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Optimization of flotation parameters for talc carbonates of Mingora emerald mine (Swat), Khyber Pakhtunkhwa, Pakistan

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Abstract

The aim of the research work is to optimize parameters affecting efficiency of flotation process for obtaining high quality talc from talc carbonates of Mingora emerald mines, Swat, KP. Different parameters of flotation process like, pH, pulp density, depressant dosage, collector dosage, were optimized for maximum grade and recovery of talc. The collector used was a mixture of equal amounts of oleic acid and kerosene oil, Depressant used was sodium hexa metaphosphate and frother used was propyl glycol. Dosage of the collector was varied from 0.6 to 1.4 kg/ton, Depressant dosage varied from 0.4 to 1.2 kg/ton and pH of the pulp was varied as 4, 7, 9, 11 and 12. Optimum grade and recovery of talc was achieved at pH 11, depressant dosage 1.0 kg/ton, collector dosage as 1.2 kg/ton, pulp density 200 gram/liter (g/l), at constant impeller speed of 1100 rpm and frother dosage of 0.1 kg/ton.

Keywords: Talc; Flotation; Recovery; Grade; Depressant; Emerald mine.

1. Introduction

The Swat emerald deposits are situated in the close proximity of Mingora town in district Swat. These deposits are at a distance of about 130 miles to the northeast of Peshawar and 200 miles northwest of Islamabad. Swat emerald mine is approachable by a good metaled road. The Mingora emerald deposits are commonly known as the Swat emerald mines (Muhammad, 2011). The host rock of emerald crystal in the deposit is talc carbonate schist. After excavation for emerald, the talc bearing host rock is thrown away as a refuse because of its low grade. Being a useful and demanded commodity the authors felt the need to take research on processing of this by- product (raw talc) of emerald mines to make it industrial grade product through flotation process so as to save the foreign exchange being spent on import of talc and talc products.

Talc is one of the naturally floatable mineral. It is mostly associated with gangue materials which determine its application as industrial mineral. Both chemical composition and physical properties like whiteness, bulk density, grain size etc. of talc are important. Talc is hydrous magnesium silicate with chemical formula $Mg_3\ Si_4\ O_{10}\ (OH)_2$. When pure, it contains 63.36% silica, 31.89% magnesia and 4.75 % water of crystallization (Siddiqui, 1993). The major elemental impurities in talc understudy were CaO, Al_2O_3, and Fe_2O_3. Various processing techniques are in use for removal of the associated gangue minerals with talc like selective mining, hand/optical sorting, differential grinding and sizing, magnetic separation, gravity separation, pneumatic separation, flotation and leaching. Processing studies have been conducted in different parts of the world for evaluation and up gradation of talc ores with varying mineralogical composition and with wide range of beneficiation techniques being adopted.

As talc is naturally floatable, therefore, worldwide most of the researchers have used flotation and leaching methods and combination of both methods for talc ore having carbonate impurities at different leaching and flotation parameters (Ge Li, 2013; Hojamberdiev et al., 2010; Ahmed et al., 2007; Kursun and Ulusoy, 2006; Akdemir, 2005; Derco and Nemeth, 2002) . So in the light of literature review flotation process was used in present research work for talc separation from the associated impurities mostly carbonates.

2. Materials and methods

Five (5) rich talc samples in lumps form were selectively collected from different excavated talc carbonate dumps, weighing about 40 Kg as a whole and about 8 Kg of each sample from Mingora emerald mine, District Swat, KP. The five samples were crushed, ground, blended and prepared in the size range of -45µm. Single step bench scale flotation tests were conducted on the blended talc carbonate samples with varying flotation parameters like pH of pulp, pulp density, effect of collector and depressant dosage were studied to obtain optimum grade and recovery of talc.

3. Experimental work

3.1. Results and discussions

Chemical analysis results of feed/ head talc carbonate samples collected from Mingora town in district Swat presented in Table 2.

Table 1. Chemical analysis of head sample.

