

FLOTATION OF ALUMINA FROM GIBBSITE BEARING-SHALE OF SOUTH WESTERN SINAI, EGYPT BY USING SODIUM DODECYL SULFATE

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Samples of gibbsite bearing-shale of south western Sinai, Egypt were studied to upgrade the low grade alumina. The assays of the samples are about 18.98% Al₂O₃, 15.45% SiO₂, 12.83% Fe₂O₃, 14.87% CaO, 5.74% P₂O₅, 5.34% MnO, 0.86% K₂O, 0.76% Na₂O, 1.50% trace elements and 23.65% loss on ignition. The aim of upgrading alumina in the concentrate is to make it suitable for the different industrial uses. Sodium dodecyl sulfate (an anionic collector) is effective in the acidic pH range. Below the isoelectric point of gibbsite where the alumina is positively charged, the sodium dodecyl sulfate was good at pH value of 2.

Under appropriate conditions (collector dosage=800g/t, pulp density=300g/l and particle size=-100+80 μm) and at pH=2, a concentrate containing 39.5% alumina at component recovery of 96.9% and mass recovery of 52.8% was obtained. At these conditions, the assays of other ore constituents in the final concentrate are as follows: SiO₂ was decreased from 14.2% to 6.4%, CaO was decreased from 14.1% to 5.2%, Fe₂O₃ was decreased from 13.1% to 5.6%, P₂O₅ was decreased from 4.3% to 3.8%, MnO was decreased from 4.2% to 3.2%, while K₂O was increased from 0.89% to 1.2%, Na₂O was increased from 0.69% to 1.1%, traces was increased from 1.6% to 2.6%, and loss on ignition was increased from 25.4% to 31.2%. The component recoveries of SiO₂, CaO, Fe₂O₃, P₂O₅, MnO, K₂O, Na₂O, and traces in the final concentrate were 23.8%, 19.5%, 22.6%, 46.6%, 40.2%, 39.1%, 33.1%, and 85.8%, respectively.

KEYWORDS: Gibbsite, alumina flotation, collectors, isoelectric point, pH, pulp density, particle size

1. INTRODUCTION

Aluminum is as considered the third most abundant element in the earth's crust and is one of the most commonly used metallic elements in civilization [1,2]. Aluminum alloys are used as a major structural material in aircraft, buildings, machinery parts, beverage cans and food warps [3]. This may be due to their high corrosion resistance and mechanical strength to mass ratio. In nature, aluminum occurs only in combination with other elements and is a part of the crystal structure of many rock forming minerals. Bauxite is the most important commercial ore of aluminum [4]. It consists of mixtures of aluminum hydroxide minerals and impurities [1].

NOMENCLATURE

$R_c(t)$ = component recovery of constituent in tailings, %	c = assay of constituent in concentrate, %
$R_m(c)$ = mass recovery of concentrate, %	C = mass of concentrate, gm
$R_m(t)$ = mass recovery of tailings, %	f = assay of constituent in feed, %
t = assay of constituent in tailings, %	F = mass of feed, gm
T = mass of tailings, gm	$R_c(c)$ = component recovery of constituent in concentrate, %

The three aluminous minerals that form bauxite are boehmite ($\gamma\text{AlO.OH}$), gibbsite ($\text{Al}(\text{OH})_3$), and diasporite ($\alpha\text{AlO.OH}$) [1]. Besides of its main use as an aluminum ore, bauxite is used also to manufacture refractory products, aluminous chemicals, abrasives, and miscellaneous applications. These applications include β -alumina solid state electrolytes and first-class refractories [3].

The major impurities of gibbsite of south western Sinai are quartz, hematite and kaolinite. Other impurities such as, rare earths and alkali occur in small percentages. Gravity, magnetic, or electrostatic separation methods are not suitable for the concentration of gibbsite ore. This may be due to the very small significant differences in the physical properties (density, magnetic and electrostatic susceptibility, etc.) between the mineral phases (gibbsite, kaolinite and quartz), which are considered the major constituents of the ore. Flotation process was then selected as a suitable and effective method for the concentration and upgrading of alumina from gibbsite bearing-shale of south western Sinai to make it suitable for the Bayer process. Many researchers [3-12] have studied the flotation of alumina using different types of collectors. The results are summarized as follows.

Bench scale experiments were used for the flotation of gibbsite/ kaolinite from quartz (Brazilian bauxite ore) using alkyl sulfates as collectors. The results were good at pH 2, where the component recovery of alumina was 97.4% and the grade of alumina was 93% at a particle size of $(-177+3)\ \mu\text{m}$ and a pulp density of 20% solids [3]. In other research, gibbsite was floated with sodium oleate from a mixture of quartz, kaolinite, iron and titanium oxides (Guyana bauxite ore) at pH values between pH 10 and pH 11. The conditions were determined at which froth flotation resulted a component recovery more than 90% of the gibbsite [5]. During the adsorption of laurylamine on gibbsite, chamosite and boehmite, it was found that the maximum floatability of all minerals was achieved at pH 8 and the adsorption of laurylamine occurred at a pH value ranged from 4 to 8 [6].

However, the flotation of gibbsite using amines as collectors can not be applied for the South Western Sinai gibbsite ore because of the presence of a significant amount of quartz. In the flotation of alumina from kyanite ore using different collectors, Bulut and Yurtsever [7] found that sodium dodecyl sulfate, as an alkyl sulfate collector, is effective in the acidic pH ranges. Dodecylamine hydrochloride (DAH), as a cationic collector, is effective in the basic pH range and potassium oleate (KOL), as an anionic collector, floats kyanite at pH value ranges from 6 to 9. In another study on the adsorption of cationic and anionic collectors on alumina surface, it was found that, in the case of using dodecylamine chloride (DDA) which is a cationic collector, the contact angles of water & alumina, at pH value larger than 10.5

was increased and hence hydrophobicity was enhanced. In the case of using anionic surfactant solutions, the contact angle of water & alumina, at pH value lesser than 9, was increased with increasing the concentration of sodium dodecyl sulfate and hence, enhanced the hydrophobicity of alumina surface [8].

Diasporic–bauxite was floated from silicates by using quaternary ammonium salt (DTAL) at a pH value ranged from 6 to 7 [9]. The surface charges of gibbsite particles were probed by potentiometric titration and subsequently analyzed to estimate intrinsic proton affinity constants of OH surface groups. It was found that the point of zero charge could be achieved at a pH value ranged from 8.1 to 9.6 [10]. The electron spin resonance (ESR) was used to study the adsorption of spin probe analogs of stearic acid on amorphous alumina [11].

