Research finds arsenic supply at highest risk

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Modern technology depends on reliable supplies of a wide variety of materials, but there is increasing concern about the dependability of those supplies.

In the first detailed assessment of metal "criticality," a team of undergraduates, master's students and research staff led by Thomas Graedel, the Clifton R. Musser Professor of Industrial Ecology, has codified a methodology that takes into account the risk of future scarcity and potential damage from shortages of metals in the periodic table.

"Criticality evaluation is increasingly vital to corporations and governments as they decide which metals to use, stockpile and avoid," said Graedel.

In the paper, "Criticality of the Geological Copper Family," published in Environmental Science *& Technology*, Graedel's team applied its methodology to the elements of the geological copper family: copper, arsenic, selenium, silver, tellurium and gold. All six are technologically important. For example, copper is essential in transmitting electricity. Gold and silver play important roles in electronics. Selenium and tellurium are major constituents in thin-film solar cells. And arsenic in the form of gallium arsenide is an essential ingredient in high-speed computer chips.

To demonstrate the methodology, Graedel's team created a fictional solar cell manufacturing firm. Arsenic was at the highest risk of supply disruption over the long-term of the six metals because there is scant

interest in mining a poisonous material, with selenium and gold almost as high a risk. Gold occurs at such low concentrations in the ore that mining and processing has the potential to cause significant amounts of air and water pollution, so it has the most severe environmental implications ranking.

"Restrictions to the availability of any of these elements would constrain a number of technological sectors, so an assessment of their criticality is vital," he said.

The criticality of a metal is specified in a three-dimensional "criticality space," which assesses the supply risk, environmental implications and vulnerability to supply restriction. Each of these factors is, in turn, the aggregation of a number of components, such as geological reserves and political governance indicators. The details of the methodology have been worked out in partnership with several corporations in the United States and Europe. Information was drawn from a broad range of datasets generated by governments and institutions worldwide.

"A central feature of criticality is that vulnerability to supply restriction is a unique organizational attribute," said Graedel. "For example, a particular metal may have high supply risk, but that information is of little interest to a corporation whose products do not use that metal."

To ensure the availability of metals vital to its operation, a corporation could choose to invest directly in a mine rather than purchase metal from the global market or to develop product designs that avoid metals with high supply risk or high environmental implications. Countries could take steps to ensure raw material supplies for their important industry sectors, as is happening in countries around the world.

Manufacturers and governments that use metals are vulnerable to supply restrictions related to the ease of substitution for a metal in a particular

application, the metal's importance to corporate or national finances and strategy, and the organization's innovative abilities should restrictions occur.

Supply restrictions might occur because of geologic scarcity, environmental concerns, geopolitics or market manipulation, among other factors.

"The additional knowledge provided by criticality assessments is likely to enable better decisions to be made in the interest of corporations, countries, and the planet," said Graedel. "This sort of thinking and action will become more and more important as ever increasing rates of material use force all of us to think more deeply about issues of resource sustainability."

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