Contents	%
SiO_2	44.74
MgO	37.22
CaO	0.92
Al_2O_3	1.42
Fe_2O_3	4.50

3.2. Flotation parameters tested

Mass and component recoveries of the flotation test products were calculated using the mass percent and assays of different constituents in the feed, concentrate and tailing by using the following formulas (Wills, 1992):

Mass recovery of the concentrate (Rm (c))
= (Concentrate mass /Feed mass)*100

Mass recovery of tailings (Rm (t))
= (Tailing mass /Feed mass)*100

Component recovery in concentrate (Rc (c))
= (Component mass in concentrate/ Component mass in feed)*100

Component recovery in tailings (Rc (t))
= (Component mass in tailing/ Component mass in feed)*100

3.2.1. Optimization of the pH value in talc flotation test

Five flotation tests were carried out at different pH values, and at constant dosage of collector (1.0 kg/t), depressant (0.8 kg/t), and pulp density (200 g/l). The Chemical analysis results of flotation tests product are presented in Table 2a, which revealed that assay value of SiO_2 and MgO decreases with increase in pH value from 4 to 12, and percentage of elemental impurities increases with increasing pH value. The component recovery and mass recovery is given in Table 2b, which shows that, when the value of pH increases from 4 to 11, the component recovery of SiO_2 and MgO increased, the component recovery of elemental impurities increases and the mass recovery also increases. While the value of pH increased from 11and 12, the component recovery of SiO_2, MgO decreasesd, the component recovery of elemental impurities increases and mass recovery decreases. The optimum grade and recovery of talc are obtained at pH value 11 which assured that 11 is the optimum pH value.

The component and mass recoveries at different pH values are presented in Figure 1.

3.2.2. Optimization of the depressant dosage effect in talc flotation test

Chemical analysis of products that obtained through five flotation tests conducted at constant dosage of collector (1.0 kg/t), pulp density (200 g/l), Ph value (11) and at different dosage of depressant (hexa metaphosphate) are presented in Table 3a. The table shows that the assay value of SiO_2 and MgO decreased with increases the dosage of depressant from 0.4 to 1.2 kg/t, and the percentages of elemental impurities increased with increasing in dosage of depressant. The component and mass recoveries are given in Table 3b, which shows that the component recovery of SiO_2, MgO and elemental impurities increases, and mass recovery also increases, when the dosage of depressant increased from 0.4 to 1kg/t. The component recovery of SiO_2 and MgO and mass recovery of concentrate started decreasing when the dosage of depressant increased from 1.0 kg/t, which increased the component recovery of elemental impurities. This means that 1.0 kg/t is the optimum dosage of depression for obtaining the optimum talc recovery and grade.

Table 2a. Assay values of flotation tests products at different pH values.

Exp. No.	pH	Concentrate Assay (Ac) &					Tailings Assay (At), %				
		SiO_2	MgO	CaO	Al_2O_3	Fe_2O_3	SiO_2	MgO	CaO	Al_2O_3	Fe_2O_3
1	4	56.31	36.17	0.39	1.04	2.98	47.63	30.24	1.35	5.57	5.88
2	7	55.74	35.91	0.47	1.17	3.13	46.54	26.91	1.44	6.24	6.89
3	9	54.67	35.44	0.51	1.23	3.29	47.28	27.54	1.62	6.93	6.08
4	11	53.59	34.82	0.58	1.31	3.57	41.91	20.48	1.94	9.74	7.63
5	12	52.91	34.11	0.69	1.39	4.28	50.34	25.73	1.19	5.89	4.94

Table 2b. Component and mass recoveries of flotation tests products at different pH values.

pH	Concentrate Component recovery Rc(c), %					Rm(c), %	Tailings Component recovery Rc(t), %					Rm(t), %
	SiO_2	MgO	CaO	Al_2O_3	Fe_2O_3		SiO_2	MgO	CaO	Al_2O_3	Fe_2O_3	
4	65.70	50.73	22.13	38.23	34.57	52.2	34.30	49.27	77.87	61.77	65.43	47.8
7	76.99	59.62	31.57	50.92	42.99	61.8	23.01	40.38	68.43	49.08	57.01	38.2
9	79.79	62.18	36.20	56.56	47.74	65.3	20.21	37.82	63.80	43.44	52.26	34.7
11	98.22	76.71	51.70	75.65	65.05	82.0	1.78	23.29	48.30	24.35	34.95	18.0
12	87.04	67.45	55.20	72.05	70.00	73.6	12.96	32.55	44.80	27.95	30.00	26.4

