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Sulfuric acid leaching of polymetallic Abu Zeneima gibbsite-shale

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Abstract

The gibbsite shales belonging to the Paleozoic sequence of sedimentary rocks occurring at the Abu Zeneima area in SW Sinai Egypt has been found to host several economic metal values. These include Al, Cu, Zn, Co, Ni, REE, and U beside several Mn minerals. In this work, the ore was subjected to sulfuric acid leaching to maximize extraction of these metal values. The optimum leaching conditions were 800 g/L acid with a Solid/Liquid ratio of 1/2 at 100 °C for 4 h and using an ore size of −60 mesh. Under these conditions, it was possible to achieve high leaching efficiencies with complete leaching of Al together with 93.0% Cu, 58.6% Zn, 69.0% Co, 92.6% Ni and 84.4% U. Extension of the leaching time to 8 and 12 h significantly improved the leaching efficiencies of Co and Zn to 91.0% and 84.0% respectively.

Keywords: Gibbsite–shale ore; Sulfuric acid leaching; Polymetallic ore; Pug leaching

1. Introduction

The Um Bogma formation in Egypt is composed of different rock faces that are mainly represented by shale, siltstone, clay, ferruginous sandstone, calcareous sandstone and feldspathic sandstone (EL Assy et al., 1986, 1996; Abdel Moneim et al., 1997). One of the most important horizons of the Um Bogma formation is the gibbsite-bearing shale which has been formed by the laterisation of some carbonate units. The gibbsite-bearing shale occurs at different locations and besides its interesting Al content, it can be considered as a polymetallic ore as it is associated with varying amounts of Mn, Zn, Cu, Co, Ni, REE, V, etc.

Several leaching studies have been performed upon comparable Abu Zeneima ore from different locations, but with different constituents and grades of the economic metal values. These studies include those of Mahdy et al. (1988); Mahdy (1989); Amer (1997); Amer et al. (2000); Abdel Fattah (2003); Abdel Moneim (2005). Mahdy et al. (1988) and Mahdy (1989), have studied the leaching characteristics of both U and Cu from a siltstone ore from the Abu Zeneima area. They concluded that both metal values could be almost completely leached by mineral acid under mild agitation or percolation leaching conditions. In the meantime, carbonate leaching of U proved successful to separate U from Cu during the leaching step.

On the other hand, Amer (1997) and Amer et al. (2000), investigated the leaching characteristics of U, Cu and Mn from a similar ore material by pug leaching using H_2SO_4 acid—as well as using $Fe_2(SO_4)_3$ or $FeCl_3$ as lixiviants. The optimum pug leaching conditions for almost complete leaching of the three metal values were 200 Kg/t acid with a curing temperature of 110 °C for

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Table 1
X-ray diffraction data of gibbsite and dolomite in the Abu Zeneima ore sample

Sample		Gibbsite		Dolomite	
		12–460		11–78	
		$Al(OH)_3$		$CaMg(CO_3)_2$	
dA	I/I_o	dA	I/I_o	dA	I/I_o
7.50	25	–	–	–	–
6.86	100	–	–	–	–
4.80	42	4.82	100	–	–
4.33	16	4.34	40	–	–
4.15	21	–	–	–	–
3.44	41	–	–	–	–
3.33	25	3.35	10	–	–
3.18	15	3.17	8	–	–
3.10	17	–	–	–	–
2.88	100	–	–	2.88	100
2.67	17	–	–	2.67	10
2.42	25	2.44	16	2.40	10
2.36	17	2.37	20	–	–
2.24	13	2.23	6	–	–
2.19	17	–	–	2.19	30
1.78	17	1.79	10	1.78	30
1.66	19	–	–	–	–

1.5 h. This was followed by water leaching in a S/L ratio of 1/3 for 6 h at room temperature. When $Fe_2(SO_4)_3$ and $FeCl_3$ was used at 100 Kg/t ore for 6 h at room temperature with a S/L ratio of 1/2; the U leach efficiency was 93.8% and 37.0% respectively whilst the Cu leaching was 69.1% and 72.8% respectively. However, Mn was almost completely leached with only 75 and 25 Kg/t of $Fe_2(SO_4)_3$ and $FeCl_3$ respectively.

