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Study of Microbial Cultures for the Bioleaching of Scandium from Alumina Industry By-Products

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† This paper is part of the oral presentation entitled "Use of Different Microbial Cultures for Bioleaching of Scandium from Bauxite Residue" presented at ERES2020, 3rd Conference on European Rare Earth Resources, 6–9 October 2020, virtual, https://eres2020.eres-conference.eu/.

Citation: Kiskira K.; Lymperopoulou Th.; Tsakanika L.A.; Pavlopoulos C.; Papadopoulou K.; Ochsenkühn K.M.; Lyberatos G.; Ochsenkühn-Petropoulou M. Study of Microbial Cultures for the Bioleaching of Scandium from Alumina Industry By-Products. *Metals* **2021**, *11*, 951. https://doi.org/10.3390/met11060951

Academic Editor: Antoni Roca

Received: 13 May 2021
Accepted: 7 June 2021
Published: 11 June 2021

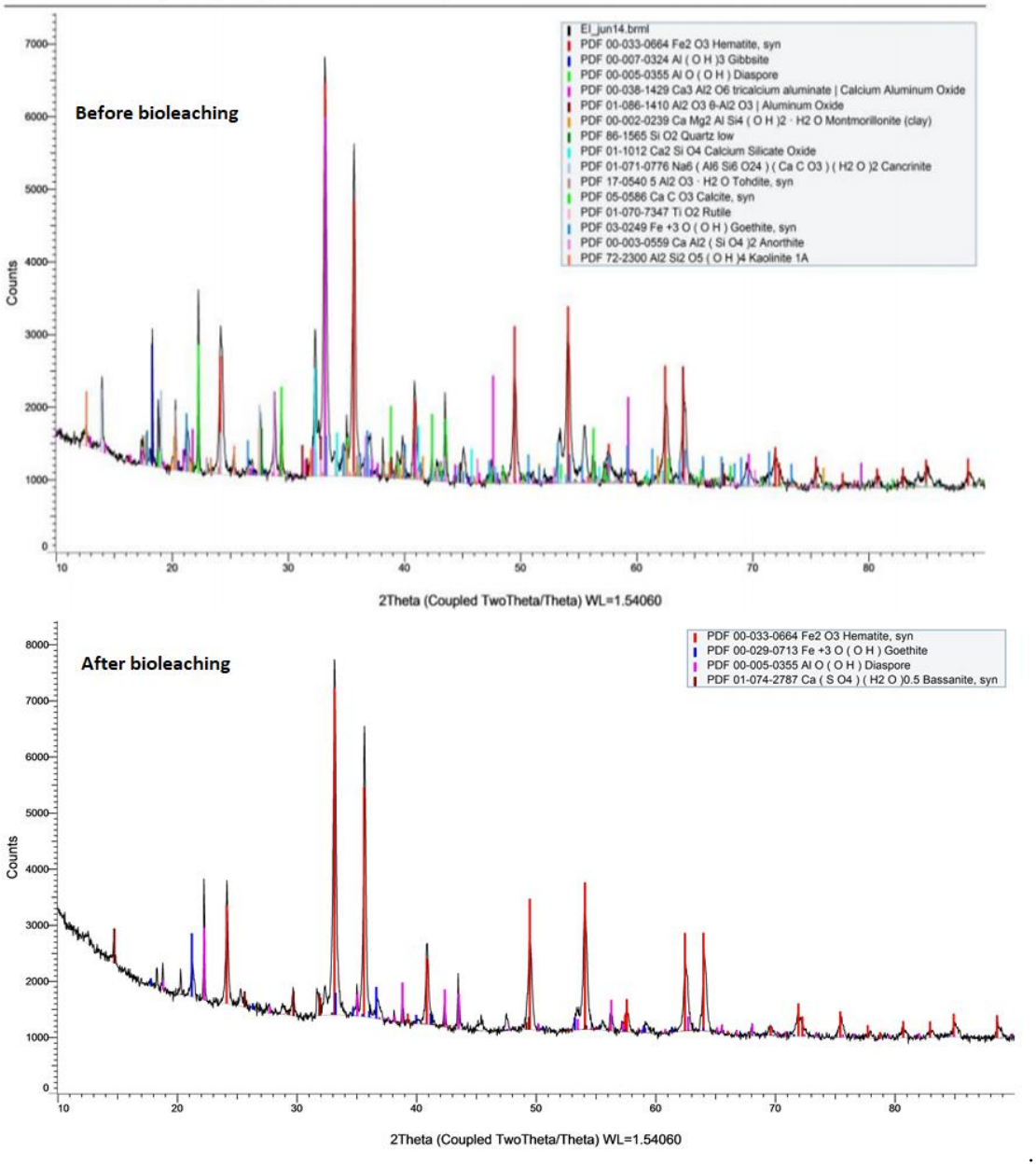

Figure S1. Mineralogical analysis of bauxite residue (BR) before and after bioleaching process with Acetobacter tropicalis.

The main mineralogical phase before the leaching process is the hematite (two peaks: 2θ = 33° and 2θ = 35.5°) (Figure S1). Also, smaller peaks of gibbsite, diaspore, tricalcium aluminate, aluminum oxide, montmorilonite, quartz, calcium silicate oxide, cancrinite, tohdite, calcite, rutile, goethite, anorthite and kaolinite were recorded. After bioleaching process, the dominate phase is also hematite while smaller amounts of goethite, diaspore and bassanite were determined (Figure S1). As it is also resulted from the semiquantitative analysis by EDX (Table S1) mainly calcium and sodium compounds were dissolved after bioleaching due to the acid formation during the process. Hematite presence as dominate phase after leaching is in good agreement with chemical analysis