Proceedings of ISERME 2025
19-20 September 2025
https://doi.org/10.31705/ISERME.2025.18

Recovery Performance of Sodium Cocoate (NaCo) as a Collector in Froth Flotation

Kumarasinghe[1] RDMM, Sajidh[1] JM, Madhushan[1] AGM, *Rohitha[1] LPS, *Rathnayake[1] NP, *Abeysinghe[1] AMKB, *Premasiri[1] HMR, *Vijitha[1] AVP and *De Silva[2] KBA

[1]Department of Earth Resources Engineering, University of Moratuwa, Sri Lanka

[2]Department of Construction Technology, University of Wayamba, Sri Lanka

*Corresponding author- rohitha@uom.lk

Abstract

Sri Lanka consists of high-grade quartz deposits with a purity level of 99.5%. However, a huge amount of low-grade quartz is abandoned in mine sites without any processing, causing resource underutilization and environmental damage. Froth flotation has proven its efficiency for processing low-grade quartz in previous studies. Conventional collectors with more than 90% of high recovery used in those studies show environmental hazards and low biodegradability. These collectors are usually fatty acids or fatty amines. In this study, the quartz flotation potential of Sodium Cocoate, (a naturally derived fatty acid salt), as a flotation collector was evaluated under controlled conditions: pH 11, temperature of 28-30 °C, particle size range of 90-150 microns, slurry density of 1007 kg/m^3, impeller speed 280 rpm and bubble rate 0.004 m^3/s. The highest average recovery obtained was 28.19±1.28% out of 100 g of the initial quartz sample, which was comparatively low, suggesting that NaCo is a weak collector.

Keywords: Anionic collector, Fatty acids, Surface activation, Quartz flotation,

1 Introduction

Quartz is often considered an important mineral due to its significant properties, including high thermal stability, chemical inertness and piezoelectricity [1]. The presence of these significant properties of quartz has a wide range of applications in glass manufacturing, water filtering, the ceramic industry, as well as in the high-tech industries [1].

Quartz is present in a variety of pegmatites, hydrothermal vein quartz, sedimentary sources and quartzite worldwide. These deposits are widely dispersed, making Si one of the most abundant elements in the Earth's crust [2]. Sri Lanka is also rich with many vein quartz deposits exceeding the purity level of 99.5% SiO_2 [3]. However, most of the time, low-grade quartz is abandoned at mine sites, causing resource underutilization, profit loss, and environmental damage. Given this context, it is important to explore potential methodologies to extract usable quartz from this waste quartz. These potential methods are based on gravity separation, magnetic separation and froth flotation mechanisms [4],[5].

Among those practices, froth flotation stands out as a promising method for the separation of quartz from waste quartz since it was proven by many studies [4]. In most scenarios, they were able to recover more than 90% of the initial samples. Froth flotation is known as "perhaps the greatest single metallurgical improvement of the modern era" [6]. It usually exploits the difference in surface properties of minerals to separate. Studies have employed froth flotation in several methods for quartz separation. They are the HF method with cationic collectors, the mixed collectors method and the anionic collectors method. In this context, it has been indicated that quartz can be separated from its associated minerals, such as feldspar, by using cationic or anionic collectors through froth flotation [1]. Conventionally HF flotation method with an amine ("primary long chain amine surfactants") cationic collector (such as dodecylamine) was used to separate quartz from its gangue in acidic conditions (pH 2-3) [4]. Collectors such as G-TAP and Flotigam V-4343 can also be used in the acidic medium in the presence of HF. Since HF consumption is catastrophic as well as to the environment and corrosive to the infrastructure, treating tailing water has become a necessity [7]. As a solution, mixed collector methods and basic media flotation with anionic collectors have been experimented. In this scenario, an anionic collector such as sodium petroleum sulfonate and a cationic collector, Alkyltrimethylene diamine acetate, were used at pH 2 in F^- free medium [8], [9]. A study has proven that the presence of metal ions in the flotation media, such as Mg^{2+}, Ca^{2+}, Cu^{2+}, Pb^{2+}, Zn^{2+}, and Fe^{3+} enhances the floatability. This study was also conducted in an HF-free basic medium, with a pH of 11. Sodium Oleate (NaOL) was used as the anionic collector [10]. Another study has also demonstrated that more than 90% of recovery can be achieved through flotation in basic media in the presence of NaOL and Mg^{2+} [11].

