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Feasibility of the Bio-Mobilization of Rare Earth Elements from Bauxite Residual Red Mud †

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Abstract: The present work was conducted to evaluate the bioleaching feasibility of red mud with Penicillium chrysogenum strain KBS3 in the presence of glucose, sawdust, and molasses as a substrate and in various leaching modes. The one-step bioleaching system involved 12 mM citric acid, 2.5 mM oxalic acid, 1.8 mM tartaric acid, and 1162 mM gluc onic acid, with glucose as the substrate. The biogenic acid production in the two-step biol eaching system involved 15 mM, 1 mM, 0.5 mM, and 152 mM, respectively, and in the spent-medium bioleaching system, it was 63 mM, 29 mM, 23 mM, and 3 mM, respectively, using glucose as the substrate and a pulp density of 3%. The concomitant bio-mobilization of rare earths investigated under different modes were observed to be: 79% Y, 28% La, and 28% Ce in one-step (mode 1) bioleaching; 63% Y, and 28% both La and Ce in the spent-medium (mode 2) bioleaching; and 67% Y, 20% La, and 15% Ce in a two-step (mode 3) bioleaching. On the other hand, the bio-mobilization of rare earths with molasses as the substrate was found to be: 57% Y, 13.5% La, and 12.7% Ce in mode 4 bioleaching; 57% Y, 14% La, and 12% Ce in mode 5 bioleaching; and 49% Y, 6.3% La, and 2.9% Ce in mode 6 bioleaching of the red mud. Insignificant results were observed using sawdust as the substrate.

Keywords: bauxite processing; red mud; rare earth elements; bio-hydrometallurgy

1. Introduction

Red Mud is the residual mass resulting from the NaOH digestion of bauxite ore (Al₂O₃·2SiO₂·2H₂O), following the Bayer process, which is the major metallurgical operation in aluminum extraction. The pH of wet red mud slurry is about 12. The global stockpile of red mud is estimated to be about 3 billion tons, which either goes to marine disposal or as a dry stack to an open space [1,2]. In both cases, it poses a great environmental threat [3]. However, red mud contains a significant amount of rare earth elements (REEs). The rare earth elements exhibit pronounced chemical similarities as a group, while individually expressing distinctive and varied chemical properties [4]. These atomistic electronic properties are extraordinarily useful and motivate the application of REEs in many modern technologies and devices. In spite of all their contributions to the mitigation of environmental impacts, their production is resource and pollution intensive, creating a dissonance between the environmentally damaging supply of rare earths and their use in environmentally friendly technologies [5]. In the current scenario, improved extraction/separation strategies to achieve a sustainable and green circular economy of rare earths from residual wastes, like red mud, are an absolute necessity [6,7]. The chemical
The composition of red mud varied widely, which might be attributed to the origin of native ore and/or operational conditions during the Bayer process [8–10].

The extraction of REEs from red mud by pyro and hydrometallurgical approaches are labor and energy intensive, have high reagent and processing costs, and are not environment friendly [1]. Considerable efforts have been made to develop the environmentally friendly biotechnological processing of unconventional sources [11,12]. Besides the use of less-hazardous biogenic lixiviants in a cost-effective manner, the operational flexibility, self-sustainability, and lower energy consumption are potential advantages of bio-based approaches [13,14].

Among potential bioleaching microbes, autotrophs are not suitable for processing red mud due to growth pH constraints and the scarcity of required energy sources (sulfur or reduced iron) for the growth of chemolithoautotrophic bacteria, like Acidithiobacillus ferrooxidans, Acidithiobacillus thiooxidans, Sulfobacillus thermostosulfidooxidans, etc. [11,15]. In contrast, heterotrophs can survive in comparatively high alkaline conditions and can excrete various metabolites (organic acids, amino acids, and proteins) for the solubilization of metals from various spent sources [11,16–19]. However, limited data exist on the bioleaching of REEs from these residual wastes [20]. Thus, the specific objective of this work was:

- To utilize the excreted metabolites of an isolated heterotrophic culture as a potential source for the extraction of REEs in an environmentally friendly manner;
- To investigate the amenability of bioleaching using glucose, molasses, and saw dust as the substrate.
- To conduct a comparative study of all leaching modes and elucidate the interplay between the biogenic metabolites and rare earth elements present in red mud.