by AAS where only a small percentage up to 5% was extracted in the leachate solution. The appearance of bassanite is due to the formation of sulfides during bioleaching (the mineral medium contains sulfur) and their following oxidation to sulfates. Regarding iron, the important increment is due to normalization which enhances iron percentage since it is the major element in

BR. The chemical composition of the constituents of BR and their mass% before and after leaching, determined by EDX, are as shown in Table S1.

Table S1. EDX data for chemical composition (mass%) present in BR before and after bioleaching.

S. No	Element	Mass (%)	
		Before	After
1	C	8.68	8.73
2	O	41.46	38.60
3	Na	4.41	0.41
4	Al	8.98	9.30
5	Si	4.77	3.36
6	Ca	5.36	2.93
7	Ti	2.61	3.97
8	V	0.11	0.13
9	Fe	19.89	30.65

The morphology of the sample was investigated by scanning electron microscopy (SEM). Figure S2 shows the SEM images of BR with different magnifications. As it can be seen from the SEM images before and after bioleaching, BR exhibits an irregular morphology and there are no well-defined structures that can be observed. BR is a very fine material and that aggregates are formed (Figure S2). BR before bioleaching consists of several sizes of particles ranging from 0.1 to more than 20 μm with poor crystalline structure. No REEs mineral phases in the BR were observed due to their low concentrations.

From SEM images of BR after bioleaching a higher amount of aggregates with smaller BR particles can be observed compared to SEM images before bioleaching due to the partial dissolution of BR (Figure S2a,b,c,d). Figure S2d shows the aggregates of globular shaped particles (cell-mineral aggregates) than can be found in bioleaching experiments. Figure S2e shows the cell of *Acetobacter tropicalis* with a size of around 2.5 μm.

