ADDIS ABABA INSTITUTE OF TECHNOLOGY,

CENTER FOR ETHIO-MINES DEVELOPMENT

Talc Beneficiation through Flotation Techniques in Ethiopia: A Case Study of Sidama Regional State, Hoko Woreda

MSc Project

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Abbreviation & Acronyms

EDX	Energy Dispersive X-Ray
FDA	Food and Drug Administration
FTIR	Fourier Transform Infrared Spectroscopy
FWHM	Full Width at Half Maximum
SEM	Scanning Electron Microscopy
XRD	X-Ray Diffraction
XRF	X-Ray Fluorescence
PIXE	Proton Induced X-Ray Emission

ABSTRACT

Talc is a hydrated magnesium layered silicate mineral. The major uses are in the plastics industry, rubber, cosmetics, ceramics, and pharmaceuticals. Properties include increasing stiffness and resistance to heat and are suitable for talcum powder and tablet formulations since it is soft and inert. This project discusses the flotation parameters of talc beneficiation, sourced from the Sidama Regional State in Ethiopia, using high-grade and high-recovery outputs. The flotation techniques have always remained favorable for talc-beneficiating processes, especially because the process achieves gangue mineral separation. The experiments showed that under optimum conditions, the pH was 11, the collector dosage was 1.2 kg/ton, and the depressant dosage was 1.0 kg/ton, maintaining the pulp density at 200 g/l and an impeller speed of 1100 rpm. Under these conditions, the talc recovery was 74.25% in the flotation process. The chemical analysis of the resulting talc concentrate showed significant improvements: SiO_2 *increased from 58.2% to 73.01%, while MgO increased from 24.22% to 24.62%. The* Fe_2O_3 *content decreased remarkably from 14.37% to 1.66%, reflecting a successful removal of impurities and a substantial increase in the purity of the final product. Results indicate that oleic acid and kerosene oil, with sodium hexametaphosphate as a depressant and propyl glycol as a frother, gave the best recovery with a grade improvement. Such a scheme of optimization of flotation conditions to improve talc quality is important in fulfilling these industrial applications in the industries of ceramics. This work contributes to an understanding of talc beneficiation techniques and forms the ground for further research on enhancing the talc recovery methods in Ethiopia and meeting the requirements of various industries for economic development.*

Key words: *Talc, Beneficiation, Flotation, Assay, and Recovery*

1. INTRODUCTION

1.1. Background of the Study

Talc is an industrial mineral of hydrated magnesium layered silicates with the theoretical formula $Mg_3Si_4O_{10}(OH)_2$ and belongs to the phyllosilicate family [1]. It's a transformation product of original or secondary magnesian minerals or rocks, due to mild hydrothermal processes, supported by simple dynamic metamorphism, and weathering [2]. Depending on the composition, talc can take on white, apple green, dark green, or brown shades & greasy to the touch. Talc is the softest of all minerals, with a Mohs hardness of 1 and 2.75 a specific gravity. It is relatively inert and water-repellent. Talc is created by converting serpentine. The resulting talc contains magnesia and water but relatively more silica than serpentine [3]. The surface of the talc is composed of two types of surfaces: basal cleavages and the edges. There are no charged groups on the surface of the faces; therefore, talc faces are considered non-polar and hydrophobic, whereas the edges are hydrophilic because of the presence of charged ions on them, the Mg^{2+} and OH^{-}[1]. The major gangue minerals in talc are carbonates, magnesite, dolomite, serpentine, chlorite, and calcite, which cause the formation of undesirable properties. Trace minerals include magnetite, pyrite, quartz, tremolite, and etc. Since talc was a hydrophobic mineral naturally, it can easily be floated using a foaming agent like pine oil with petroleum as an accelerator [4]. While talc was known to form in many geological environments, mineable talc deposits are formed by the alteration of two compositionally different protoliths. Those of carbonate origin and those of mafic/ultramafic origin represent the two lithologies from which, in most cases, the required increase in SiO_2 for the formation of talc is provided by the country rock [5].

One of the most important physicochemical separation processes is flotation, basically applied for separating minerals. During the process of flotation, the particles are suspended in an aqueous solution with low surface wettability and later combined with air bubbles for removal from the process space in foam form. The principal functions of the flotation cell are mixing and agitating the slurry, aerating and promoting collisions between particles and bubbles, continuous discharge of residues, and formation of a foam layer together with its removal for product recovery. Flotation has many advantages over the other techniques, with improved metallurgical performance and control, lower energy consumption, and reduced capital investment [6]. This project paper deals with the processing of talc by flotation to produce high-purity talc concentrates for industrial applications, such as filler, coating, lubricant, and absorbent in industries such as paper, plastics, paints, cosmetics, pharmaceuticals, and many others.

1.2. Statement of the Problem

The problem of talc ore beneficiation in Ethiopia is crucial because the country has talc mineral deposits. Currently, local industries like Tabor Ceramic Share Company use unprocessed talc ore, which results in low-quality ceramic products based in Hawassa, Ethiopia [7]. The products range from tiles, sanitary ware, tableware, and ceramic insulators, all of which fail to meet quality standards. Most problems face Ethiopian ceramics production due to quality of talc, as there is no process for beneficiation by flotation and it does not meet the standard parameters for its use in industrial applications. This now forces Ethiopia to import high-quality ceramics products to meet the requirements, further worsening the economic challenges and currency constraints [6, 8–14]. In this respect, the project on the beneficiation of talc ore through flotation techniques from Sidama region was to the problems.

1.3. Objective

1.3.1 General Objective

The project's general objective was the beneficiation of talc through flotation to produce talc.

1.3.2 Specific Objectives

- Characterization of the mineralogical analysis and elemental analysis of talc ore.
- Investigate the effects of reagent dosages and pulp density in flotation of talc.
- Analyze the chemical composition of talc after the beneficiation process.

1.4 Scope of Study

The Talc Beneficiation through Flotation Techniques in Ethiopia: Case Study of Sidama Regional State, Hoko Woreda, Eletama Kebele project investigates the quality of talc using flotation methods, since there is no processing plant in Ethiopia. The project was conducted at Addis Ababa Institute of Technology (AAiT). The study included mineralogical and elemental analyses for characterizing the talc and to evaluate the efficacy of the flotation techniques to improve purity. The flotation technique was efficient and selective for talc processing to contribute to much sustainable use of talc in Ethiopia.

2 LITERATURE REVIEW

2.1. Introduction of Talc Ore

Talc ore is a naturally occurring mineral applied very widely in many industrial sectors. Talc is anhydrous magnesium sheet silicate and therefore one of the naturally hydrophobic gangue minerals that are found in most sulfide ores. It is comprised of the elements magnesium, silicon, and oxygen, with its chemical formula being $H_2Mg_3(SiO_3)_4$ or $Mg_3Si_4O_{10}(OH)_2$. Talc has been found to have various industrial uses as filler in polymer, cosmetics, paper, and paint industries, in ceramics, rubber, and many other products. Another research study reviewed the safety of talc for use in cosmetics [10, 15, 16]. Talc ore is, generally, a widely applicable mineral that has been put into quite a number of uses and has been the subject of a number of studies.

2.2. Geologic Occurrence of Talc Ore from Serpentine

Talc ore deposits in Ethiopia are associated with ultramafic meta-volcanic rocks and serpentines, as has been manifested by various studies of talc deposits in different regions. Geologic environments in which the occurrence of talc was found include alpine periodontitis that have metamorphosed into talc schist, tremolite-chlorite schist, and actinolite schist [17]. Talc deposits also have a high content of talc, mostly in the form of the embedded `in mica schist, with an association of ultrabasic protoliths, indicating that talc has a metamorphic origin within the upper green schist facies [18]. Also, samples of talc are characterized by high mineralogical and chemical purity, with low iron content and high purity, applicable to a number of industries: cosmetics, paint, polymers, and ceramics [19]. Generally, the geology of talc deposits in Ethiopia is similar, and they share the origin [20]

2.3. Ethiopia Talc Deposits

Metamorphism of Alpine-type peridotites has resulted in talc deposits in Sidama, giving rise to talc shales, tremolite chlorite shales, and actinolite shales. Sidama serpentines, being of ultrabasic origin, have undergone weathering processes that have resulted in magnesite replacement with opal and chalcedony veins, concentrating nickel during soil formation and, therefore, resulting in nickel-bearing lateritic soils [17]. It is further postulated that the Adola placer gold of the area has ultimately come from ultrabasic rocks now composed of serpentinites and talc shales, in which gold quartz veins were formed during serpentinization and later eroded to form the gold in placers in conglomerates and soils concentrating [21]. These results underline the geological processes and mineral transformations that formed the talc and associated mineral deposits in the Sidama region. The main exploration target for talc in the past years was around Sidama regional state. Talc lenses were reported in the surrounding serpentinite bodies around Ula Ulo, Tulla, Anno, Bedakesa, Gayo, and Adola areas. Other talc lenses were also reported near Negele and Hagere Mariam areas [22].

2.4. Global Talc Market

The global talc key drivers include increasing demand in industries such as cosmetics, plastics, and ceramics [23, 24].

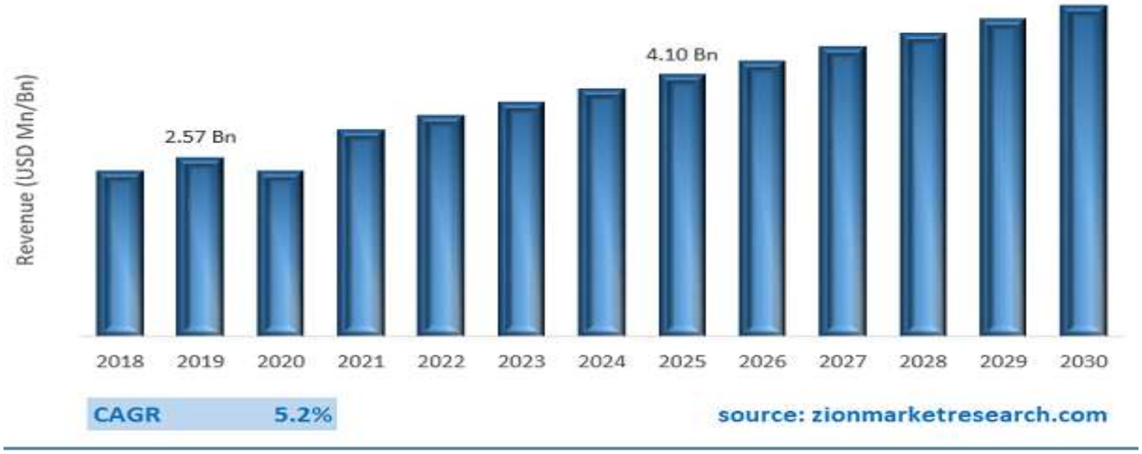

Figure 1: The global talc market size from 2018-2030

The global talc market size was at $2.57 billion in 2019 and is projected to reach $4.10 billion by 2025. Also, it is expected to rise at a compound annual growth rate of more than 5.2% from 2019 to 2025. The research presents an estimate and analysis of regional and global talc markets. The report contains an in-depth analysis of industry competition, challenges, opportunities, forecasts, revenue estimates, current and future trends, and industry-validated market data. Further, value-based ($ billion) estimates for 2019 to 2025 are provided with an analysis of the historical data from 2015 to 2018.

2.5. Talc powder trend imports in Ethiopia

Product: 2526 natural staitite, quite or not, via saw or cut with square or rectangular blocks or plates. Talc

Table 1: Talc product imported to Ethiopia from 2014-2023

Years	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Quantity in tons	710	649	571	537	647	1,026	1,183	1,105	849	854
Value in 000` US dollars	333	249	255	223	222	757	1,135	903	1,314	1,044

Sources: ITC calculations based on Ethiopian Revenues and Customs Authority statistics since January 2007. ITC calculations based on UN COMTRADE statistics until January 2007.

2.6. Types of Talc Ore

2.6.1. Talc-Carbonate Deposits

The talc carbonate ores contain all types of geological settings, mineralogical features, and their respective formation processes. Talc is evidently found in successions with carbonate-inclined early Neoproterozoic platform margins, indicating early diagenetic formation affected by microbial activities and geochemical factors [25]. Characterization of the talc ores on their part showed associations with carbonates and chlorite, which would lower its commercial value but show uses for polymer reinforcement [26]. Further, the talc-carbonate unit of the North Pole Dome is an example of a structural dome of mafic volcanics and felsic formations, indicating another hydrothermal model of talc formation in this setting [27]. Talc deposits in the Inner Lesser Himalayas of Kumaun have magnesite-silica reactions for the more complex talc-forming mineralogical processes involving fluid inclusions and burial-related transformations [28].

2.6.2. Talc Chlorite Deposits

Talc chlorite deposits are formed by metasomatic alteration of Paleozoic meta sediments by saline aqueous fluids at temperatures between 250 and 300 °C and depths of less than 5 km. They date to 120-90 million years ago and are due to the thinning of the continental crust during the opening of the Gulf of Gascony [29]. The deposits, commonly referred to as pot-stone or soapstone, are composed of talc, magnesite, and chlorite and have been traditionally utilized for their ability to retain heat in cooking pots and kitchen tools [30]. Studies carried out on talc and chloritoid in ultrahigh-stress metamorphic rocks have found the mentioned crystallographic favored orientations that affect seismic anisotropy in subduction zones. Talc and chloritoid show off outstanding P-wave and S-wave anisotropy in contrast to garnet. Furthermore, the alteration of talc-chlorite deposits on Mars analogs due to submit depositional weathering underscores the importance of thinking of aqueous procedures in enhancing mineral compositions all through time [31]. While talc formation at the slab-mantle interface in subduction zones is limited, chlorite is expected to be more abundant and likely to play a very important role in the processes taking place at the slab-mantle interface [32].

2.6.3. Soapstone

Soapstone deposits are typically composed of talc, magnesite, chlorite, and other such minerals [33]. They are considered a kind of soft rock, which, because of specific characteristics such as high specific heat capacity and low thermal coefficient of expansion, has made them a material for buildings and daily objects [30]. The origin of soapstone is related to local metamorphism and shear zones acting as channelways for CO_2-rich aqueous solutions; these play a significant role in its formation. The available petrographic and mineralogical data show variation to characterize the soapstone occurrences: while some of them show a definitive textural zonation, others show no obvious relation [34]. A proper understanding of the geological processes and mineral reactions that control the genesis of soapstone is fundamental in the delineation of potential deposit regions and harnessing the diverse applications of this versatile material.

2.6.4. Talc Ore Mineralogy

The general ore mineralogy of talc is simply represented by talc as the major mineral and other colorful minerals depending on the deposit. The general analyses of the talc-carbonate ore can thus be given as talc, 45-65; carbonate, 30-50; chlorite, 0-4; and magnetite, 0-3% [35]. The dominant minerals of soapstone are talc and carbonates. Other common minerals include chlorite and blustery. Minor minerals are oxides and sulfides. Oxide, most commonly magnetite, acts as the principal accessory mineral, while in many iron-rich soapstones. Ferri chromite, chromian magnetite, and ilmenite are found in quite low proportion. Also sulphides mainly pyrrhotite and pentlandite, occasionally in sparse quantities. Mainly the lone carbonate is magnesite. Some varieties of soapstone, however, can hold dolomite, determining as much as 45% of the entire carbonate content [36].

