

IMPROVEMENT OF EGYPTIAN TALC QUALITY FOR INDUSTRIAL USES BY FLOTATION PROCESS AND LEACHING

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Talc is an industrial mineral that is widely used. It is always associated with other minerals, which determine the quality of talc samples for industrial purposes. Various operating variables control the natural floatability of talc. For enhancement of talc flotation, sodium hexametphosphate is used as a depressant for associated gangue minerals. In addition, oleic acid (in an equal mixture with kerosene) is used as an anionic collector. The results presented in this paper provided useful and important information on how to improve the quality of talc for industrial uses. The optimum conditions were obtained at pH = 11, depressant dosage = 1.0 kg/t, collector dosage = 1.2 kg/t and pulp density = 200 g/L. At these conditions, SiO₂ assay increased from 54.10% to 54.94%, MgO assay increased from 29.90% to 31.76%, CaO decreased from 0.80% to 0.42%, Al₂O₃ decreased from 5.50% to 3.11%, Fe₂O₃ decreased from 8.20% to 7.24%, the whiteness increased from 75.4% to 83.7%, and the loss on ignition decreased from 6.64% to 5.21%. The mass recovery of final concentrate was 92.4%. The component recoveries of SiO₂ and MgO (the major constituents of talc) in the final concentrate were 93.8% and 98.2%, respectively. More improvement of talc quality was obtained by leaching of final concentrate of flotation with 10% dilute hydrochloric acid. The mass recovery of final product was about 85% of initial feed. In this final product, Fe₂O₃ decreased to 3.12%, CaO decreased to 0.38%, and Al₂O₃ decreased to 3.01%. The assay of SiO₂ increased to 58.96%, MgO percent was nearly the same, the whiteness increased to 88.5%, and the loss on ignition decreased to 4.03%. The final product is suitable for many industrial uses such as low-loss electronics (a type of ceramics), paints, rubber, plastics, roofing, textiles, refractories, insecticides and coating of welding rods.

KEYWORDS: *Talc, flotation, pH, depressant, collector, pulp density, sodium hexametphosphate, oleic acid, leaching, industrial purposes.*

NOMENCLATURE

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

INTRODUCTION

Talc is an industrial mineral, which is composed of hydrated magnesium sheet-silicates with theoretical formula of $Mg_3Si_4O_{10}(OH)_2$ that belongs to the phyllosilicate family [1-4]. It consists of a two dimensional sheet structure forming two layers of silica tetrahedral held together with octahedral brucite, $Mg(OH)_2$ [5]. The talc surface is comprised of two types of surface area, the basal cleavage faces and the edges. The faces surface has no charged group therefore, it is believed that the talc faces are non-polar and hydrophobic, whereas the edges are hydrophilic due to the presence of charged ions (Mg^{2+} and OH^-) [5-6]. The major gangue minerals of talc are carbonates, magnesite, dolomite, serpentine, chlorite and calcite, which contribute to production of undesirable characteristics. The trace minerals including magnetite, pyrite, quartz and tremolite [7-11]. The percentage of some constituents in talc such as calcium oxide, iron oxide and aluminum oxide determine the quality of talc samples for market demands [1]. Talc is used in many industries such as paints, paper, plastic, polymers, rubbers, fertilizers, insecticides, ceramics and cosmetics [1,12-16]. Concentrating tables are used to remove high-gravity products containing nickel, cobalt and iron minerals. Flotation, magnetic separation and a combination of froth flotation and high-intensity magnetic separation may be applied for the removal of iron bearing minerals [9,17-20]. Flotation is the preferred concentration technique to remove impurities [4,19]. Various factors that control the flotation of talc including particle size, pH, collector dosage, depressant dosage, pulp density and frother dosage were studied by many authors [2,9,19,21-23]. Chemical treatments using acids may be applied to further increase the grade of concentrate. The basis of the proposed technique is the fact that talc is inert in most chemical reagents. Depurated talc minerals were leached with HCL solution. Some deficiencies may be corrected to satisfy industrial requirement. The iron content may be reduced but the economic feasibility of this treatment may be evaluated by assessing the balance between the operating costs and the price difference of products [7]. In another research, the iron content can be decreased or removed by treating the final concentrate with a dilute hydrochloric acid having a concentration of (10%) and $SnCl_2$ (300 ppm). In this case, the final product was suitable for different industrial purposes like paper, cosmetics, paints, plastics and rubbers [9]. The purpose of this paper is to determine the optimum conditions of flotation process and the possibility of using leaching to improve the quality of talc to

be suitable for industrial purposes such as low-loss electronics (a type of ceramics), paints, rubber, plastics, roofing, textiles, refractories, insecticides and coating of welding rods [14].

EXPERIMENT

Materials

Talc ore sample

The sample used in the present work was obtained by mixing of different samples obtained from Shalatin area. Petrographically, the talc samples were classified into five different types. From the geochemical point of view, the samples were classified into three groups. This work is interested with the second group. The details and characteristics of these samples and groups were discussed in a previous published paper [1]. The final sample was crushed to minus 35 mm in a semi-industrial jaw crusher, then to minus 4.75 mm in a laboratory jaw crusher. A wet attrition scrubbing was used because the friable nature of talc. A wet attrition scrubbing conditions were as follow: pulp density = 50%, motor speed = 1720 rpm and attrition time = 45 minutes. A particle size of minus 75 μm (the desired size for flotation process) was obtained from the attrition process [19]. The final product was collected, filtered and dried. The chemical analysis of the studied head sample is given in **Table 1**. The particle size distribution of the flotation feed is shown in **Table 2**.

Table 1: Chemical analysis of the studied head sample.

Assay (A_f), %									
SiO ₂	MgO	CaO	Al ₂ O ₃	Fe ₂ O ₃	P ₂ O ₅	Na ₂ O	K ₂ O	MnO	SO ₃
54.10	29.90	0.80	5.50	8.20	0.52	0.12	0.15	0.16	0.43

Table 2: The particle size distribution of the flotation feed.

Size fraction, μm	wt. ret., %	cum. wt. ret., %
-75+53	10.0	10.0
-5.3+45	42.0	52.0
-45+38	8.0	60.0
-38	40.0	100.0
Σ	100.0	

Reagents

The flotation tests were carried out using oleic acid (in an equal mixture with kerosene) as a pure collector for analysis (iodine value 85-95, acid value 196-204 and molecular weight 282.47). The dosage was varied from 0.6 to 1.4 kg/t [19]. Sodium hexametaphosphate (SHMP) were employed as a selective depressant of carbonates. It was changed from 0.4 to 1.2 kg/t [19,27,28]. The frother agent used for all tests was pine oil (a dosage of 0.1 kg/t). Sodium hydroxide and hydrochloric acid (30%-34%) are used to adjust the pH of the medium. Tap water is used to maintain the flotation pulp level and for all other experimental purposes.

