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Research Paper

Recovery of Talc Mineral from the Tailings of Golgohar Iron Processing Plant

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Abstract: In the iron ore mines of Gol-Gohar, talc presents along with magnetite mineral, which goes to waste thickeners after recovery of magnetite. Considering that talc constitutes more than 20% of waste, it can be sold as a by-product with a high added value, if it is recovered and purified. In this study, the extraction of talc from the tailings of the Gol-Gohar complex has been investigated. Sampling was done from the central thickener underflow, which contained 65% of dust factory tailings and 35% of concentrate factory tailings. Based on characteristic studies, the tailings from the central thickener had about 23% talc. Flotation tests were performed using different chemicals, such as pine oil and polypropylene glycol as frothers, oleic acid as collector, Armac C and Armac T, and pH 7 and 11. In the best condition, pH=11, polypropylene glycol as a frother, and not using a collector, a talc concentrate with a purity of more than 95%, a weight recovery of 10.4%, and a talc recovery of 42% was produced. Also, flotation kinetic tests were performed under optimal conditions, and it was shown that most of the first-order kinetic models and the second-order kinetic model excellently match the talc flotation recovery over the time.

Keywords: Recycling, Talc, Tailings, Flotation, Kinetic.

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INTRODUCTION

Talc mineral is present along with iron oxide minerals in the eastern part of pit number one of Golgohar company, and a significant amount of talc mineral is observed in the tailings of the processing plants of the Golgohar Mining and Industrial Complex. In general, talc processing is done using crushing, granulation, flotation, magnetic separation of iron oxides, and removal of soluble minerals by leaching. Because the talc mineral is highly hydrophobic, it floats easily and only by using a frother.

Muhammad et al. investigated the purification and removal of hematite from talc by acid leaching using chlorination techniques [1]. Baba et al. investigated the purification of vermiculite-phillipsite-rich talc by flotation [2]. Bazar et al. did an overview of talc flotation [3]. Luckeneder et al. compared the efficiency of electrostatic separation of talc mineral samples to produce high-grade talc concentrate by flotation [4]. Ye et al. investigated the selective flotation of chalcopyrite from talc by N-methylenephosphonic chitosan (NMPC) as a depressant [5]. Wu et al. studied the flotation of molybdenite from talc using zinc sulfate in a sodium silicate system [6]. Walczyk et al. investigated the physical and chemical properties of alkaline modified talc and its use in catalysis [7]. Xue et al. examined the reduction of talc floatability using sodium silicate and sodium carboxymethyl cellulose (CMC) as depressants [8]. In this article, technical studies have been carried out for the feasibility of extracting talc from the tailings of Golgohar iron ore processing plants using flotation.

METHODS

Sampling was performed on the underflow of the central thickener (accepts the tailings of dust and wet processing plants). Flotation tests were performed on the underflow of the central thickener at pH=7 and 11 using a Denver device, a 2.5 L cell, sodium hydroxide as a pH regulator, and PPG and PO frothers. Also, the effect of oleic acid collector in two different concentrations of 500 and 1000 g/t was investigated. The experiments were designed using a full factorial design with three variables at two levels and three central points. The effects of the frother type, pH, and the collector concentration were evaluated using DX13 software. The complete design of the mentioned experiments is given in Table 1.

Table 1. Design of the flotation tests

Run	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Frother	PPG	PPG	PPG	PPG	PPG	PPG	PPG	PPG	PO	PO	PO	PO	PO	PO	PO	PO
pH	7	7	7	7	11	11	11	11	7	7	7	7	11	11	11	11
Collector conc. (g/t)	0	500	500	1000	0	500	500	1000	0	500	500	1000	0	500	500	1000

The flotation kinetics test was performed under optimal conditions obtained from the experimental design. i.e., pH=11, no collector, and with 200 g/t PPG. Different kinetic models [9], including the classical first order (Equation 1), the modified Kelsal first order (Equation 2), first order models with kinetic constant distribution function such as Klimpel (Equation 3), Imaizumi, Inoue and Loveday (Equation 4), and sinusoidal (Equation 5) as well as the classic second-order kinetic model (Equation 6) were applied to the data to obtain the kinetics constant (K) and the infinite recovery (R_∞).