Moreover, talc ores may contain appurtenant minerals such as quartz, Al-Fe-bearing phases kaolinite, chlorite, oxyhydroxides, and minor rudiments like SiO_2, MgO, Fe_2O_3, and Al_2O_3 [37]. It should be noted that the purity of talc may vary from deposit to deposit, where some are more chemically pure and less impure, which can then find application in a wide range of industries, including cosmetics, paints, polymers, and ceramics [38].

2.7. Composition of Talc Ore

Talc ore from serpentine is mainly made up of talc and chlorite, with an assortment of serpentine minerals. The normal composition ranges from 30% to 100% talc and from 0% to 70% chlorite, depending on the geologic setting. The formation process for talc in serpentine includes the metamorphism of magnesium-rich minerals under severe high-pressure and temperature conditions in the presence of carbon dioxide and water. Besides talc and chlorite, other components that serpentine may have include antigorite, lizardite, magnetite, and others that ensure its general diversity in mineral composition. Talc has the chemical formula $Mg_3Si_4O_{10}(OH)_2$, while serpentine minerals are generally of similar compositions whose differences lie in structure or variations in minor elements [39, 40].

2.8. Physical and chemical properties of talc ore

Talc ore, derived from serpentine, is essentially composed of talc and chlorite, with minor minerals such as lizardite and antigorite. It can vary in color and texture; it has a foliated to fibrous habit and a perfect basal cleavage that allows easy sheet spitting [41, 42]. Chemical toughness, high thermal stability, and low coefficient of thermal expansion give talc usefulness in food processing, baby powder, pharmaceuticals, and refractory materials. Its unique synthetic properties add to its mechanical uses and allure [43, 44].

2.9. Talc Processing

Talc processing generally involves some basic steps from mining talc ore to delivering usable products. Talc is mined in an open-pit process, followed by the crushing and grinding into different size fractions. The milled talc may also be subjected to additional processing, such as flotation and drying, in order to achieve improved quality for specific applications [45].

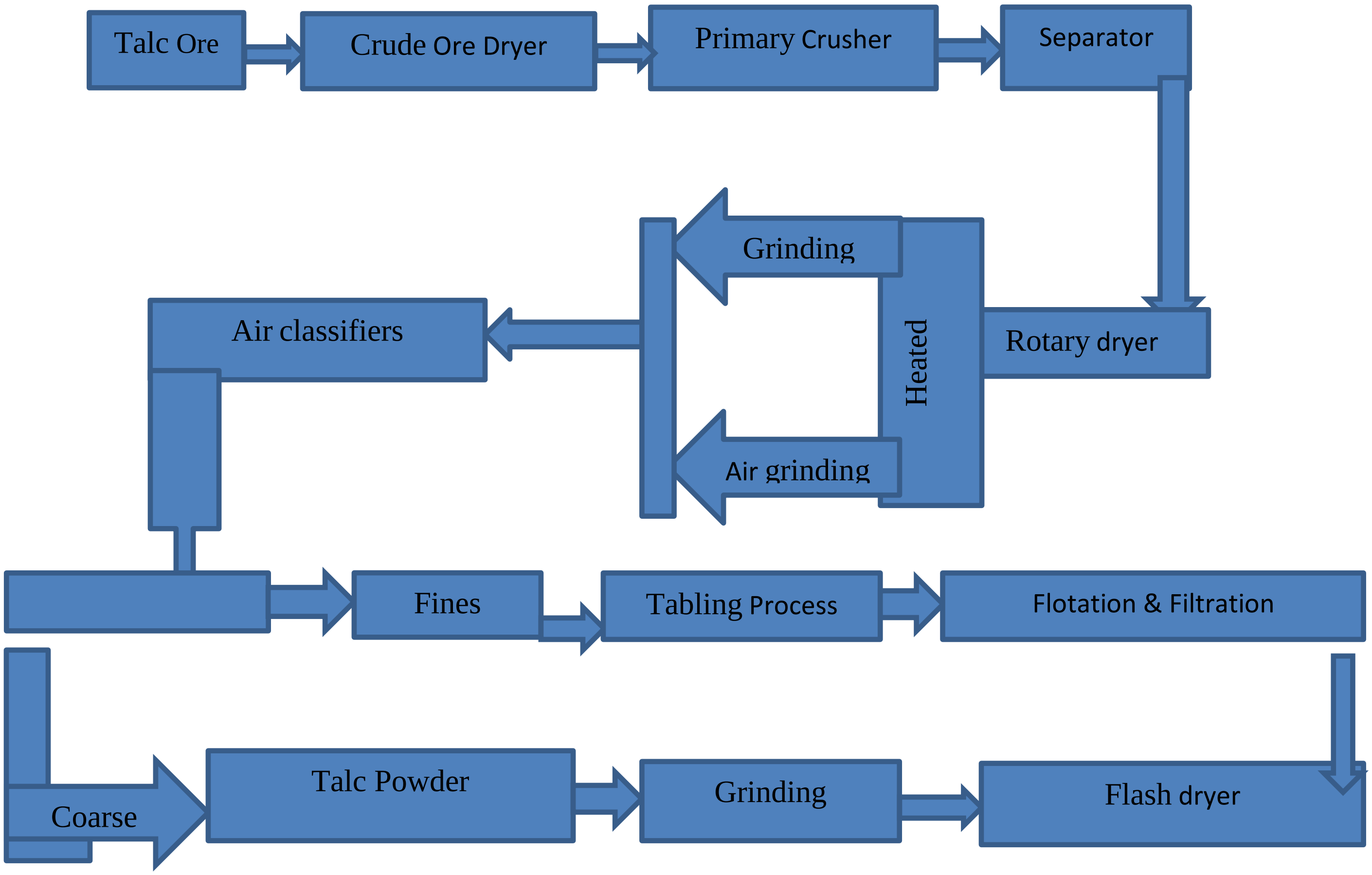

Figure 2: Process flow chart for talc separation from ores

2.10. Talc Ore Beneficiation Techniques

Beneficiation of talc ore froth flotation, wet grinding, column flotation, and flocculants to obtain the quality talc for industrial purposes. The froth flotation separates talc from gangue minerals, while wet grinding improves platy contents in body powders. Column flotation and flocculants work within set industrial standards that convert low-grade talc deposits to high-grade talc, resulting in end products suitable for the cosmetics, plastics, and pharmaceuticals industries, among many more [1, 10, 46–48]

2.10.1. Talc Ore Beneficiation through Flotation

The processing of talc ore by flotation is an approach widely used because of the inherent floatability of this mineral and the need for its increased purity in further industrial applications. Generally, the sequence of flotation of talc ore normally starts with crushing and grinding of the ore to enable the talc particles to be free from associated gangue minerals. The ground ore, pH adjusted, is mixed with water to form slurry, and the conditions for separation were optimized. Collectors, kerosene, or specially selected quaternary amines are added, by which the talc is made hydrophobic and enabled to attach itself to the air bubbles, thus floating to the top as froth. This froth is skimmed off, and a talc concentrate was obtained. Further scrubbing with attrition might increase the concentrate quality by washing off more resilient gangue minerals. Further, selective depressants such as soda ash would enhance the flotation efficiency by decreasing the unwanted flotation of carbonate minerals. Such processes are typical when producing talc concentrates at low levels of impurities, and these concentrates can be used in many uses ranging from cosmetics and plastics to ceramics. By adequately controlling the parameters of flotation, it was believed that high-quality talc concentrates can be produced that will meet the rigid requirements of various industries [10, 11, 46].

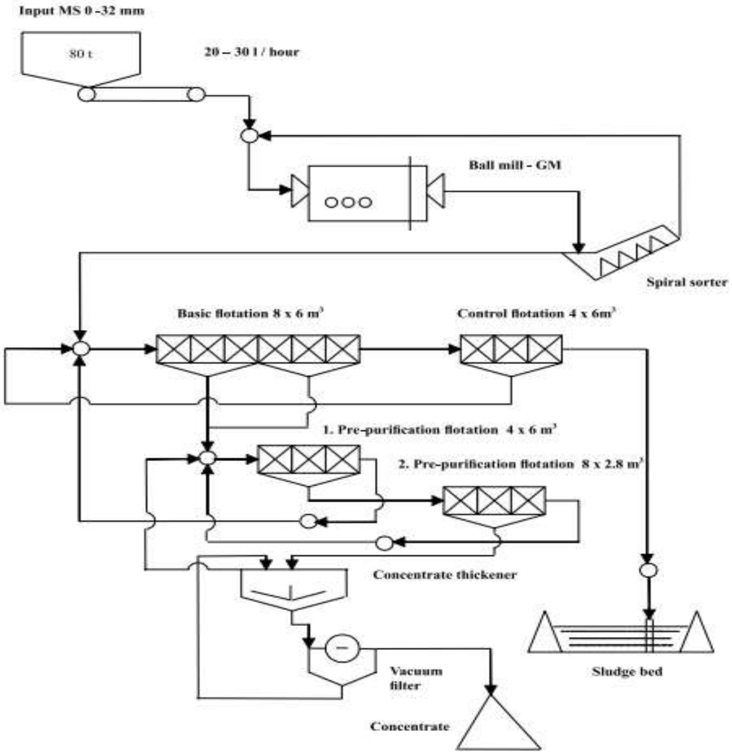

Figure 3: Technological scheme of the functioning part of the flotation

2.10.2. Talc Ore Beneficiation by Flotation: Advantage and Disadvantage

Extensive research on talc ore beneficiation by flotation has been conducted to come up with high-quality talc products. This means optimizing variables of depressants and frothier dosages, solid concentration, and operating variables for attaining high-quality talc concentrates [6]. As a result of the hydrophobic nature of talc, its selective separation from sulfide ores has always been very difficult. Therefore, in pursuit of enhancing the flotation efficiency, surface properties, zeta potential, and contact angle [10]. Attrition scrubbing and flotation processes for the beneficiation of Egyptian talc ores have shown some promising results in terms of recovering good quality talc concentrates for application in various industrial applications. Furthermore, it was found that the flotation flow sheet process with regrinding steps might be an effective process to obtain high-grade talc concentrate with considerable recovery rates [24]. Furthermore, frother and leaching treatment processes improve the grade of talc ores obtained from Nigeria for industries such as paints, paper, and cosmetics [4].

Indeed, flotation is one of the most frequently used processes to beneficiate talc ores associated with high selectivity and efficiency of separation of talc from gangue minerals [49]. This, therefore, exploits the natural hydrophobic property of talc, its ability to naturally attach itself to air bubbles, and after which it is collected as froth, thereby producing high-purity talc concentrates that find very extensive applications in industry. Apart from this, column flotation technology further drives the process toward better metallurgical performance with low energy consumption and reduced capital investment because of an absence of moving parts in the flotation cell. It has been shown by studies that flotation can recover more than 80%, hence making the process cheap for the treatment of low-grade talc ores [50].

Although it is a very versatile and largely applied process in mineral beneficiation, flotation still shows its own challenges and disadvantages. For example, changes in operational conditions, that is, in pH and with the presence of other minerals, are liable to affect the efficiency and selectivity of talc recovery [51, 52]. This creates a tricky problem in the management of flotation chemical reagents, associated with environmental concerns during its disposal and possible toxicity, thus raising questions of sustainability [53].

2.11. The main challenges in achieving high-quality talc through flotation

From the talc's nature, being hydrophobic-hydrophilic, whose surface possesses hydrophilic and hydrophobic sites; these make the flotation of talc to a high quality difficult. This is evident from the inconsistency of its flotation behavior under critical measurement in the flotation environment, pH, and reagents. Moreover, separation of talc with selective depressants, especially in ores with mixed compositions, is rather tricky. Optimizing chemical reagents, such as collectors and frothers, can enhance flotation performance; however, they remain ore-dependent and complex. Froth stability is of paramount importance regarding concentrate quality and overall recovery [10, 11, 54].

2.11.1. Talc ore beneficiation by magnetic separation

Magnetic separation is an essential technique in talc ore beneficiation because of many advantages, which include de-ironing, separation of talc from other minerals of different magnetic properties, and upgrading talc ore into higher-grade products. It is uncomplicated, cheap, and does not have adverse effects on the environment since chemicals and water are not used in the process. However, there are potential environmental effects and economic limitations, besides which it does not remove. It is unsuitable for all talc ores, and hence photoelectric separation and other processes might be more suitable for some ores. Generally, the magnetic separation techniques are useful to a limit [46, 47, 55–58]. Magnetic separation of high-quality talc is confronted with some difficulties because of magnetic minerals, process cycles, and characteristics of the ore. The presence of common minerals such as chlorite and serpentine complicates separation and lowers yield. Efficiency enhancement techniques include pulsating high gradient magnetic separation and surface oxidation treatment [4, 58].

2.12. Talc ore beneficiation by gravity separation

Gravity separation enhances the quality and purity of talc ore by subjecting the talc to regular particle sizes. Additionally, it separates platy talc particles through a fluid separation system from the non-platy ones. This process has some disadvantageous characteristics due to its hydrophobic nature. The efficiency of talc flotation is significantly influenced by factors such as surface properties, zeta potential, and particle size. Depressants like ions of Ca^{2+} and pretreatments such as ultrasonic and thermal treatments enhance the talc depression. New selective depressants or pretreatments must be developed for efficient selective separations. Due to its hydrophobic properties and attached minerals, including magnesium carbonate, talc production by gravity separation at high purity is challenging. Sometimes, clear separation could not be achieved because the bulk densities of talc and some accompanying minerals partially overlap. Gravity separation efficiency is greatly dependent on feed particle size and equipment type. Traditional methods may not give a high degree of purity and hence need more advanced methods or combinations with other methods like flotation. Despite these challenges, gravity separation still offers promise for talc beneficiation, and with more careful process design and optimization, superior results are possible to be achieved for high-quality talc [6, 10, 47].

2.13. Talc Ore Beneficiation by Electrostatic Separation

The friction coefficient and hydrophilic properties of talc differ from those of gangue minerals in the process of electrostatic beneficiation for separating talc ore. This can be enhanced using an electrostatic modification reagent. Electrostatic separation of talc and its gangue minerals, quartz, dolomite, and magnesite, presents a number of advantages compared to the conventional techniques, such as high separation efficiency, little dust, few risks to operating staff, and good working environments. However, electrostatic separation requires fine-tuning and adjustment in the electric field since any changes in the latter alter performance and quality. Besides, high voltage and dryness in electrostatic separation can result in safety and environmental impacts. Challenges of electrostatic separation are the triboelectric charging process, high hydrophobicity of talc, and the need for accurate representation of talcum particles and modern image processing methods. These challenges make the electrostatic separation of talc ore difficult to perform efficiently and therefore require further research with new solutions [59, 60].

2.14. Talc Ore Beneficiation by Calcination

Calcination is an essential process in making talc deposits, especially those with organic impurities, improve their properties. It is a kind of thermal treatment that heats talc ore at high temperature, reduces impurities, and increases mechanical strength. This process has been necessary for industrial production and led to high whiteness and superfine talcum powder. The response of selective separation in flotation is dependent on hydrophobic talc nature; it would be improved by calcination to enhance the whiteness of the final product. These processes are through such unit operations as crushing, removal of impurities, grinding, and magnetic separation. In addition, fluidization technology during calcination represents a competitive technique due to high efficiency, reduction of energy consumption, and reduced CO_2 emissions. Calcination improves magnesium availability for phosphate in relation to cement phase formation and modifies the physical properties. However, this leads to the loss of valuable minerals and non-valuable by-products, and in addition, is energy-inefficient [61–63].