The point of zero charge (ZPC) of gibbsite at a pH value equals to 9.1. The electrokinetic potential and contact angle measurements were used to show the adsorption mechanism of sodium dodecyl sulfate and dodecylamine chloride on the alumina surface. From these results, it was found that, sodium dodecyl sulfate and dodecylamine chloride converted the alumina surface to a hydrophobic one at a pH less than ZPC and a pH more than ZPC, respectively [12]. Zhenghe et al. [4] have used the reverse flotation technology to float alumina from aluminosilicates using a cationic collector. The purpose of this paper is to determine the optimum conditions of flotation process to upgrade the alumina in gibbsite ore to make it suitable for industrial purposes, such as aluminous chemicals, abrasives, building stones, road surfacing, and alumina refractories [3].

2. MINERALOGY

Based on petrography and EDX technique, several minerals were identified in the studied samples as follows:

Gibbsite is turbid cryptocrystalline heavily stained black, orange and brown colors. It occurs as radial aggregate embedded in marly matrix. The matrix is mainly composed of equal amounts of fine-grained quartz and carbonate. It contains minute grains of Fe and Mn oxy-hydroxides. The BSE of gibbsite is shown in Fig. 1. Quartz is monocrystalline, medium-grained, well sorted and subround to well round. The cryptocrystalline quartz occurs as filling pore spaces between grains and as overgrowths. The BSE of quartz is shown in Fig. 2.

Kaolin occurs as amorphous dusts and patches with aggregate polarization in crossed nicols. It mostly resulted from acidic ground water whereas the unstable minerals dissolve releasing Si, Al to the pore waters that can be produced by flushing of the gibbsite by fresh water. The BSE of kaolin is shown in Fig. 3.

Halite appears as disseminated small cubic crystals encountered in gibbsite. Calcite occurs as rhombohedral crystals, anhedral grains and aggregates radiating fibrous. It exhibits twinning and perfect rhombohedral cleavages.

Hematite occurs either as disseminated anhedral crystals or occasionally as minutes. It is steel-black with metallic luster in reflected light with a tendency to a marginal red. Generally, the iron is associated with manganese forming Mn-Fe minerals.

Gypsum exists as white massive and acicular prismatic crystals of different shape and sizes. They exhibit aggregates of subhedral to anhedral crystals having

vitreous luster. Few crystals show the perfect cleavage of the growing crystals. The occurrence of the gypsum in the studied gibbsite can be explained by the upward movement of brine by capillary action and its evaporation at the surface.