Apparatus

Laboratory flotation tests were carried out in a 2800 cm³ Wemco Fagergren cell. A water perspex tank was used to maintain the pulp level at a constant value. Hand skimming was used to collect the froth overflow.

Procedure

All flotation tests were carried out at room temperature. The impeller speed was fixed at 1100 rpm and an aeration rate of 6 L/min was used. The total conditioning time was 10 min. The talc sample was added slowly and conditioned with water for five min. Further water was then added to bring the liquid level to the required 10 mm below the overflow lip. The pH modifiers were added to adjust the required pH. The depressant dosage sodium hexametaphosphate (SHMP) was added at the end of the initial conditioning period and was allowed to condition for 2 min. with the pulp. The collector dosage (oleic acid and kerosene mixture) was added at the end of the previous period and was allowed to condition for 2 min. with the pulp. The frother dosage was then added and a further 1 min. of conditioning was allowed prior to aeration. The air supply was gradually opened. The required pulp level was maintained constant.

In each experiment, after allowing 15 seconds for froth to form, a hand skimmer was used to collect the froth over until the froth is stopped. After the process being finished, the products (concentrate and tailings) were dried, weighed and chemically analyzed. The experimental part of this paper was done in the ore dressing laboratories of the Mining and Metallurgical Department, Faculty of Engineering, Assuit University.

RESULTS AND DISCUSSION

Calculations of Experimental Mass and Component Recoveries of Flotation Products

Using the direct mass percent and assays of different constituents of the feed, concentrate, and tailings, the experimental values of the mass and component recoveries of the flotation products can be calculated as follows:

$$\text{Mass recovery of concentrat e} = R_m(c) = 100 \cdot \frac{C}{F} \quad (1)$$

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

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

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

Effect of pH

Table 3a includes the chemical analysis of constituents in flotation products of experiments carried out at different pH values. This table showed that the percentages of SiO₂ and MgO (the major constituents of talc) decreased in the concentrate product

with increasing pH value from 4 to 12. Conversely, the percentages of CaO, Al₂O₃ and Fe₂O₃ (the main wastes in talc) increased. These results are illustrated also in **Figures 1a** through **1e**. From **Figures 1a** and **1b**, it can be seen that, the SiO₂ assay decreased from pH 4 to pH 12 (57.02% to 54.30%), as well as, MgO assay decreased from pH 4 to pH 12 (34.0% to 31.8%). This may be interpreted due to the tendency of magnesium to precipitate or hydrolysis with increasing pH, which leads to decrease its content, especially at the alkaline values [24-25].

Figures 1c through **1e** showed that with increasing the value of pH from 4 to 12, CaO increased (from 0.35% to 0.72%), Al₂O₃ increased (from 2.17% to 4.30%), and Fe₂O₃ increased (from 6.22% to 8.10%). This may be attributed to that, the carbonates content increase with increasing pH. These results are in agreement with the work of Al-Wakeel [9].

The percentage of iron oxide is still high due to the association of iron oxide with all mineral components of the sample, which sometimes appearing as yellowish brown threads along its schistose structure and in other cases, associating with the banded talc- chlorite structure [19].

The effect of pH values on the mass recovery of concentrate is shown in **Table 3b** and **Fig. 1f**. From this figure, it can be seen that, the mass recovery increased from 53% to 84.5%, as the value of pH increased from pH 4 to pH 11. More increase of the pH value, above 11, decreased the mass recovery.

Table 3a: The chemical analysis of constituents in flotation products of experiments carried out at different pH values.

Exp. No.	pH	Concentrate					Tailings				
		Assay (A _c), %					Assay (A _t), %				
		SiO ₂	MgO	CaO	Al ₂ O ₃	Fe ₂ O ₃	SiO ₂	MgO	CaO	Al ₂ O ₃	Fe ₂ O ₃
1	4	57.02	34.00	0.35	2.17	6.22	50.81	25.28	1.31	9.26	10.43
2	7	56.15	33.39	0.42	2.62	6.53	50.41	23.61	1.48	10.69	11.21
3	9	55.9	33.03	0.44	2.78	6.85	50.45	23.55	1.53	11.02	10.94
4	11	55.71	32.92	0.50	3.03	7.14	45.32	13.44	2.44	18.97	13.98
5	12	54.3	31.81	0.72	4.3	8.10	53.40	23.24	1.08	9.68	8.55

Table 3b: The mass recoveries of flotation products and the component recoveries of constituents of experiments carried out at different pH values.

pH	Concentrate						Tailings					
	Component recovery R _c (c), %					R _m (c), %	Component recovery R _c (t), %					R _m (t), %
	SiO ₂	MgO	CaO	Al ₂ O ₃	Fe ₂ O ₃		SiO ₂	MgO	CaO	Al ₂ O ₃	Fe ₂ O ₃	
4	55.9	60.3	23.2	20.9	40.2	53.0	44.1	39.7	76.8	79.1	59.8	47.0
7	66.7	71.8	33.8	30.6	51.2	64.3	33.3	28.2	66.2	69.4	48.8	35.7
9	69.2	74.0	36.9	33.9	56.0	67.0	30.8	26.0	63.1	66.1	44.0	33.0
11	87.0	93.0	52.8	46.6	73.6	84.5	13.0	7.0	47.2	53.4	26.4	15.5
12	78.0	82.7	69.9	60.7	76.8	77.7	22.0	17.3	30.1	39.1	23.2	22.3

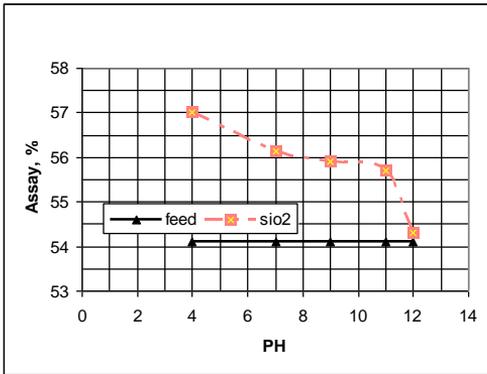


Fig. 1a: SiO₂ assay with pH.

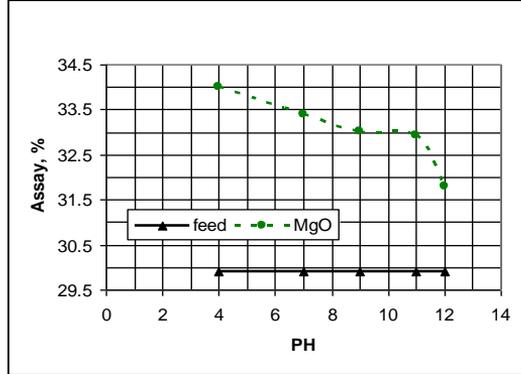


Fig. 1b: MgO assay with pH.