These conventional collectors used in quartz flotation are either fatty amines or salts of fatty acids. They render heteropolar properties on mineral surfaces in aqueous solutions [6]. While being effective with more than 90% recovery, these chemical reagents often present limitations such as high cost and low biodegradability, raising environmental and economic concerns in waste quartz processing [12]. As a result, there is a growing need to identify alternative, low-cost, and environmentally friendly collectors that offer comparable flotation performance. In this context, the present study investigates the potential of Sodium Cocoate(NaCo), a naturally derived and abundantly available fatty acid salt, as a sustainable collector for the beneficiation of low-grade quartz sourced from abandoned mine sites.

2 Methodology

The methodology flowchart is illustrated in Figure 1.

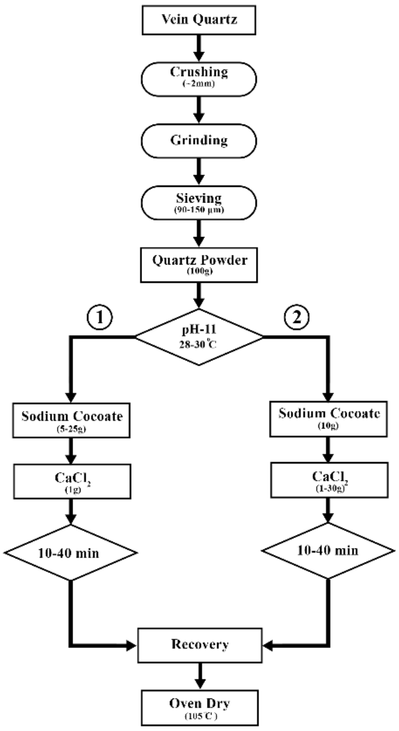

Figure 1 : Methodology Flow Chart

2.1 Sampling

Samples were collected from three abandoned mines in the Balangoda area, Sri Lanka. Abandoned waste quartz (Figure 2) samples were handpicked randomly from abandoned stockpiles.

Figure 2 : Ore Samples

2.2 Flotation Reagents

Sodium Cocoate(NaCo), a naturally derived fatty acid salt, was used as the primary collector. Calcium Chloride (assay ≥ 98%) ($CaCl_2$) was employed as a source of Ca^{2+} ions to activate the quartz surface, and 10% Sodium Hydroxide (NaOH) was used as a pH regulator to maintain the desired alkaline conditions during flotation. A commercial shampoo (Lifebuoy, Unilever) was used as a froth-generating agent. It contains common surfactants such as Sodium Laureth Sulfate, which acts as a froth-generating agent. It was used as a substitute for standard frothers such as pine oil or MIBC, since they were not available.

2.3 Sample Preparation

All the samples were washed to remove any dirt from the mine site, dried and crushed using the Fritsch jaw crusher (Funnel P-1 V2A), then ground with the N.V. Tema Laboratory Disc Mill (model T.100) (Figure 3). 100 g of samples were prepared from the portion passing through the 150 microns sieve and retained on the 90 microns sieve. These samples were subjected to magnetic separation before flotation experiments to remove any metal particles mixed during the crushing and grinding phases.