2. Materials and Methods

2.1. Collection of Red Mud and a Fungal Sample

The fine aggregates of bauxite red mud sample were further dried at 105 °C for 12 h and passed through a 500 μm sieve before leaching studies. For analyzing the chemical composition of red mud, the process according to US EPA SW 846 Method 3050B was used to totally digest the samples [16]. The metal ions in the supernatant were analyzed using an inductively coupled plasma optical emission spectrometer (iCAP 7400 Duo, Thermo Fisher Scientific: Waltham, MA, USA). The morphology was investigated by scanning electron microscopy (SUPRA40VP, Carl zeiss: Oberkochen, Germany). The pH value of the red mud samples were determined using a digital pH meter (Orion, Thermo Scientific, Waltham, MA, USA).

The samples for the isolation of a fungal culture were collected from iron ore deposits (Kalabagh). The serially diluted sample solution was plated on 3.9% potato dextrose agar (Becton Dickinson: Franklin Lakes, NJ, USA) plates and kept in an incubator for 3 days at 30 °C. For culturing in a liquid medium, 1 mL of spore suspension was added to 100 mL of a growth medium with a composition of (g/L) 100 glucose or the required amount of pretreated substrate, 0.5 KH₂PO₄, 1.5 NaNO₃, 0.025 KCl, 0.025 MgSO₄.7H₂O, and 1.6 yeast extract. The cultures, in 250 mL Erlenmeyer flasks were maintained at 30 °C in a shaking incubator at 120 rpm. The 18S rRNA genes of the isolate were amplified, sequenced, analyzed, and submitted to Gen Bank (accession number; GQ228447).

2.2. Pretreatment of the Substrate and Leaching Experiments

Before the addition of substrates in the media, the substrates were subjected to a pretreatment, as shown in Table 1.
Leaching experiments were performed in different modes, as described in Table 2. It was observed, during preliminary studies, that biomass production starts to decrease sharply with the prolonged lag phase, while moving from a 3% to 10% pulp density, so a 3% pulp density was chosen as the optimal in the current study.

Effluents of bioleaching were first filtered through Whatman No. 1 filter paper to remove solid particles and then centrifuged at 10,000 rpm for 10 min to remove the microbial mass, and the supernatant was analyzed for metal ions and pH values. For comparison with chemical leaching, commercial organic acid equivalent to biogenic acids (at optimum conditions) were chosen.

Table 1. Pretreatment of the substrates for the leaching experiment.

| Substrates | Pretreatment                                              | Quantity Used (g/L) |
|------------|-----------------------------------------------------------|---------------------|
| Glucose    | Filter sterilized                                         | 100                 |
| Molasses   | Autoclaved                                                | 100                 |
| Saw dust   | Soaked in sulfuric acid, dried, and homogenized           | 100                 |

2.3. Analysis of Organic Acids

Analysis of organic acid metabolites was carried out using a modified method by Escobal et al. [21]. The organic acid components were investigated using high-performance liquid chromatography (HPLC, Sykam GmbH, Kleinostheim, Germany), equipped with a S-1121 dual piston solvent delivery system and S-3210 UV/VIS diode array detector and C18 column, with a mobile phase consisting of acetic acid solution (0.25%) and a flow rate of 1.0 mL min\(^{-1}\) at 30 °C. The detection was performed at a wavelength of 254 nm. The organic acids were identified by comparing the retention times and quantified on the basis of peak areas.

3. Results and Discussion

3.1. Characterization of Residual Waste

The fine aggregates of the bauxite red mud sample mainly contain hematite, gibbsite, goethite, diaspore, and calcite minerals, along with a significant amount of rare earths. Thermal analysis showed that a good amount of water loss with temperature confirms the
existence of hydrated minerals in red mud. Table 3 provided the concentrations of various metal ions present in the material.