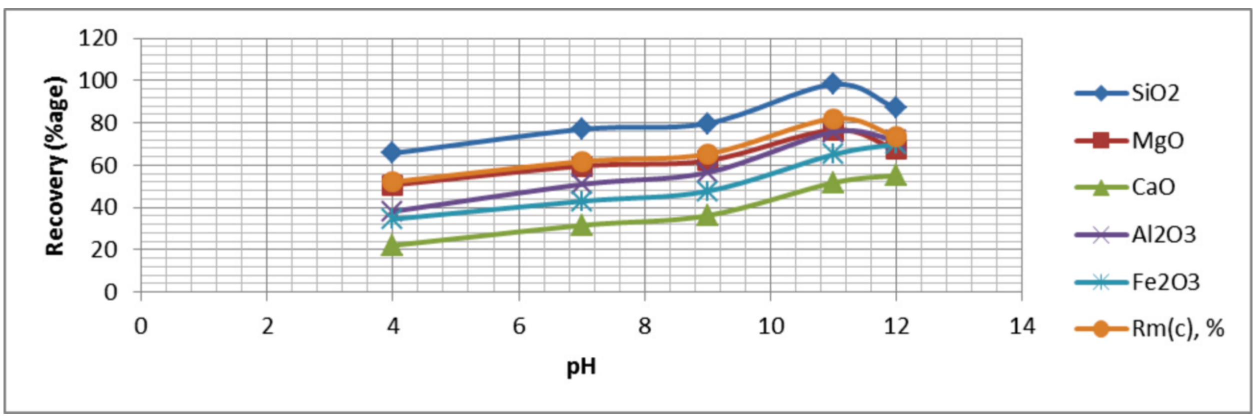

Fig. 1. Component and mass recoveries at different pH values.

Table 3a. Assay values of flotation tests products at different depressant dosage.

Exp. No.	Depressant dosage, kg/t	Concentrate Assay (Ac) &					Tailings Assay (At), %				
		SiO_2	MgO	CaO	Al_2O_3	Fe_2O_3	SiO_2	MgO	CaO	Al_2O_3	Fe_2O_3
1	0.4	57.14	39.86	0.86	1.08	2.89	46.74	21.79	1.16	13.46	12.24
2	0.6	56.21	39.11	0.77	1.19	2.97	42.38	17.92	1.51	15.69	12.87
3	0.8	54.93	38.61	0.69	1.29	3.29	41.96	14.18	2.48	16.84	11.96
4	1.0	54.23	37.83	0.54	1.33	3.36	37.00	15.76	3.34	19.98	13.02
5	1.2	53.96	37.14	0.76	1.38	4.43	50.68	26.48	1.14	6.47	7.44

Table 3b. Component and mass recoveries of flotation tests products at different depressant dosage.

Depressant dosage, kg/t	Concentrate						Tailings					
	Component recovery Rc(c), %					Rm(c), %	Component recovery Rc(t), %					Rm(t), %
	SiO_2	MgO	CaO	Al_2O_3	Fe_2O_3		SiO_2	MgO	CaO	Al_2O_3	Fe_2O_3	
0.4	78.16	65.54	57.21	46.55	39.30	61.2	21.84	34.46	42.79	53.45	60.70	38.8
0.6	83.49	69.82	55.62	55.69	43.86	66.45	16.51	30.18	44.38	44.31	56.14	33.55
0.8	86.36	72.97	52.76	63.90	51.43	70.34	13.64	27.03	47.25	36.10	48.57	29.66
1.0	97.65	81.88	47.29	75.45	60.15	80.56	2.35	18.12	52.71	24.55	39.85	19.44
1.2	90.18	74.61	61.77	72.66	73.61	74.77	9.82	25.39	38.23	27.34	26.39	25.23

The component and mass recoveries at different depressant dosage given in Figure 2.

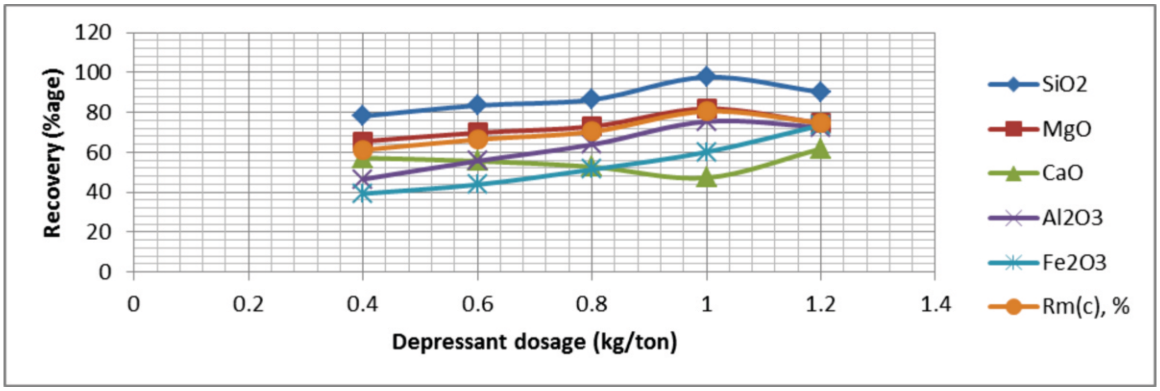

Fig. 2. Component and mass recoveries at different depressant dosage.