Figure 3 : Prepared quartz samples

2.4 Flotation Tests

Two types of tests were conducted using 100g quartz samples. Overall, 72 flotation tests were conducted, 18 for NaCo dosage and 54 for $CaCl_2$ dosage. 1. Varying the collector dosage (5, 10, 12.5, 15, 20, 25)g for a constant $CaCl_2$ dosage(1g) 2. Varying the $CaCl_2$ dosage (1, 5, 10, 12.5, 15, 17.5, 20, 22.5, 25, 30)g for a constant NaCo(10g) dosage. 15g, 20g, and 22.5g of $CaCl_2$ tests were repeated for more accuracy. Tests were done using a laboratory-embedded flotation cell with a 9-litre capacity (impeller speed - 280 rpm, air flow rate- 0.004 m^3/s, slurry density-1007 kg/m^3). NaCo was added as the collector. $CaCl_2$ was added as a Ca^{2+} ion supplier to activate quartz particles. The pH value was maintained at 11. Flotation was done within 10-minute intervals for 40 minutes. Each flotation test was conditioned for 5 minutes. The first set of flotation tests was done by varying the amount of collector added to the flotation medium.

The other set of flotation tests was done by varying the amount of $CaCl_2$ to adjust the Ca^{2+} ion concentration in the medium. The collector's amount was selected as 10g as it gave the highest recovery of quartz in the previous set of tests. $CaCl_2$ dosage was varied mostly with a step size of 2.5g. It started from 1g and ended at 30 g. The recovered samples of quartz were washed using distilled water, then oven-dried at 105 ºC. The dry weights of the recovered samples were measured.

3 Results and Discussion

3.1 Effect of NaCo Dosage on Quartz Recovery

Figure 4 illustrates the variation in the quartz recovery percentage of each quartz sample within 10-minute intervals, for each NaCo dosage at room temperature (28-30 ºC). The results indicated how the NaCo dosage affects the flotation kinetics of quartz flotation.

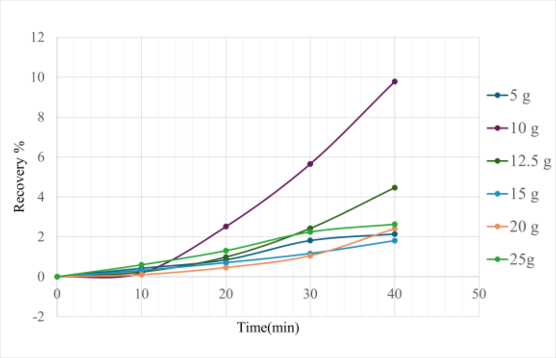

Figure 4 : Recovery% over time for varying collector amounts under 1g of $CaCl_2$, pH-11, 28-30 ºC

The highest recovery was obtained at 10g dosage, and up to 25 g of collector dosage, the recovery has reduced. This can be explained by the fact that the pH of the flotation media also has to be optimized, along with the collector dosage [13]. In this study, the pH was maintained at a constant value of 11, as Chen et al. [10] explained that it was the optimum pH for quartz surface activation. Furthermore, the adsorption of the molecular fatty acid onto the mineral surface is also possible [13]. Fatty acid collectors have two forms in the flotation media, either as molecular acid (Cocoate acid) or in anionic form. For higher collector dosages,high concentrations of molecular acids tend to precipitate.

3.2 Effect of Ca^{2+} ion on Quartz Recovery

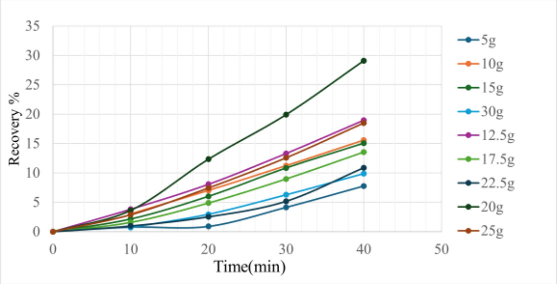

Figure 5 : Recovery percentage over time for varying $CaCl_2$ amounts under 10 g of NaCo, pH-11, 28-30 °C

