BENEFICIATION OF IRON-RICH TAILINGS FROM THE MINING INDUSTRY

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Introduction

To produce one ton of aluminium, the Bayer process requires treating about four tons of bauxite ore. The insoluble residues of this process are called red mud or bauxite residue. The main constituents of the red mud are oxides of Fe, Al, Si, Ti, Na and Ca, as well as a fraction of minor constituents such as vanadium and chromium oxides. It is estimated that about 70 million tons of red mud are produced each year worldwide.[1] Most research on red mud suggests using this residue (i) as a building material[2], (ii) as a pollutant adsorbent[3] or (iii) as a source of rare earth elements[4]. In order to provide another solution for the management of red mud, this study proposes to extract iron by electrochemical techniques. To carry out this research, we relied on previous works dealing with the production of electrolytic iron from hematite in a highly alkaline medium.[5]

Objectives

The objectives of this study are mainly (i) to reduce the waste volume, (ii) to produce electrolytic iron, thus creating added value, (iii) to provide access to other metals contained in the residues (such as titanium) and (iv) to study the possibility of reusing the residues depleted of heavy metals for other applications.

Analysis and characterisation

Chemical composition

The chemical composition of the red mud used was determined by ICP-AES (Inductively Coupled Plasma Atomic Emission Spectroscopy). For those, 1 gram of red mud was dissolved in 40 mL of hydrochloric acid 8 M, the insoluble residue was then dissolved in 40 mL of sulphuric acid 3 M at room temperature. In total 90% of the sample was dissolved in both acids. As can be seen from the results (Table 1, in oxide

equivalent), the red mud consists mainly of hematite, titanium oxide, lime and alumina. There are also traces of phosphate and chromium.

Table 1: Chemical composition of red mud (ICP-AES)

	Fe_2O_3	Al_2O_3	SiO_2	TiO_2	CaO	Na_2O	residues
wt%	52.3	10.2	0.190	3.28	2.83	2.41	10

Morphological analysis and particle size

In order to know whether hematite was in the form of independent particles, the red mud was observed by scanning electron microscopy coupled to EDX (Figure 1a). The morphological analysis shows that red mud consists of a pile of particles adjacent to each other. The analysis of particles size (Figure 1b) was carried out by Mastersizer 2000 type granulometer (Malvern Instrument). Examination of the curve shows that red mud contains two families of (i) smaller particles near 10 µm and (ii) large particles of about 80 µm.

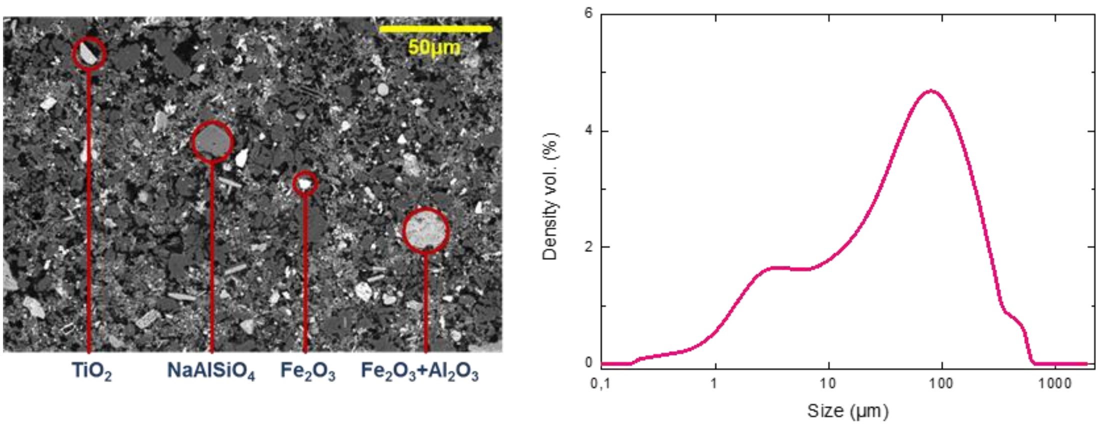

Figure 1: a) Morphological analysis and b) particles size distribution

X-ray Diffraction

XRD analysis was used to characterise the mineralogical composition of the red mud. The diffractogram (Figure 2) shows that the red mud is mainly composed of hematite. Also, as observed by SEM analysis, we note the presence of aluminosilicates, titanium oxide and alumina. This result also confirms the results of elementary analysis by ICP-AES.