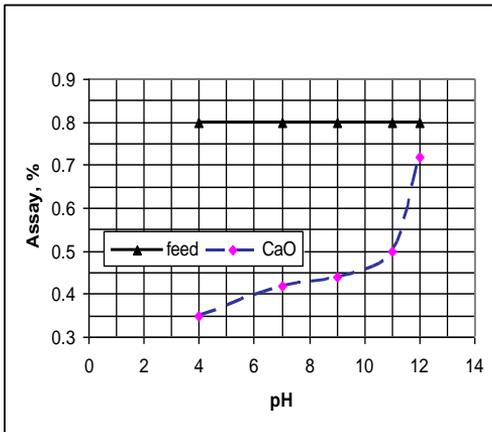


Fig. 1c: CaO assay with pH.

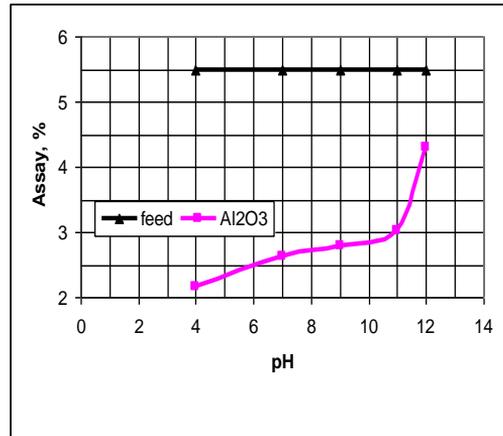


Fig. 1d: Al₂O₃ assay with pH.

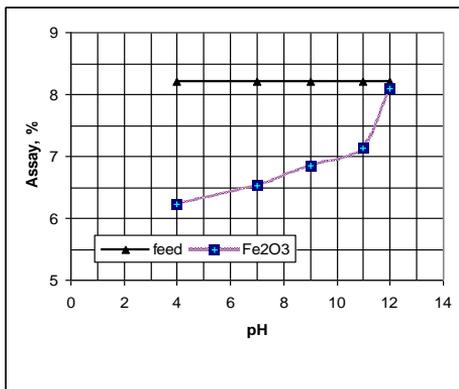


Fig. 1e: Fe₂O₃ assay with pH.

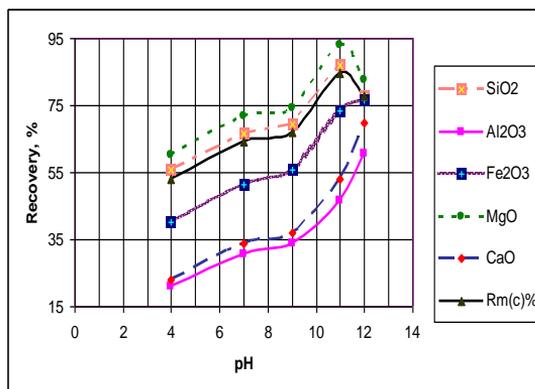


Fig. 1f: Mass and component recoveries with pH.

Fig. 1: Effect of pH values on the mass recovery, as well as, on the assays and component recoveries of different constituents in concentrate.

The effect of pH values on the component recoveries of constituents in concentrate is illustrated also in **Table 3b** and **Fig. 1f**. From this figure, it can be shown that, the component recovery of SiO_2 increased from 56% to 87%, as well as, the component recovery of MgO increased from 60% to 93% as the pH value increased from pH 4 to pH 11. Any increase of pH value decreased the component recoveries of these two constituents. On the other hand, the component recoveries of CaO , Al_2O_3 and Fe_2O_3 increased with increasing the pH value.

The above results can be interpreted such that, the hydrophobicity of talc surface increases as pH increases from 2 to 11. The floatability of talc is slightly affected by increasing of H^+ (from pH 2 to 7) and is more affected by increasing OH^- (from pH 7 to 11) [9]. The anisotropy nature of talc revealed that their crystals consist of faces, which are being hydrophobic and not charged, and edges being hydrophilic and charged. The bubbles will attach to the hydrophobic faces where they are not affected by the edge charge. At a higher pH value, over 11, the overall charge on the particle may give a rise to a high repulsion of air bubbles. This may be due to that some dissolution of particles takes place at high pH and adsorption of hydrolyzed species may contribute to increase of hydrophilicity [2]. Although the talc has a point of zero charge (ZPC) at pH 1.8 [9], the using of oleic acid, as an anionic collector, will change zeta potential of talc from a negative to a positive value at pH 11 [26].

From **Table 3a**, it can be seen that the assays of SiO_2 and MgO were at their lowest values in tailings, as well as, the assays of CaO , Al_2O_3 and Fe_2O_3 were at their highest ones at the same value of pH 11. This assures that the optimum conditions of these experiments can be obtained at pH 11.

Effect of Depressant Dosage

Table 4a contains the chemical analysis of constituents in flotation products of experiments executed at different depression dosages of sodium hexametaphosphate (SHMP). The table showed that the percentages of SiO_2 and MgO (the major constituents of talc) decreased in the concentrate product with increasing the depression dosage from 0.4 to 1.2 kg/t. Conversely, the percentages of CaO , Al_2O_3 and Fe_2O_3 (the main wastes in talc) increased. These results are also revealed in **Figures 2a** through **2e**. From **Figures 2a** and **2b**, it can be seen that, SiO_2 decreased (from 57.23% to 54.46%) with increasing the depression dosage from 0.4 to 1.2 kg/t, as well as MgO decreased (from 34.13% to 31.29%) with the same dosage.

Figure 2c shows that CaO decreased (from 0.72% to 0.42%) if the depression dosage was increased from 0.4 Kg/t to 1.0 Kg/t. More increasing of the dosage will lead to increase the final percent of CaO . This trend can be explained due to the ability of sodium hexametaphosphate (SHMP) to sequester the calcium cations (Ca^{2+}) and forming with the calcium a strong hydrophilic complex compound [27-28]. **Figures 2d** and **2e** showed that with increasing the depression dosage from 0.4 to 1.2 kg/t, Al_2O_3 increased (from 1.98% to 4.21%), as well as Fe_2O_3 increased (from 5.88% to 8.07%). This may be interpreted to the interaction of sodium hexametaphosphate (SHMP) anions with the exposed atoms of Al giving complexed anions but the action of sodium hexametaphosphate towards aluminum is a weak to sequester the aluminum sites [27].

Table 4a: The chemical analysis of constituents in flotation products of experiments carried out at different depression dosages.