Figure 5 represents the recovery percentage of each quartz sample within 10-minute intervals, for each $CaCl_2$ dosage with constant NaCo of 10g at pH 11 and room temperature. It shows that the highest recovery was obtained at a dosage of 20g of $CaCl_2$. Initially, recovery increased with the increase in the Ca^{2+} concentration; however, beyond the 20g point, it declined. Quartz can be recovered in basic media in the presence of metal ions such as Mg^{2+}, Ca^{2+}, Cu^{2+}, Pb^{2+}, Zn^{2+}, and Fe^{3+}, etc. Quartz surfaces become negative in the basic medium. These metal ions can hydrolyse into $M(OH)^+$ M^{2+} and adsorb onto negatively charged quartz surfaces, making them positive, which influences the adsorption of the anionic collector onto the quartz surface. This is an essential procedure to convert hydrophilic quartz into a hydrophobic phase, enabling its attachment to air bubbles and subsequent recovery in the froth. In other words, it activates the quartz surface [10]. In the second experimental batch, it is evident that the $CaCl_2$ dosage has positively affected the recovery of quartz, which has led to an average recovery of 28.19±1.28%. The decline in recovery beyond 20g of $CaCl_2$ may be due to the alkalinity (presence of OH^-) of the media, which leads to the precipitation of $Ca(OH)_2$ in the presence of excess $CaCl_2$ dosages instead of surface activation of quartz. Optimum concentrations of activator increase anionic collector adsorption onto mineral surface, but at excess concentrations, it forms a double layer with OH^- ions [14]. Figure 6 represents the statistics of the 20g of $CaCl_2$ dosage with NaCo 10g at 10, 20, 30, and 40 minutes; the error bars indicate standard deviations of $\pm 2.83\%$, $\pm 0.11\%$, $\pm 0.06\%$ and $\pm 0.28\%$ respectively. The variability of the repeated tests remains within the error range. However, the overall recovery is comparatively low, indicating that NaCo shows a limited effectiveness under the given conditions.

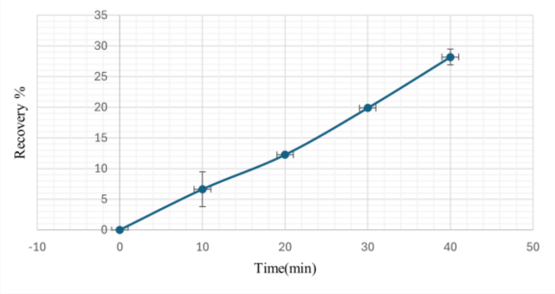

Figure 6 : Standard Deviation error bars for the repeated tests of the highest recovery (NaCo-10g, $CaCl_2$-20g)

3.3 Flotation time

The recoveries achieved by flotation are comparatively low under the applied conditions. In the first test series, the highest recovery was obtained from 10 g of NaCo. The rate of change in quartz recovery for 10g of NaCo is illustrated in Figure 7. The corresponding curve illustrates a typical flotation curve. As seen in Figure 7, the recovery rate initially increases with a rapid rise, indicating that in the early flotation phase, there are more particles available in the bubble-particle interface. The curve reaches a peak around 30-35 minutes and begins to decline after that. Therefore, beyond that limit, flotation becomes inefficient to continue. This indicates that the most floatable quartz has recovered within the first 40 minutes and proves that 40 minutes is a practical upper limit for the next series of tests.

