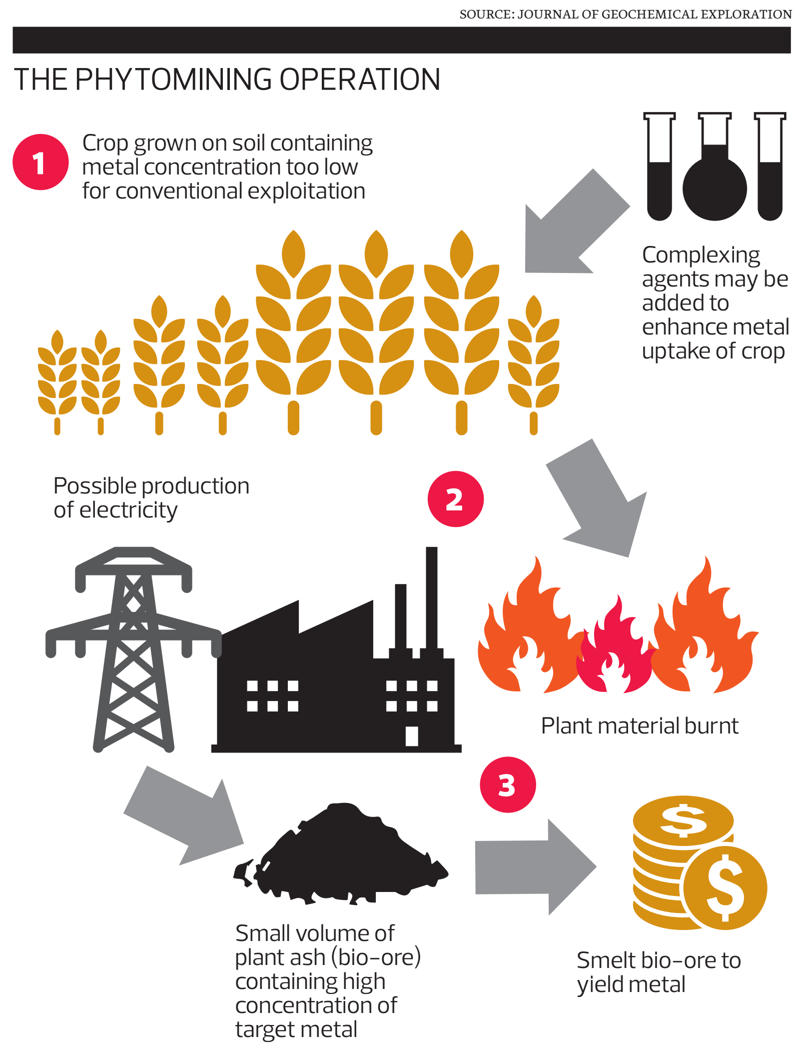
NEW HORIZONS

PROFITING FROM THE EARTH



BY EMILY CHOW

Rows of crops typically denote farming activity. But some types of plants, when planted in soil with metal content, are able to harvest or mine for minerals. This is called phytomining.

"Unlike conventional mining, where the earth is dug out and the metals are refined, phytomining uses plants to accumulate metals," says Dr Ille Gebeshuber, a professor at Vienna University of Technology's Institute of Applied Physics, who has been working in Malaysia for the last six years.

Plants called hyperaccumulators have the ability to extract and accumulate metals from the soil. They are able to absorb high amounts of heavy metals — 10 to 100 times the level found in most species — without suffering phytotoxic effects.

This is a natural occurrence in such plants. According to Gebeshuber's report, titled "Raw Materials Synthesis from Heavy Metal Industry Effluents with Bioremediation and Phytomining: A Biomimetic Resource Management Approach", many heavy metals are essential or beneficial for the growth and metabolism of plants, but are dangerous if found in high concentrations. These include cobalt, copper, iron, manganese, nickel and zinc.

There are several hypotheses about why some plants are able to absorb metals from the soil, one of which is that the toxicity of the metals act as a deterrent and protect the plants from being eaten. It is also natural for soil to contain metals, sometimes in highly dissolved forms.

"In phytomining, you cannot think of it as plants taking out little nuggets of gold from the ground. What they do instead, and what conventional mining cannot do, is take out highly dissolved and diluted metals from the soil. The metals are not concentrated," explains Gebeshuber.

"So, plants with their root system, by taking water from the soil, also take the metals and accumulate them in their bodies."

Different plants absorb different types of minerals or metals. According to Gebeshuber's report, there are 440 types of hyperaccumulators, 75% of which are nickel hyperaccumulators. Other plants accumulate other metals, such as cadmium, arsenic, manganese, sodium, thallium and zinc.

When the metal ions have been extracted and concentrated in the plant's tissue, they are harvested, dried, ground and burnt as part of the metal extraction process. After the plant or biomass is burnt to produce bio-ore, it is treated with chemicals to get refined metals.