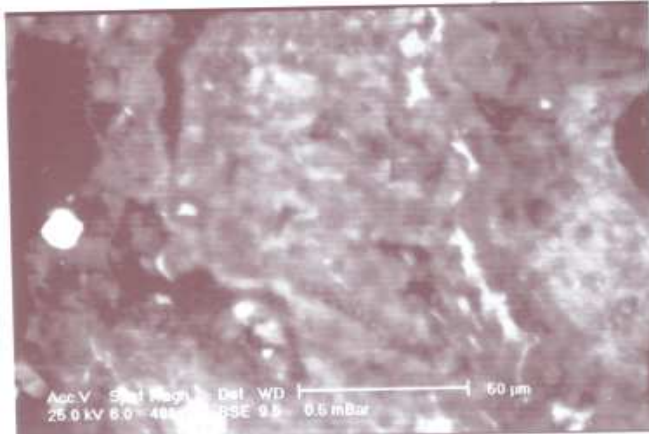


Fig. 1: The BSE image of gibbsite

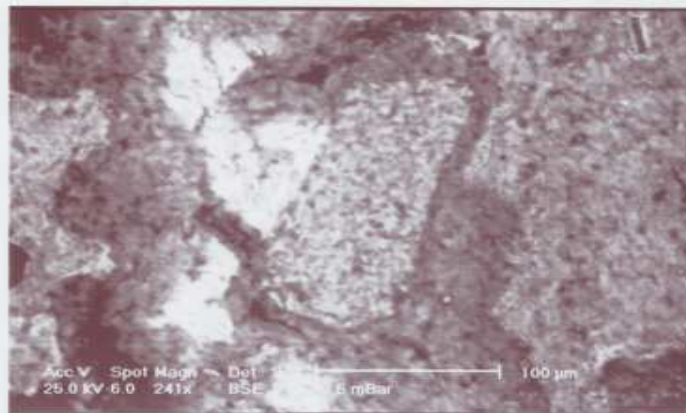


Fig. 2: The BSE image of quartz

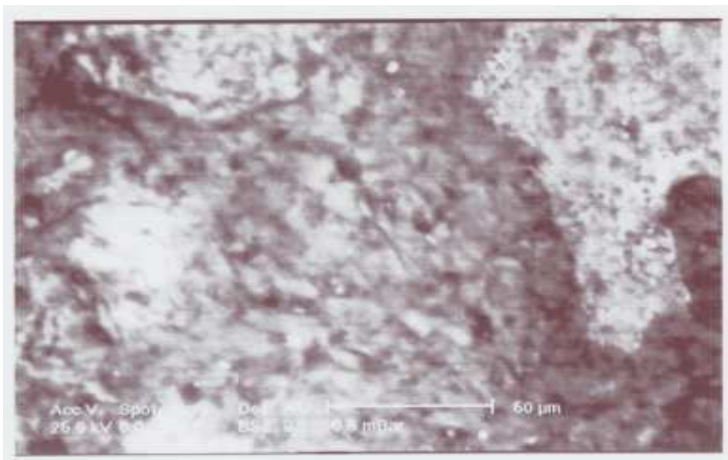
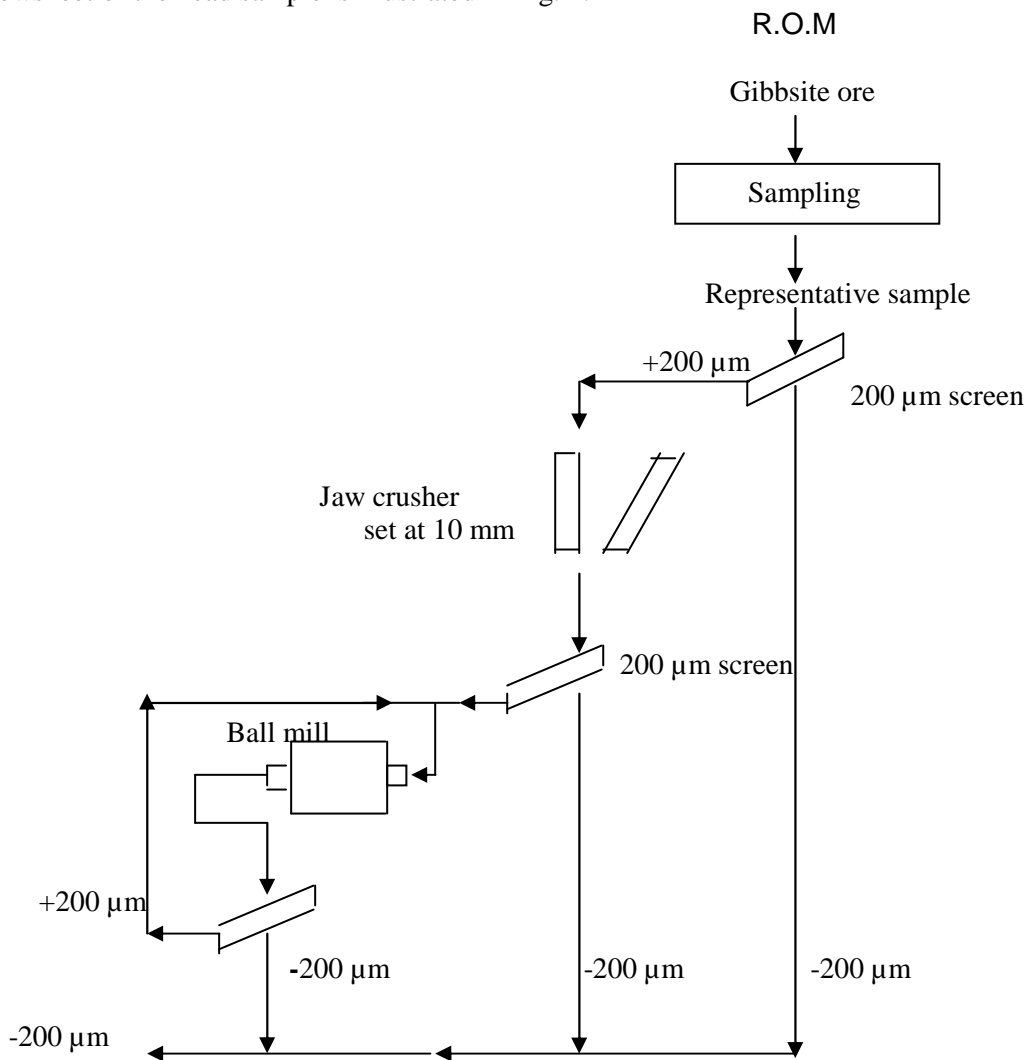


Fig. 3: The BSE image of kaolin

3. EXPERIMENTAL WORK

3.1 Materials

The samples used in this present work were obtained from the Southwest of Sinai (Abu Thur). A batch representative sample of about 250 kg was taken from the gibbsite zone. The obtained sample was split to smaller ones and crushed to minus 10 mm in a laboratory jaw crusher. The crusher product was sieved on a screen of 200 μm size. The screen oversize (+200 μm) was ground in a closed circuit ball mill to minus 200 μm . Grinding conditions were as follows: slope of mill = 0°, ball-to-ore ratio = 3:1, mill speed = 60 rpm, and grinding time = 20 minutes. The crushing and grinding flowsheet of the head sample is illustrated in Fig. 4.



To flotation process

Fig. 4: Crushing & grinding flow-sheet of the head sample

A representative sample was taken and chemically analyzed for the determination of the different constituents. The chemical analysis of the studied head sample is given in Table 1.

Table 1: Chemical analysis of the head sample of gibbsite ore from South Western Sinai (Abuthur)

Al ₂ O ₃	SiO ₂	Fe ₂ O ₃	CaO	P ₂ O ₅	MnO	K ₂ O	Na ₂ O	Traces	L.O.I.	Total
18.98	15.45	12.83	14.87	5.74	5.34	0.86	0.76	1.50	23.65	99.98

3.2 Reagents

All flotation tests were carried out using sodium dodecyl sulfate as a collector, while hydrochloric acid was used as pH modifier. Tap water used for maintaining the flotation pulp at a constant level, as well as, all the other experimental purposes.

3.3 Apparatus

Laboratory flotation tests were carried out in a 3000 ml Wemco Fagergern cell. A hand skimming was used to skim the froth.

3.4 Experimental Procedures

The impeller speed, during all flotation tests, was fixed at 1250 rpm and an aeration rate of 6 L/min was used. The total conditioning time was 15 min. The studied operating parameters were the pH value, collector dosage, pulp density and particle size. The gibbsite sample was added slowly and then conditioned with water for 5 minutes.

The pH value was adjusted at the end of the initial conditioning period and allowed to condition for 5 minutes with the pulp. The collector dosage was added at the end of the second conditioning period and was allowed to condition for 5 min with the pulp prior to the aeration. The air supply valve was gradually opened. The required pulp level was maintained constant during the flotation experiments.

In each experiment, and after allowing 15 sec for the froth to form, the concentrate was collected during batch flotation tests. The collected products (concentrate and tailings) were dried, weighed and chemically analyzed. The component recovery of alumina and other constituents in the concentrate and tailings were calculated.

4. RESULTS AND DISCUSSION

4.1 Calculations of Experimental Mass and Component Recovery of Flotation products

Using the mass percent and assays of alumina in feed, concentrate, and tailings, the experimental value of the mass recovery and component recovery of alumina in concentrate and tailings can be calculated as follows:

$$\text{Mass recovery of concentrate} = R_m(c) = 100 \cdot \frac{C}{F}$$

(1)

$$\text{Mass recovery of tailings} = R_m(t) = 100 \cdot \frac{T}{F} \quad (2)$$

$$\text{Component recovery in concentrate} = R_c(c) = 100 \cdot \frac{C.c}{F.f} \quad (3)$$

$$\text{Component recovery in tailings} = R_c(t) = 100 \cdot \frac{T.t}{F.f} \quad (4)$$

4.2 Results of Using Sodium Dodecyl Sulfate as a Collector

4.2.1 Effect of pH value

Table 2 and Figure 5a show the effect of pH value on the alumina content, the component recovery of alumina in the concentrate, and mass recovery of concentrate. These experiments were executed at a particle size of $-200 \mu\text{m}$, pulp density of 150 g/l, and collector dosage of 800 g/t. From this figure, it is noticed that the best selectivity was achieved at a pH value of 2, where the component recovery of alumina in the concentrate was 64.2%, the grade was 35.5%, and mass recovery of concentrate was about 34.3%.

