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New technology of extracting the amount of rare earth metals from the red mud

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Abstract. The paper outlined the environmental and economic problems associated with red mud – the waste generated in processing of bauxite ore for aluminum production. The chemical analysis of red mud has identified a number of useful elements including rare earth metals. The electromembrane technology of red mud processing with extraction of valuable elements is described. A possible scheme of separation of these metals through electrolysis is also given.

I. Introduction

One of the most urgent problems of resource saving and environmental safety in the mining industry and metallurgy is the disposal of processing waste. Production of aluminum from bauxite ores is accompanied by formation of large quantities of waste in the form of red mud [1]. The production of one ton of commercial aluminum using the Bayer process gives about three tons of red mud. Its chemical composition is determined by the content and properties of leached bauxite, as well as by duration and storage conditions in tailings ponds. They occupy vast areas suitable for agriculture. The leak of red mud caused a real ecological disaster in Hungary in 2010, when in the result of explosion at the aluminum plant the dam holding back a reservoir of these toxic wastes was destroyed. Then the state of emergency for several months was introduced in three areas of the country, also some regions of Croatia have been suffered.

Modern plants for aluminum production do not have the technology of complex processing of bauxite and stored waste in the tailings ponds, considering their further processing as economically not viable, thus creating an environmental hazard due to the high alkalinity and dispersity of the red mud. In Russia it is accumulated more than 100 million tons of red mud.

Table 1 and 2 show the average chemical composition (in wt.%) of red mud produced during the processing of alumina from bauxite rocks of Russian Federation and Iran. Both samples had a moisture content of 40-60%, the alkalinity (pH) - 10-13 and dispersity - 80% fraction of less than 5 microns. As can be seen from the tables, the compositions of both samples are about the same.

As red mud contains a large amount of iron and aluminum, it seems it would be better to turn it into a source of valuable secondary raw material. But processing of red mud in undivided form is difficult task, since it contains too much iron oxide, and it cannot be used as the iron ore as it contains too much aluminum oxide. Moreover, it also contains impurities of sulfur, phosphorus, so it is necessary to find a method of processing based on a significant difference in chemical properties of the compounds of Fe_2O_3 and Al_2O_3 , and use it for their separation, or find a way to use this mixture as a raw material to produce the commercial or intermediate products.





Figure 1. A typical red mud tailing pond

Table 1. Composition of red mud of Ural plant

Fe_2O_3	CaO	SiO_2	Al_2O_3	MgO	TiO_2	S	P_2O_5	Na_2O
40-55	8-11	5-15	14-16	0.5-1.4	2-5	up to 2	0.2-0.5	up to 2

Table 2. Composition of red mud of Iran plant

Fe_2O_3	CaO	SiO_2	Al_2O_3	MgO	TiO_2	S	P_2O_5	Na_2O
44 - 46	8-11	8-9.5	13-18	0.2-1.6	4-5	3.6	0.2-0.65	2.5-6.5

2. Extraction the amount of valuable and rare earth elements

It turned out that the red mud contains rare earth metals in industrial interest, in particular, scandium and yttrium, as shown in Tables 3 and 4.

We have carried out a study on the extraction of these metals from the bulk of the red mud. In the result, a laboratory method based on the method electromembrane separation was elaborated. The main process steps are shown in Figure 2.

Previously, in a special electrolyzer, the sodium hypochlorite was synthesized. Then, from the slurry tank the red mud was supplied in a glass jar - reactor. A calculated amount of sodium hypochlorite was also poured into this reactor. After a certain time, the dissolved part of the red mud obtained during a mild leaching was selected in a separate reactor and sent to a solution treatment unit. There it was subjected to a special activation that is our know-how. Insoluble part of red mud depleted by rare metals was poured into another slurry tank. Its alkalinity has already been within 7 - 9.

Further, the treated solution was subjected to a electromembrane processing in the system of electrolyzers. As a result, a separate aqueous concentrate of rare, rare earth and other valuable elements were obtained, as well as the NaOH solution, which was directed to the beginning of the process. Solutions were periodically analyzed by the mass spectrometer, and the time of process

completion was determined. Simultaneously the chemical composition of the processed red mud has been analyzed (Table 5 and 6).

Table 3. Composition of minor elements in red mud of alumina production in RF

Element	g/kg	Element	g/kg
Sc	0.025060	Cu	0.031695
Ti	31.446005	Zn	0.048848
V	0.566959	Ge	0.004281
Cr	0.255851	Ga	0.035668
Mn	0.226875	As	0.027688
Fe	78.244009	Y	0.053365
Co	0.046470	Mo	0.029679
Ni	0.086609	Cd	0.000808

Table 4. Composition of minor elements in red mud of alumina production in Iran

Element	g/kg	Element	g/kg
Sc	0.019358	Cu	0.068480
Ti	24.298205	Zn	0.235932
V	0.277970	Ge	0.005525
Cr	0.151777	Ga	0.030868
Mn	2.974695	As	0.031339
Fe	78.037918	Y	0.001937
Co	0.078870	Mo	0.002424
Ni	0.303276	Cd	0.001026