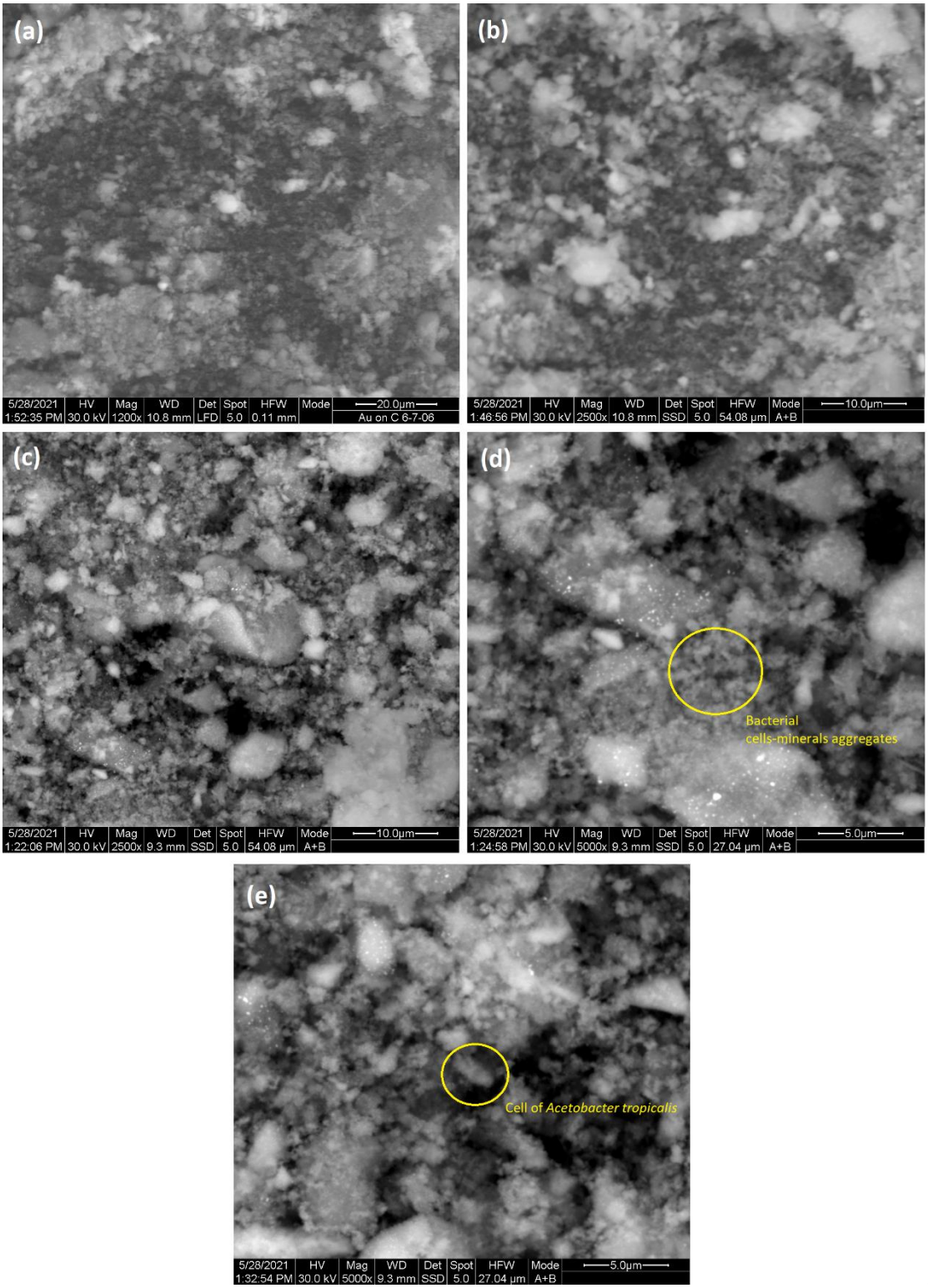

Figure S2. SEM images: (**a**) SEM image of BR before bioleaching (1200×); (**b**) SEM image of BR before bioleaching (2500×); (**c**) SEM image of BR sample after 20d bioleaching using Acetobacter tropicalis in 20% w/w suspension with 1% S/L ratio of BR solution (2500×); (**d**) Bacterial cells-minerals and BR aggregates (Acetobacter tropicalis in 20% w/w suspension with 1% S/L ratio of BR solution) (5000×); (**e**) Cell of Acetobacter tropicalis (20% w/w biomass suspension with 1% S/L ratio of BR solution)(5000×).