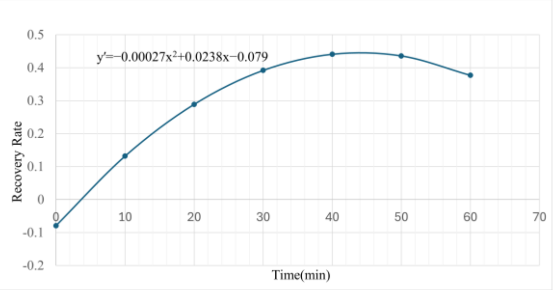

Figure 7 : Recovery rate of Quartz over time under collector 10g and $CaCl_2$ 20g

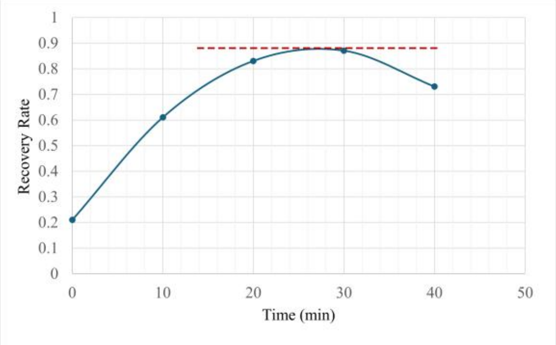

Figure 8 : Recovery rate of Quartz over time under collector 10g and $CaCl_2$ 20g

The rate of change of recovery for a collector dosage of 10g and $CaCl_2$ dosage of 20g is illustrated in Figure 8. As seen in Figure 8 recovery rate initially increases but declines exponentially after 25-30 minutes. This indicates that most of the floatable quartz has readily floated within the first 30 minutes of flotation. And explains that, for the conditions provided, 0-30 minutes of flotation is enough to recover the maximum floatable amount.

Therefore, extending the flotation process beyond 30 minutes is not operationally efficient. It may lead to a higher energy use and processing time with negligible recovery gain.

3.4 Combined effect of NaCo and Ca^{2+} ions

After Ca^{2+} ions were introduced in higher dosages (with NaCo held constant at 10 g), quartz recovery improved significantly. The recovery increased from 9% to ~29% with 20 g of $CaCl_2$, which is almost three times higher than using NaCo alone. This implies a strong coactive effect between NaCo and Ca^{2+} ions. This scenario explains that adding an activator increases the recovery rather than the collector alone.

The collector and activator dosages employed in this study are higher than typical industrial scale. However, the primary objective of this study was to assess the suitability of NaCo as an anionic collector for quartz flotation rather than optimizing the collector. These laboratory-scale conditions were designed to obtain the highest recovery possible, to confirm whether NaCo can function as a collector. Not representing a comparison of data with a conventional collector, such as Sodium Oleate, and not using a standard froth generator are limitations of this study. Therefore, future research could focus on optimizing the reagent dosages under industrial conditions, comparing NaCo performance with conventional collectors under industrial conditions once the suitability of NaCo is established.

4 Conclusion

After analysing the experimental results, the following conclusions were made.

1. The recovery highly depends on the NaCo dosage to some extent under the given conditions.
2. Under the given conditions, the recovery curves represented a gradual decrease in quartz recovery with time for all concentrations of NaCo and Ca^{2+} ions. But after 30 minutes, the rate of recovery tends to decline, indicating most of the floatable quartz particles are recovered within the first 30 minutes.
3. The gradual increment of Ca^{2+} ion dosage causes a gradual increase in the recovery, with a plateau at 20g. This observation explains that surface activation through metal ions in quartz flotation is effective up to some extent.
4. The combined application of NaCo and Ca^{2+} yielded much higher recovery compared to NaCo alone. This represents a synergistic effect where the collector and activating ions work together to enhance flotation performance.

Acknowledgements

The authors would like to extend their gratitude to all the academic and non-academic staff of the Department of Earth Resources Engineering, University of Moratuwa. Special thanks go to Dr. Upekha Samaradiwakara of the Wayamba University of Sri Lanka, and academic and non-academic staff at the Nanotechnology Research Laboratory, Wayamba University of Sri Lanka.

References

[1] K. Mohanty, J. Oliva, P. Alfonso, C. H. Sampaio, and H. Anticoi, "A Comparative Study of Quartz and Potassium Feldspar Flotation Process Using Different Chemical Reagents," *Minerals*, vol. 14, no. 2, p. 167, Feb. 2024, doi: 10.3390/min14020167.