$$R = R_\infty[1 - \exp(-Kt)] \tag{1}$$

$$R = (R_\infty - \varphi)[1 - \exp(-K_f t)] + \varphi[1 - \exp(-K_s t)] \tag{2}$$

$$R = R_\infty\left\{1 - \frac{1}{Kt}[1 - \exp(-Kt)]\right\} \tag{3}$$

$$R = R_\infty\left\{1 - \left[\frac{1}{1 + \frac{t}{K}}\right]\right\} \tag{4}$$

$$R = R_\infty \left\{1 - \left[\frac{1 + \exp(-2Kt) - 2\exp(Kt)}{(Kt)^2}\right]\right\} \quad (5)$$

$$R = \frac{R_\infty^{\ 2} Kt}{1 + R_\infty Kt} \quad (6)$$

Where:
R_∞ :is the infinite recovery of talc (%),
K : is the kinetic constant (1/min),
t :is the time (min), and R is the flotation recovery (%).
K_f and K_s : are the kinetic constants of fast and slow floating particles,
φ : is the final recovery of slow floating particles.
The talc grade was calculated from Equation 7.

$$G_{talc} = [(G_{MgO} \times 0.603) - (G_{Al_2O_3} \times 0.4766)] \times 5.2 \quad (7)$$

Where:
M and G : are the molar mass (g/mol) and the grade (%), respectively.

FINDINGS AND ARGUMENT

The underflow of the central thickener contains 34.3% SiO_2, 19.2% MgO, 16.7% Fe_2O_3, 6% Al_2O_3, 8.2% CaO, 0.3% TiO_2, and 15.4% LOI. Also, it includes 23% talc, 29% chlorite, 16% calcite, 8% quartz, 7% biotite, 12% opaque, 3% amphibole, and 2% other minerals. Moreover, D_{80} of the sample was 60.8 micron. The results of the 16 designed flotation experiments, including talc content of the concentrate, mass and talc recovery to the concentrate, are presented in Table 2.

Table 2. Results of the flotation tests

Run	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Talc (%)	94.1	88.3	89.0	84.1	95.8	91.6	92.5	90.7	92.5	86.8	86.5	77.1	92.7	91.8	91.9	88.5
Mass recovery (%)	10.9	11.7	11.8	13.1	10.4	10.8	10.8	12.4	10.8	12.0	11.8	13.1	10.3	10.7	11.2	12.8
Talc recovery (%)	43.5	43.8	44.8	46.8	42.5	41.9	42.6	47.7	42.4	44.2	43.5	42.8	40.6	41.9	43.6	48.2

According to the analysis of variance (ANOVA), 200 g/t PPG is better than PO at the same concentration. In addition, the pH change from 7 to 11 in the absence of the collector has no significant effect on the talc grade. Considering the talc grade, the best talc concentrate contains 59.7% SiO_2, 31.3% MgO, 1.2% Fe_2O_3, 0.9% Al_2O_3, 1.3% CaO, and 5.6% LOI. This concentrate corresponds to run 5 with PPG at pH=11 and without collector. Also, the collector concentration, pH, and the type of frother have the most significant effect on the talc grade of the concentrate. The model for predicting the talc content of the concentrate based on the type and the concentration of frother and pH value is given in Equation 8, where A indicates the type of frother (+1: PPG and -1: PO), B indicates pH (+1: pH=11 and -1: pH=7), and C is the concentration of the collector in g/t of the ore. The correlation coefficient of the model is 94%.

$$\text{T.C. }\% = 11.72 - 0.05A - 0.36B + 1.13C - 0.08AC \quad (8)$$

According to Figure 1A, the PPG frother had a relatively better performance than PO and the talc grade increased from 88% to 91% as a result of PPG application. Figure 1B shows the effect of the pH factor on the talc grade. With increasing pH from 7 to 11, the percentage of talc increased from 86% to 92%. Finally, according to Figure 1C, collectorless flotation is better than the tests in which collector was applied to float talc particles. If collector is used, the talc grade decreases from 94% to 85%. Because, in addition to talc