Table 3. Concentration of organic acids in fermented media (after 10 days).

| Organic Acid Production Using Glucose as the Substrate | mode-1 | mode-2 | mode-3 |
|--------------------------------------------------------|--------|--------|--------|
| Citric acid (mM)                                       | 12     | 15     | 63     |
| Oxalic acid (mM)                                       | 2.5    | 1      | 29     |
| Tartaric acid (mM)                                     | 1.8    | 0.5    | 24.5   |
| Gluconic acid (mM)                                     | 1162   | 152    | 123    |

| Organic Acid Production Using Molasses as the Substrate | mode-4 | mode-5 | mode-6 |
|--------------------------------------------------------|--------|--------|--------|
| Citric acid (mM)                                       | 4.21   | 3.57   | 44.8   |
| Oxalic acid (mM)                                       | 1.55   | 1.0    | 15.0   |
| Tartaric acid (mM)                                     | 1.18   | 0.95   | 14.8   |
| Gluconic acid (M)                                      | 210.19 | 52.5   | 11     |

| Organic Acid Production in the Absence of Red Mud     | Glucose | Molasses | Saw dust |
|--------------------------------------------------------|---------|----------|----------|
| Citric acid (mM)                                       | 63      | 45       | 0.67     |
| Oxalic acid (mM)                                       | 28      | 15       | 0.7      |
| Tartaric acid (mM)                                     | 25      | 15       | 0.3      |
| Gluconic acid (M)                                      | 122     | 11       | 0.75     |

3.2. Extraction of Metals in Various Leaching Modes

Prior to bioleaching studies, the native culture of *Penicillium chrysogenum* strain KBS3 was grown in liquid growth media, supplemented with various substrates until it reached the stationary phase, in order to determine the optimal time period for incubation with red mud in leaching mode 2, 3, 5, 6, 8, and 9.

The maximum hydrolysis of the substrates on the 3rd day indicated that the *Penicillium chrysogenum* strain KBS3 is in the active growth phase. Therefore, after 3 days of incubation, the red mud was added to the fungal culture in leaching mode 2, 5, and 8. The maximum biomass and minimum pH value were reached on the 10th day of incubation. Therefore, the cell-free medium was obtained through filtering the culture after the 10th day of incubation for leaching mode 3, 6, and 9.

The metal solubilization from red mud by heterotrophic microorganisms may be due to an enzymatic reduction of highly oxidized metal compounds or the production of organic acids (acidolysis) and compounds with hydrophilic reactive groups [11,22] However, the most important mechanism is acidolysis. The related reactions between the different organic acids and metal ions are depicted below (M\textsuperscript{m+} represents the metal ions with variant valence):

\[ C_{6}H_{12}O_{7} \rightarrow C_{6}H_{11}O_{7}^{-} + H^{+} \ (pK_{a} = 3.86) \]  (1)

\[ n[C_{6}H_{11}O_{7}^{-}] + M^{m+} \rightarrow M[C_{6}H_{11}O_{7}]_{n} \]  (2)

\[ C_{2}H_{2}O_{4} \rightarrow C_{2}H_{2}O_{4}^{-} + H^{+} \ (pK_{a} = 1.25) \]  (3)

\[ C_{2}H_{4}O_{4} \rightarrow C_{2}H_{2}O_{4}^{-} + H^{+} \ (pK_{a} = 4.14) \]  (4)

\[ n[C_{2}H_{2}O_{4}^{-}] + M^{m+} \rightarrow M[C_{2}H_{2}O_{4}]_{n} \]  (5)

\[ n[C_{2}O_{4}^{2-}] + 2M^{m+} \rightarrow M_{2}[C_{2}O_{4}]_{n} \]  (6)

\[ C_{6}H_{8}O_{7} \rightarrow C_{6}H_{7}O_{7}^{-} + H^{+} \ (pK_{a} = 3.09) \]  (7)

\[ C_{6}H_{7}O_{7} \rightarrow C_{6}H_{6}O_{7}^{2-} + H^{+} \ (pK_{a} = 4.75) \]  (8)

\[ C_{6}H_{3}O_{7}^{2-} \rightarrow C_{6}H_{2}O_{7}^{3-} + H^{+} \ (pK_{a} = 6.40) \]  (9)