There are two types of hyperaccumulation in phytomining — natural and induced. Natural hyperaccumulation occurs when plants absorb heavy metals as a normal function of their growth. Induced hyperaccumulation occurs when chemicals are added to the soil to manipulate the environment so that the metal becomes soluble. This is used in phytomining elements such as gold because plants do not naturally accumulate them.

The chemical catalyst needed for phytomining gold is cyanide — a poisonous chemical compound usually used in insecticides, pest control and conventional mining methods to extract gold and silver. While there are environmental concerns about adding chemical agents to the soil, certain plants such as soybeans naturally emit cyanide and can be planted near hyperaccumulators to dissolve the gold in the soil. This is a more environmentally friendly way to phytomine gold.

ADAPTATION AND COMMERCIAL USES

While different hyperaccumulators absorb different minerals and metals, the plants are location-specific and need a suitable climate to grow and thrive.

Phytomining takes one crop season (three to six months) to accumulate metal, depending on the plant. The amount of metal absorbed depends on the type of plant (see table). The Indian mustard plant, for example, can accumulate 10mg of gold per kg of its dry weight, while the sweet alyssum plant can absorb more than 13,000mg of nickel.

THE HISTORY OF PHYTOMINING

Phytomining, or the accumulation of metals using plants, is not new. The concept was first mooted in 1983 for the use of phytoremediation, or the process of using hyperaccumulators to clean up soil that has been contaminated by metals.

"If there is lead in the soil, for example, many plants cannot grow anymore because lead pollutes the earth and plants are very sensitive to lead," explains Dr Ille Gebeshuber, a professor at Vienna University of Technology's Institute of Applied Physics.

"In this case, you can plant a lead hyperaccumulator in the soil to drag the lead out of the soil. Then, you take away the plant and dispose of it. There are many plants that accumulate lead, one of which is the sunflower, which can also accumulate copper. This is done wherever you have metal mining."

According to Gebeshuber, the practice of phytoremediation has been around for many generations, thus exactly when it was discovered cannot be determined. The first recorded field trials for phytomining, however, were carried out at the US Bureau of Mines in Nevada, the US, in 1994. A nickel hyperaccumulator was used in soil containing 0.35% of the metal, well below the economic range for conventional mining. The trial revealed that a yield of 100kg of nickel per hectare could be produced via phytomining. In 1999, when field studies were conducted in Italy, it was found that a nickel level of 0.8% yielded 72kg of nickel per hectare.

Gebeshuber believes these numbers are productive enough for mineral extraction. While it can never be comparable to the production rates of conventional mining, phytomining allows metals to be extracted from soils that are considered uneconomic by conventional mining methods, or for phytoremediation purposes (the restoration of polluted soil).

Another limitation of phytomining is that hyperaccumulators are only able to extract metals on the surface of the soil. "Mines go down hundreds and hundreds of metres, taking out all the soil and metals. But for plants, their roots only go down to two to four metres," says Gebeshuber.

Despite the limitations, one man is attempting to make phytomining work on a commercial, albeit small, scale. Dr Chris Anderson, principal scientist at Croesus Projects Ltd, has spent the past decade developing gold phytomining in China, Mexico and Indonesia.

> In phytomining, you cannot think of it as plants taking out little nuggets of gold from the ground. What they do instead, and what conventional mining cannot do, is take out highly dissolved and diluted metals from the soil. > ***Gebeshuber***

He founded Croesus, an environmentally focused education and investment consultancy, in 2005. The company specialises in environmental geochemistry, with a focus on environmental pollution related to mining and industrial operations, and specific competencies in environmental impact assessments and phytoremediation.

Later, Croesus became a founding investor in New Zealand-based gold phytomining company Tiaki International Ltd.

"While Tiaki continues to work on gold phytomining, primarily in North America, my main focus with Croesus is applying gold and nickel phytomining technology to developing countries," says Anderson. "The primary aim here is remediation and agricultural development, rather than straight profit."

In order to carry out phytomining, one first needs to obtain land with the target metal. The soil needs to have a certain level of metal so that the operation is economically viable. This may be hard to come by as existing mine wastes are tightly controlled by mining companies.

"There is plenty of nickel- and gold-rich soil worldwide, but not much platinum- and palladium-rich soil. For this reason, large-scale platinum and palladium phytomining has never been considered viable, as we cannot get access to the resource," says Anderson.

Once land is obtained though, the operations are simple enough. The hyperaccumulators are farmed, and this process is not costly as there is not a lot of intellectual property in the area of farming. The risks faced in this venture would be agricultural-related — drought, crop failure and floods. It gets tricky when the crops are ready for harvesting. The crops or biomass need to be processed so the metals can be recovered. This can be done immediately or they can be stored for as long as needed. Anderson says this is an expensive process, as there is no good and proven technology yet to carry it out in an efficient and economical manner.

"Significant investment is needed to develop a good processing system for nickel- and gold-rich biomass. I don't think any economically profitable phytomining operation will be possible until this is done," he says.