Table 2: The effect of pH value on the grade, component recovery of alumina, and the mass recovery.

Exp. No.	pH value	Product	Mass Recovery, %	Alumina, %	
				Grade	Recovery
1	2	Concentrate	34.3	35.5	64.2
		Tailings	65.7	10.4	35.8
		Feed	100	19	100
2	4	Concentrate	29.9	34.5	54.2
		Tailings	70.1	12.4	45.8
		Feed	100	19	100
3	6	Concentrate	28.1	31.1	46.1
		Tailings	71.9	14.3	53.9
		Feed	100	19	100
4	8	Concentrate	26.6	29.9	41.8
		Tailings	73.4	15.1	58.2
		Feed	100	19	100
5	10	Concentrate	31.6	32.2	53.5
		Tailings	68.4	12.9	46.5
		Feed	100	19	100
6	12	Concentrate	33.6	30.1	53.2
		Tailings	66.4	13.4	46.8
		Feed	100	19	100

The grade of alumina was decreased from 35.5 % at a pH value of 2 to 29.9% at a pH value of 8, and then increased at higher pH values. The selectivity decreased significantly when the pH value approached the gibbsite point of zero charge value which occurred at a pH value of (8.1–9), then increased again at higher pH values.

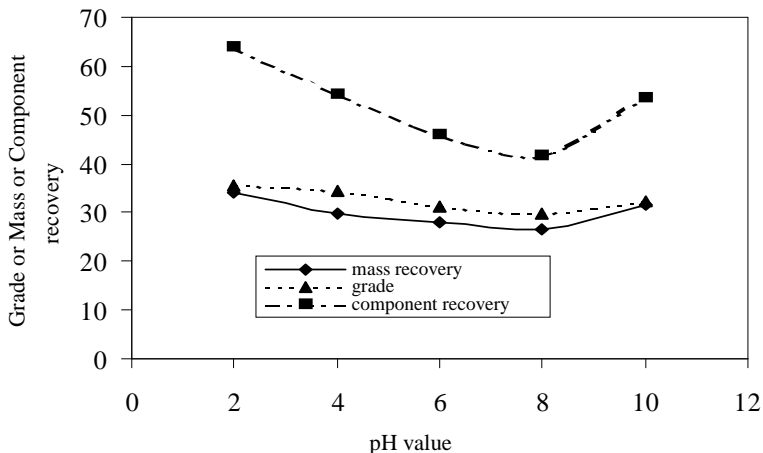


Fig. 5a: Effect of pH value on the grade, component recovery of alumina in the concentrate, and the mass recovery of concentrate.

Sodium dodecyl sulfate (alkyl sulfate) is an anionic collector and is effective in the acidic pH range. This collector is adsorbed on alumina by means of electrostatic and hydrophobic bonding [8]. Alumina is positively charged in pure water till a pH reaches a value of (8.1–9), after which charge reversal occurs [12]. Addition of sodium dodecyl sulfate converts the positive value of zeta potential of alumina to a negative one at a pH value greater than 2, so it is adsorbed on alumina surface in a significant amount at a pH value of 2 and makes the alumina surface more hydrophobic.

Figure 5b shows the effect of pH value on the grade, component recovery of alumina in the tailings, and the mass recovery of tailings.

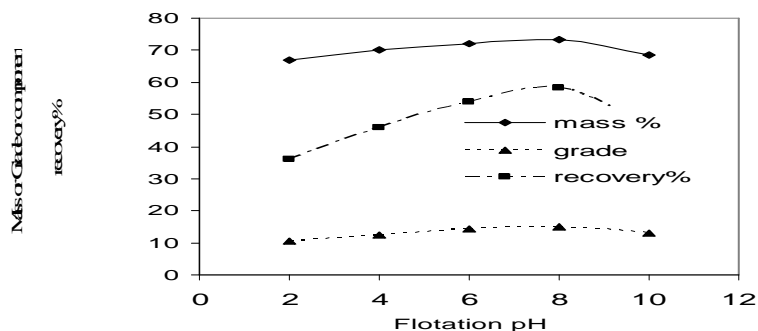


Fig. 5b: Effect of pH value on the grade, component recovery of alumina in the tailings, and the mass recovery of tailings.

From this figure it is shown that the component recovery of alumina in tailings increases from pH value of 2 to pH value of 8 where the best selectivity of alumina in the concentrate is at a pH value of 2, while the least recovery of alumina in the concentrate is at pH value of 8. At pH values greater than 8, the component recovery of alumina in the tailings was decreased. The grade of alumina was increased from 10.4% at pH value of 2 to 15.1% at pH value of 8, and then decreased at higher pH values.

4.2.2 Effect of sodium dodecyl sulfate concentration

Table 3 and Figure 6a show the effect of SDS concentration on the mass recovery, grade, and component recovery of alumina in the concentrate at the optimum value of pH (2) obtained from the previous experiments, which were carried out at the same conditions of pulp density and particle size. From Fig. 6a, it is clear that the component recovery of alumina increases from 64.2% at a concentration of 800 g/t sodium dodecyl sulfate to about 73.5% at a dosage of 2800 g/t. The grade of alumina decreases from 35.5% to 27.2% at the same concentration. The mass recovery of concentrate increases from 34.3% to 51.8% at the same concentration.

At relatively low values of sodium dodecyl sulfate concentration, the individual sulfate ions are adsorbed as counter ions at the alumina surface. As the concentration of sodium dodecyl sulfate increases, the adsorption of sulfate ions increases and form a monolayer of the collector on the alumina surface, hence the recovery of alumina increases. An addition of higher concentrations of collector results in lower floatability.