2.15. Talc Ore Beneficiation through Selective Flocculation

Beneficiation of talc ore by selective flocculation: Pulverized talc ore is rendered into slurry along with deionized water. Such slurries usually undergo attrition or scrubbing actions that cause easy separation of the platy particles of talc from their associated gangue minerals, such as dolomite. Attrition helps to maintain optimum talc dispersion in water during subsidence, which avoids collecting unwanted dolomitic fines. The concentrates obtained may undergo further talc upgrading during leaching action with diluted hydrochloric acid. The advantages of selective flocculation are smaller viscosity and stability in the flotation foam, higher efficiency of processes, and an improvement in the working environment. However, there are some disadvantages, one of which is high hydrophobicity in talc that challenges selective separation. Different approaches were studied; it was found that different selective flocculants, including starch or polyethylene glycol, reduce foam stability and viscosity during flotation. Low-grade talc ore can be upgraded through various methods, including attrition scrubbing and then flotation with selective collectors and depressants to produce cleaner talc concentrates for a broad range of industrial applications [11, 60, 64, 65].

2.16. Talc Ore Beneficiation through Chemical Leaching

Various chemical leaching have been conducted in Nigeria and Pakistan using polyethylene glycol to detach talc from the associated gangues. In the case of the samples from Pakistan, acid leaching with hydrofluoric acid removed iron oxide from the ore substantially. These improve the quality and industrial value of talc ores and make them workable for industries. However, the process was time-and energy-consuming since it requires optimized conditions and special chemicals. In addition, generated wastes have to be disposed of using proper measures to avoid environmental contamination. In spite of these disadvantages, chemical leaching is an effective method for upgrading low-grade talc ores [4, 24, 66].

2.17. Talc ore elemental analysis techniques

Advanced techniques involved in the analysis of talc ore for its composition include AAS and XRF. To analysis the chemical composition and elemental analysis of the ore [67–69].

2.18. Talc ore mineralogical analysis

The talc ore can be analyzed by the modern techniques of XRD, SEM, EDX, PLM, and thermal gravimetric analysis. XRD helps to find the mineral phases in talc, whereas SEM gives information on microstructure and contamination. EDX provides quantitative elemental analysis, whereas PLM and oil immersion give information on the optical properties of talc. The techniques of differential thermal analysis and thermal gravimetric analysis provide information on the thermal behavior and purity of the talc sample [67, 70, 71].

3. METHODOLOGY

3.1. Location

The talc deposit was in the Sidama Regional State, which was in the eastern zone of Hoko Woreda in the Eletama locality. It is about 373 kilometers from Addis Ababa.

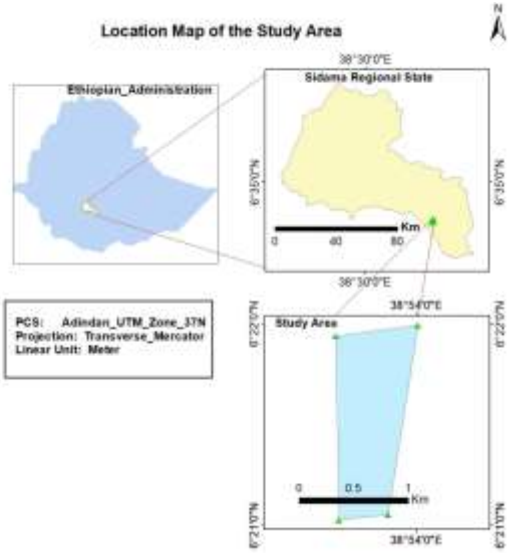

***Figure 4**:* Sidama regional state in the eastern zone of Hoko woreda talc deposit

3.2. Instruments and Chemicals

The following instruments and equipment were utilized in this experiment: Wedag flotation unit (Groppel 98, West Deutschland), cut mill, sieve vibrator (RETCH A200, Deutschland), jaw crusher (RoHs53743, Deutschland), XRD, FTIR, SEM, XRF, oven, kerosene, oleic acid, polyethylene glycol, NaOH, and sodium Metahexaphosphate.

3.3. Sources of Data

The project was concerned with the talc flotation process. Original data were collected through lab experiments using analysis methods such as SEM, XRD, FTIR, and XRF. In addition, some qualitative observations were performed in order to observe the effectiveness of the flotation process. Secondary data was obtained from book and articles.

3.4. Sampling Techniques

Simple random sampling was employed in the study of talc beneficiation in the Sidama Regional State of Ethiopia to ensure the correct representation of talc deposits in Hoko Woreda. Such a method minimized systematic errors and caught the inherent variability of talc ore, hence increasing the reliability of the sample. The samples, weighing 12 kg each, were then transported to the Addis Ababa Institute of Technology for analysis.

3.5. Research Approach

The researcher applied an experimental project approach mixed with research methodology, which combines both qualitative and quantitative methods. Qualitative was on the mineralogical characteristics analysis of talc extracted from run-off mine material, while quantitative was on assay and recovery rates of talc after its beneficiation by flotation to upgrade the quality of talc.

3.6. Sample preparation and Experiment

For this purpose, fineness up to -63 microns was necessary for talc samples prepared for flotation techniques to achieve optimum flotation performance. First of all, the size of the raw talc ore is reduced by the primary crusher; then it was ground in a cut mill. After grinding, the talc was screened by sieve to remove the particles that were too small to pass through a -63 micron sieve, which separates the finer from the coarser. Talc grains less than 63 microns are significant in industrial applications enhancing product functionality and flotation reagent efficiency [72]. The final product, comprising mainly talc particles less than -63 microns, was prepared for beneficiation through flotation.

Laboratory flotation tests were carried out in a 2800 cm^3 Wemco Fagergren cell. The impeller speed was fixed at 1100 rpm. An aeration rate of 6 L/min was used. Water Perspex tank was used to maintain the pulp level at a constant value. Hand skimming was used to collect the froth overflow [47, 73]. All flotation tests were performed at room temperature. The total conditioning time for the samples was set at 10 minutes. The talc sample was introduced gradually and mixed with water for 5 minutes to ensure proper dispersion. Dispersion allows reagents to coat talc particles more easily, with enhanced hydrophobic/hydrophilic properties for flotation. Efficient mixing exposes more surface area for efficient reagent adsorption and improved flotation kinetics [6]. Additional water was added to maintain the liquid level at 10 mm below the overflow lip, important in effective froth formation. pH modifiers were added to adjust the pH to the desired levels, critical in optimizing flotation performance. The reagents alter the ionic strength and pH of the solution to obtain maximum performance of depressants and collectors. Sodium hexametaphosphate was used as a depressant added at the end of the initial conditioning period and left to condition with the pulp for another 2 minutes. A mixture of oleic acid and kerosene at a 1:1 ratio was added and conditioned for another 2 minutes. The reagent adsorb selectively onto the surface of the target mineral (talc), making it hydrophobic (water-repellent) so that it will adhere onto air bubbles. Add the frother, a mixture of polyethylene glycol and the air bubbles are stabilize and create a froth layer which allows efficient separation of hydrophobic minerals from gangue. There was then another minute of conditioning time before the initiation of aeration. The air supply was then slowly turned on and adjusted such that the pulp level was maintained through the duration of flotation. Following 15 seconds, which gave ample time for froth formation, a hand skimmer was used to scoop the froth until no more froth was obtained. After flotation was complete, the concentrate was dried, weighed, and assayed chemically. This ensures that each of the steps carefully controlled the recovery rates so as to give better quality from the flotation test concentrates [11, 73, 74].

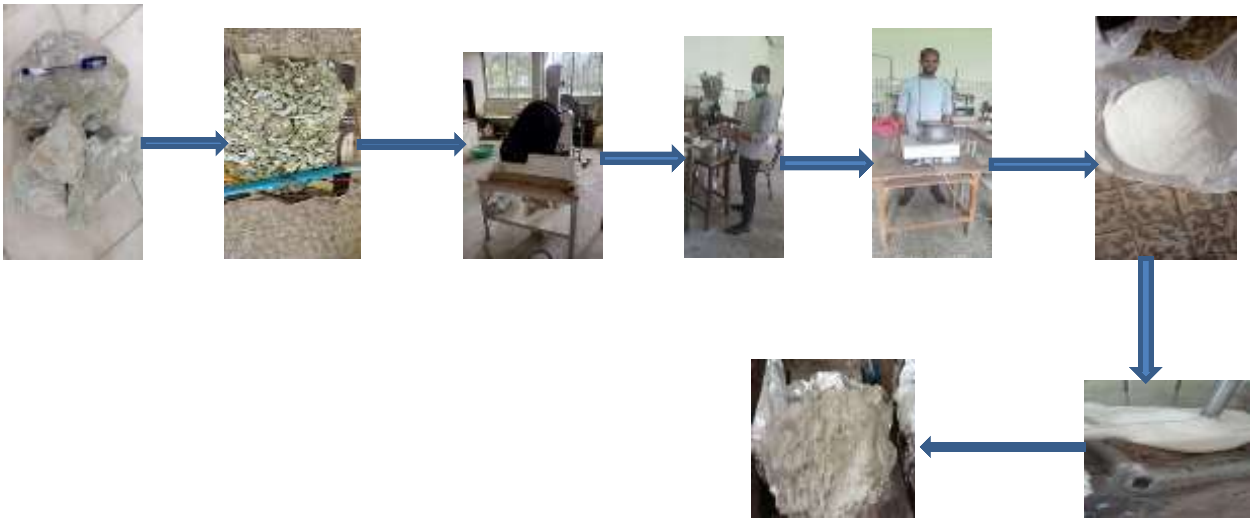

Figure 5: *Talc flotation process*

4. RESULT AND DISCUSSION

4.1. Chemical analysis of feed sample

Table 3: Chemical analysis of feed

Oxide	NiO	CoO	Fe_2O_3	MnO	Cr_2O_3	Al_2O_3	SiO_2	MgO
%	1.294	0.233	14.373	0.339	1.12	0.221	58.2	24.22

As shown in Table 3, The XRF composition of the rock sample of talc shows the oxides composition is as follows [75]. Some of the primary ones are silicon dioxide (SiO_2) having been at a level of 58.2%, characteristic for talc since it principally consists of magnesium silicate (24.22%); iron oxide being 14.373%. However, 1.294% NiO and 0.233% CoO would indicate that the talc formed in an environment that is influenced by ultramafic rocks, known to harbor such elements due to their genetic relationship with mafic and ultramafic. This association was further supported by Cr_2O_3 at 1.12%, bearing that chromium and nickel when found together are indicators of such deposits. Values of Al_2O_3 (0.221%), MnO (0.339%), and MgO (24.22%) respectively indicated composition for talc, as talc usually consists of magnesium but can vary in trace metal content depending on the specific geological context.

4.2. Fourier Transform Infrared Spectra of Talc

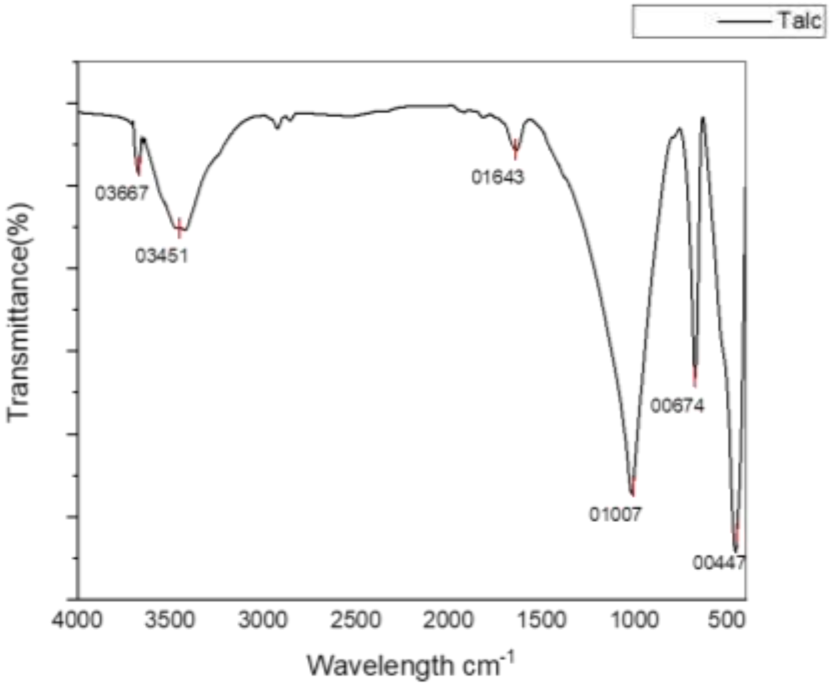

Figure 6: Talc's FTIR Spectrum displays its peak

FTIR spectra analysis of talc showed in figure 6 serious vibrational characteristics in different spectral regions. The strong O-H stretching vibrations in the range of 4000-3000 cm^{-1} confirm the presence of hydroxyl groups that are very important for the hydration state and physical and chemical properties of talc. The region between 3000 and 2000 cm^{-1} is of less importance for talc, mainly reflecting C-H stretching vibrations of organic materials, which may alter the properties of talc. The region from 2000 to 1500 cm^{-1} emphasizes silicate vibrations, mainly Si-O stretching modes, crucial for the investigation of the silicon bonding environment in talc. Between 1500 and 1000 cm^{-1}, there are mainly Si-O bending vibrations, which further evidence the layered silicate structure of talc and provide information about crystal symmetry and bonding. These peaks of FTIR are important in defining the functional groups, impurities, and hence define the industrial applications of talc [26, 62, 76–79].