Table 4a. Assay values of flotation tests products at different collector dosage.

Exp. No.	Collector dosage, kg/t	Concentrate					Tailings				
		Assay (Ac) &					Assay (At), %				
		SiO_2	MgO	CaO	Al_2O_3	Fe_2O_3	SiO_2	MgO	CaO	Al_2O_3	Fe_2O_3
1	0.6	56.08	39.47	0.36	1.19	2.88	41.38	20.43	2.27	10.17	11.64
2	0.8	54.79	38.89	0.44	1.25	3.17	44.66	19.37	2.66	13.92	10.23
3	1.0	53.87	38.24	0.55	1.31	3.24	40.58	17.06	3.76	21.63	12.37
4	1.2	53.64	37.63	0.57	1.36	3.91	39.86	10.11	5.77	22.00	1591
5	1.4	52.91	36.86	0.62	1.40	4.19	46.28	26.74	2.41	10.24	7.73

Table 4b. Component and mass recoveries of flotation tests products at different collector dosage.

Collector dosage, kg/t	Concentrate						Tailings					
	Component recovery Rc(c), %					Rm(c), %	Component recovery Rc(t), %					Rm(t), %
	SiO_2	MgO	CaO	Al_2O_3	Fe_2O_3		SiO_2	MgO	CaO	Al_2O_3	Fe_2O_3	
0.6	83.29	70.47	26.00	55.69	42.53	66.45	16.71	29.53	74.00	44.31	57.47	33.55
0.8	83.69	71.41	32.68	60.16	48.14	68.34	16.31	28.59	67.32	39.84	51.86	31.66
1.0	91.11	77.74	45.24	69.81	54.48	75.67	8.89	22.26	54.76	30.19	45.52	24.33
1.2	98.58	83.13	50.94	78.75	71.44	82.22	1.42	16.87	49.06	21.25	28.56	17.78
1.4	92.63	77.57	52.79	77.23	72.93	78.33	7.37	22.43	47.21	22.77	27.07	21.67

The component and mass recoveries at different collector dosage given in Figure 3.

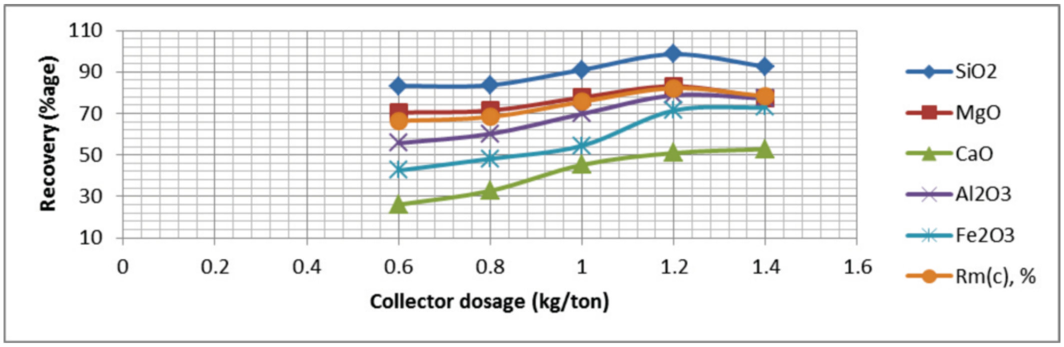

Fig. 3. Component and mass recoveries at different collector dosage.

Table 5a. Assay values of flotation tests products at different pulp densities.

Exp. No.	Pulp density, g/L	Concentrate					Tailings				
		Assay (Ac) &					Assay (At), %				
		SiO_2	MgO	CaO	Al_2O_3	Fe_2O_3	SiO_2	MgO	CaO	Al_2O_3	Fe_2O_3
1	100	56.43	35.62	0.33	0.96	2.90	42.36	24.31	2.37	11.35	12.26
2	150	55.71	36.64	0.38	1.04	2.94	41.44	20.54	3.14	15.84	13.86
3	200	54.86	36.95	0.48	1.13	3.04	38.67	14.66	5.66	22.63	15.47
4	250	54.23	37.34	0.59	1.27	3.89	49.35	24.74	2.16	12.93	7.11
5	300	53.07	30.24	0.75	1.39	4.19	53.71	26.94	1.73	7.04	5.24

Table 5b. Component and mass recoveries of flotation tests products at different pulp density.