Abdel Fattah (2003) studied the leaching and extraction efficiency of Al, Cu, Zn and U from a gibbsite ore material of west central Sinai and proposed 2 flowsheets. In the alkali flowsheet, both U and Al were leached by caustic soda containing some Na_2CO_3; then by passing CO_2 into this liquor, Al was precipitated while U could be recovered from the filtrate by anion exchange resin. The Cu and Zn left behind in the ore were then leached by dilute H_2SO_4 acid followed by metallic Cu precipitation by Zn dust. The dissolved Zn was recovered by precipitation at pH 8.4 after Fe(III) removal at pH 3.0–3.5. In the acid flowsheet; Al, Cu, Zn and U were leached by H_2SO_4. After Cu recovery by metallic Zn at pH 1, U was recovered by anion exchange resin. The solution pH was then adjusted to pH 5.3 to precipitate Al (III) and Fe (III) for later separation by selective caustic soda leach of Al. The filtrate from the Al–Fe cake was treated for the recovery of dissolved Zn values by pH adjustment to 7.5.

Finally, Abdel Moneim (2005) studied selective dilute acid leaching for U and Cu from a uraniferous shale sample from Abu Zeneima using 100 g/L H_2SO_4 at room temp. for 4 h in a S/L ratio of 1/3. Alternatively, selective alkaline leaching of U was achieved using 200 g/L Na_2CO_3 at 90 °C for 4 h with a S/L ratio of 1/3. After U/Cu leaching, V leaching carried out by either pug leaching using 0.9 t acid/t ore at 150 °C for 4 h; or by roasting the ore with 10% NaCl at 850 °C for 3–4 h followed by water leaching. Bulk acid pug leaching for U, Cu and V can be achieved also by using 0.45 t acid/t ore and curing at 200 °C for 4 h.

2. Experimental

2.1. Ore material

In the present work, a proper sample of the gibbsite-bearing shale was collected from the Um El Moghirat locality of Abu Zeneima. It assayed about 27% Al_2O_3 together with other metal contents of 2.7% Zn, 1900 ppm Cu, 1000 ppm Co, 730 ppm Ni, and 400 ppm U. The total rare earth elements (REE) content was 6200 ppm and in addition the ore assays 8.4% MnO mainly as pyrolusite (MnO_2).

2.2. Leaching procedure

Different leaching conditions were studied to attain the maximum possible leaching efficiency of the metal values. These conditions include the reagent concentration, time,

Table 2
X-ray diffraction data of iron minerals in the Abu Zeneima ore sample

Sample		Goethite		Hematite		Pyrite	
		17–536		13–534		6–710	
		$Fe_2O_3–H_2O$		Fe_2O_3		FeS_2	
dA	I/I_o	dA	I/I_o	dA	I/I_o	dA	I/I_o
7.50	25	–	–	–	–	–	–
6.86	100	–	–	–	–	–	–
4.80	42	–	–	–	–	–	–
4.33	16	–	–	–	–	–	–
4.15	21	4.18	100	–	–	–	–
3.44	41	–	–	–	–	–	–
3.33	25	3.88	10	–	–	–	–
3.18	15	–	–	–	–	–	–
3.10	17	–	–	–	–	3.13	35
2.88	100	–	–	–	–	–	–
2.67	17	2.69	30	2.69	100	2.70	85
2.42	25	2.45	25	–	–	2.42	65
2.36	17	–	–	–	–	–	–
2.24	13	–	–	–	–	–	–
2.19	17	2.19	20	2.20	30	–	–
1.78	17	1.17	8	1.83	40	–	–
1.66	19	1.69	10	1.69	60	1.64	100