4.3. X-ray Diffraction of Talc

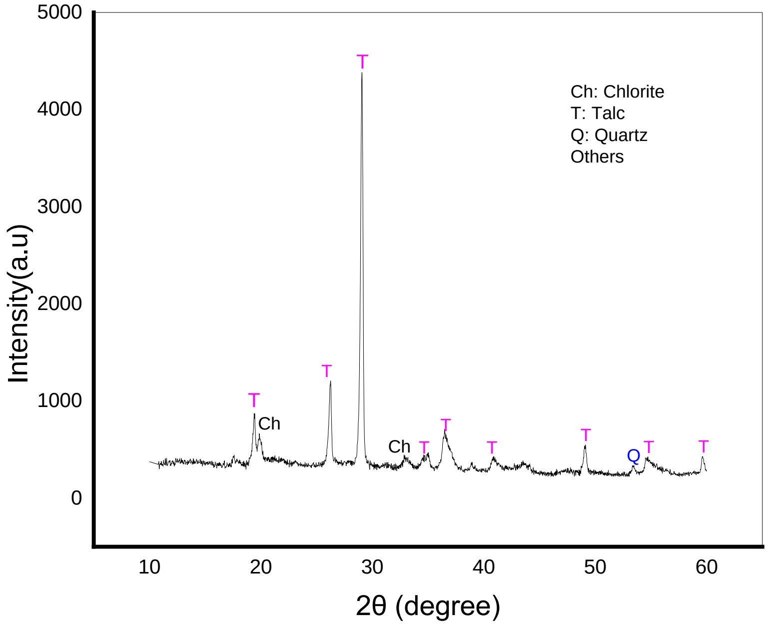

Figure 7: XRD spectra of talc before beneficiation

Table 4: Spectral determination of talc before beneficiation

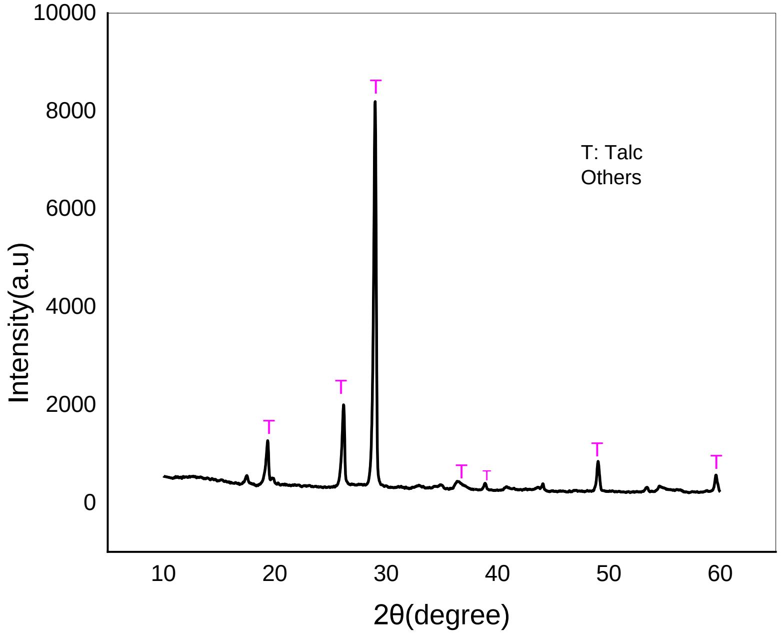

Figure 8: XRD spectra of beneficiated talc

A crystal size and mineral quality investigation of talc before and after flotation showed a significant difference: the crystallite size before flotation was about 32.5 nm, which was coarser in structure. The presence of minerals such as chlorite, talc, quartz, chromite, manganite, cobaltite, & pentlandite suggests a complex mineralogy that may impact the purity of the talc. After flotation, size of the crystallite was reduced to 31.92 nm calculated by Scherrer equation, showing finer and possibly more homogeneous products. Such a decrease in size can enhance the quality of talc and offer better applicability in the ceramics industry, which generally requires finer particle sizes for better dispersion and value. Thus, the 2θ values are 19.31°, 19.92°, 26.24°, 29.05°, 33.07°, 35.01°, 40.85°, 43.66°, 49.13°, 53.39°, 54.85°, and 59.72°. The disappearance of some which might enhance. The presence of more hydrophobic platy talc particles showed that aspect ratio and surface characteristics could be critical factors determining flotation behavior, which has been confirmed by XRD analyses correlating particle morphology with the flotation response of talc particles [26, 62, 80–85].

$$\beta(\text{radians}) = \frac{(\text{FWHM degrees} * \pi)}{180}$$

$$\text{Dp} = \frac{(\text{K} * \lambda)}{\beta * \text{COS}(\theta)} \qquad \text{Scherrer equation}$$

FWHM	Full Width at Half Maximum
Dp	Average crystallite size
K	Shape factor (typically taken as 0.94 for spherical particles)
λ	Wavelength of X-rays (e.g., 0.15418 nm for Cu Kα radiation)
β	FWHM in radians
θ	Bragg angle (half of the peak position)

4.4. Scanning Electron Microscope determination of talc

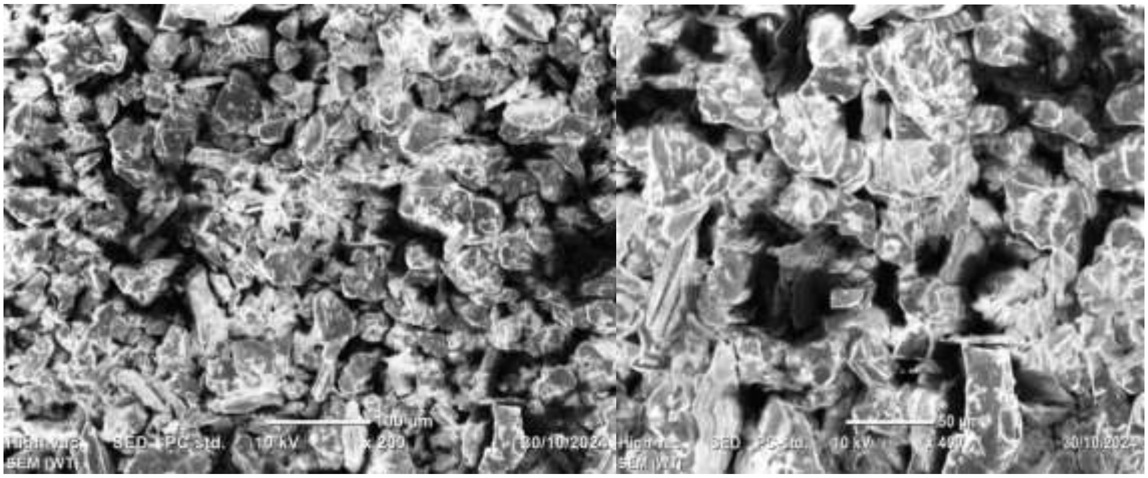

Figure 9: SEM image of talc before flotation

The given images are SEM micrographs of some sort of solid material. From the topography and microstructure seen in these high-magnification images, the following can be suggested for the material: Morphological analysis of talc, typically by Scanning Electron Microscopy (SEM), is helpful in determining particle shape, size, and distribution. SEM micrographs reveal the characteristic plate-like or flaky morphology of talc, and layered talc exhibits different shapes such as fine shreds, plates, sheets, and flakes. The size and shape of crystallites are varied; some larger features were observable at 200x, while smaller, intricate structures could be observed at 400x. It points to a material comprising a variety of crystalline phases, which may further indicate heterogeneous microstructure [26, 86–88].

4.5. Mass of concentrate and tailing

Table 4: *Mass of concentrate and tailing*

Parameter	Collector Dosage(kg/t)			Depressant Dosage			Pulp density			pH		
	C1	C1.2	C1.4	D1.2	D1	D0.8	Feed 150g	Feed 200g	Feed 250g	10	11	12
Concentrate (g)	139.3	148.2	142.5	140.8	148.5	137.4	103.8	148.3	162.7	142.9	148.4	139.9
Tailing (g)	60.7	51.8	57.5	59.2	51.5	62.6	46.2	51.7	87.3	57.1	51.6	60.1

C (Collector) & D (Depressant)

Table 4 shows the mass of concentrate and tailings under varied experimental conditions, including different collectors, depressants, dosages of talc, and pH. The collector C (1.2) gives a maximum concentrates mass of 148.2 g with a minimum of 51.8 g in the tailing, showing a good recovery. pH also influences the result; pH 11 gives a high concentrate mass at 148.4 g with low tailings at 51.6 g.

At lower dosages (1 kg/t), there may not be adequate collector to cover the talc completely and therefore obtain lower recovery. At more elevated dosages (1.4 kg/t), however, the excess collector can form competitive adsorption on other minerals or render the talc particles too hydrophobic for flotation to proceed. The 1.2 kg/t dosage achieves a balance that maximizes talc recovery while simultaneously minimizing unwanted minerals flotation. A 1.2 kg/t collector dosage is sufficient to cover the talc particles so that their hydrophobicity is enhanced, allowing them to adhere to air bubbles more effectively so that they are floated to the surface.

With low doses (0.8 kg/t), the quantity of depressant may not be sufficient to effectively restrain the gangue minerals from floating, leading to a lower concentrate mass. With high doses (1.2 kg/t), the floatability of the talc would also be depressed by the depressant, with a consequent concentrate mass being lower. Therefore, 1 kg/t imparts the optimal amount of depression for enhancement of talc recovery. Because 1 kg/t of depressant dose is the best dose, it maximizes selective depression of gangue mineral flotation while keeping talc floatable. This selective activity is vital to the enhancement of mass recovery of the concentrate. Higher pH levels will also be capable of decreasing thickness in slime layers on talc particles, causing hindrance in flotation. A pH level of 10 sees a decrease in concentrate mass through perhaps insufficient hydrophobicity, while with a pH of 12, excess alkalinity may induce detrimental effects on flotation performance. For pH 11 and 200g/L surface charge on talc particles is supposed to favor flotation. The increased pH level can enhance talc's hydrophobic nature, causing it to adhere preferentially to air bubbles. Higher pH levels will also be capable of decreasing thickness in slime layers on talc particles, causing hindrance in flotation [84, 89–91].

The major oxide assay decrease with collector dosages below 1 kg/t due to poor flotation. Collector dosages above 1.4 kg/t improve assay recovery and attachment efficiency but can lead to gangue mineral entrainment and affect selectivity due to increased entrainment. Therefore the assay was decreased below 1 kg/t and above 1.4 kg/t collector dosage [92]. The assay of the major oxide lies at depressed levels below 0.8 kg/t presumably as a result of the depressant not being sufficient to fully repress flotation of gangue minerals, and thereby contaminating the concentrate and reducing the assay. Contrastingly, above 1.2 kg/t dosage, the assay increases as a result of excess depressant that over-suppresses gangue minerals and reduces recovery of the valuable minerals unintentionally, thereby concentrating the target oxide within the concentrate. So that below and above 1 kg/t depressant dosage of assay was become decrease [93, 94]. At below and above pH 11 the component recoveries of these major oxide constituents were decrease [1].

4.6. Effect of collector dosage on assay in talc flotation test

Among the factors that affect flotation performance, collector dosage, which has been varied at 1.0, 1.2, and 1.4 kg/t, greatly influences it while keeping other variables constant at pH 11, flotation time of 10 minutes, talc dosage at 200 g, depressant dosage at 1 kg/t, and frother dosage at 0.6 ml.

Table 5: *Component assay value at different collector dosages*

This analysis discusses the effects of collector dosage on each oxide's assay percentage NiO, CoO, Fe_2O_3, MnO, Cr_2O_3, Al_2O_3, SiO_2, and MgO. Each oxide's response to changes in collector dosages was explored to understand their effect on overall flotation.

Collector dosage, Kg/t	Concentrate Assay (A_c), %								Tailing Assay (A_t), %							
	NiO	CoO	Fe_2O_3	MnO	Cr_2O_3	Al_2O_3	SiO_2	MgO	NiO	CoO	Fe_2O_3	MnO	Cr_2O_3	Al_2O_3	SiO_2	MgO
1.0	0.15	0.03	0.51	0.03	0.04	0.03	73.39	25.77	3.82	46.18	46.18	1.05	3.59	0.66	23.34	20.66
1.2	0.16	0.05	2.72	0.09	0.06	0.05	72.08	24.74	4.52	47.70	47.70	1.06	4.15	0.71	18.49	22.74
1.4	0.27	0.14	2.93	0.19	0.10	0.07	71.95	24.29	3.83	42.71	42.71	0.71	3.65	0.59	24.12	24.05

4.6.1. Determination of the assay of SiO_2 at different collector dosages

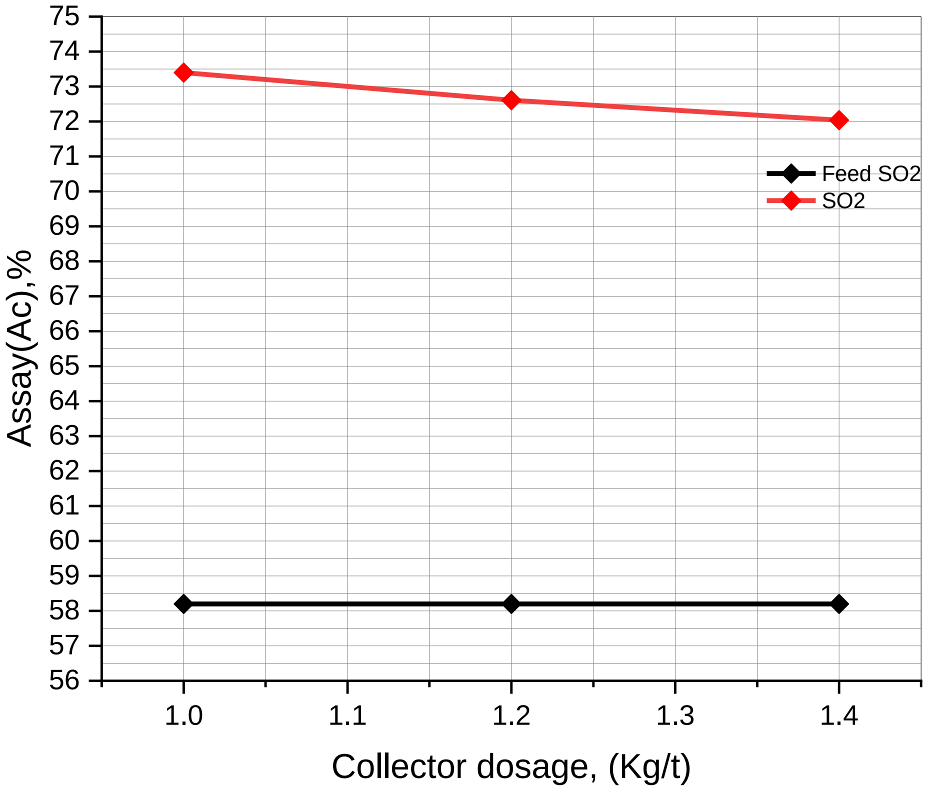

Figure 10: Assay of SiO_2 at different collector dosages

The SiO_2 assays are trending in a decreasing mode with the increase in collector dosages from 1.0 kg/t up to 1.4 kg/t, where the SiO_2 content drops from 73.39% to 71.95%. This tendency suggests that using higher dosages of collector is likely to further float gangue minerals together with talc, thus reducing the SiO_2 content in the concentrate. With the increase in the collector concentration, it increases not only the hydrophobicity of the target minerals but also that of other associated minerals and hence their unwanted assay. The saturation of talc surfaces by collector molecules is probably the attribute for the same, which may increase impurities floatation, decreasing the overall talc concentrate assay [54, 91, 95].