Exp. No.	Depression dosage, kg/t	Concentrate					Tailings				
		Assay (A_c), %					Assay (A_t), %				
		SiO ₂	MgO	CaO	Al ₂ O ₃	Fe ₂ O ₃	SiO ₂	MgO	CaO	Al ₂ O ₃	Fe ₂ O ₃
1	0.4	57.23	34.13	0.72	1.98	5.88	46.36	19.44	1.00	14.20	13.94
2	0.6	56.57	33.67	0.63	2.14	6.35	45.59	16.91	1.39	17.07	14.57
3	0.8	55.71	32.92	0.50	3.03	7.14	45.32	13.44	2.44	18.97	13.98
4	1.0	54.97	31.89	0.42	3.08	7.21	41.36	15.31	3.59	23.25	15.46
5	1.2	54.46	31.29	0.68	4.21	8.07	52.96	25.5	1.18	9.59	8.61

Table 4b: The mass recoveries of flotation products and the component recoveries of constituents of experiments executed at different depression dosages.

Depression dosage, kg/t	Concentrate						Tailings					
	Component recovery $R_c(c)$, %					$R_m(c)$, %	Component recovery $R_c(t)$, %					$R_m(t)$, %
	SiO ₂	MgO	CaO	Al ₂ O ₃	Fe ₂ O ₃		SiO ₂	MgO	CaO	Al ₂ O ₃	Fe ₂ O ₃	
0.4	75.3	81.3	64.0	25.6	51.1	71.2	24.7	18.7	36.0	74.4	48.9	28.8
0.6	81.0	87.3	61.0	30.2	60.0	77.5	19.0	12.7	39.0	69.8	40.0	22.5
0.8	87.0	93.0	52.8	46.6	73.6	84.5	13.0	7.0	47.2	53.4	26.4	15.5
1.0	89.4	93.9	46.2	49.3	77.4	88.0	10.6	6.1	53.8	50.7	22.6	12.0
1.2	76.5	79.5	64.6	58.2	74.8	76.0	23.5	20.5	35.4	41.8	25.2	24.0

The effect of depression dosages on the mass recovery of concentrate is shown in **Table 4b** and **Fig. 2f**. From this figure, it can be seen that, the mass recovery increased from 71.2% to 88.0%, as the value of depression dosage increased from 0.4 to 1.0 kg/t. More increase of the depression dosage, above 1.0 kg/t, decreased the mass recovery. The effect of depression dosages on the component recoveries of constituents in concentrate is illustrated also in **Table 4b** and **Fig. 2f**. From this figure, it can be seen that, the component recovery of SiO₂ increased (from 75.3% to 89.4%), as well as, the component recovery of MgO increased (from 81.3% to 93.9%) as the depression dosage increased from 0.4 to 1.0 kg/t. Any increase of depression dosage above this value decreased the component recoveries of these two constituents. From **Fig. 2f**, it can be also revealed that the component recovery of CaO decreased (from 64.0% to 46.2%) as the depression dosage increased from 0.4 to 1.0 kg/t and then increased by increasing of depression dosage above 1.0 kg/t. On the other hand, the component recoveries of Al₂O₃ and Fe₂O₃ increased with increasing the depression dosage value.

From **Table 4a**, it can be seen that the assays of SiO₂ and MgO were at their lowest values in tailings, as well as, the assays of CaO, Al₂O₃ and Fe₂O₃ were at their highest ones at the same value of depression dosage (1.0 kg/t). This assures that the optimum conditions of these experiments may be obtained at a depression dosage of 1.0 kg/t.

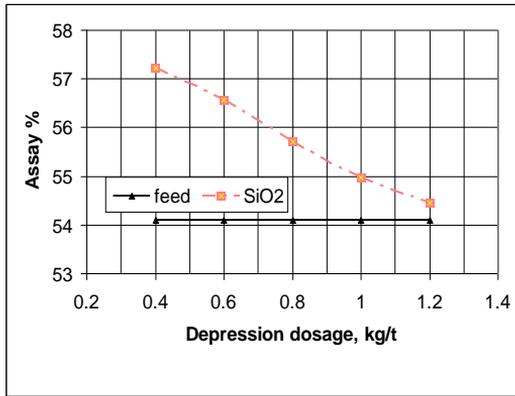


Fig. 2a: SiO₂ assay with depression dosage

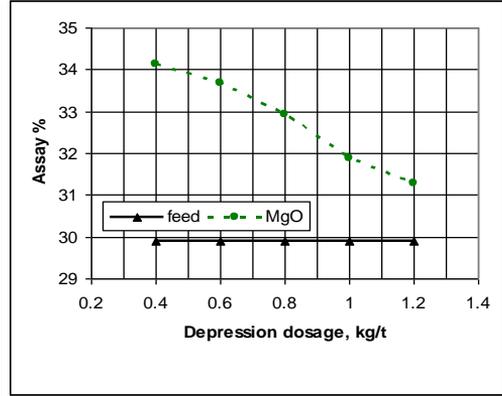


Fig. 2b: MgO assay with depression dosage

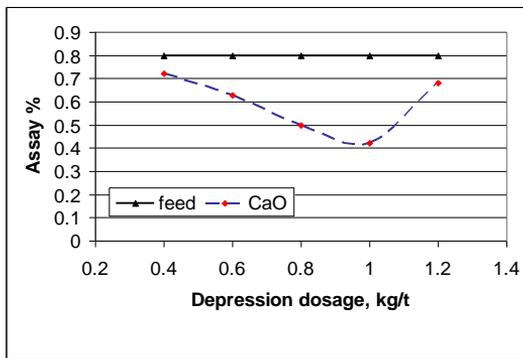


Fig. 2c: CaO assay with depression dosage

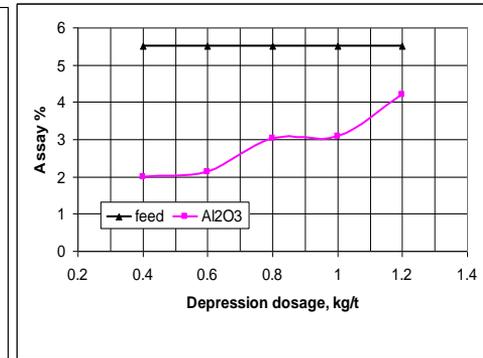


Fig. 2d: Al₂O₃ assay with depression dosage

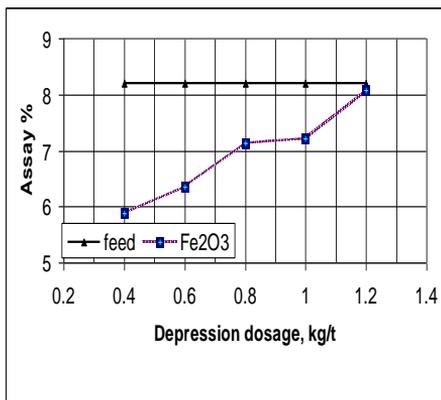


Fig. 2e: Fe₂O₃ assay with depression dosage

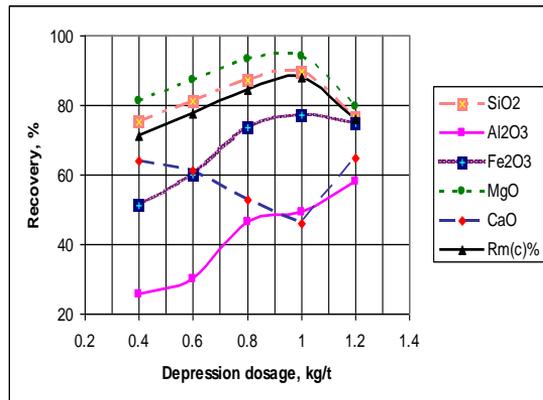


Fig. 2f: Mass and component recoveries with depression dosage

Fig. 2: Effect of depression dosage on the mass recovery, as well as, on the assays and component recoveries of different constituents in concentrate