Table 3: the effect of sodium dodecyl sulfate concentration on the mass recovery, grade, and component recovery of alumina

Exp. No.	Collector dosage, g/t	Product	Mass Recovery, %	Alumina, %	
				Grade	Recovery
1	800	Concentrate	34.3	35.5	64.2
		Tailings	65.7	10.4	35.8
		Feed	100	19	100
2	1200	Concentrate	38.9	31.5	64.5
		Tailings	61.1	11	35.5
		Feed	100	19	100
3	1600	Concentrate	42.1	30.3	67.1
		Tailings	57.9	10.8	32.9
		Feed	100	19	100
4	2400	Concentrate	49.4	27.2	70.8
		Tailings	50.6	10.9	29.2
		Feed	100	19	100
5	2800	Concentrate	51.8	27	73.5
		Tailings	48.2	10.4	26.5
		Feed	100	19	100

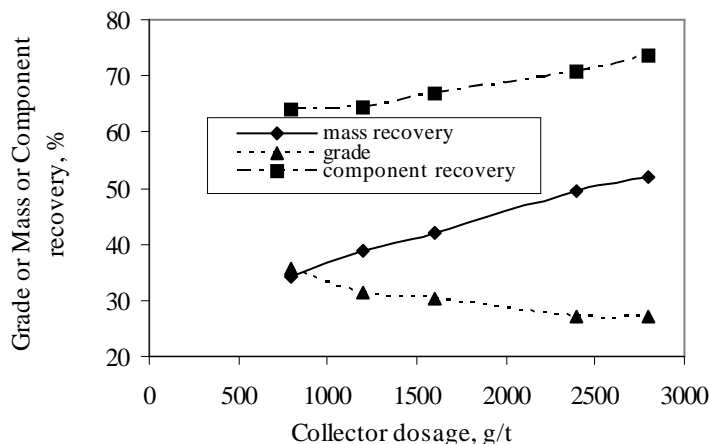


Fig. 6a: Effect of sodium dodecyl sulfate on the grade, component recovery of alumina in concentrate, and mass recovery of concentrate

At higher dosages of sodium dodecyl sulfate, the adsorption density of sulfate ions becomes sufficiently high, hence the interaction between hydrocarbon chains of sulfate ions occur through Van Der Waals forces. This phenomenon results in hemimicelles formation with the polar groups pointing towards the aqueous phase. The mineral surface, although coated with collector, becomes, therefore, hydrophilic and so the recovery of alumina decreases at higher collector concentrations [12–13–14].

Figure 6b shows the effect of sodium dodecyl sulfate concentration on the grade, component recovery of alumina in the tailings, and the mass recovery of tailings. From this figure, it is seen that the component recovery of alumina in the tailings and the mass recovery of tailings decreases as the collector dosage increased. The component recovery of alumina in tailings decreases from 35.8% at a dosage of 800 g/t to about 26.5% at a dosage of 2800 g/t of sodium dodecyl sulfate.

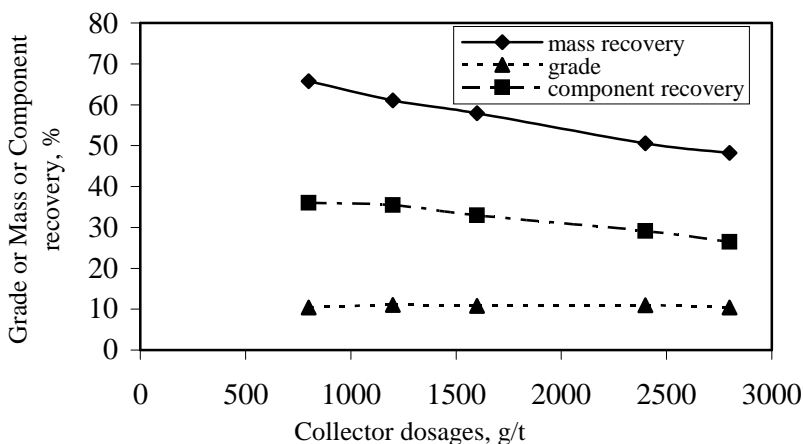


Fig. 6b: Effect of sodium dodecyl sulfate on the grade, component recovery of alumina in tailings, and mass recovery of tailings

The mass recovery of tailings decreases from 65.7% to about 48.2% at the same conditions. From Fig. 6b, it is noticed also that the alumina content in tailings did not change with the increase of sodium dodecyl sulfate concentration.

4.2.3 Effect of pulp density

Table 4 and Figure 7a show the effect of pulp density on the grade, component recovery of alumina in the concentrate, and the mass recovery of the concentrate. These experiments were carried out at a pH value of 2, 800 g/t concentration of SDS, and with the same previous particle size. From Fig. 7a, it can be noticed that the component recovery of alumina increases from 75.4% at a pulp density of 200 g/l to 94.1% at 350 g/l, then decreases to 90.3% at a pulp density of 400 g/l.

Table 4: The effect of pulp density on the mass recovery, grade, and component recovery of alumina

Exp. No.	Pulp density, g/l	Product	Mass Recovery, %	Alumina, %	
				Grade	Recovery
1	200	Concentrate	33.9	42.4	75.4
		Tailings	66.1	7.1	24.6
		Feed	100	19	100
2	250	Concentrate	37.2	40.1	78.4
		Tailings	62.8	6.6	21.6
		Feed	100	19	100
3	300	Concentrate	44.9	37.5	88.8
		Tailings	55.1	39	11.2
		Feed	100	19	100
4	350	Concentrate	63.4	28.2	94.1
		Tailings	36.6	3.1	5.9
		Feed	100	19	100
5	400	Concentrate	58.9	29.2	90.3
		Tailings	41.1	4.5	9.7
		Feed	100	19	100

From this figure, it can be revealed that the grade of alumina decreases from 42.4% at a pulp density of 200 g/l to 28.2% at 350 g/l, then increases to 29.2% at a pulp density of 400 g/l. The mass recovery of concentrate increases from 33.9% at a pulp density of 200 g/l to 63.4% at 350 g/l, and then decreases to 58.9% at 400 g/l. The above obtained results assure that the pulp density has a great effect on the flotation of alumina. This behavior may be due to that, with the increase of the pulp density, both the retention time of pulp in the flotation machine and the volumetric reagent concentration increase. The increase in the pulp density increases the levitation by decreasing the effective gravitational pull on the particles and increases solution

concentration with the collector addition and hence, increases reaction rate. The best results of the flotation are obtained at higher pulp densities. However, excessive pulp density will result in adverse effects such as, deterioration of the pulp aeration and floatability of large size particles, and increase the floatability of fine gangue particles, which result in reducing the quality of the concentrate [15,16].