4.6.2. Determination of the assay of MgO at different collector dosages

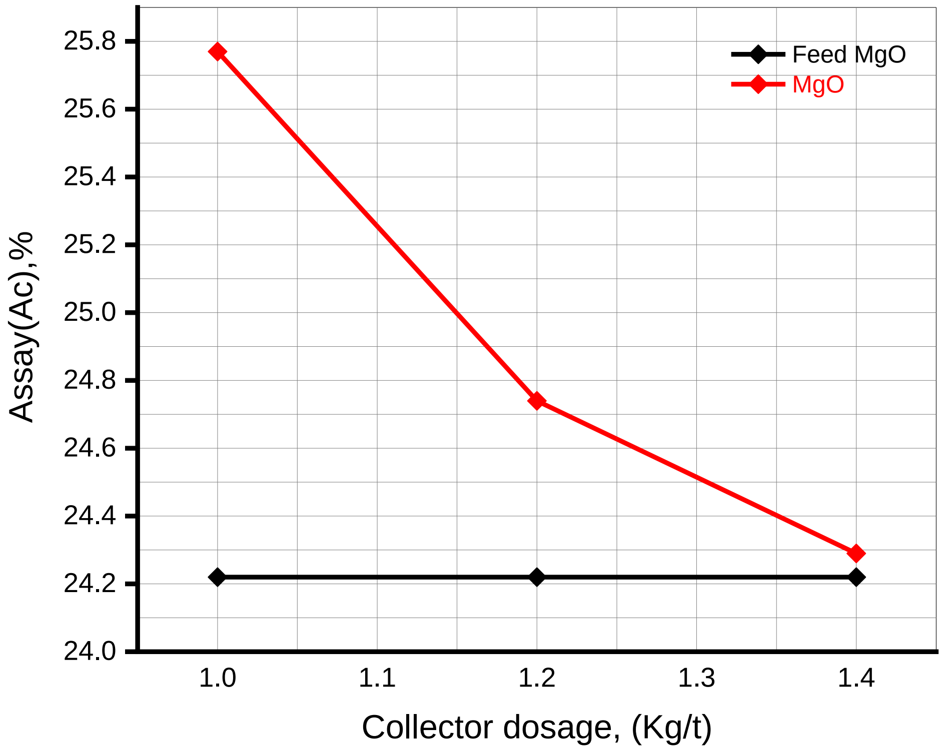

Figure 11: Assay of MgO at different collector dosages

It is also observed in the assay for MgO that the content drops in the concentrate from 25.77% at 1.0 kg/t to 24.29% at 1.4 kg/t. This trend therefore suggests that although the initial increase in collector dosage improves assay by increasing hydrophobicity, excessive amounts reduce selective flotation of MgO-rich minerals. This higher hydrophobicity, with increased dosages, can lead to further gangue minerals of low MgO content floating along with talc and hence affect the purity of the final product [85, 91, 96].

4.6.3. Determination of the assay of Fe_2O_3 at different collector dosages

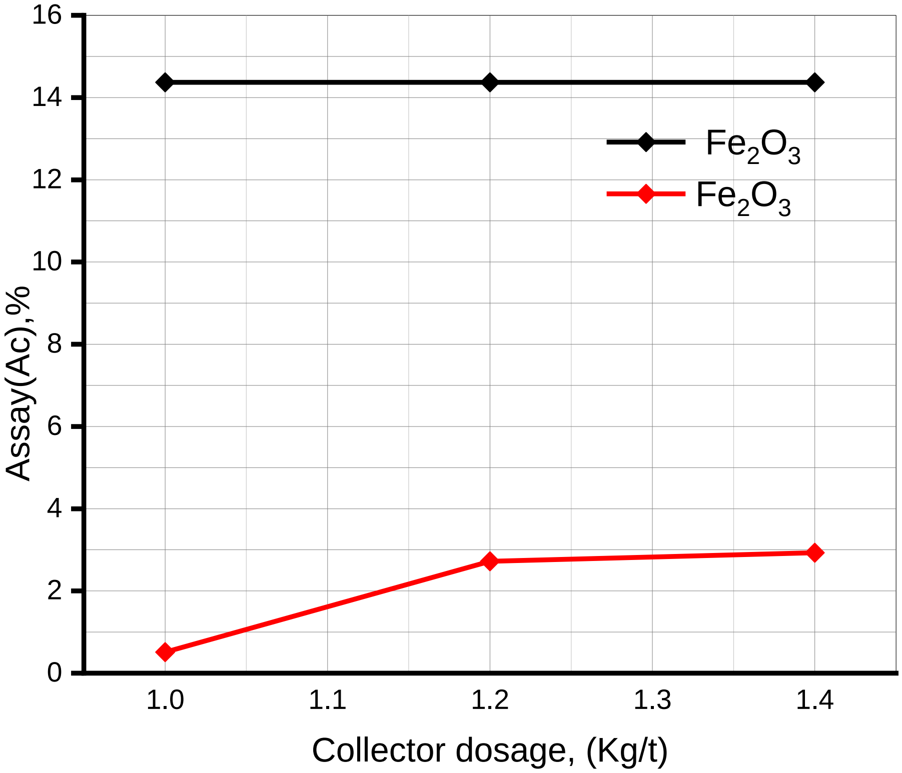

Figure 12: Assay of Fe_2O_3 at different collector dosages

The dosage of the collector applied shows an exponential trend in Fe_2O_3 assay during talc flotation, with assays showing varied results at different dosages. At 1.0 kg/t, the assay of Fe_2O_3 is 0.51% in the concentrate, 2.72% at 1.2 kg/t, and 2.93% at 1.4 kg/t. This trend indicates that as the dosage of the collector increases, the assay of Fe_2O_3 also increases, which means higher oleic acid concentrations make iron-bearing minerals more hydrophobic, which could be beneficial to flotation efficiency. However, the increase in Fe_2O_3 assay can be considered a problem since this may imply selectivity reduction where minerals other than talc are being collected. In mineral processing, the higher dosages improve assay, they may also increase undesirable flotation of gangue minerals like Fe_2O_3, thereby reducing concentrate purities [6, 97–100].

4.6.4. Determination of the assay of other oxides at different collector dosages

Assay data showing the effect of collector dosage on assay of gangue minerals during talc flotation, such as NiO, CoO, MnO, Cr_2O_3, and Al_2O_3, in collector dosages of 1.0, 1.2, and 1.4 kg/t, is presented. Thus, in the concentrate at 1.0 kg/t, relatively low assays were obtained for NiO (0.15%) and CoO (0.03%), while higher values of 73.39% SiO_2 and 25.77% MgO were recorded in the tailings, which mean that most gangue minerals are still uncollected. It follows that with the addition of reagent up to 1.2 kg/t, there is a fair improvement in the concentrate assays of NiO, 0.16%, and CoO, 0.05%, reflecting improved assay because of better hydrophobicity imparted by oleic acid on the mineral surfaces. This is also reflected in the tailing's assays, which have a slight buildup of Fe_2O_3 and Cr_2O_3, indicating thereby that some of the gangue minerals are being collected along with the minerals of interest. Where it goes up to 0.27% at an assay for NiO and to 0.14% for CoO at 1.4 kg/t. It means that while the assay of target minerals improves, there is also an increased risk of collecting unwanted gangue minerals due to the excessive presence of collectors, leading to reduced selectivity. This trend is indicative of a very delicate balance in flotation processes whereby optimum collector dosage may enhance assay but at the same time result in lower grades of concentrate if not appropriately managed [92, 101, 102]. The assay sequence of NiO, CoO, Fe_2O_3, MnO, Cr_2O_3, and Al_2O_3 is indeed increasing, hydrophobic improvement by collector and selective adsorption at the mineral water interface. Optimal dosage ensures efficient dosing for maximum assay with an increasing selectivity order [103, 104].

$$\text{Assay concentrate} = \frac{\text{Mass of oxide in concentrate}}{\text{Mass of concentrate}} * 100$$

$$\text{Assay tailing} = \frac{\text{Mass of oxide in tailing}}{\text{Mass of tailing}} * 100$$

4.7. Component & mass recovery of flotation product at different collector dosages

Table 6: Component & mass recovery at different collector dosages

Collector dosage Kg/t	Concentrate Component Recovery Rc (c), %								Rm (c)	Tailing Component Recovery Rc(t), %								Rm (t)
	NiO	CoO	Fe_2O_3	MnO	Cr_2O_3	Al_2O_3	SiO_2	MgO	%	NiO	CoO	Fe_2O_3	MnO	Cr_2O_3	Al_2O_3	SiO_2	MgO	%
1	10.08	8.70	2.47	5.88	2.68	9.09	87.83	74.11	69.65	89.92	91.30	97.53	94.12	97.32	90.91	12.17	25.89	30.35
1.2	9.30	15.22	14.02	19.12	4.02	15.91	91.77	75.68	74.1	90.70	84.78	85.98	80.88	95.98	84.09	8.23	24.32	25.9
1.4	14.73	43.48	14.54	39.71	6.25	22.73	88.08	71.45	71.25	85.27	56.52	85.46	60.29	93.75	77.27	11.92	28.55	28.75

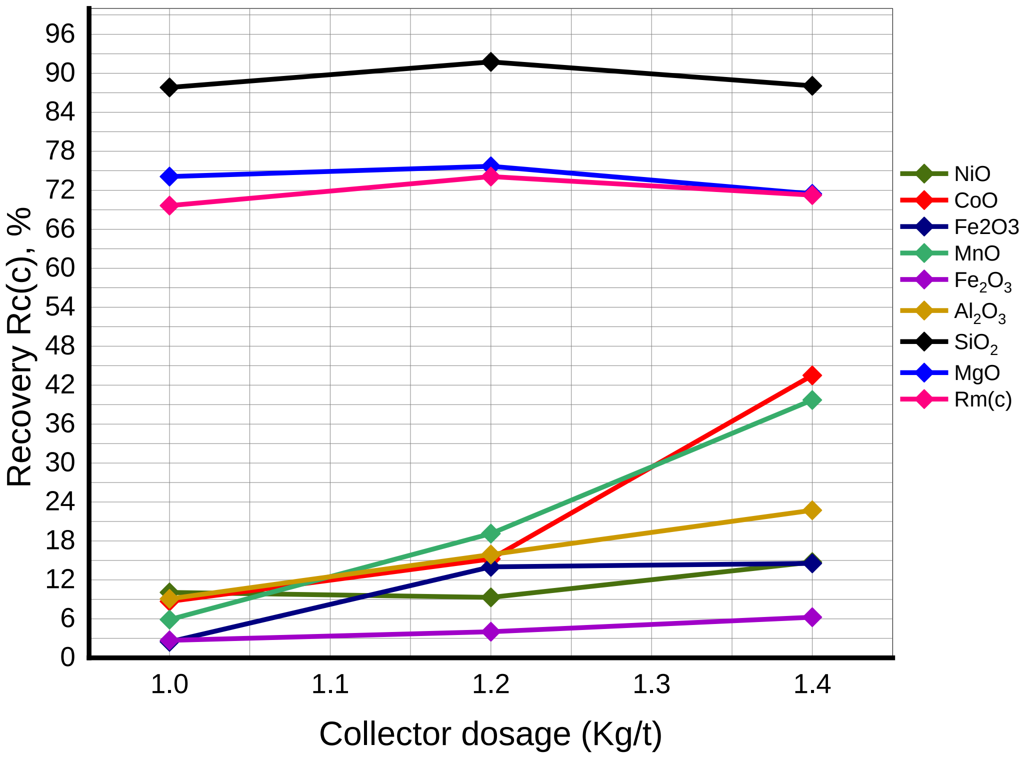

Figure 13: component & mass recovery at different collector dosages

Table 6 and figure 13 presented how each oxide was treated in depth on its response to the variation in collector dosage Component & mass recovery of oxides at different collector dosages agrees with [1, 10, 101, 105–109]. As presented in Table 6, the general trend is observed for the recovery of target minerals, including SiO_2 and MgO, among other oxide components like NiO, CoO, Fe_2O_3, MnO, Cr_2O_3, and Al_2O_3 in the case of collector dosage variations of 1, 1.2, and 1.4 kg/t. The recoveries for SiO_2 and MgO are relatively high at about 87.83% and 74.11%, respectively, at 1 kg/t. However, while increasing the dosage to 1.2 kg/t and further to 1.4 kg/t, the recovery rates of SiO_2 and MgO decline slightly to 91.77% and 75.68%, respectively, at 1.2 kg/t, and further at 1.4 kg/t, 88.08% and 71.45%, respectively. This reflects that increasing the dosages of collector in the medium range improves recoveries for some minerals in a suitable amount; however, higher dosages lead to losses in certain components like SiO_2 and MgO.

On examination of the trends in overall oxide recoveries for the various components versus the dosage of collector used, as shown in Table 6, it appears that a higher dosage promotes increasing recoveries in non-valuable minerals, such as NiO and CoO, to their peak with a dosage of 1.4 kg/t at recoveries of 14.73% and 43.48%, respectively. This is, however, at the expense of the other oxides; for instance, Al_2O_3 recovery increases from 9.09% at 1 kg/t to 22.73% at 1.4 kg/t and also follows a similar trend for other oxides.

While the optimal dosage of the collector is approximately 1.2 kg/t, there is a need to balance recovery rates among target minerals for the overall efficiency in mineral processes. This dosage provides a reasonable compromise in the enhancement of valuable minerals recovery, such as SiO_2 and MgO.

Talc recovery during flotation was generally low with the increase in collector dosages, as this anionic collector enhances the hydrophobicity by forming a water-repellent monomolecular layer on particle surfaces. At low dosages, only the slightly hydrophobic faces of talc are coated, decreasing recovery, while with increasing dosage, even the hydrophilic edges are coated, enhancing recovery. However, dosages higher than 1.2 kg/t may show a decline in recovery because of multilayer formation of the collector on the surface. Too much collector begins to coat other minerals; hence, the recovery of the concentrate decreases due to loss of selectivity [91, 110].

4.7.1. Collector dosages and mass recovery (Rm (c), %)

As observed in Table 6, the recovery of mass in concentrate Rm (c), % and tailing Rm (t), % at a dosage of 1 kg/t, the recovery in concentrate is 69.65%, while the tailing recovery is 30.35%. Increasing the dosage to 1.2 kg/t increased the recovery in concentrate to 74.1%, reducing the recovery by tailing to 25.9%. However, the recovery of the concentrate falls slightly to 71.25% at 1.4 kg/t, while the recovery of the tailings increases to 28.75%. Such fluctuation indicates that, though moderate increases in collector dosage improve talc recovery, excessive dosage may lead to diminishing returns because of changes in surface properties affecting flotation efficiency. The inherent hydrophobicity of talc is the most important factor in these recoveries, as its crystalline structure and surface chemistry dictate its interaction with collectors and frothier during flotation processes [6, 11, 110].

$$Mass\ recovery\ of\ the\ concentrate = Rm(c) = 100 * \frac{C}{F}$$

$$Component\ recovery\ in\ concentrate = Rc(c) = 100 * \frac{C * c}{F * f}$$

$$Component\ recovery\ in\ tailing = Rc(t) = 100 * \frac{T * t}{F * f}$$

Where:

C	mass of concentrate, g
T	mass of tailings, g
F	mass of feed, g
c	assay of constituent in concentrate, %
t	assay of constituent in tailings, %
f	assay of constituent in feed, %
Rm(c)	mass recovery of concentrate, %
Rm(t)	mass recovery of tailings, %
Rc(c)	component recovery in concentrate, %
Rc(t)	component recovery in tailings, %

4.8. Effect of depressant dosage on assay in talc flotation test

The depressant dosage was varied at 0.8, 1.0, and 1.2 kg/t while maintaining other conditions constant (pH: 11; flotation time: 10 minutes; collector: 1.2 kg/t; talc dosage: 200 g; frother: 0.6 mL).