\[ n[C_{6}H_{2}O_{7}^{-}] + M^{m+} \rightarrow M[C_{6}H_{2}O_{7}]_{n} \]  (10)
\[ n[C_6H_5O_2]^- + 2M^{n+} \rightarrow M_2[C_6H_6O_7]_n \]  
\[ n[C_6H_4O_2]^- + 3M^{n+} \rightarrow M_3[C_6H_3O_7]_n \]  
\[ C_4H_6O_6 \rightarrow C_4H_5O_5^- + H^+ \quad (pK_a = 2.98) \]  
\[ C_4H_5O_5^- \rightarrow C_4H_4O_4^- + H^+ \quad (pK_a = 4.34) \]  
\[ n[C_6H_5O_2]^- + M^{n+} \rightarrow M[C_6H_5O_2]_n \]  
\[ n[C_6H_4O_2]^- + 2M^{n+} \rightarrow M_2[C_6H_4O_2]_n \]  

Figure 1 shows the solubilization of REEs in various leaching modes. The leaching efficiency was lowest in leaching mode 3 (63% Y, 28% Ln, 28% Ce) using glucose as the substrate and in leaching mode 6 (49% Y, 6.3% Ln, 2.9% Ce) using molasses as the substrate, while the highest leaching efficiencies were observed in leaching mode 1 (79% Y, 29% Ln, 29% Ce) and 4 (57% Y, 13.5% Ln, 12.77% Ce), with glucose and molasses as the substrate. This was probably due to the stimulating effect of REEs on microbial growth and enzyme activity [17,23].

Compared to leaching mode 1 (79% Y, 29% Ln, 29% Ce) and 4 (57% Y, 13.5% Ln, 12.77% Ce), the metal extraction efficiency in a commercial acid mixture of an equivalent concentration (leaching mode 10) was lower (53% Y, 11% Ln, 25% Ce), indicating that besides biogenic organic acids, some other metabolites, like amino acids and proteins, form complexes with the metals and facilitate their solubilization [11,19].

An insignificant leaching of metal in leaching mode 7 (13% Y, 7% Ln, and 7% Ce), mode 8 (12% Y, 9% Ln, and 7% Ce), and mode 9 (17% Y, 3.5% Ln, and 3% Ce) was observed due to an incomplete hydrolysis of saw dust as the substrate.

Figure 1. Mobilization of rare earth elements in various leaching modes.

Figures 2–7 show the changes in the pH profile with various pulp densities in various leaching modes using glucose and molasses as the substrate. With an increasing pulp density, a slow decrease in pH was observed in all leaching modes. This may be due to the higher toxicity of metals ions at higher pulp densities, limiting the microbial metabolic activities by inactivating the enzymes. At 6% or a higher pulp density, the pH value increased at the beginning of bioleaching, before the strain grew abundantly. This may be due to the continual dissolution of substantial alkaline minerals in red mud taking more time to reach chemical equilibrium under laboratory conditions [14,16,18].
In the optimal leaching condition (3% pulp density and 1-step leaching), the biomass production rate was higher using glucose as the substrate (25 g/L), compared to molasses (20 g/L) and saw dust (10 g/L) as shown in Figure 8. The high biomass production in leaching mode 1 may be due to the rapid hydrolysis of the substrate and easy availability of a carbon source required for heterotrophic growth, compared to molasses and saw dust as the substrate.

Figure 2. pH profile at various pulp densities for leaching mode 1.

Figure 3. pH profile at various pulp densities for leaching mode 2.
Figure 4. pH profile at various pulp densities for leaching mode 3.

Figure 5. pH profile at various pulp densities for leaching mode 4.

Figure 6. pH profile at various pulp densities for leaching mode 5.
3.3. Production of Organic Acids

Organic acids have two main functions, which are very important in bioleaching, as they can facilitate the dissolution of metals ions via chelation and also destabilize the bonds between the surface metal and bulk leaching materials [24].

The organic acids secreted by *Penicillium chrysogenum* strain KBS-3 were analyzed at various pulp densities of red mud in leaching mode 1-6 and compared with a native system supplemented with the required substrate, but without feed material (Table 3).