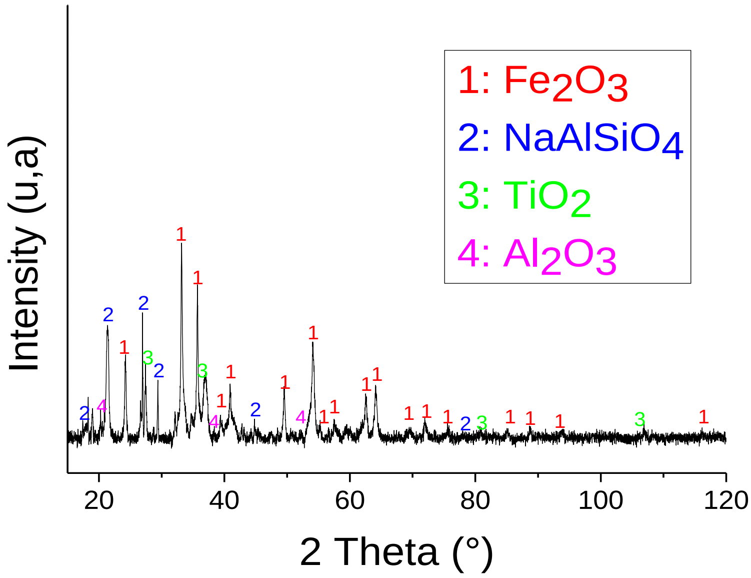

Figure 2: X-ray diffraction of the red mud

Experimental

Iron electrodeposition was conducted in a double wall borosilicate glass cell of 600 mL from a suspension containing 33 wt%. of red mud and 12.5 M of NaOH solution. The NaOH solution was prepared by dissolving the sodium hydroxide pellets (purity 98%) in distilled water. The suspensions were prepared by mixing a certain mass of red mud with a solution of sodium hydroxide (NaOH) 12.5 M so as to obtain a solid (g) : liquid (mL) ratio of 1 : 3. Metal iron was electrodeposited at 110°C on a cylindrical graphite cathode with an area of 16.74 cm². The electrodeposition tests were undertaken under several conditions of current densities (300, 600 and 1000 A/m²).

Results and Discussion

Chemical composition of deposits

The quality of the deposit was studied by ICP-AES analysis.

Table 2: Chemical composition of deposits

	% Fe	% Na	% Al
Fe-hematite	99.6	0.125	0.251
Fe-red mud	97.3	0.222	0.134

Thus, as can be seen in the Table 2, the electrolytic deposits contain mainly the electrolytic iron (greater than 97%) both from hematite and red mud. There is also

the presence of some impurities (Al, Na) which can be removed by washing the deposit.

Faradaic yields

The calculated faradaic yields are shown in Figure 3. As can be seen, faradaic yields obtained from hematite are of the order of 30, 50 and 93% for current densities of 300, 600 and 1000 A/m² respectively. On the other hand, in the framework of electrodeposition of iron from red mud, the maximum faradaic yield obtained was 20%. This dramatic drop in faradaic efficiency can be explained by several parameters (i) presence of impurities (such as aluminosilicates) or (ii) electrochemical loops (due to vanadium for example). Indeed, it is possible that the hematite is agglomerated with other oxides (Al, Si, Ti). In this case, its reactivity could be much slower. To remedy this problem, it would be interesting to grind the red mud to release the hematite particles before the electroreduction step.