Table 7: *Component assay at different depressant dosages*

Depressant dosage Kg/t	Concentrate Assay (A_c), %								Tailing Assay (A_t), %							
	NiO	CoO	Fe_2O_3	MnO	Cr_2O_3	Al_2O_3	SiO_2	MgO	NiO	CoO	Fe_2O_3	MnO	Cr_2O_3	Al_2O_3	SiO_2	MgO
0.8	0.14	0.03	0.88	0.04	0.07	0.07	73.05	25.69	3.82	0.67	43.98	1.01	3.42	0.54	25.61	20.99
1	0.33	0.07	1.66	0.07	0.13	0.09	73.01	24.62	4.06	0.70	51.01	1.13	3.98	0.60	15.50	23.07
1.2	0.46	0.11	2.08	0.12	0.28	0.14	72.17	24.60	3.26	0.52	43.60	0.86	3.13	0.41	24.98	23.33

4.8.1. Determination of the assay of SiO_2 at different depressant dosages

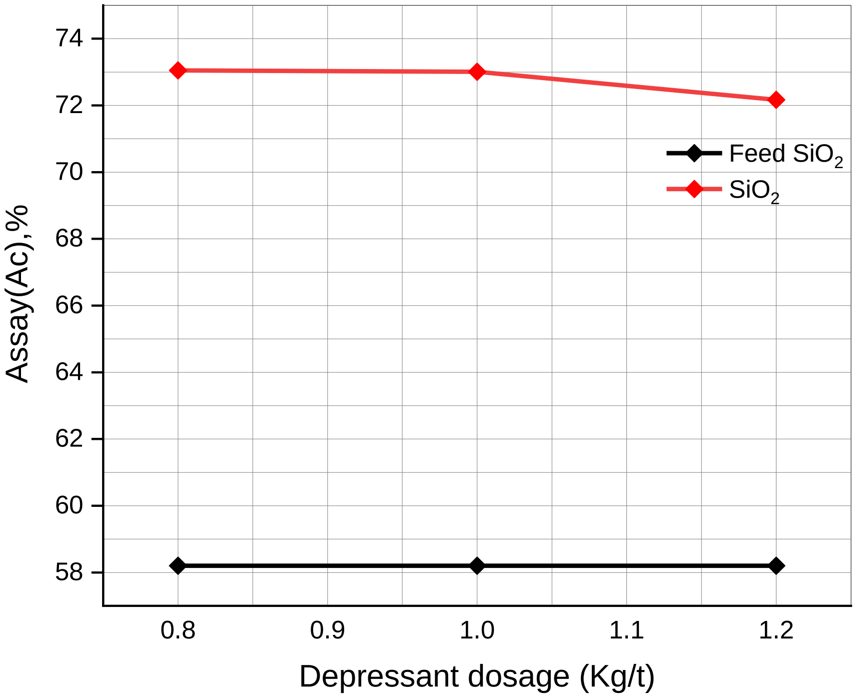

Figure 14: *Assay of SiO_2 at different depressant dosages*

SiO_2 decreases effectively from 73.05% at 0.8 kg/t to 72.17% at 1.2 kg/t of depressant dosage, as valuable materials. This decreased silicon confirms the presence of increasing amounts of depressants, which were reducing silica in the concentrate. The decrease in SiO_2 assay in the concentrate can be explained by the increase in the depression effect of depressants on talc. With increasing dosage, depressants adsorb more strongly onto the surface of talc, increasing its hydrophobicity and reducing its floatability, thus leading to a greater loss of SiO_2 in tailings instead of recovery to the concentrate. Inhibiting talc selectively decreases the interaction of talc with air bubbles, an essential event in flotation, resulting in decreased recovery of SiO_2 [62, 108, 111].

4.8.2. Determination of the assay of Magnesium Oxide at different depressant dosages

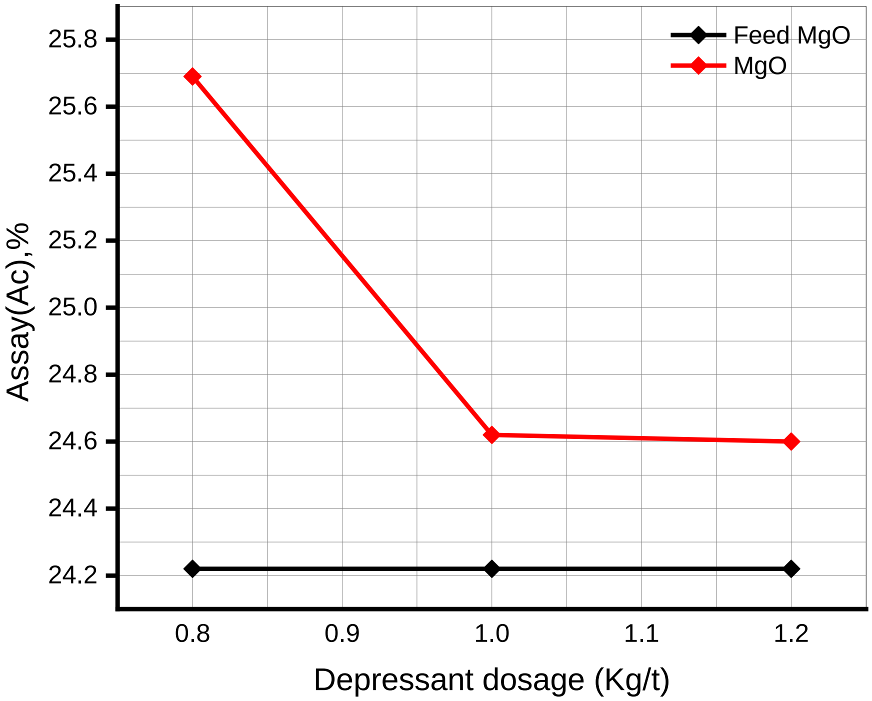

Figure 15: Assay of MgO at different depressant dosages

MgO grade in the concentrate is 25.69% at a depressant dosage of 0.8 kg/t, which decreases to 24.62% at 1 kg/t and remains stable at 1.2 kg/t with a content of 24.60%. As the depressant dosage increase the assay of MgO slightly decrease. This decline in MgO assay within the concentrate could be attributed more to increased depressant efficiency with increased dosages. Adsorption of depressants onto talc changes its surface properties, making it less floatable. At higher dosages of depressant, a portion of the valuable minerals are being lost due to their intimate associations with talc [1, 10, 54, 73, 107, 112–115].

4.8.3. Determination of the assay of Iron Oxide (Fe_2O_3) at different depressant dosages

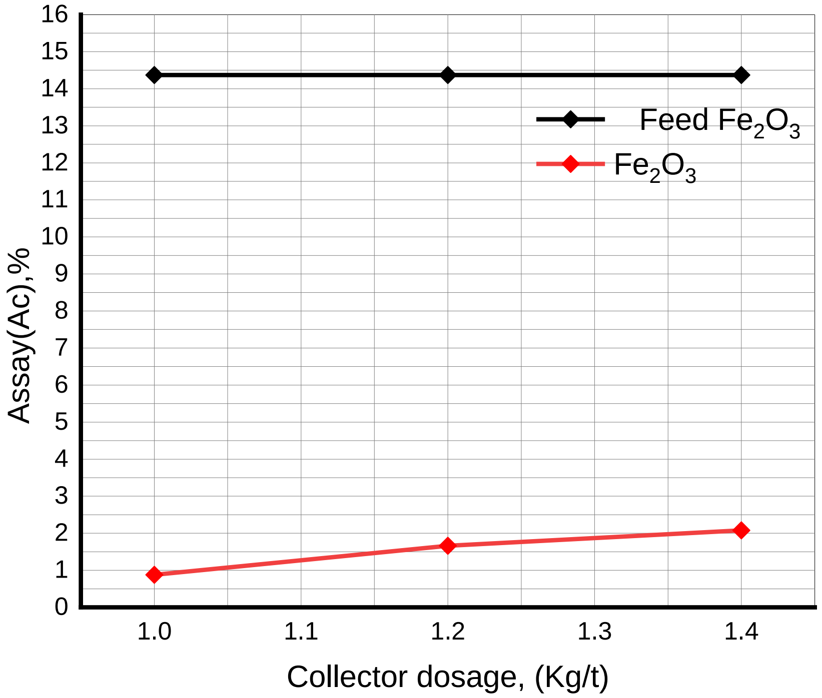

Figure 16: Assay of Fe_2O_3 at different depressant dosages

The Fe_2O_3 assay increases significantly from 0.88% at 0.8 kg/t to 2.08% at 1.2 kg/t of depressant dosage. It is attributed to the increase in Fe_2O_3 assay in the concentrate, increasing its floatability compared to talc upon the use of SHMP. Selectively depressing talc and other silicate minerals, while iron oxides remain more floatable, was the result of using the reagent. Therefore, as more talc becomes depressed and removed from the concentrate, a relatively higher proportion of Fe_2O_3 is recovered in the concentrate. This selective depression mechanism is important, as it improves the general quality of the talc concentrate by depleting the impurities and inadvertently increasing the gangue mineral assays such as Fe_2O_3 [116, 117].

4.8.4. Determination of the assay of other oxides at different depressant dosages

The NiO assay increases significantly from 0.14% at 0.8 kg/t to 0.46% at 1.2 kg/t, showing an upward trend. For CoO, the assay also increases from 0.03% to 0.11% as the depressant dosage increases from 0.8 kg/t to 1.2 kg/t. Results of the MnO assay depict a progressive increase from 0.04% to 0.12% with an increase in the dosage of depressant. Cr_2O_3 increases from 0.07% at 0.8 kg/t to 0.28% at 1.2 kg/t of depressant dosage. The Al_2O_3 assay was increasing from 0.07% to 0.14%, which reflects that as the depressant dosage increases.

The increase in concentrate assay percentages of gangue minerals such as NiO, CoO, Fe_2O_3, MnO, Cr_2O_3, and Al_2O_3 with increasing dosages of SHMP in talc flotation is basically due to the mechanism of selective depression. The depressant SHMP selectively adsorbs on the surface of talc particles, which imparts hydrophilic characteristics to talc and hinders its floatability. Therefore, talc particles that are richer in SiO_2 and MgO are less likely to attach to air bubbles and report to the froth product. However, gangue minerals may not be strongly affected through SHMP depression because their surfaces are different from that of talc, thus allowing it to remain floatable or even relatively more concentrated in the froth product as talc is increasingly depressed. Besides, the addition of SHMP can change the pulp chemistry due to the dispersion of fine particles and the reduction of slime coatings at the surface of the minerals and subsequently increase gangue minerals floating into the concentrate [6, 115].

$$Assay\ concentrate = \frac{Mass\ of\ oxide\ in\ concentrate}{Mass\ of\ concentrate} * 100$$

$$Assay\ tailing = \frac{Mass\ of\ oxide\ in\ tailing}{Mass\ of\ tailing} * 100$$

4.9. Component & mass recovery at different depressant dosages

Table 8: *Component & mass recovery at different depressant dosages*

Depression dosage, kg/t	Concentrate Component Recovery Rc(c), %								Rm(c)	Tailing Component Recovery Rc (t), %								Rm(t)
	NiO	CoO	Fe_2O_3	MnO	Cr_2O_3	Al_2O_3	SiO_2	MgO	%	NiO	CoO	Fe_2O_3	MnO	Cr_2O_3	Al_2O_3	SiO_2	MgO	%
0.8	7.34	8.58	4.21	7.37	4.46	22.62	86.23	72.87	68.70	92.35	90.13	95.77	92.92	95.54	76.92	13.77	27.13	31.30
1	18.93	21.46	8.59	14.75	8.48	29.41	93.14	75.47	74.25	80.76	77.25	91.38	85.55	91.52	70.14	6.86	24.53	25.75
1.2	25.12	32.19	10.19	25.07	17.41	45.25	87.29	71.49	70.40	74.57	66.52	89.78	75.22	82.59	54.30	12.71	28.51	29.60

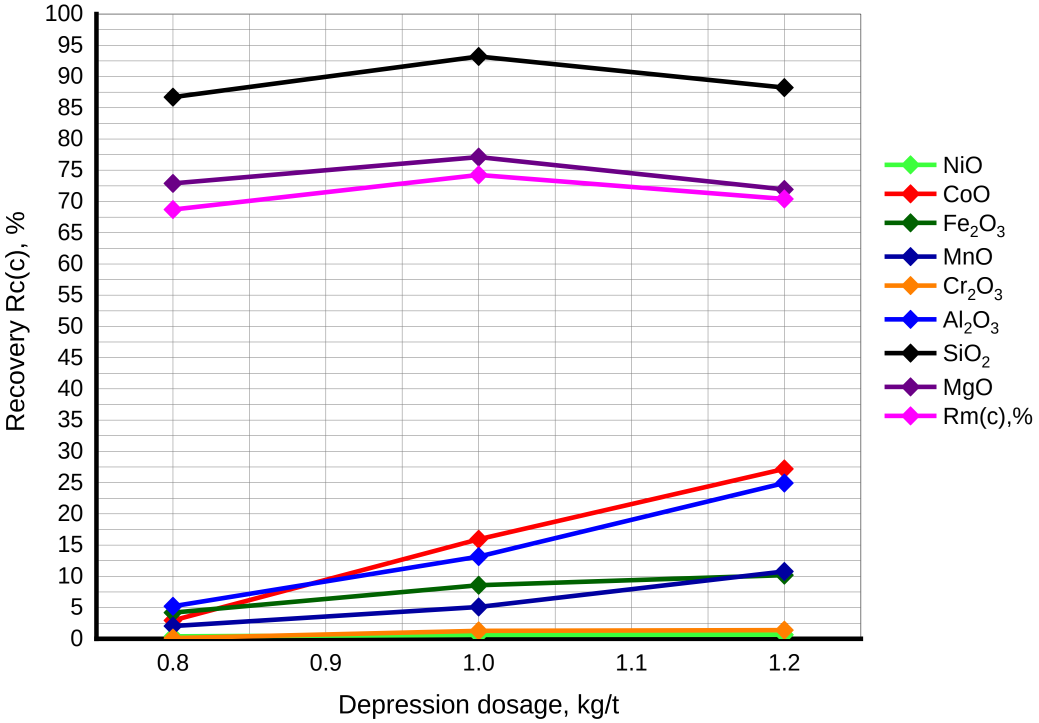

Figure 17: Component & mass recovery at different depressant dosages

As Table 8 and Figure 17 indicate, at a dosage of 0.8 kg/t in depression, the NiO recovery (Rc) is 7.34% and increases up to 18.93% when the dosage increases to 1.0 kg/t, while the dosage with 1.2 kg/t further raises the recoveries of NiO to 25.12%. The mass recovery was increased from 68.7% at 0.8 kg/t to 74.25% at 1 kg/t and declined to 70.40% at 1.2 kg/t. The CoO recovery in the concentrate is 8.58% at a depression dosage of 0.8 kg/t, & CoO recovery dramatically rises to 21.46% & 32.19% at 1 kg/t & 1.2 kg/t, respectively.

Iron oxide recovery in the concentrate at a depression dosage of 0.8 kg/t was 4.21%, and with the increase in dosage to 1 kg/t and 1.2 kg/t, it was increased to 8.59% and 10.19%. MnO recovery in the concentrate starts at 7.37% at a depression dosage of 0.8 kg/t. When dosage was increased to 1 kg/t, it significantly boosted MnO recovery to 14.75%. At the highest dosage of 1.2 kg/t, MnO recovery surges to 25.07%. This trend suggests that the higher dosages of depression significantly increase the recovery of MnO in flotation. The significant increase in the recovery of MnO at higher dosages indicates that the collector becomes more effective and hence increases the flotation of MnO particles.