Anderson was the one who pioneered gold phytomining in 1998 when he discovered that a chemical called thiocyanate caused plants to absorb gold. While he says plants can be made to accumulate just about any metal, the practical applicability of this technology depends on cost. Generally only the semi-valuable metals (like nickel, silver and copper) and valuable metals such as gold and platinum are realistic targets.

"For nickel, probably 200kg per hectare would be feasible. My target for gold continues to be 1kg per hectare. I think these levels would sustain a business," he says.

"But note that these must be considered as part of the package, that it also creates jobs and provides opportunities for agricultural training. The question is, where will we find the resources, or the land, that will support these yields?"

Anderson is realistic about what phytomining can and cannot achieve. It cannot be directly compared with conventional mining because mining companies take into consideration the volume of minerals produced, which phytomining never does. Phytomining can produce 10,000 tonnes of metal from a hectare of plant biomass over one crop season, while large-scale mining processes the same amount of rock in hours.

What phytomining can do, however, is sustain a community — by providing an economic incentive to miners whose land is subjected to illegal gold mining owing to the residue left behind.

There is usually plenty of gold left in mining wastes, Anderson says, so the revenue generated from "farming" this waste pays for the extraction of the metal and the management of pollutants that would otherwise be discharged into the soil and water.

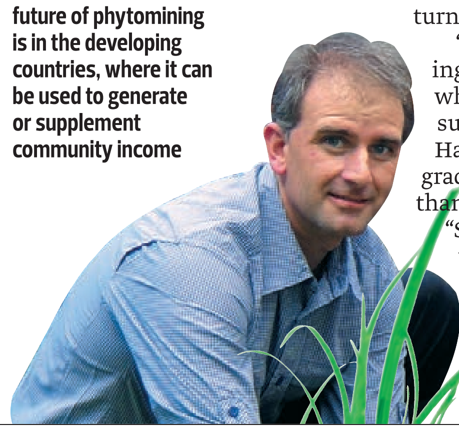
"I am supporting several small operations in Indonesia, but these are not large commercial operations. They are artisanal and small-scale gold mines in Lombok, Sumbawa and Java," he says. "In collaboration with the University of British Columbia in Vancouver, Canada, we have been working to apply gold phytomining to this same scenario in Ecuador and Peru."

Reiterating that phytomining has a strong social and environmental purpose, Anderson says that despite receiving about NZ$1.5 million (RM4.1 million) in investment, Tiaki has never turned a profit.

HYPERACCUMULATORS USED IN PHYTOMINING

METAL	HYPERACCUMULATOR: SCIENTIFIC NAME	HYPERACCUMULATOR: COMMON NAME	CONCENTRATION OF METALS (MG/KG DRY WEIGHT)	BIOMASS (TONNE/HA)
Cadmium	Thlaspi caerulescens caerulescens	Alpine Penny-cress	3,000	4
Cobalt	Haumaniastrum robertii	Copper Flower	10,200	4
Copper	Haumaniastrum katangense	Copper Flower	8,356	5
Gold (induced hyperaccumulation)	Brassica juncea	Indian Mustard	10	20
Lead	Thlaspi rotundifolium	Round-leaved Penny-cress	8,200	4
Manganese	Macadamia neurophylla	Macadamia plant (one of various types)	55,000	30
Nickel	Alyssum bertolonii	One of ten European species of Alyssum that hyperaccumulate Nickel	13,400	9
	Berkheya coddii	South African Nickel hyperaccumulator	17,000	22
Thallium	Biscutella laevigata	Buckler Mustard	4,055	4
Zinc	Thlaspi caerulescens calaminare	Alpine Penny-cress	10,000	4

SOURCES: AMSE JOURNAL, JOURNAL OF GEOCHEMICAL EXPLORATION



Anderson: I believe the future of phytomining is in the developing countries, where it can be used to generate or supplement community income

"I believe the future of phytomining is in the developing countries, where it can be used to generate or supplement community income. Harvesting metal from poor or degraded soil is perhaps a better option than growing food," he opines.

"So, to large mining companies, the value of phytomining is in the use of the plants to clean up the mess, to remediate waste land or to use in mine closure. Mining companies are not receptive to the phytomining aspects of the technology. But if the technology could help them achieve environmental targets, then they would be."

A Malaysian miner who is asked whether his company would be interested in phytomining, agrees that the research results are noble, but he does not consider it an economic activity.

"It would take too long. If you want to produce metal, this can't be used as a source," he says.

"It is useful for land rehabilitation after mining to remove contaminants. But planting tons of crops for the metal content generated is not worthwhile."

While soaring gold prices typically push mining companies towards better profit margins, Anderson says this makes phytomining harder to pursue. Higher gold prices allow conventional miners to recover metal from low grade soil more economically. This also means fewer land resources for phytomining.

"The future of phytomining would be more secure with a lower gold price. If prices go down, mining companies will struggle to make money from low-grade resources, making it available to phytomining," he says.

"I think there is tremendous potential for phytomining in Southeast Asia, but this requires collaboration between Western science and technology and Asian investment and business." E