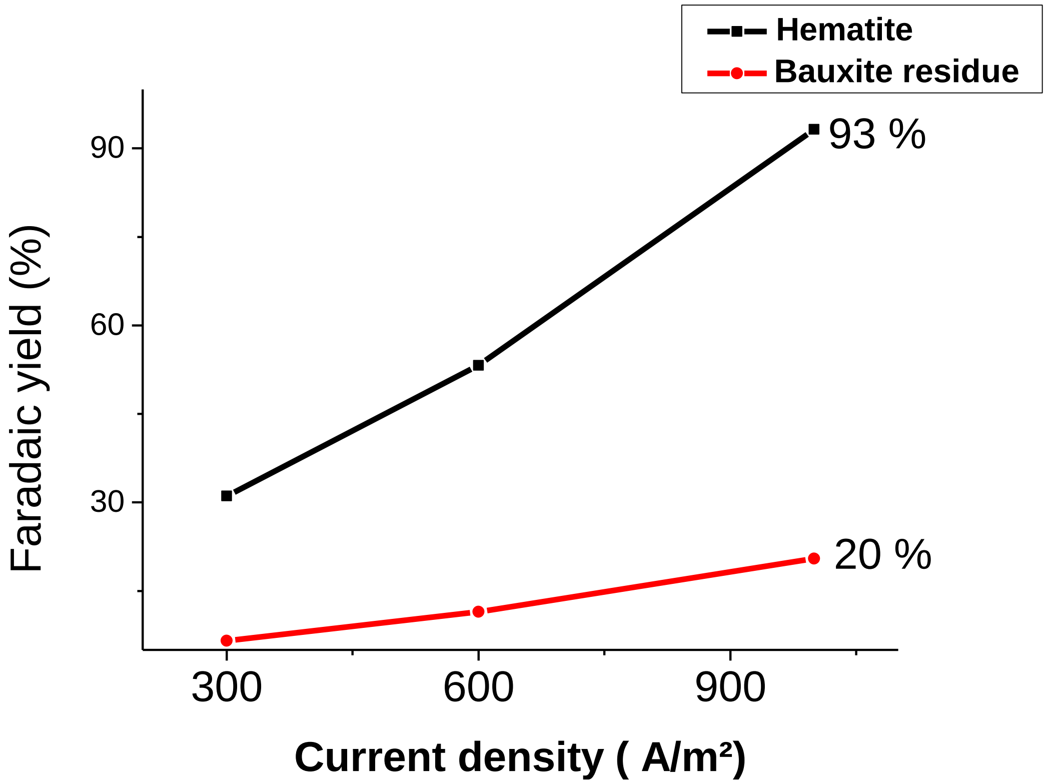

Figure 3: Faradaic yields *vs.* current density in a suspension 12.5 M NaOH-hematite (black curve) and 12.5 M NaOH-bauxite residue (red curve) for a mass solid : liquid ratio of 1:3 at 110°C, 4 h

Morphology and mineralogical composition of deposits

Electrolytic iron deposits, obtained from hematite and red mud, were characterised by scanning electron microscopy. Figure 4a and 4b show that in both cases the deposits present a homogeneous structure in the form of dendrites. Also, in the case

of red mud, there are also traces of impurity that are probably aluminium and sodium. The examination of the X-ray results of the electrolytic deposits obtained from hematite and red mud are presented in Figure 5. These results show that the deposits contain essentially the electrolytic iron. These results are in agreement with those obtained by ICP-AES and SEM.