Effect of Collector Dosage

Table 5a included the chemical analysis of constituents in flotation products of experiments carried out at different collector dosages of oleic acid (in an equal mixture with kerosene). The table showed that the percentages of SiO₂ and MgO (the major constituents of talc) decreased in the concentrate product with increasing the collector dosage from 0.6 to 1.4 kg/t. Conversely, the percentages of CaO, Al₂O₃ and Fe₂O₃ (the main wastes in talc) increased. These results are illustrated also in **Figures 3a** through **3e**. From **Figures 3a** and **3b**, it can be shown that, SiO₂ decreased (from 57.46% to 54.15%) at increasing of the collector dosage from 0.6 to 1.4 kg/t, as well as MgO decreased (from 34.22% to 30.69%) at the same collector dosage. This may be attributed to the powerful of oleic acid (anionic collector) to produce a water-repulsion and monomolecular layer on particle surfaces (starvation level), thereby imparting hydrophobicity to the particles [29].

Figures 3c through **3e** showed that as the collector dosage increased from 0.6 to 1.4 kg/t, CaO increased (from 0.30% to 0.54%), Al₂O₃ increased (from 2.09% to 3.95%), and Fe₂O₃ increased (from 5.90% to 7.97%).

The effect of collector dosages on the mass recovery of concentrate is shown in **Table 5b** and **Fig. 3f**. From this figure, it can be revealed that, the mass recovery increased from 72.1% to 92.4%, as the collector dosage increased from 0.6 to 1.2 kg/t. More increase of the collector dosage above 1.2 kg/t decreased the mass recovery.

Table 5a: The chemical analysis of constituents in flotation products of experiments carried out at different collector dosages.

Exp. No.	Collector dosage, kg/t	Concentrate					Tailings				
		Assay (A _c), %					Assay (A _t), %				
		SiO ₂	MgO	CaO	Al ₂ O ₃	Fe ₂ O ₃	SiO ₂	MgO	CaO	Al ₂ O ₃	Fe ₂ O ₃
1	0.6	57.46	34.22	0.30	2.09	5.90	45.42	18.74	2.09	14.31	14.14
2	0.8	55.78	32.83	0.36	2.75	6.78	47.16	17.80	2.62	16.85	14.06
3	1.0	54.97	31.89	0.42	3.08	7.21	41.36	15.31	3.59	23.25	15.46
4	1.2	54.94	31.76	0.42	3.11	7.24	41.35	7.29	5.42	24.20	19.87
5	1.4	54.15	30.69	0.54	3.95	7.97	49.13	24.98	2.14	13.52	8.05

Table 5b: The mass recoveries of flotation products and the component recoveries of constituents of experiments carried out at different collector dosages.

Collector dosage, kg/t	Concentrate						Tailings					
	Component recovery R _c (c), %					R _m (c), %	Component recovery R _c (t), %					R _m (t), %
	SiO ₂	MgO	CaO	Al ₂ O ₃	Fe ₂ O ₃		SiO ₂	MgO	CaO	Al ₂ O ₃	Fe ₂ O ₃	
0.6	76.6	82.5	27.0	27.4	51.9	72.1	23.4	17.5	73.0	72.6	48.1	27.9
0.8	83.0	88.4	36.2	40.3	66.6	80.5	17.0	11.6	63.8	59.7	33.4	19.5
1.0	89.4	93.9	46.2	49.3	77.4	88.0	10.6	6.1	53.8	50.7	22.6	12.0
1.2	93.8	98.2	48.5	52.3	81.6	92.4	6.2	1.8	51.5	47.7	18.4	7.6
1.4	83.9	86.0	56.6	60.2	81.5	83.8	16.1	14.0	43.4	39.8	18.5	16.2

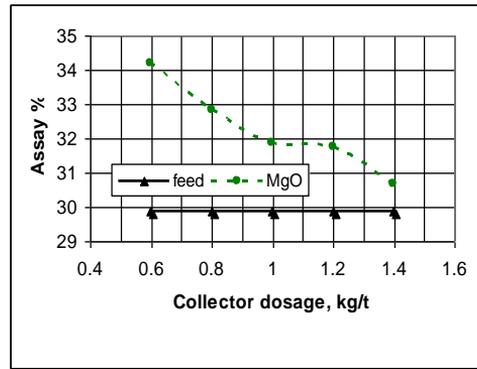
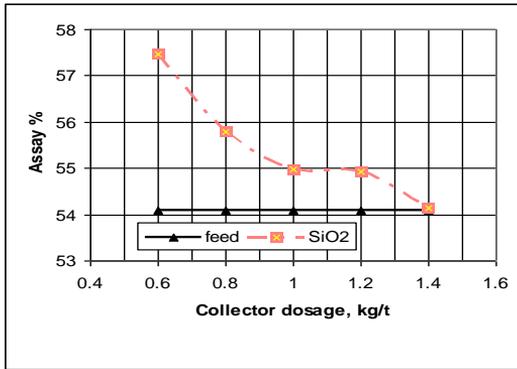


Fig. 3a: SiO₂ assay with collector dosage. **Fig. 3b:** MgO assay with collector dosage

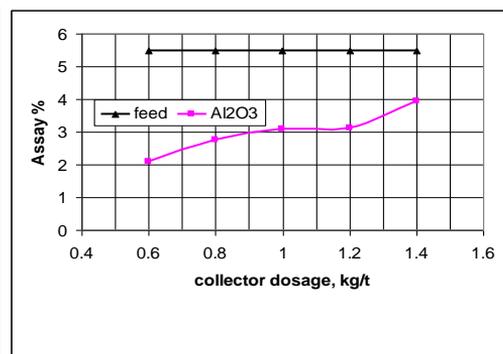
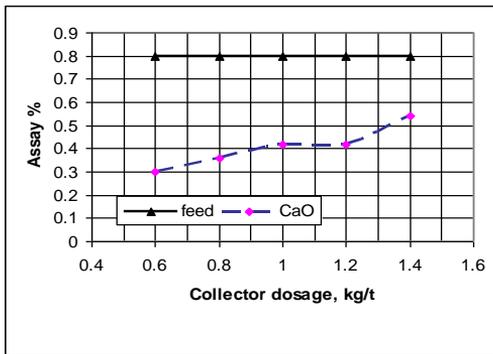


Fig. 3c: CaO assay with collector dosage. **Fig. 3d:** Al₂O₃ assay with collector dosage.