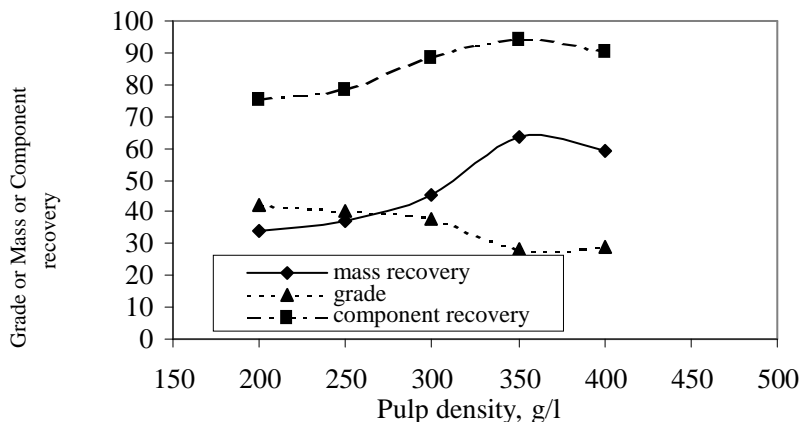


Fig. 7a: Effect of pulp density on the grade, component recovery of alumina in concentrate, and the mass recovery of concentrate.

Figure 7b shows the effect of pulp density on the grade, component recovery of alumina in the tailings, and the mass recovery of tailings. From this figure, it is seen that the component recovery of the alumina in the tailings decreases from 24.6% at a pulp density of 200 g/l to 5.9% at 350 g/l, then increases to 9.7% at a pulp density of 400 g/l. The mass recovery of tailings decreases from 66.1% to 36.6% at the same pulp densities, and then increases to 58.9% at 400 g/l. The grade of alumina decreases from 7.1% to 3.1% at the same pulp densities, and then increases to 4.5% at 400 g/l. The higher pulp density leads to appearance of a lower grade mineral in the concentrate and increases the recovery of alumina in tailings.

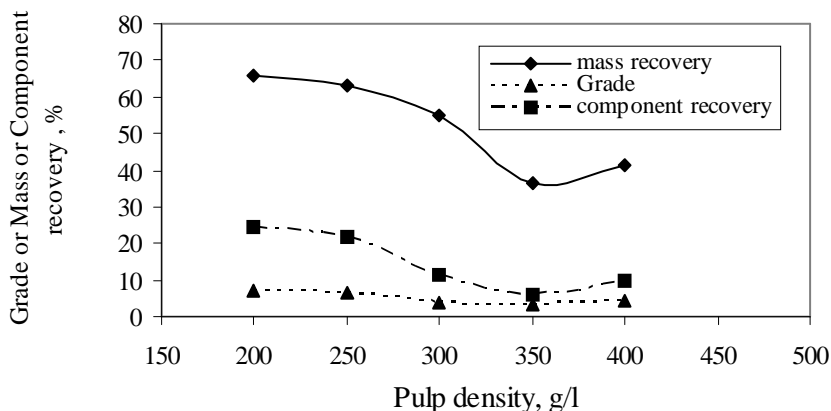


Fig. 7b: Effect of pulp density on the grade, component recovery of alumina in tailings, and the mass recovery of tailings.

4.2.4 Effect of particle size

Table 5 and Figure 8a show the effect of particle size on the grade, component recovery of alumina in concentrate, and the mass recovery of concentrate. These experiments were executed at a pH value of 2, 800 g/t concentration of SDS, and a pulp density of 300 g/l. From Fig. 8a, it is shown that particles of various sizes did not float equally well. For coarse particles, the recovery decreases due to the incomplete liberation, very small contact angle, and very violent agitation. The component recovery of alumina increases from 57.8%, at a particle size of (-200+160) μm to 97.9% μm at (-80+63) μm , and then decreases to 94.5% at (-63+0) μm .

The mass recovery of concentrate increases from 19.9% to 65.1% at the same particle sizes, and then decreases to 59.2% at (-63+0) μm . From Fig. 8a, it can be also seen that the grade of alumina in concentrate decreases from 44.1% at a particle size of (-200+160) μm to 33.1% at (-80+63) μm , and then increases to 33.5% at (-63+0) μm .

Table 5: The effect of particle size on the mass recovery, grade, and component recovery of alumina

Exp. No.	Particle size, μm	Product	Mass Recovery, %	Alumina, %	
				Grade	Recovery
1	-200 +160	Concentrate	19.9	44.1	57.8
		Tailings	80.1	8.1	42.2
		Feed	100	15.2	100
2	-160+125	Concentrate	26.4	43.4	73.9
		Tailings	73.6	5.5	26.1
		Feed	100	15.5	100
3	-125+100	Concentrate	40.2	41.8	92.3
		Tailings	59.8	2.3	7.7
		Feed	100	18.2	100
4	-100+80	Concentrate	52.8	39.5	96.9
		Tailings	47.2	1.4	3.1
		Feed	100	21.5	100
5	-80+63	Concentrate	65.1	33.1	97.9
		Tailings	34.9	1.3	2.1
		Feed	100	22	100
6	-63+0	Concentrate	59.2	33.5	94.5
		Tailings	40.8	2.8	5.5
		Feed	100	21	100

The particle size is known to be an important parameter for the high performance of the flotation process [17]. The component recovery decreases as the particle size increases, because the recovery rates of coarser particles are affected by disruption of particle-bubble aggregate in turbulent zones, as well as, a decrease in buoyancy of the particle bubble aggregate relative to the pulp [18]. From Fig. 8a, it

can be seen that the component recovery of alumina and the mass recovery of concentrate are increased as the particle size is decreased. This increase is due to the increase of the liberated part of alumina in the feed. On the other hand, the grade of alumina in the concentrate decreased, as the particle size of $(-63+0)$ μm contains fine and super fine particles.