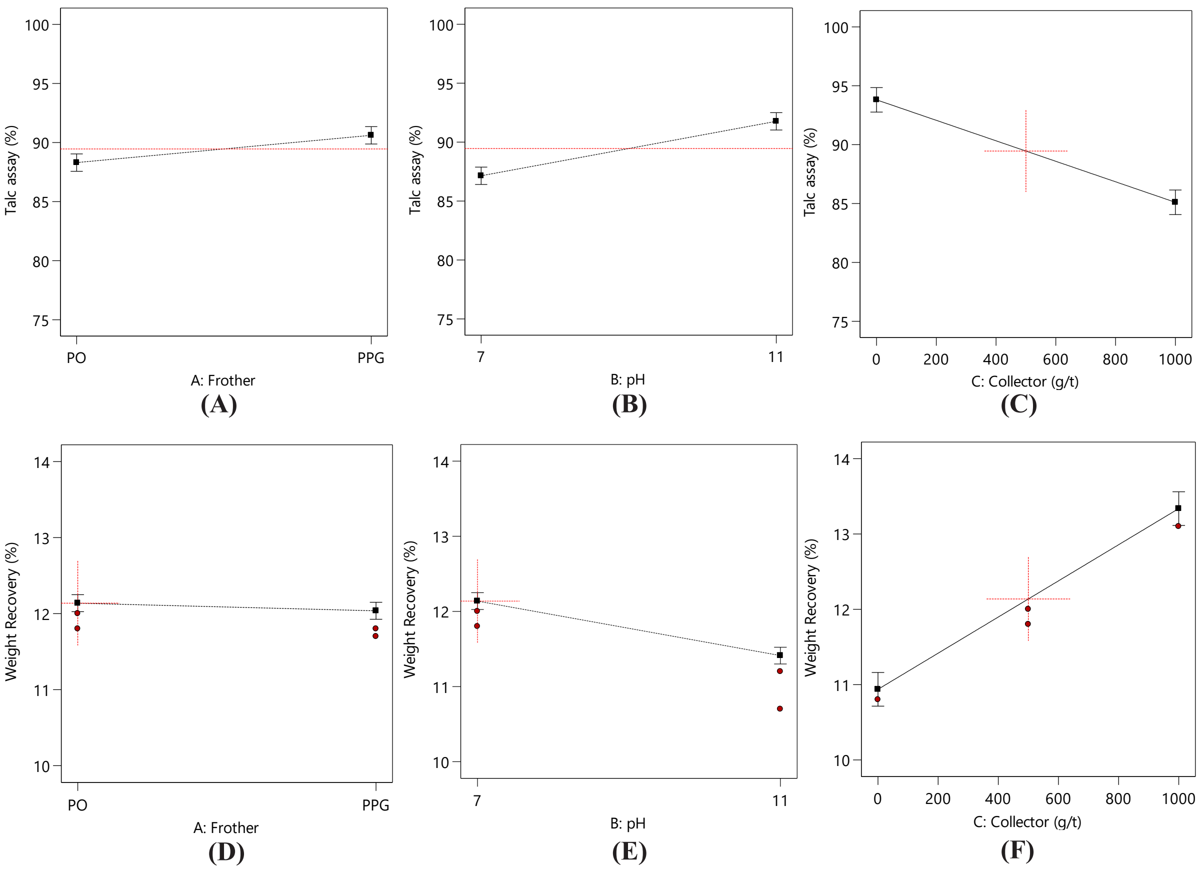

Figure 1. The effects of **A:** frother type, **B:** pH, and **C:** collector concentration on the talc grade. The effects of **D:** frother type, **E:** pH, and **F:** collector concentration on the mass recovery

particles, gangue particles enter the concentrate.

The mass recovery model with the correlation coefficient of 97% is presented in Equation 9.

$$M.R.\% = 89.46 + 1.15A + 2.31B - 4.35C + 2.02BC \quad (9)$$

According to Figure 1D, changing the type of the foaming agent from PPG to PO did not improve the mass recovery. Figure 1E shows that the increase in pH from 7 to 11 decreases the mass recovery from about 12% to 11.5%. The reason for this observation is the more selective flotation of talc in alkaline environment and the reduction of the gangue recovery. Finally, based on Figure 1F, the mass recovery has increased from 11% to 13% by the collector concentration, which is due to the collection of the gangue particles and their recovery to the concentrate along with the talc.

Table 3. Results of the model fitness on the experimental data

Kinetic model	R^2 (%)	R_∞ (%)	K (1/min)
First order	99.14	42.5	0.34
Modified Kelsal	99.10	35.2 and 43.3	0.41 and 0.28
Klimple	99.79	47.0	0.68
Imaizumi, Inoue, Loveday	99.83	50.2	2.68
Sinusoidal	99.87	48.1	0.18
Second order	99.83	50.2	0.007

The results of the kinetic studies are presented in Table 3. As seen, among the investigated models, the first-order sinusoidal model with a correlation coefficient of 99.87%, and then, both the first-order model of Imaizumi, Inoue and Loveday and the second-order classical model have the most compatibility with the data.

CONCLUSIONS

Tailings of the Golgohar iron processing plants were mineralogically and chemically characterized. PPG frother produces a talc concentrate with higher purity compared to the pine oil. In the optimal conditions, a concentrate with 95.8% talc and 42.5% recovery can be obtained. The frother type, pH, and the collector concentration are respectively the most effective variables on the talc grade and the mass recovery. More than 10% wt. of the thickener underflow can be recovered as a talc concentrate. The flotation kinetics of talc follows the 1st-order model of Imaizumi, Inoue and Lovedy, as well as the second-order classical model.

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