Geology In

Extracting rare-earth elements from coal could soon be economical in US

These rare-earth oxides are used as tracers to determine which parts of a watershed are eroding. Clockwise from top center: praseodymium, cerium, lanthanum, neodymium, samarium, and gadolinium.

The U.S. could soon decrease its dependence on importing valuable rare-earth elements that are widely used in many industries, according to a team of Penn State and U.S. Department of Energy researchers who found a cost-effective and environmentally friendly way to extract these metals from coal byproducts.

Rare-earth elements are a set of seventeen metals—such as scandium, yttrium, lanthanum and cerium—necessary to produce high-tech equipment used in health care, transportation, electronics and numerous other industries. They support more than $329 billion of economic output in North America, according to the American Chemistry Council, and the United States Geological Survey expects worldwide demand for REEs to grow more than 5 percent annually through 2020. China produces more than 85 percent of the world's rare-earth elements, and the U.S. produces the second most at just over 6 percent, according to the USGS.

"We have known for many decades that rare-earth elements are found in coal seams and near other mineral veins," said Sarma Pisupati, professor of energy and mineral engineering, Penn State. "However, it was costly to extract the materials and there was relatively low demand

until recently. Today, we rely on rare-earth elements for the production of many necessary and also luxury items, including computers, smart phones, rechargeable batteries, electric vehicles, magnets and chemical catalysts. We wanted to take a fresh look at the feasibility of extracting REEs from coal because it is so abundant in the U.S."

Using byproducts of coal production from the Northern Appalachian region of the U.S., the team investigated whether a chemical process called ion exchange could extract REEs in a safer manner than other extraction methods. For example, past research has examined "roasting," a process that is energy intensive and requires exposure to concentrated acids. In contrast, ion exchange is more environmentally friendly and requires less energy. Ion exchange involves rinsing the coal with a solution that releases the REEs that are bound to the coal.

"Essentially, REEs are sticking to the surface of molecules found in coal, and we use a special solution to pluck them out," said Pisupati. "We experimented with many solvents to find one that is both inexpensive and environmentally friendly."

The team reported in their findings, published in the current issue of Metallurgical and Materials Transactions E, that ammonium sulfate was both environmentally friendly and able to extract the highest amount of REEs. Extracting 2 percent of the available REEs would provide an economic boon to companies, the team said.

"We were able to very easily extract 0.5 percent of REEs in this preliminary study using a basic ion exchange method in the lab," said Pisupati. We are confident that we can increase that to 2 percent through advanced ion exchange methods."

The researchers used coal byproducts in their study, some of which were discarded or marked as refuse during mining operations due to poor quality. Finding more uses for discarded coal could provide yet another economic benefit to companies.

In their study, the team also identified the locations within the coal seam that contained the highest amounts of REEs. Often the highest concentration is found in the poorest quality coal, said Pisupati.

"You find some REEs in the coal itself, but the highest concentration is in what we call the coal shale, or the top layer of a coal seam. Knowing this, we can further target our operations to be more efficient," he said.

The team is now collaborating with several Pennsylvania coal-mining companies to explore the viability of a commercial REE-extraction operation.