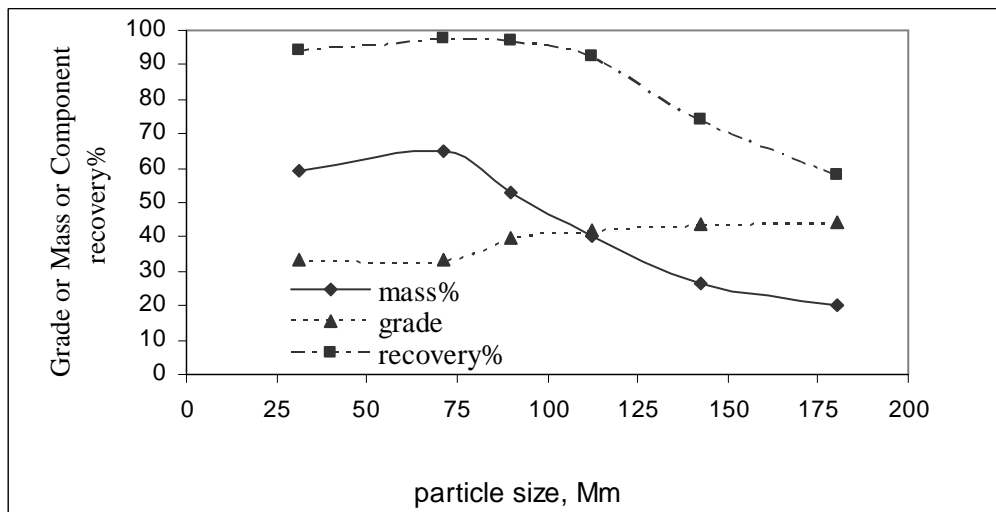


Fig. 8a: Effect of particle size on the grade, component recovery of alumina in concentrate, and the mass recovery of concentrate.

Fine particles are not only slow to float, but also they become almost unresponsive to reagents even to exorbitant quantities of reagents. At the same time, the gangue particles are activated till the difference in the response between valuable mineral and the gangue minerals is totally lost. The poor response of very fine particles in any flotation pulp seems to be ascribable not only to the poorer chance for mineral bubble encounter in the fine sizes, but also due to the fact that very fine particles have older surfaces than coarser ones, so fine sizes are extensively affected by ions derived from other minerals, by oxygen, or by water [14,18].

Figure 8b shows the effect of particle size on the grade, component recovery of alumina in the tailings, and the mass recovery of tailings. From this figure, it is revealed that the component recovery of alumina in tailings decreases from 42.2% at a particle size of $(-200+160)$ μm to 2.1% at $(-80+63)$ μm , then increases to 5.5% at $(-63+0)$ μm . The mass recovery in the tailings decreases from 80.1% to 34.9% at the same particle sizes, then increases to 40.8% at a particle size of $(-63+0)$ μm . The grade of alumina in tailings decreases from 8.1% at a particle size of $(-200+160)$ μm to 1.3% at $(-80+63)$ μm , then increases to 2.8% at $(-63+0)$ μm . From this figure, it can be also noticed that the rise of assays values in tailing in the coarser fractions might be due to a progressive decrease in the liberation and failure to float coarse free mineral.

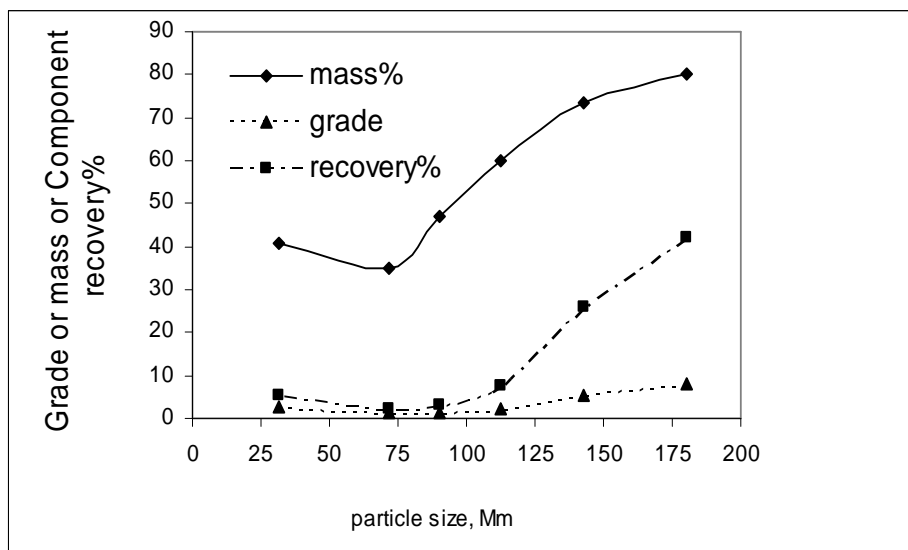


Fig. 8b: Effect of particle size on the grade, component recovery of alumina in tailings, and the mass recovery of tailings.

5. CONCLUSIONS

From the results and discussions in this research the following conclusions can be drawn:

1. Sodium dodecyl sulfate was used as an anionic collector. Cationic collectors can not be applied for the gibbsite ore under studied conditions due to the presence of significant amount of quartz.
2. The values of the studied parameters at the optimum conditions were as follows: 800 g/t sodium dodecyl sulfate, pulp density = 300 g/l, pH value = 2, and a particle size of (-100+80) μm . Under these optimum values, a concentrate with a mass recovery of 52.8% containing 39.5% Al_2O_3 with an alumina recovery of 96.9% was obtained. The grades of other ore constituents in the final concentrate were as follows: 6.4% SiO_2 , 5.2% CaO , 5.6% Fe_2O_3 , 3.8% P_2O_5 , 3.2% MnO , 1.2% K_2O , 1.1% Na_2O , 2.6% traces, and 31.2% loss on ignition. The component recoveries of SiO_2 , CaO , Fe_2O_3 , P_2O_5 , MnO , K_2O , Na_2O , and traces in the final concentrate were 23.8%, 19.5%, 22.6%, 46.6%, 40.2%, 39.1%, 33.1%, and 85.8%, respectively.
3. The final obtained product is suitable for many industrial purposes such as aluminous chemicals (aluminum sulfate and sodium aluminate are used for water treatment and aluminum chloride is used in refining crude petroleum) and abrasive products (coated abrasives, sharpening stones and grinding wheels). The final product may be also suitable for alumina refractories and aluminium extraction after its processing by Bayer process.