[2] A. Jennings, A. Senior, K. Guerin, P. Main, and J. Walsh, "A review of high-purity quartz for silicon production in Australia," *Aust. J. Earth Sci.*, vol. 71, no. 8, pp. 1085–1097, Nov. 2024, doi: 10.1080/08120099.2024.2362296.

[3] S. S. Pathirage, P. V. A. Hemalal, L. P. S. Rohitha, and N. P. Ratnayake, "Production of industry-specific quartz raw material using Sri Lankan vein quartz," *Environ. Earth Sci.*, vol. 78, no. 3, Feb. 2019, doi: 10.1007/s12665-019-8060-3.

[4] E. Larsen and R. A. Kleiv, "Flotation of quartz from quartz-feldspar mixtures by the HF method," *Miner. Eng.*, vol. 98, pp. 49–51, Nov. 2016, doi: 10.1016/j.mineng.2016.07.021.

[5] Y. Zhang *et al.*, "Systematic review of feldspar beneficiation and its comprehensive application," *Miner. Eng.*, vol. 128, pp. 141–152, Nov. 2018, doi: 10.1016/j.mineng.2018.08.043.

[6] B. A. Wills and J. E. Finch, *Wills' mineral processing technology: an introduction to the practical aspects of ore treatment and mineral recovery*, Eighth edition. Amsterdam Boston, Mass Heidelberg: Elsevier, 2016.

[7] G. W. Heyes, G. C. Allan, W. J. Bruckard, and G. J. Sparrow, "Review of flotation of feldspar," *Miner. Process. Extr. Metall.*, vol. 121, no. 2, pp. 72–78, Jan. 2012, doi: 10.1179/1743285512Y.0000000004.

[8] Y. He *et al.*, "Application of dodecyl amine/dodium petroleum sulfonate mixed collector in quartz-feldspar flotation separation," *Physicochem. Probl. Miner. Process.*, Mar. 2024, doi: 10.37190/ppmp/185553.

[9] F. Burat, O. Kokkilic, O. Kangal, V. Gurkan, and M. S. Celik, "Quartz-feldspar separation for the glass and ceramics industries," *Min. Metall. Explor.*, vol. 24, no. 2, pp. 75–80, May 2007, doi: 10.1007/BF03403362.

[10] Y. Chen, Y. Chen, X. Guo, Z. Liao, and J. Huang, "The role of phosphate in inhibiting the activation of quartz flotation induced by Mg2+," *J. Mol. Liq.*, vol. 398, p. 124278, Mar. 2024, doi: 10.1016/j.molliq.2024.124278.

[11] N. Sun *et al.*, "Selective flotation of quartz from feldspar using hydroxypropyl starch as depressant," *Miner. Eng.*, vol. 195, p. 108022, Apr. 2023, doi: 10.1016/j.mineng.2023.108022.

[12] K. Goto, C. Lin, T. Kadono, M. Hirono, K. Uezu, and T. Kawano, "ECO-TOXICITY OF A SOAP COMPONENT (SODIUM OLEATE) AND A SYNTHETIC DETERGENT COCKTAIL USING GREEN PARAMECIA ASSAYED IN NATURAL WATER SAMPLES FROM EAST ASIA".

[13] B. Kawenski Cook, M. Aghamirian, and C. E. Gibson, "Optimization of spodumene flotation with a fatty acid collector," *Miner. Eng.*, vol. 204, p. 108412, Dec. 2023, doi: 10.1016/j.mineng.2023.108412.

[14] Y. Yu, L. Ma, M. Cao, and Q. Liu, "Slime coatings in froth flotation: A review," *Miner. Eng.*, vol. 114, pp. 26–36, Dec. 2017, doi: 10.1016/j.mineng.2017.09.002.