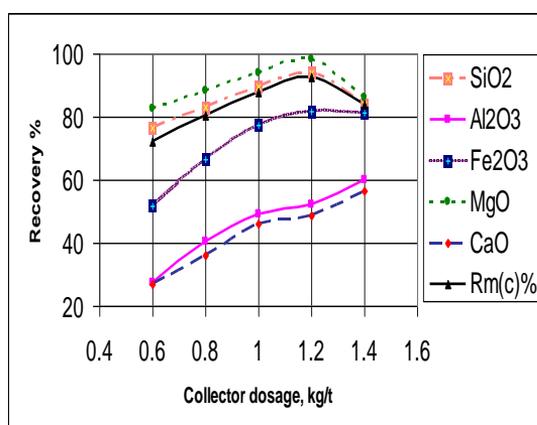
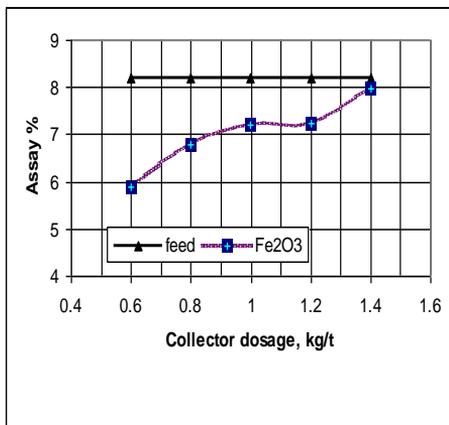


Fig. 3e: Fe₂O₃ assay with collector dosage.

Fig. 3f: Mass and component recoveries with collector dosage.

Fig. 3: Effect of collector dosage on the mass recovery, as well as, on the assays and component recoveries of different constituents in concentrate.

The increase of the flotation recovery with the collector dosage may be explained due to the more rapid reaction at higher concentration or due to more rapid approach of the exchanger adsorption equilibrium at higher concentration. This trend can be explained also due to the displacement of the exchange-adsorption equilibrium more and more toward complete collector adsorption as concentration of the collector is increased [30]. The effect of collector dosages on the component recoveries of constituents in concentrate are illustrated also in **Table 5b** and **Fig. 3f**. From this figure, it can be shown that, the component recovery of SiO_2 increased (from 76.6% to 93.8%), as well as, the component recovery of MgO increased (from 82.5% to 98.2%) as the collector dosage increased from 0.6 to 1.2 kg/t. This may be interpreted due to that, at lower concentration of collector dosage, only the surface of faces (hydrophobic) can be float. When the collector increased, the surface of faces and edges (hydrophilic) become more hydrophobic [30]. In addition, at a collector concentration of 1.2 kg/t, the collector adsorbs on the negatively charged particle edges, thereby covering up the hydrophilic sites on the particle surface [2]. An excessive addition of collector dosages (above 1.2 kg/t) lead to an inverse effect and hence decreased the component recoveries of SiO_2 and MgO . Possibly, due to the development of collector multi-layers on the particles, reducing the proportion of hydrocarbon radicals oriented into the bulk solution. The hydrophobicity of the particles is reduced and tends to float other minerals, reducing selectivity and floatability [29].

On the other hand, the component recoveries of CaO , Al_2O_3 and Fe_2O_3 increased with increasing the collector dosages.

From **Table 5a**, it can be seen that the assays of SiO_2 and MgO were at their lowest values in tailings, as well as, the assays of CaO , Al_2O_3 and Fe_2O_3 were at their highest ones at the same value of collector dosage (1.2 kg/t). This assures that the optimum conditions of these experiments are obtained at a collector dosage of 1.2 kg/t.

Effect of Pulp Density

Table 6a contains the chemical analysis of constituents in flotation products of experiments executed at different pulp densities. The table showed that the percentages of SiO_2 and MgO (the major constituents of talc) decreased in the concentrate product with increasing the pulp density from 100 to 300 g/L. Conversely, the percentages of CaO , Al_2O_3 and Fe_2O_3 (the main wastes in talc) increased. These results are illustrated also in **Figures 4a** through **4e**.

From **Figures 4a** and **4b**, it can be seen that, as the pulp density increased from 100 to 300 g/L, SiO_2 decreased (from 57.60% to 54.23%), as well as, MgO decreased (from 34.30% to 30.88%).

Figures 4c through **4e** revealed that CaO increased (from 0.29% to 0.68%), Al_2O_3 increased (from 2.02% to 4.86%), and Fe_2O_3 increased (from 5.59% to 8.04%) as the pulp density increased from 100 to 300 g/L.

The effect of pulp density on the mass recovery of concentrate is shown in **Table 6b** and **Fig. 4f**. From this figure, it can be seen that, the mass recovery increased from 70.0% to 92.4%, as the value of pulp density increased from 100 to 200 g/L. More increase of the pulp density, above 200 g/L, decreased the mass recovery.

The effect of pulp density on the component recoveries of constituents in concentrate is illustrated also in **Table 6b** and **Fig. 4f**. From this figure, it can be seen

that the component recovery of SiO_2 increased from 74.5% to 93.8%, as well as, the component recovery of MgO increased from 80.3% to 98.2% as the pulp density increased from 100 to 200 g/L. Any increase of pulp density above 200 g/L decreased the component recoveries of these constituents. Feng and Aldrich [23] stated that an 8% solids concentration was optimal with respect to the lowest recovery of talc. Higher pulp concentrations had a detrimental effect on flotation. Wills [29] has reported that the denser the pulp, the less cell volume is required in the commercial plant and fewer reagents are required, since the effectiveness of most reagents is a function of their concentration in solution. The optimum pulp density is of great important, as in general the more dilute the pulp, the cleaner the separation.

From **Figure 4f**, it can be seen that the component recoveries of CaO , Al_2O_3 and Fe_2O_3 increased with increasing pulp densities.

From **Table 6a**, it can be seen that the assays of SiO_2 and MgO were at their lowest values in tailings, as well as, the assays of CaO , Al_2O_3 and Fe_2O_3 were at their highest ones at the same value of pulp density (200 g/L). The whiteness improved from 75.4% to 83.7% and the loss on ignition decreased from 6.64% to 5.21% in the final product. This assures that the optimum condition of these experiments is obtained at a pulp density of 200 g/L.