REFERENCES

1. Burkin, A.R., "Production of aluminum and alumina", John & Sons, New York, pp. 3–13, 1987.
2. O'Connor, D.J., "Alumina extraction from non bauxitic materials", Aluminum-Verlag GmbH, Germany, pp. 1–10, 1988.
3. Bittencourt, L.R.M., Lin, C.L., and Miller, J.D., "Flotation recovery of high purity gibbsite concentrates from a Brazilian bauxite ore", In: *Advanced Materials–Application Mineral and Metallurgical Processing Principles*, Society of Mining Engineers of AIM, pp. 77–85, 1990.
4. Zhenghe, X., Plitt, V., and Liu, Q., "Recent advances in reverse flotation of diasporic ores–A Chinese experience", *Minerals Engineering*, Vol. 17, pp. 1007–1015, 2004.
5. Hinds, S.A., Husain, K., and Liu, N., "Beneficiation of bauxite tailings", *Light Met.*, Vol. 54, pp. 17–30, 1985.
6. Andreev, P.I., Anishchenko, N.M., and Mishakenkova, N.P., "Mechanism of the action of amines during the flotation of bauxite ore minerals", *Tsvetnye Metally*, Vol. 18, pp. 13–17, 1975.
7. Bulut, G. and Yurtsever, C., "Flotation behaviour of bitlis kyanite ore", *Int. J. Miner. Process.* Vol. 73, pp. 29–36, 2004.
8. Doss, S.K., "Adsorption of dodecyltrimethylammonium chloride on alumina and its relation to oil–water flotation", *Min. Process. Extr. Metall.*, C195–C199, 1976.
9. Wang, Y., Hu, Y., He, P., and GU, G., "Reverse flotation of silicates from diasporic–bauxite", *Minerals Engineering*, Vol. 17, pp. 63–68, 2004.
10. Marie, C.J., Fabien, G., and Bernard, H., "Limitations of potentiometric studies to determine the surface charge of gibbsite γ -Al(OH)₃ particles", *Journal of Colloid and Interface Science*, Vol. 6, pp. 1–11, 2005.
11. Murray, B.M., "Adsorption of fatty acid spin probes on amorphous alumina", *Journal of Colloid and Interface Science*, Vol. 76, pp. 393–398, (1980).
12. Hu, Y. and Dai, J., "Hydrophobic aggregation of alumina in surfactant solution", *Minerals Engineering*, Vol. 16, pp. 1167–1172, 2003.
13. Somasunaran, P. and Huang, L., "Adsorption/aggregation of surfactants and their mixtures at solid–liquid interface", *Advances in Colloid and Interface Science*. Vol. 88, pp. 179–208, 2000.
14. Jain, S.K., "Mineral Processing", 2nd ed., CBS, New Delhi, pp. 248–260, 2001.
15. Vijayendra, H.G., "Handbook on mineral dressing", 2nd ed., Vikas, New Delhi, pp. 195–210, 1995.
16. Wills, B.A., "Mineral Processing technology", Elsevier Ltd., 7th ed., pp. 283–293, 2006.
17. Vamvuka, D. and Agridiotis, V., "The effect of chemical reagents on lignite flotation", *Int. J. Min. Process.*, Vol. 61, pp. 209–224, 2000.
18. Feng, D. and Aldrich, C., "Effect of particle size on flotation performance of complex sulfide ores", *Minerals Engineering*, Vol. 12, pp. 721–731, 1999.

تعويم الالومينا في خام طفلة جنوب غرب سيناء الحاملة للجبسيات باستخدام SODIUM DODECYL SULFATE

في هذا البحث تم دراسة عينات من خام الطفلة الحاملة للجبسيات المتواجدة بجنوب غرب سيناء بهدف زيادة تركيز الالومينا بها باستخدام تكنولوجيا التعويم بالهواء. وقد تبين من التحليل الكيميائي للعينه أن نسبة $Al_2O_3 = 18.98\%$ ونسبة $SiO_2 = 15.45\%$ ونسبة $Fe_2O_3 = 12.83\%$ ونسبة $CaO = 14.87\%$ ونسبة $P_2O_5 = 5.74\%$ ونسبة $MnO = 5.43\%$ ونسبة $K_2O = 0.86\%$ ونسبة $Na_2O = 0.76\%$ ونسبة $trace\ elements = 1.50\%$ ونسبة فاقد الحرق $= 23.65\%$. بهدف رفع تركيز الالومينا في خام الطفلة الحاملة للجبسيات إلي الحصول على منتج بمواصفات مناسبة لانتاج الالومينا عالية التركيز مناسبة للصناعات المختلفة.

في هذا البحث تم استخدام sodium dodecyl sulfate كمجمع وقد وجد من النتائج أن sodium dodecyl sulfate فعال في الوسط الحمضي وخاصة عند $pH = 2$ وعند هذه القيمة وعند الظروف المثلى لمتغيرات التشغيل الأخرى التي درست قد تم الحصول على ركاز بالمواصفات الآتية: نسبة $Al_2O_3 = 39.5\%$ بنسبة استرجاع $= 96.9\%$ ونسبة $SiO_2 = 6.4\%$ بنسبة استرجاع $= 23.8\%$ ونسبة $CaO = 14.87\%$ بنسبة استرجاع $= 19.5\%$ ونسبة $Fe_2O_3 = 5.6\%$ بنسبة استرجاع $= 22.6\%$ ونسبة $P_2O_5 = 3.8\%$ بنسبة استرجاع $= 46.6\%$ ونسبة $MnO = 3.2\%$ بنسبة استرجاع $= 40.2\%$ ونسبة $K_2O = 1.2\%$ بنسبة استرجاع $= 39.1\%$ ونسبة $Na_2O = 0.76\%$ بنسبة استرجاع $= 33.1\%$ ونسبة $trace\ elements = 2.6\%$ بنسبة استرجاع $= 85.8\%$. وقد تم الحصول على 52.8% استرجاع للكثله بالنسبة لكثله الخام المغذى لخلية التعويم.

ويمكن استخدام هذا المنتج في العديد من الأغراض الصناعية مثل المواد الكيميائية المستخدمة في معالجة المياه (sodium aluminate, aluminum sulfate) و المواد المستخدمة في تكرير البترول مثل ال aluminum chloride وكذلك الصنفره و صناعة الحراريات و استخلاص الالومنيوم بعد تركيزها بطريقة Bayer