Recovery of Cr_2O_3 in the concentrate starts off at 4.46% at a 0.8 kg/t depression dosage. At 1 kg/t, Cr_2O_3 recovery increases to 8.48%; at 1.2 kg/t, it rises to 17.41%. This clearly follows a trend that Cr_2O_3 recovery increased with an increase in the dosages. The recovery of Al_2O_3 in the concentrate was 22.62% at a depression dosage of 0.8 kg/t. It became 29.41% when the dosage increased to 1 kg/t. At a 1.2 kg/t dosage, the recoveries increase to 45.25%. Recovery of SiO_2 in the concentrate was high, starting at 86.23% at a depression dosage of 0.8 kg/t. When the dosage increases to 1 kg/t, SiO_2 recovery rises to 93.14%. For 1.2 kg/t, the SiO_2 recovery fell slightly to 87.29%. This trend has shown that SiO_2 recovery was generally high and may have fallen slightly with the rise in dosages. The high recovery in all dosages of SiO_2 indicates the efficiency of the collector towards SiO_2 particles.

With a 0.8 kg/t depression dosage, MgO recovery in the concentrate is 72.87%. When increasing the dosage to 1 kg/t, MgO recovery improves to 75.47%. At a higher dosage of 1.2 kg/t, MgO recovery decreases to 71.49%. This trend suggests MgO recoveries were generally high; however, it may show a slight decline at elevated dosages. High recovery of MgO at the optimal depressant dosages suggested strong flotation efficiency of the MgO.

The mass recovery at the beginning is 68.70% with a depression dosage of 0.8 kg/t, while increasing the dosages to 1.0 kg/t improves it to 74.25%, showing that this dosage was more efficient during flotation. However, further increase in the dosage at 1.2 kg/t resulted in a slight depression of mass recovery to 70.40%, revealing that too high a dosage reduces the overall flotation efficiency due to overcollection of unwanted minerals. Improvement in mass recovery at 1 kg/t indicates an optimal interaction of the depressant with the target minerals and hence increased recovery of the valuable oxides, including SiO_2 and MgO. The optimal dosage of depressant seems to be at 1 kg/t, where both SiO_2 and MgO show high recovery rates, and mass recovery are maximized. The result of component & mass recovery of oxides at different depressant dosages in Table 8 was agreed upon in [11, 96, 110, 112, 113].

$$Mass\ recovery\ of\ the\ concentrate = Rm(c) = 100 * \frac{C}{F}$$

$$Component\ recovery\ in\ concentrate = Rc(c) = 100 * \frac{C * c}{F * f}$$

$$Component\ recovery\ in\ tailing = Rc(t) = 100 * \frac{T * t}{F * f}$$

Where:

C	mass of concentrate, g
T	mass of tailings, g
F	mass of feed, g
c	assay of constituent in concentrate, %
t	assay of constituent in tailings, %
f	assay of constituent in feed, %
Rm(c)	mass recovery of concentrate, %
Rm(t)	mass recovery of tailings, %
Rc(c)	component recovery in concentrate, %
Rc(t)	component recovery in tailings, %

4.10. Effect of pH on assay in talc flotation test

The pH levels (10, 11, and 12) significantly affect the flotation process when other parameters are held constant (talc dosage: 200 g; flotation time: 10 minutes; depressant dosage: 1 kg/t; frother: 0.6 mL; collector: 1.2 kg/t).

Table 9: *Chemical analysis of the components in the flotation products of experiments at different pH values*

pH	Concentrate Assay (A_c), %								Tailing Assay (A_t), %							
	NiO	CoO	Fe_2O_3	MnO	Cr_2O_3	Al_2O_3	SiO_2	MgO	NiO	CoO	Fe_2O_3	MnO	Cr_2O_3	Al_2O_3	SiO_2	MgO
10	0.08	0.06	0.46	0.10	0.04	0.01	73.66	25.54	4.33	0.65	49.18	0.95	3.82	0.75	19.51	20.91
11	0.12	0.07	1.16	0.14	0.10	0.02	73.65	24.76	4.65	0.70	52.36	0.91	4.05	0.79	13.76	22.67
12	0.15	0.09	1.57	0.16	0.15	0.10	73.43	24.34	3.94	0.55	44.16	0.77	3.38	0.50	22.75	23.94

4.10.1. SiO_2 assay with pH in talc flotation test

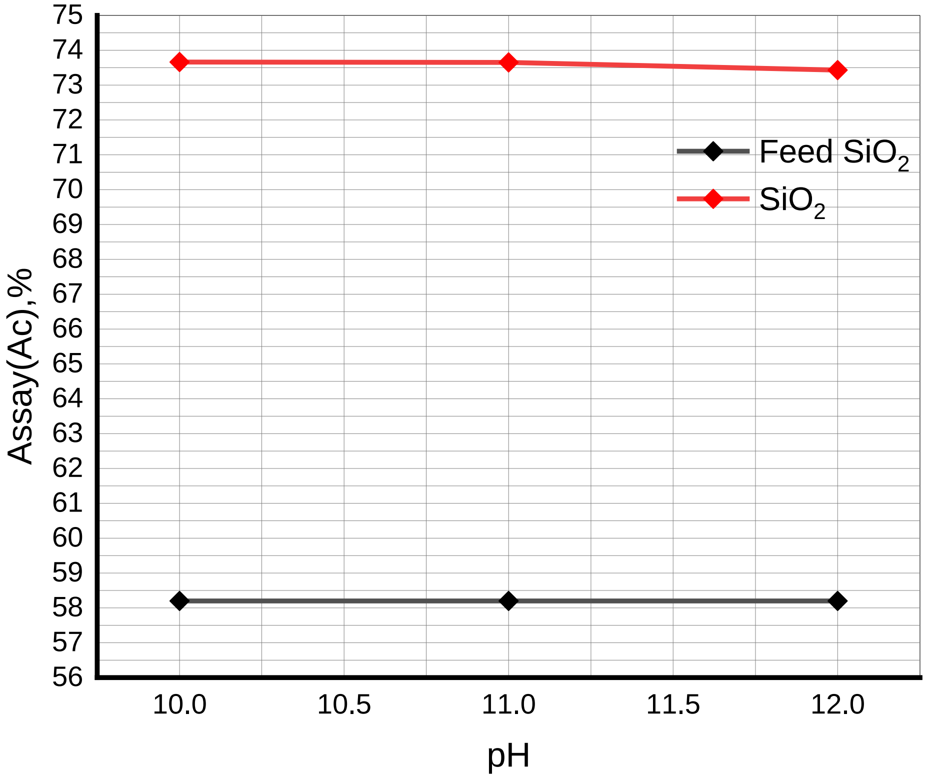

Figure 18: *Assay of SiO_2 at different pH values*

Table 9 and Figure 18 show the assays of SiO_2 73.66% at pH 10, reflecting efficient concentration and certainty that most silica fed is collected in the concentrate. At pH 11, a SiO_2 assay of 73.65% is closely related to the pH 10 concentration case, showing concentration remains effective under this condition also. At pH 12, assays of SiO_2 at 73.43% were a little decreased but were still effective, while the separation efficiencies had slightly fallen.

4.10.2. MgO assay with pH

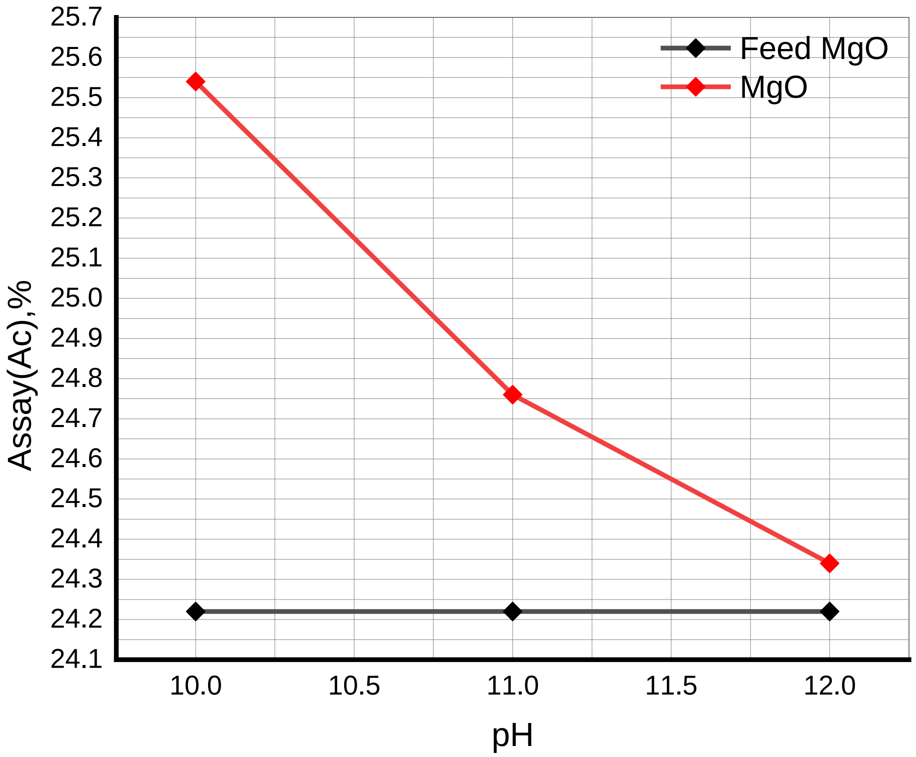

Figure 19: *Assay of MgO at different pH values*

At pH 10, the MgO assay of 25.54% reflects that the concentration efficiency of magnesium was efficient; hence, the flotation process successfully isolates this primary component of talc. At pH 11, the MgO assay of 24.76% indicated a slight decline in concentration efficiency compared to the pH 10 concentration but is effective. At pH 12, the 24.34% MgO assay is the lowest of the three pH values, which might be due to a further lowering of concentration efficiency, possibly as a result of less selective separation.

With the increase in pH, the surface of talc becomes more negative due to increased deprotonation of surface hydroxyl groups. This affects the adsorption of depressant by talc. At high values of pH, for instance, metal ions may precipitate as hydrophilic hydroxides, reducing the adsorption of depressant on talc surfaces. This may result in the decreased floatability of talc and valuable minerals such as SiO_2 and MgO due to the fact that they become less hydrophobic.

In addition, the increased pH increases the assay of some gangue minerals while simultaneously decreasing that of talc. Therefore, with an increased pH, although gangue minerals become more recoverable because of enhanced hydrophilicity, thereby reducing the competition for adsorption of the depressant, on the contrary, the valuable minerals lose their floatability because of their surface chemistry and with interactions involving the flotation reagent. This drop in valuable mineral assays in concentrates with increasing pH appears to be a consequence of the changes in mineral surface charges and altered depressant interactions that are unfavorable for assay of valuable minerals relative to gangue.

4.10.3. Iron Oxide (Fe_2O_3) assay with pH

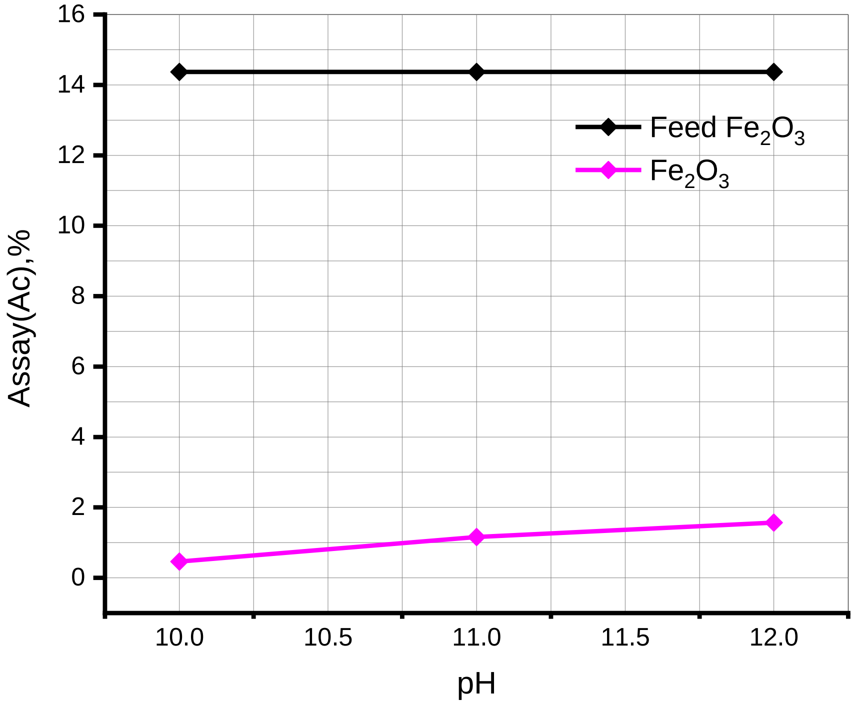

Figure 20: *Assay of Fe_2O_3 at different pH values*

From Table 9 and Figure 20, the lowest Fe_2O_3 content in the concentrate is 0.46% at pH 10, showing the highest separation efficiency. The Fe_2O_3 content in the concentrate increases to 1.16% with the increase in pH change to 11 and further increases to 1.57% at pH 12, reflecting low efficiency in the separation of this impurity.

4.10.4. Assay of concentrate and tailing constituents in flotation at different pH values

As presented in Table 9, at pH 10, the concentration assay for NiO is about 0.08%, meaning very good separation occurs. At a pH of 11, this assay increases to 0.12%, while at a pH of 12, it was raised to 0.15%. In the case of CoO, it is 0.06% at pH 10, 0.07% at pH 11, and 0.09% at pH 12. From this, the increase in CoO with increased pH reflects the reduced separation efficiency, hence increasing impurities due to cobalt oxide in the concentrates. MnO assays in the concentrate were 0.10% at pH 10, 0.14% at pH 11, and 0.16% at pH 12. The trend was upward. Higher pH appears to make the exclusion of MnO difficult, resulting in higher impurity levels in the concentrate. At pH 10, the Cr_2O_3 content is 0.04%; at pH 11, the content is 0.10%, while at pH 12, it is 0.15%. Increasing assays reflect a loss in separation efficiency at the higher pH values, with increasing chromium oxide impurities. The concentrate assay increases from 0.01% at pH 10 to 0.02% at pH 11 and 0.10% at pH 12 for Al_2O_3.

