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Phytomining for Rare Earth Elements: A Comparative Life Cycle Assessment

Authors : Mohsen Rabbani, Trista McLaughlin, Ehsan Vahidi

Abstract : the remediation of polluted sites with heavy metals, such as rare earth elements (REEs), has been a primary concern of researchers to decontaminate the soil. Among all developed methods to address this concern, phytoremediation has been established as efficient, cost-effective, easy-to-use, and environmentally friendly way, providing a long-term solution for addressing this global concern. Furthermore, this technology has another great potential application in the metals production sector through returning metals buried in soil via metals cropping. Considering the significant metal concentration in hyper-accumulators, the utilization of bioaccumulated metals to extract metals from plant matter has been proposed as a sub-economic area called phytomining. As a recent, more advanced technology to eliminate such pollutants from the soil and produce critical metals, bioharvesting (phytomining/agromining) has been considered another compromising way to produce metals and meet the global demand for critical/target metals. The bio-ore obtained from phytomining can be safely disposed of or introduced to metal production pathways to obtain the most demanded metals, such as REEs. It is well-known that some hyperaccumulators, e.g., fern Dicranopteris linearis, can be used to absorb REE metals from the polluted soils and accumulate them in plant organs, such as leaves and stems. After soil remediation, the plant species can be harvested and introduced to the downstream steps, namely crushing/grinding, leaching, and purification processes, to extract REEs from plant matter. This novel interdisciplinary field can fill the gap between agriculture, mining, metallurgy, and the environment. Despite the advantages of agromining for the REEs production industry, key issues related to the environmental sustainability of the entire life cycle of this new concept have not been assessed yet. Hence, a comparative life cycle assessment (LCA) study was conducted to quantify the environmental footprints of REEs phytomining. The current LCA study aims to estimate and calculate environmental effects associated with phytomining by considering critical factors, such as climate change, land use, and ozone depletion. The results revealed that phytomining is an easy-to-use and environmentally sustainable approach to either eliminate REEs from polluted sites or produce REEs, offering a new source of such metals production. This LCA research provides guidelines for researchers active in developing a reliable relationship between agriculture, mining, metallurgy, and the environment to encounter soil pollution and keep the earth green and clean.

Keywords : phytoremediation, phytomining, life cycle assessment, environmental impacts, rare earth elements, hyperaccumulator
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