Table 6a: The chemical analysis of flotation products of different experiments carried out at different pulp densities.

Exp. No.	Pulp density, g/L	Concentrate					Tailings				
		Assay (A_c), %					Assay (A_t), %				
		SiO_2	MgO	CaO	Al_2O_3	Fe_2O_3	SiO_2	MgO	CaO	Al_2O_3	Fe_2O_3
1	100	57.60	34.30	0.29	2.02	5.59	45.93	19.63	1.99	13.62	14.29
2	150	56.24	33.07	0.34	2.63	6.49	43.43	14.09	3.09	19.82	16.73
3	200	54.94	31.76	0.42	3.11	7.24	41.35	7.29	5.42	24.20	19.87
4	250	54.75	31.65	0.52	3.69	7.83	50.56	20.36	2.33	15.37	10.22
5	300	54.23	30.88	0.68	4.86	8.04	53.62	26.26	1.25	7.88	8.79

Table 6b: The mass recoveries of flotation products and the component recoveries of constituents of experiments executed at different pulp densities.

Pulp density, g/L	Concentrate						Tailings					
	Component recovery $R_c(c)$, %					$R_m(c)$, %	Component recovery $R_c(t)$, %					$R_m(t)$, %
	SiO_2	MgO	CaO	Al_2O_3	Fe_2O_3		SiO_2	MgO	CaO	Al_2O_3	Fe_2O_3	
100	74.5	80.3	25.4	25.7	47.7	70.0	25.5	19.7	74.6	74.3	52.3	30.0
150	86.6	92.1	35.4	39.8	65.9	83.3	13.4	7.8	64.6	60.2	34.1	16.7
200	93.8	98.2	48.5	52.3	81.6	92.4	6.2	1.8	51.5	47.7	18.4	7.6
250	85.5	89.5	54.9	56.7	80.7	84.5	14.5	10.5	45.1	43.3	19.3	15.5
300	78.0	81.4	67.0	69.6	77.3	78.8	22.0	18.6	33.0	30.4	22.7	21.2

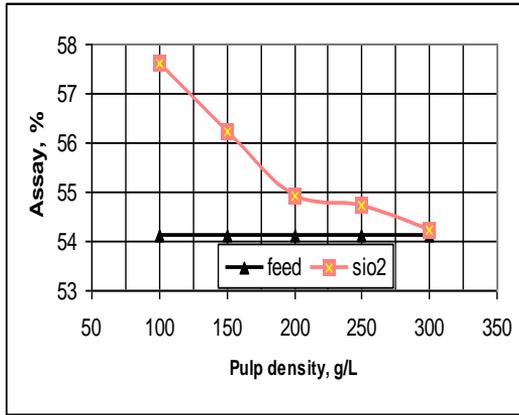


Fig. 4a: SiO₂ assay with pulp density.

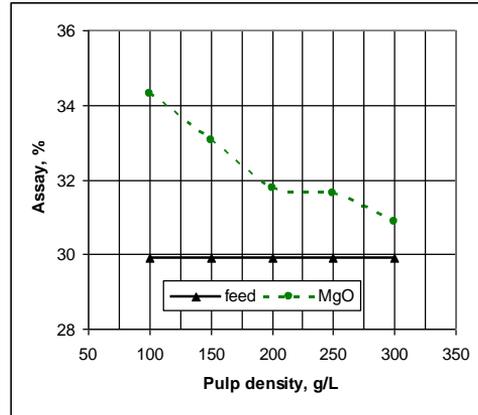


Fig. 4b: MgO assay with pulp density.

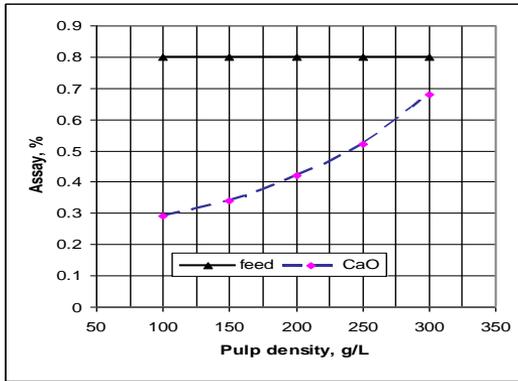


Fig. 4c: CaO assay with pulp density.

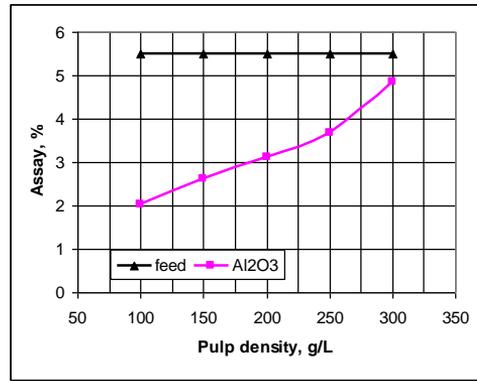


Fig. 4d: Al₂O₃ assay with pulp density.

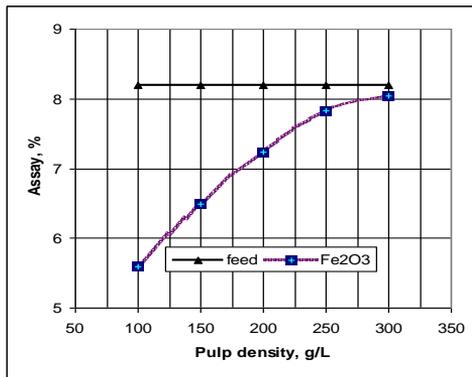


Fig. 4e: Fe₂O₃ assay with pulp density.

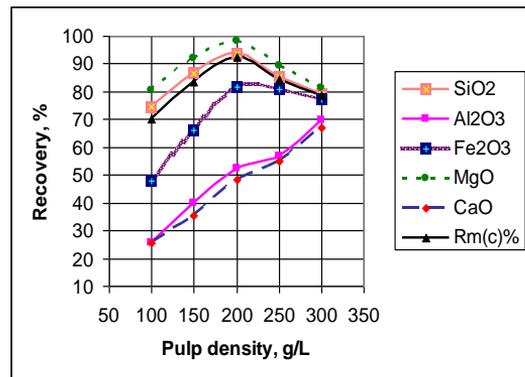


Fig. 4f: Mass and component recoveries with pulp density.

Fig. 4: Effect of pulp density on the mass recovery, as well as, on the assays and component recoveries of different constituents in concentrate.