In the absence of red mud, the fungus secreted 28 mM oxalic acid, 63 mM citric acid, 25 mM tartaric acid, and 122 mM gluconic acid with glucose as the substrate, while 15 mM oxalic acid, 45 mM citric acid, 15 mM tartaric acid, and 11 mM gluconic acid was observed using molasses as the substrate, after 7 days of incubation. An insignificant biogenic organic acid production (0.67 mM citric acid, 7 mM oxalic acid, 3 mM tartaric acid, and 0.75 mM gluconic acid) was observed with saw dust as the substrate during 7 days of incubation. At the optimal pulp density (3%), the concentration of citric, oxalic, and tartaric acid produced in leaching mode 1, 2, 4, 5, and 6 was lower than that produced in...
leaching mode 3, where it was comparable to the native one. It is noteworthy that a significant increase in the concentration of gluconic acid occurred at a 3% pulp density in leaching mode 1 and 4, compared to the native. Additionally, the presence of glucose as the substrate activates the enzyme glucose oxidase, which converts glucose to hydrogen peroxide and, finally, hydrolyzes it to gluconic acid. Therefore, gluconate was sufficiently produced in the presence of red mud/residual waste and with glucose as the substrate in leaching mode 1 [16].

4. Conclusions

The present study elucidated the potential of bioleaching for REEs’ extraction from red mud residue from a secondary reservoir generated during the Bayer process of bauxite.

One-step bioleaching yielded a higher extraction efficiency of REEs from red mud, as compared to the two-step and spent-medium bioleaching.

Bioleaching is strongly influenced by the pulp density. The inhibition of fungal growth at higher pulp densities is due to the higher concentration of toxic components, as well as an increase in the initial pH of the medium.

The reverse solubility of REEs in the presence of metabolite organic acid excreted by Penicillium chrysogenum strain KBS3 and glucose substrate using another system than one-step bioleaching can be the possible reason behind the exhibited phenomenon.

More fundamental studies on metabolites and the solubility of REEs are required.