Pulp density, g/L	Concentrate						Tailings					
	Component recovery Rc(c), %					Rm(c), %	Component recovery Rc(t), %					Rm(t), %
	SiO_2	MgO	CaO	Al_2O_3	Fe_2O_3		SiO_2	MgO	CaO	Al_2O_3	Fe_2O_3	
100	82.27	62.43	23.40	44.10	42.04	65.23	17.73	37.57	76.60	55.90	57.96	34.77
150	84.54	66.83	28.04	49.72	44.35	67.89	15.46	33.17	71.96	50.28	55.65	32.11
200	90.20	73.03	38.38	58.54	49.69	73.56	9.80	26.97	61.62	41.46	50.31	26.44
250	98.58	81.59	52.16	72.74	70.31	81.33	1.42	18.41	47.84	27.26	29.69	18.67
300	91.57	62.72	62.93	75.57	71.88	77.2	8.43	37.28	37.07	24.43	28.12	22.8

The component and mass recoveries at different pulp densities given in Figure 4.

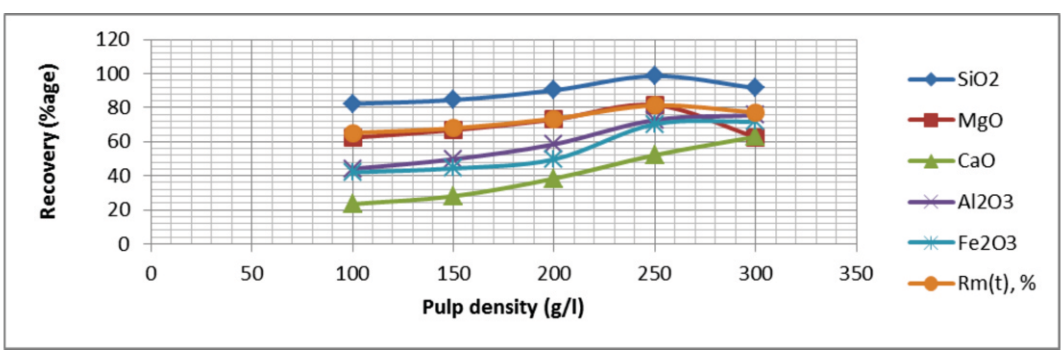

Fig. 4. Component and mass recoveries at different pulp densities.

3.2.3. Optimization of the collector dosage effect in talc flotation test

Five flotation tests were conducted for optimization of collector dosage at different dosage of the mixture of oleic acid and kerosene oil (mixed in equal proportions) used as collector and at constant dosage of depressant (1.0 kg/t), pulp density (200 g/l) and ph value (11) as given in Table 4a. This table revealed that the assay value of SiO_2 and MgO decreases, while the percentages of elemental impurities increases with increasing the dosage of collector from 0.6 to 1.4 kg/t. The component recoveries of SiO_2, MgO, and elemental impurities increases and mass recoveries also increases as dosage of collector increases from 0.6 to 1.2 kg/t as shown in Table 4b. The component recovery of SiO_2 and MgO and mass recovery of concentrate decreased and component recoveries of elemental impurities increased when the dosage of collector increases from 1.2 kg/t. This means that the optimum grade and recovery of talc is obtained at dosage of collector 1.2 kg/t.

3.2.4. Optimization of the pulp density effect in talc flotation test

Five flotation tests were conducted at different pulp densities and at optimum dosage of collector, depressant and pH value. Chemical analysis of tests products results are given in Table 5a, which shows that the assay value of SiO_2 and MgO decreases, while the percentages of elemental impurities increases as pulp density increased from 100 to 300 g/l. The component recovery of SiO_2, MgO and elemental impurities increases and mass recovery also increases with increases in pulp density from 100 to 200 g/l. The optimum results were obtained at pulp density of 200g/l as shown in Table 5b. This was also confirmed by chemical analysis of tailing products.

4. Conclusion

Talc recovery increases up to pH value of 11 but start decreasing as pH value is increased further from 11. Recovery of talc increases as pulp density increased from 100 g/l to 200g/l. Pulp density above 200 g/l resulted in decrease of recovery. Recovery of talc increases at optimum depressant dosage of 1.0 kg/t by using sodium hexa metaphospahte as depressant, but start decreasing when dosage of depressant increase from 1.0 kg/t. Talc recovery with increase in collector dosage up to 1.2 kg/t, by using oleic acid with kerosene oil as collector. The optimum dosage for collector was found as 1.2 kg/t and above this dosage the recovery of talc decreases.

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