From **Table 6** and **Fig. 4**, it can be seen that there are another operating conditions, which give better result of the characteristics of talc in concentrate but with lower mass recovery. This conclusion was obtained at a pulp density of 100 g/L. At this condition, the assays of SiO₂ (57.60%) and MgO (34.30%) were at their highest values in concentrate, as well as, the assays of CaO (0.29%), Al₂O₃ (2.02%) and Fe₂O₃ (5.59%) were at their lowest ones. The mass recovery was the lowest one (70%), as well as, the component recovery of talc constituents were also the lowest ones (74.5% and 80.3% respectively).

Leaching of Final Concentrate of Flotation

More improvement of talc quality was obtained by leaching of final concentrate of flotation with a dilute hydrochloric acid having a concentration of 10%, solid-liquid ratio (1:2), at a temperature of 60° C for a period of 30 minutes using a mechanical stirrer. The residues of leaching process were washed with acidulated hot water and then with pure water. After the process being finished, the concentrate was dried, weighed and chemically analyzed. The final results of chemical analysis of talc constituents, mass recovery, whiteness, and loss on ignition in feed, final concentrate of flotation, and leaching product are shown in **Table 7**. The mass recovery of final product was about 85% of initial feed. In this final product, Fe₂O₃ decreased to 3.12%, CaO decreased to 0.38%, and Al₂O₃ decreased to 3.01%. The assay of SiO₂ increased to 58.96%, MgO percent was nearly the same, the whiteness increased to 88.5%, and the loss on ignition decreased to 4.03%. The improvement of whiteness may be attributed to the reduction of iron content in the final product.

Table 7: The final results of chemical analysis of talc constituents, mass recovery, whiteness, and loss on ignition in feed, final concentrate of flotation, and leaching product.

		Feed	Final concentrate of flotation	Leaching Product
Assay, %	SiO ₂	54.10	54.94	58.96
	MgO	29.90	31.76	31.73
	CaO	0.80	0.42	0.38
	Al ₂ O ₃	5.50	3.11	3.01
	Fe ₂ O ₃	8.20	7.24	3.12
Mass recovery, %		100	92.40	85.00
Whiteness, %		75.4	83.7	88.5
Loss on ignition, %		6.64	5.21	4.03

CONCLUSIONS

From the results of this investigation, the following conclusions can be drawn:

1. The floatability of talc increased as the pH increased up to a value of 11. Above this value, the floatability of talc decreased.
2. The CaO and Al₂O₃ can be partially sequestered using sodium hexametaphosphate as a selective depressant at a certain limit. The optimum value was found at 1.0 kg/t.

3. The floatability of talc depends upon its degree of hydrophobicity. This hydrophobicity increased with increasing the collector dosage up to 1.2 kg/t.
4. The recovery of talc increased as the pulp density increased up to 200 g/L, above which the recovery of talc decreased.
5. At the optimum operating variables of flotation process, SiO₂ assay increased (from 54.10% to 54.94%), MgO assay increased (from 29.90% to 31.76%), CaO decreased (from 0.80% to 0.42%), Al₂O₃ decreased (from 5.50% to 3.11%), Fe₂O₃ decreased (from 8.20% to 7.24%), the whiteness increased from 75.4% to 83.7%, and the loss on ignition decreased from 6.64% to 5.21%. The mass recovery of final concentrate was 92.4%. The component recoveries of SiO₂ and MgO (the major constituents of talc) in the final concentrate were 93.8% and 98.2%, respectively.
6. The final concentrate of flotation was leached with a dilute hydrochloric acid (10%). In the final product, SiO₂ assay increased to 58.96%, MgO assay was nearly the same, CaO decreased to 0.38%, Al₂O₃ decreased to 3.01%, and Fe₂O₃ decreased to 3.12%. The mass recovery was about 85% of the initial feed, whiteness was improved to 88.5%, and the loss on ignition decreased to 4.03%.
7. The final product is suitable for many industrial uses such as low-loss electronics (a type of ceramics), paints, rubber, plastics, roofing, textiles, refractories, insecticides and coating of welding rods.

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تحسين جودة خام التلك المصرى للأغراض الصناعية باستخدام التعويم بالهواء والإذابة بالأحماض

التلك معدن ذو أهمية اقتصادية عالية لاستخداماته العديدة وذلك لخصائصه المرغوبة مثل انه من المعادن قليلة الصلادة، خامل كيميائياً، وفي نفس الوقت له قابلية امتصاص ضعيفة للماء. المعادن المصاحبة للتلک تحدد نوعه وتركيبه وكذلك جودته للأغراض الصناعية المختلفة.

تعويم التلك يمكن تحسينه باستخدام الصوديوم هيكساميتافوسفات كمنشط للمعادن الغير مرغوبة والمصاحبة للتلک، بالإضافة إلى استخدام حمض الاوليک (كخليط مع الكيروسين) كمجمع سالب الشحنة. النتائج الموجودة في هذا البحث تعطى معلومات مفيدة وهامة في كيفية تحسين جودة التلك لامكانية استخدامه في التطبيقات الصناعية المختلفة ومن ثم تم استخدام طريقة التعويم بالهواء لأنها من افضل الطرق بالنسبة لهذه النوعية من الخامات.

الظروف المثلى تم الحصول عليها عند وسط قاعدى ($pH = 11$)، جرعة المثبط = 1.0 kg/t ، جرعة المجمع = 1.2 kg/t وكثافة المعلق = 200 g/L . وعند هذه الظروف تم الحصول على SiO_2 بنسبة جودة % 54.94، MgO بنسبة جودة % 31.76، CaO بنسبة جودة % 0.42، Al_2O_3 بنسبة جودة % 3.11، Fe_2O_3 بنسبة جودة % 7.24، درجة البياض تحسنت من 75.4 % الى 83.7 % وقل فاقد الاحتراق من 6.64% الى 5.21% وقد تم الحصول على نسبة % 92.4 استرجاع للكتلة. وعند هذه الظروف المثلى كان استرجاع المكونات الرئيسية للتلک كالتى: SiO_2 بنسبة استرجاع 93.8% و MgO بنسبة استرجاع 98.2%.

امكن كذلك تحسين جودة التلك عن طريق اذابة الناتج النهائى من التعويم فى حمض الهيدروليك المخفف عند تركيز % 10. وباستخدام هذه الطريقة تم الحصول على Fe_2O_3 بنسبة جودة % 3.12، CaO بنسبة جودة % 0.38، Al_2O_3 بنسبة جودة % 3.01، SiO_2 بنسبة جودة % 58.96، MgO بنسبة جودة مماثلة للسابقة، درجة البياض زادت الى 88.5 %، وقل فاقد الاحتراق الى % 4.03 وقد تم الحصول على 85 % استرجاع للكتلة بالنسبة لكتلة الخام المغذى لخلية التعويم. ويمكن استخدام هذا المنتج فى صناعة الدهانات، بعض أنواع السيراميك، المطاط، البلاستيك، التغطيات، المنسوجات، الحراريات، طلاء قضبان اللحام، والمبيدات الحشرية.