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References
1. Klauber, C.; Gräfe, M.; Power, G. Bauxite residue issues: II. options for residue utilization. Hydrometallurgy 2011, 108, 11–32, doi:10.1016/j.hydromet.2011.02.007.
2. Kumar, S.; Kumar, R.; Bandopadhyay, A. Innovative methodologies for the utilisation of wastes from metallurgical and allied industries. Resour. Conserv. Recycl. 2006, 48, 301–314, doi:10.1016/j.resconrec.2006.03.003.
3. Power, G.; Gräfe, M.; Klauber, C. Bauxite residue issues: I. Current management, disposal and storage practices. Hydrometallurgy 2011, 108, 33–45, doi:10.1016/j.hydromet.2011.02.006.
4. Ilyas, S.; Kim, H.; Srivastava, R.R. Extraction equilibria of cerium(IV) with Cyanex 923 followed by precipitation kinetics of cerium(III) oxalate from sulfate solution. Sep. Purif. Technol. 2021, 254, 117634, https://doi.org/10.1016/j.seppur.2020.117634.
5. Ilyas, S.; Kim, H.; Srivastava, R.R.; Choi, S. Cleaner production of rare earth elements from phosphorus-bearing sulfuric acid solution of vein deposit monazite. J. Clean. Prod. 2021, 278, 123435, doi:10.1016/j.jclepro.2020.123435.
6. Akcil, A.; Akhmadiyeva, N.; Abdulvaliyev, R.; Abhilash, P.; Meshram, P. Overview on extraction and separation of rare earth elements from red mud: Focus on scandium. Miner. Process. Extr. Metall. Rev. 2018, 39, 145–151, doi:10.1080/08827508.2017.1288116.
7. Binnemans, K.; Jones, P.T.; Blanpain, B.; Van Gerven, T.; Pontikes, Y. Towards zero-waste valorisation of rare-earth-containing industrial process residues: A critical review. J. Clean. Prod. 2015, 99, 17–38, doi:10.1016/j.jclepro.2015.02.089.
8. Evans, K. The history, challenges, and new developments in the management and use of bauxite residue. J. Sustain. Metall. 2016, 2, 316–331, doi.org/10.1007/s40831-016-0060-x.
9. Mongelli, G. Ce-anomalies in the textural components of Upper Cretaceous karst bauxites from the Apulian carbonate platform (southern Italy). Chem. Geol. 1997, 140, 69–79, doi:10.1016/S0009-2541(97)00042-9.
10. Ochsenkühn-Petropulu, M.; Lyberopulu, T.; Parissakis, G. Direct determination of landthanides, yttrium and scandium in bauxites and red mud from alumina production. Anal. Chim. Acta 1994, 296, 305–313, doi:10.1016/0003-2670(94)80250-5.
11. Srivastava, R.R.; Ilyas, S.; Kim, H.; Choi, S.; Trinh, H.B.; Ghauri, M.A.; Ilyas, N. Biotechnological recycling of critical metals from waste printed circuit boards. J. Chem. Technol. Biotechnol. 2020, 95, 2796–2810.
12. Ilyas, S.; Bhatti, H.N.; Bhatti, I.A.; Sheikh, M.A.; Ghauri, M.A. Biogeadting of metal ions from low grade sulphide ore: Process optimization by using orthogonal experimental array design. Afr. J. Biotechnol. 2010, 9, 2801–2810.
13. Ghorbani, Y.; Oliazadeh, M.; Shahvedi, A. Aluminum solubilization from red mud by some indigenous fungi in Iran. J. Appl. Biosci. 2008, 7, 207–213.
14. Vachon, P.; Tyagi, R.D.; Auclair, J.C.; Wilkinson, K.J. Chemical and biological leaching of aluminum from red mud. Environ. Sci. Technol. 1994, 28, 26–30.
15. Ilyas, S.; Srivastava, R.R.; Kim, H. O2-enriched microbial activity with pH-sensitive solvo-chemical and electro-chlorination strategy to reclaim critical metals from the hazardous waste printed circuit boards. J. Hazard. Mater. 2021, 416, 125769.
16. Wu, H.Y.; Ting, Y.P. Metal extraction from municipal solid waste (MSW) incinerator fly ash—Chemical leaching and fungal bioleaching. Enzyme Microb. Technol. 2006, 38, 839–847, doi:10.1016/j.enzmictec.2005.08.012.
17. Santhiya, D.; Ting, Y.P. Bioleaching of spent refinery processing catalyst using Aspergillus niger with high-yield oxalic acid. J. Biotechnol. 2005, 116, 171–184, doi:10.1016/j.jbiotec.2004.10.011.
18. Brandl, H.; Bosshard, R.; Wegmann, M. Computer-munching microbes: Metal leaching from electronic scrap by bacteria and fungi. Hydrometallurgy 2001, 59, 319–326, doi:10.1016/S0304-886X(00)00188-2.
19. Ilyas, S.; Lee, J. Fungal leaching of metals from electronic scrap. Mining, Metallurgy & Exploration 2013, 30, 151–156, doi:10.1007/BF03402261.
20. Qu, Y.; Lian, B. Bioleaching of rare earth and radioactive elements from red mud using Penicillium tricolorRM-10. Bioresour. Technol. 2013, 136, 16–23, doi:10.1016/j.biortech.2013.03.070.
21. Escobar, A.; Gonzalez, J.; Iriondo, C.; Laborra, C. Liquid chromatographic determination of organic acids in txakoli from Bizkaia. Food Chem. 1997, 58, 381–384, doi:10.1016/S0308-8146(96)00032-5.
22. Burgstaller, W.; Schinner, F. Leaching of metals with fungi. J. Biotechnol. 1993, 27, 91–116.
23. d’Aquino, L.; Morgana, M.; Carboni, M.A.; Staiano, M.; Antisari, M.V.; Re, M.; Woo, S.L. Effect of some rare earth elements on the growth and lanthanide accumulation in different Trichoderma strains. Soil Biol. Biochem. 2009, 41, 2406–2413, doi:10.1016/j.soilbio.2009.08.012.
24. Gräfe, M.; Power, G.; Klauber, C. Bauxite residue issues: III. Alkalinity and associated chemistry. Hydrometallurgy 2011, 108, 60–79, doi:10.1016/j.hydromet.2011.02.004."