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# Bioleaching of lithium from spent lithium-ion batteries: unveiling the potential of siderophores produced by *Pseudomonas aeruginosa* and kinetic insights

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The widespread use of lithium-ion batteries (LIBs) in electric vehicles and energy storage systems has accelerated the demand for lithium metal, leading to resource scarcity and the accumulation of discarded batteries. Recycling spent LIBs is critical to maintain the supply chain of raw materials for battery manufacturing for a circular economy and eco-sustainability. In this study, a novel microbial siderophore-mediated bioleaching approach for Li extraction from spent LIBs black powder was attempted. *Pseudomonas aeruginosa* was employed for producing siderophores because of its strong affinity for $Fe^{3+}$ and the ability to form stable complexes with various metals [1]. Optimal conditions for maximizing siderophore production using the Na-succinate (SS) medium were investigated, focusing on the influence of pH (5–9) and glucose content (1–5 g/L). Subsequently, the effect of pulp density (1–5 g/L) and culture growth period (48–120 h) on Li bioleaching was evaluated under constant conditions: 35°C temperature and 150 rpm shaking speed. Results indicated that the maximum siderophore production of approximately 52 psu (% siderophore units) was achieved within 48 hours at pH 7 with a glucose content of 1 g/L. Qualitative and quantitative analyses confirmed the production of mixed-type siderophores, including catecholate and hydroxamate types, further corroborated by the FTIR analysis. Employing a 120-hour old bacterial culture for siderophore production and a pulp density of 1 g/L resulted in exceeding 99% Li extraction within 144 hours. Kinetic analysis based on the shrinking core model revealed that diffusion processes dominate Li extraction from spent LIBs. The mechanism involves the diffusion of the lixiviant into the solid LIB particles and the dissolution of the product layer away from the particle surface, further substantiated by XRD and FE-SEM analyses of the bioleached residues. Thus, the study suggests a promising alternative bioleaching approach for sustainable Li extraction from spent LIBs, employing microbial siderophores.

References:

[1] Mohwinkel, D., Kleint, C., and Koschinsky, A., (2014). Phase associations and potential selective extraction methods for selected high-tech metals from ferromanganese nodules and crusts with siderophores. Appl. Geochemistry. 43, 13-21.