and biodiversity, they suggested.

Timothy Oleson

Arctic sea ice harboring filaments of the algae *Melosira arctica*.

Courtesy of Mar Fernández-Méndez, Alfred Wegener Institute

of Queensland in Australia, is scouring the rainforests of Malaysia for nickel hyperaccumulators that thrive in tropical regions. The *Alyssum* cultivars that Chaney helped develop are native to dry, temperate climates and won't survive in an equatorial rainforest. Having a viable, tropical alternative is critical to attracting interest among mining companies, Van der Ent says.

The last U.S. nickel mine, located in Oregon, closed in 1987. Today, the U.S. imports all 120,000 tons of the nickel it uses each year. According to Chaney, there are millions of hectares of nickel-containing soils throughout the Western U.S. that have never been mined, because they contain too little nickel to attract traditional mining operations. The land is underutilized, because it's difficult to grow most crops on these soils. If these soils were planted with nickel hyperaccumulators, Chaney estimates that the U.S. could grow as much as half of the nickel it consumes.

However, experts don't think that phytomining could supplant traditional mining. "It's just not the same scale. For one, plant extraction is confined to how deep the roots can grow," says Chris Anderson, an environmental geochemist at Massey University in New Zealand.

But, "nickel-rich laterite soils are virtually endless — there will be no shortage of them for years to come," Van der Ent says. "As these enormous mines fall under increasing public and media scrutiny, rehabilitating and remediating old mine sites, as well as progressively rehabilitating new and operating mines, is becoming more important. I see phytomining as part of that strategy."

Many poor, tropical countries in which the bulk of nickel mining occurs lack the environmental regulations to hold polluters responsible for the messes they leave behind.

"The beauty of nickel phytomining is the value in the pollutant itself," says J. Scott Angle, an agronomist at the University of Georgia. "Instead of [pollutants] costing [them] money, companies may be able to make money while rehabilitating laterite soils."

Lindsey Konkel