A dozen exotic bacteria are found to passively collect rare earth elements from wastewater

February 28 2023

An image of Cyanobacteria, Tolypothrix. Credit: Wikipedia / CC BY-SA 3.0

Rare earth elements (REEs) are a group of 17 chemically similar metals, which got their name because they typically occur at low concentrations (between 0.5 and 67 parts per million) within Earth's crust. Because they are indispensable in modern technology such as light-emitting diodes, mobile phones, electromotors, wind turbines, hard disks, cameras, magnets and low-energy lightbulbs, the demand for them has increased steadily over the past few decades, and is predicted to rise further by 2030.

As a result of their rarity and the demand, they are expensive: for example, a kilo of neodymium oxide currently costs approximately €200, while the same amount of terbium oxide costs approximately €3,800. Today, China has a near-monopoly on the mining of REEs, although the discovery of promising new finds (more than one million metric tons) in Kiruna, Sweden was announced with great fanfare in January 2023.

Circular economy

The advantages of moving from a wasteful "linear" economy to a "circular" economy, where all resources are recycled and reused, are obvious. So could we recycle REEs more efficiently, too?

In *Frontiers in Bioengineering and Biotechnology*, German scientists have shown that the answer is yes: The biomass of some exotic photosynthetic cyanobacteria can efficiently absorb REEs from wastewater; for example those derived from mining, metallurgy, or the recycling of e-waste. The absorbed REEs can afterwards be washed from the biomass and collected for reuse.

"Here we optimized the conditions of REE uptake by the cyanobacterial biomass, and characterized the most important chemical mechanisms for binding them. These cyanobacteria could be used in future eco-friendly processes for simultaneous REE recovery and treatment of industrial wastewater," said Dr. Thomas Brück, a professor at the Technical University of Munich and the study's last author.

Highly specialist strains of cyanobacteria

Biosorption is a metabolically passive process for the fast, reversible binding of ions from aqueous solutions to biomass. Brück and colleagues measured the potential for biosorption of the REEs lanthanum, cerium, neodymium, and terbium by 12 strains of cyanobacteria in laboratory culture. Most of these strains had never been assessed for their biotechnological potential before. They were sampled from highly specialized habitats such as arid soils in Namibian deserts, the surface of lichens around the world, natron lakes in Chad, crevices in rocks in South Africa, or polluted brooks in Switzerland.

The authors found that an uncharacterized new species of Nostoc had the highest capacity for biosorption of ions of these four REEs from aqueous solutions, with efficiencies between 84.2 and 91.5 mg per g biomass, while Scytonema hyalinum had the lowest efficiency at 15.5 to 21.2 mg per g. Also efficient were Synechococcus elongates, Desmonostoc muscorum, Calothrix brevissima, and an uncharacterized new species of Komarekiella. Biosorption was found to depend strongly on acidity: it was highest at a pH of between five and six, and decreased steadily in more acid solutions. The process was most efficient when there was no "competition" for the biosorption surface on the cyanobacteria biomass from positive ions of other, non-REE metals such as zinc, lead, nickel, or aluminum.

The authors used a technique called infrared spectroscopy to determine which functional chemical groups in the biomass were mostly responsible for biosorption of REEs.

"We found that biomass derived from cyanobacteria has excellent adsorption characteristics due to their high concentration of negatively charged sugar moieties, which carry carbonyl and carboxyl groups. These negatively charged components attract positively charged metal ions such as REEs, and support their attachment to the biomass," said first author Michael Paper, a scientist at the Technical University of Munich.

Fast and efficient, with great potential for future applications

The authors conclude that biosorption of REEs by cyanobacteria is possible even at low concentrations of the metals. The process is also fast: for example, most cerium in solution was biosorbed within five minutes of starting the reaction.

"The cyanobacteria described here can adsorb amounts of REEs corresponding to up to 10% of their dry matter. Biosorption thus presents an economically and ecologically optimized process for the circular recovery and reuse of rare earth metals from diluted industrial wastewater from the mining, electronic, and chemical-catalyst producing sectors," said Brück.

"This system is expected to become economically feasible in the near future, as the demand and market prices for REEs are likely to rise significantly in the coming years," he said.

More information: Rare earths stick to rare cyanobacteria: future potential for bioremediation and recovery of rare earth elements, *Frontiers in Bioengineering and Biotechnology* (2023). DOI: 10.3389/fbioe.2023.1130939

Provided by Frontiers

Citation: A dozen exotic bacteria are found to passively collect rare earth elements from wastewater (2023, February 28) retrieved 19 June 2024 from
https://phys.org/news/2023-02-dozen-exotic-bacteria-passively-rare.html

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