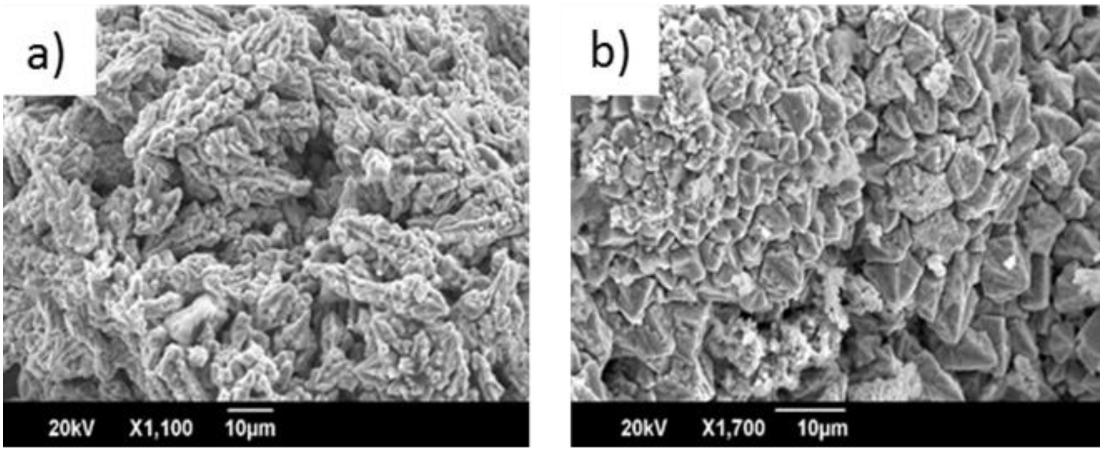

Figure 4: Electrolytic iron: a) Fe-hematite; b) Fe-Red mud

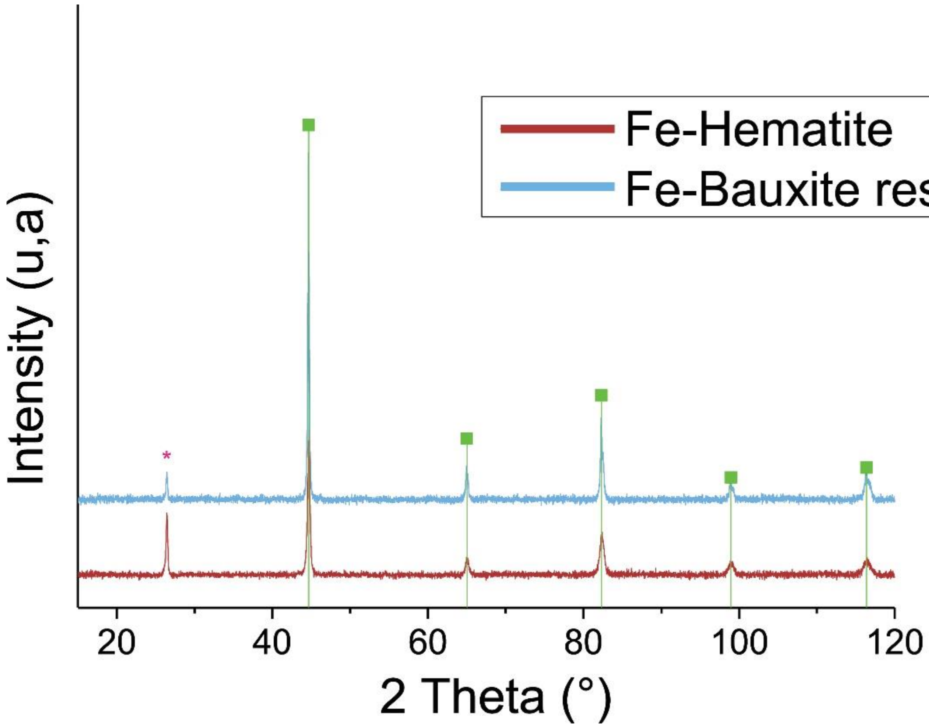

Figure 5: Diffractograms of electrolytic iron deposits: red = Fe - hematite, blue = Fe - red mud

Conclusion

The goal of this work was to study the feasibility of producing electrolytic iron from red mud. The electrodeposition was conducted in a bath containing a suspension of

red mud or hematite and soda solution. The faradaic efficiency was respectively 93 and 20% for hematite and red mud at 1000 A/m². This drop in faradaic efficiency can be explained by the presence of impurities such as aluminosilicates or vanadium. The analysis of the electrolytic iron shown that the deposits obtained had a purity higher than 97% both in the case of hematite and red mud. These results confirm the feasibility of producing electrolytic iron from red mud. To improve the faradaic yields, several methods will be studied in forthcoming work: (i) pre-treatment of red mud to concentrate in hematite, (ii) reduction of hematite to magnetite, magnetic separation and finally electrodeposition of iron from magnetite-rich residues.

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