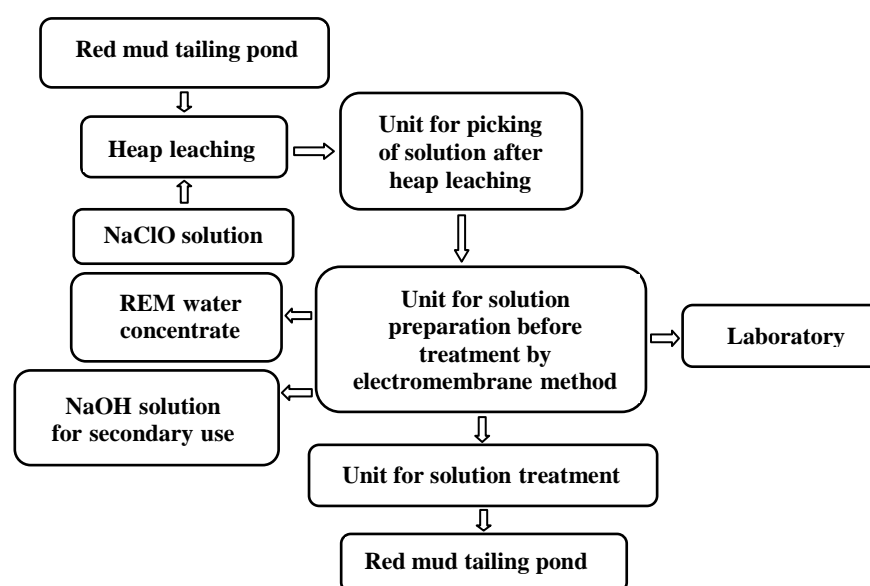


Figure 2. Technological scheme of red mud processing.

Table 5. Composition of red mud of RF after processing

Element	mg/kg	Element	mg/kg
Sc	0.092628	Cu	1.248894
Ti	0.989895	Zn	1.497201
V	2.831367	Ge	0.003759
Cr	0.363909	Ga	0.864186
Mn	0.011424	As	0.714249
Fe	1.405755	Y	0.001866
Co	0.002025	Mo	1.217775

As shown in Tables 4 and 5, the composition of useful elements the red mud significantly decreased after treatment, suggesting that most of them are passed into the solution. The subsequent separation of these elements and the production of metals in its pure form is not the subject of this article, but we consider it necessary to describe the possible technologies of such processing. Various organizations conduct laboratory experiments to extract valuable metals. For example, the pyrometallurgical method - smelting reduction of red mud to obtain a slag rich in valuable elements with further dissolving of slag in respective solutions, its smelting accompanied by separation of solid and liquid fractions, and then the complex processes of cooling and recrystallization [2].

Table 6. Composition of red mud of Iran after processing

Element	mg/kg	Element	mg/kg
Sc	0.136449	Cu	2.043684
Ti	1.462806	Zn	1.629492
V	29.265636	Ge	0.003486
Cr	0.636222	Ga	0.226401
Mn	0.134481	As	1.483803
Fe	5.904255	Y	0.004251
Co	0.004638	Mo	0.092148
Ni	0.022359	Cd	0.000561

Another example is the separation of rare earth elements on the cascade of centrifugal extractors designed by LLC "LIT" of companies group "Skaygrad" (Moscow) [3]. Similar technologies of scandium extraction are developed in National University of Science and Technology (MISIS) [4].

As a possible alternative, we propose the separation of rare, rare earth and other valuable metals using the method of electrolysis based on the difference in electrochemical potentials of metal deposition [5]. A block diagram of this method is shown in Figure 3.

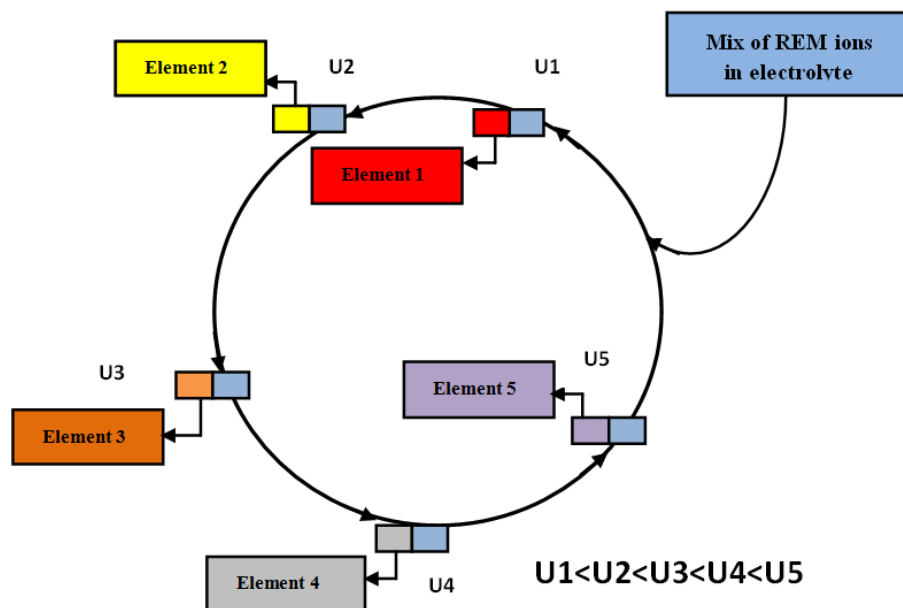


Figure 3. Block diagram of metals separation from the mix of the ions

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