With the increase in pH, the deprotonation of hydroxyl groups on the surface of talc and other gangue minerals increases their negative surface charge further, thereby increasing the electrostatic repulsion between talc and these negatively charged gangue minerals, floating these gangue minerals while depressing the flotation of valuable minerals such as SiO_2 and MgO, perhaps due to some different surface characteristics at this high pH level. This leads, inevitably, to an increase in the gangue minerals' concentration within the flotation concentrate. Table 9 and figure 18, 19, & 20 indicates the effect of pH on the flotation of talc was agreed upon in [46, 73, 110, 118–120].

$$Assay\ concentrate = \frac{Mass\ of\ oxide\ in\ concentrate}{Mass\ of\ concentrate} * 100$$

$$Assay\ tailing = \frac{Mass\ of\ oxide\ in\ tailing}{Mass\ of\ tailing} * 100$$

4.11. Mass recoveries and component recoveries of flotation products at different pH values

Table 10: *Mass recoveries of flotation products and component recoveries of constituents of experiments performed at different pH values*

pH	Concentrate Component Recovery Rc(c), %								Rm (c)	Tailing Component recovery Rc(t), %								Rm (t)
	NiO	CoO	Fe_2O_3	MnO	Cr_2O_3	Al_2O_3	SiO_2	MgO	%	NiO	CoO	Fe_2O_3	MnO	Cr_2O_3	Al_2O_3	SiO_2	MgO	%
10	4.25	19.31	2.30	20.65	2.68	2.26	90.43	75.35	71.45	95.44	79.40	97.68	79.65	97.32	97.29	9.57	24.65	28.55
11	6.96	21.46	5.98	30.97	6.70	6.79	93.90	75.85	74.20	92.74	77.25	93.99	69.32	93.30	92.76	6.10	24.15	25.80
12	8.11	27.90	7.65	32.45	9.38	31.67	88.26	70.29	68.45	91.58	70.82	92.32	67.85	90.63	67.87	11.74	29.71	31.55

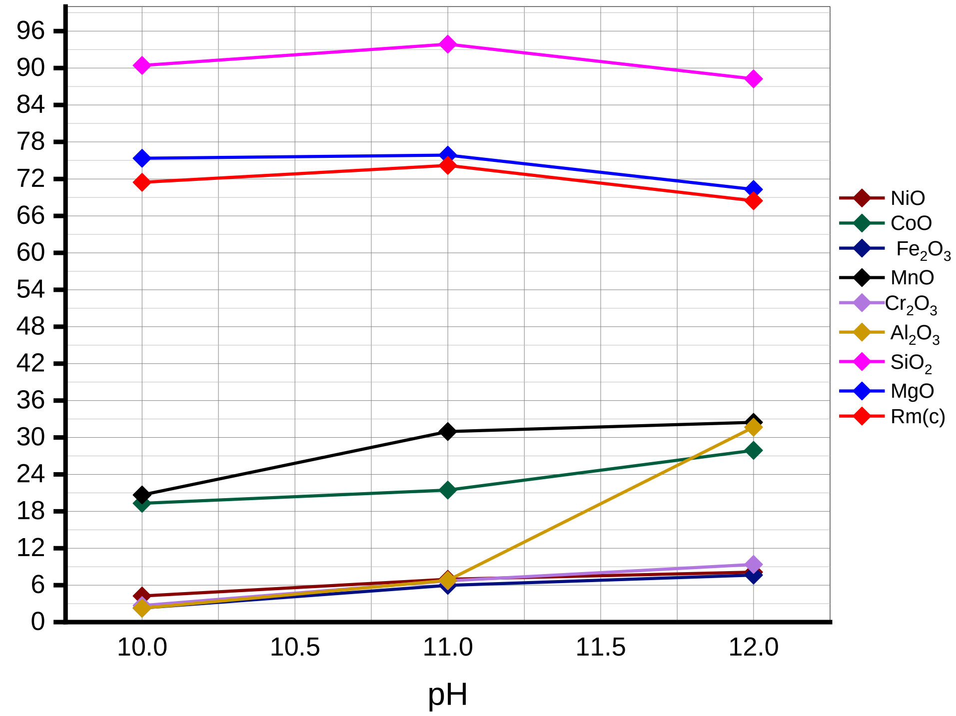

Figure 21: *Component & mass recovery of flotation product at different pH values*

As it was shown in Table 10 and Figure 21, SiO_2 recovery at pH 10 was 90.43% and MgO recovery at pH 10 is 75.35%, which indicates very efficient concentration with respect to the target oxides. Such high values indicate that this flotation process was quite effective in isolating valuable minerals. The recovery rates for the gangue minerals are relatively lower: NiO 4.25%, CoO 19.31%, Fe_2O_3 2.30%, MnO 20.65%, Cr_2O_3 2.68% and Al_2O_3 2.26% with 71.45% mass recovery. At pH 11, recovery percentages for target oxides are marginally greater: SiO_2 (93.90%) and MgO (75.85%). This clearly means that a concentration process was more effective than the one at pH 10. The Rm(c) percentage for SiO_2 was 74.2 %, which proves that most of the target oxides are concentrated. The decline is notable for pH 12; SiO_2 has a recovery of 88.26% and MgO 70.29% with 68.45% mass recovery. The best pH for the maximum recovery of oxides was at about 11, while improved recoveries of SiO_2 and MgO and higher values of NiO and CoO occurred at more acidic pH.

The crystals of talc have hydrophobic faces and hydrophilic edges. Bubbles attach to hydrophobic faces. The high pH values in particle dissolution may result in the adsorption of hydrolyzed species with high air bubble repulsion that affects the overall charge. Table 10 and Figure 21 shows component & mass recovery at different pH values of talc flotation test was agreed with [46, 91, 110, 121–123].

$$\text{Mass recovery of the concentrate} = \text{Rm(c)} = 100 * \frac{\text{C}}{\text{F}}$$

$$\text{Component recovery in concentrate} = \text{Rc(c)} = 100 * \frac{\text{C}*\text{c}}{\text{F}*\text{f}}$$

$$\text{Component recovery in tailing} = \text{Rc(t)} = 100 * \frac{\text{T} * \text{t}}{\text{F} * \text{f}}$$

Where:

C	mass of concentrate, g
T	mass of tailings, g
F	mass of feed, g
c	assay of constituent in concentrate, %
t	assay of constituent in tailings, %
f	assay of constituent in feed, %
Rm(c)	mass recovery of concentrate, %
Rm(t)	mass recovery of tailings, %
Rc(c)	component recovery in concentrate, %
Rc(t)	component recovery in tailings, %

4.12. Effect of pulp density on assay in talc flotation test

The pulp density, at which the test was conducted with similar conditions of pH 11, flotation time of 10 minutes, frother dosage of 0.6 mL, depressant dosage of 1 kg/t, and collector dosage of 1.2 kg/t, was at 150, 200, and 250 kg/t, influencing the efficiency of flotation by changing the properties of the suspension of the mineral particles.

Table 11: *Chemical analysis of the components in the flotation products of experiments at different pH values*

Pulp density (g/L)	Concentrate Assay (A_c), %								Tailing Assay (A_t), %							
	NiO	CoO	Fe_2O_3	MnO	Cr_2O_3	Al_2O_3	SiO_2	MgO	NiO	CoO	Fe_2O_3	MnO	Cr_2O_3	Al_2O_3	SiO_2	MgO
150	0.17	0.04	0.63	0.06	0.04	0.01	73.90	25.16	3.81	0.67	45.26	0.97	3.55	0.69	22.92	22.10
200	0.19	0.06	2.42	0.09	0.07	0.11	72.41	24.68	4.45	0.72	48.65	1.06	4.14	0.54	17.43	22.90
250	0.40	0.10	2.67	0.16	0.10	0.15	72.02	24.40	2.97	0.48	36.17	0.68	3.02	0.36	32.44	23.88

4.12.1. Silicon Dioxide (SiO_2) assay with different pH values

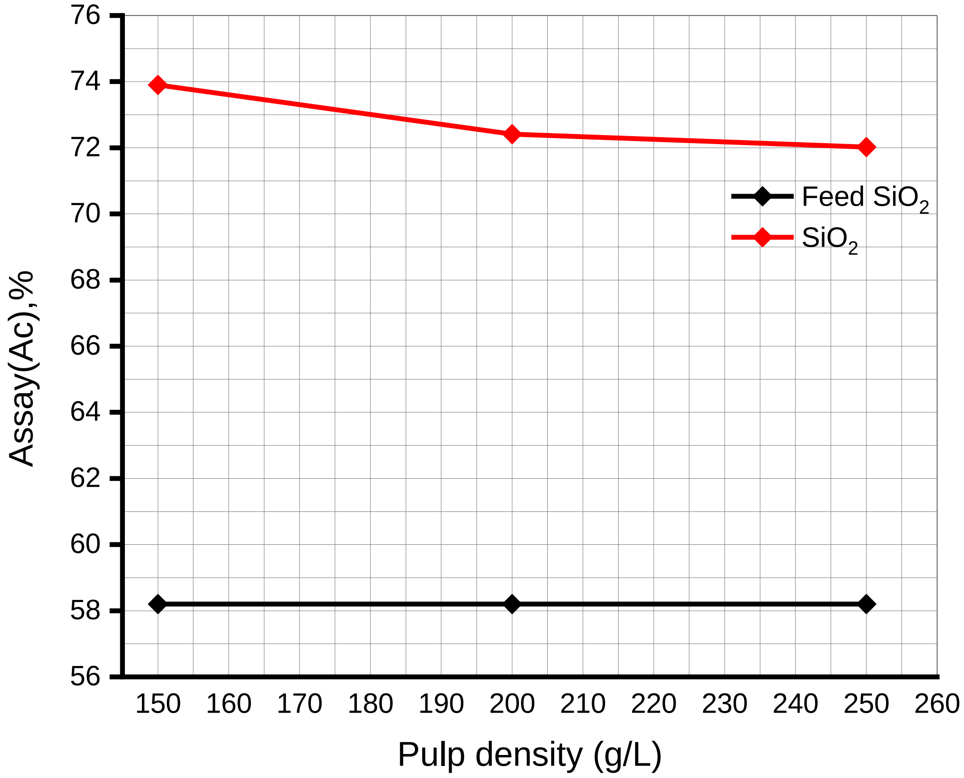

Figure 22: *Assay of SiO_2 at different pulp densities*

As it was shown in Table 11 and Figure 22, at 150 g/L, the high SiO_2 assay of 73.90% means that the flotation process works efficiently to concentrate silica, most of which is talc. This would mean that the silica contained in the feed is mostly separated and collected in the concentrate. The SiO_2 assays have subsequently dropped to 72.41% and 72.02% at 200 g/L and 250 g/L, respectively. While these values are actually pretty high, there is a slight fall in concentration efficiency with an increase in pulp density. This decrease could be attributed to a less selective separation process at high pulp densities [99, 124, 125].

4.12.2. Magnesium Oxide (MgO) assay with different pH value

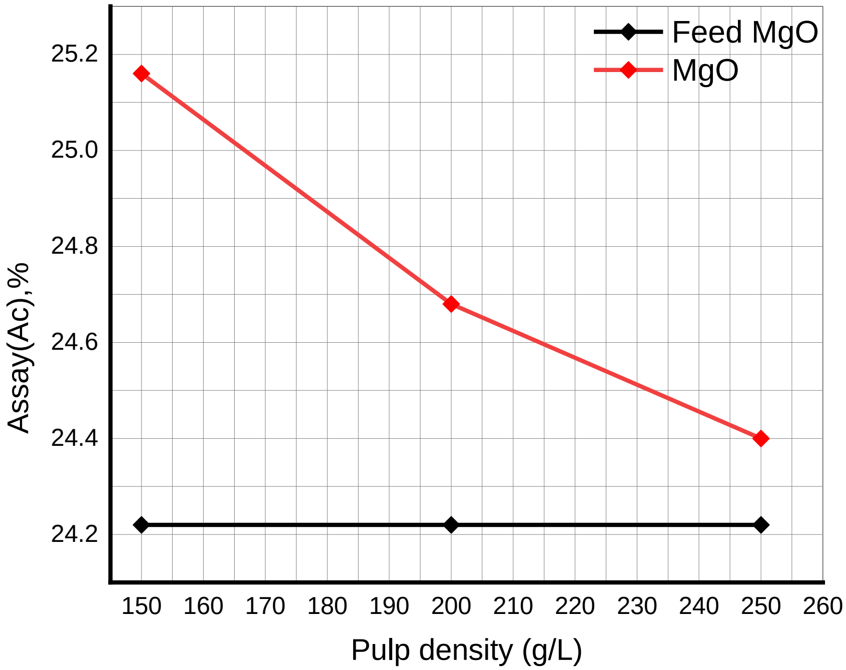

Figure 23: *Assay of MgO at different pulp densities*

As it was shown in Table 11 and Figure 23, the corresponding MgO assay of 25.16% at 150 g/L indicates an efficient concentration of magnesium, another major element of talc. This high value shows that the majority of the magnesium is efficiently removed in the concentrate, as confirmed by its high-quality performance. The MgO numbers get lower from 24.68% down to 24.40% at 200 g/L and 250 g/L, respectively. Like SiO_2, the concentration efficiency slightly drops with the increase in pulp density, which indicates higher pulp densities have less selective separation and lower-grade concentrates [73, 85, 91, 126].

4.12.3. Iron oxide (Fe_2O_3) assay with pulp densities

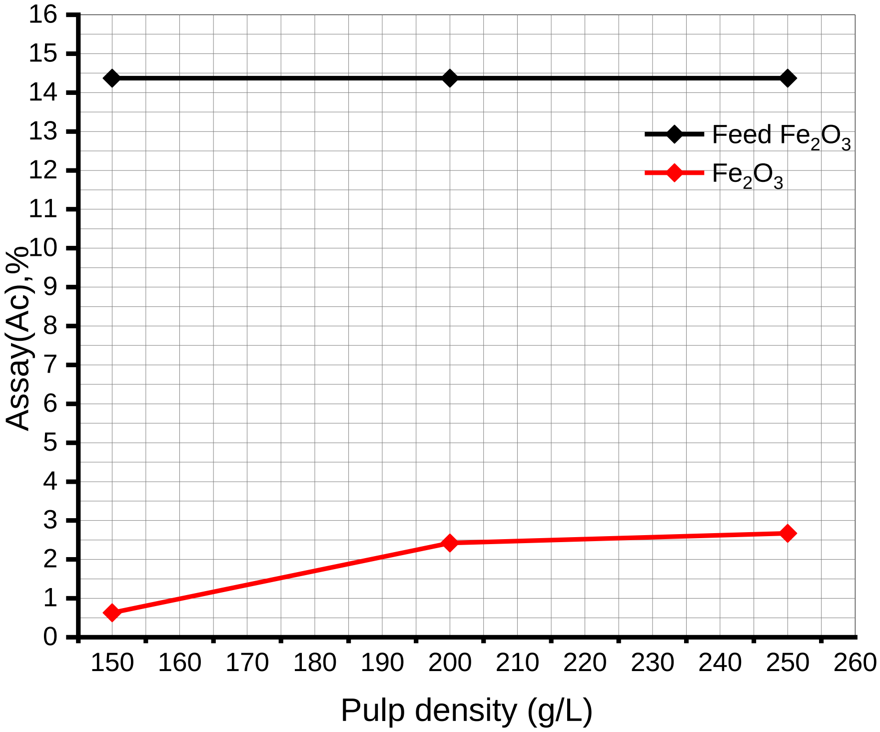

Figure 24: *Assay of Fe_2O_3 at different pulp densities*

As it was shown in Table 11 and Figure 24, at 150 g/L, the assay of Fe_2O_3 in the concentrate was 0.63%. At 200 g/L, the assay of Fe_2O_3 in the concentrate rises remarkably to 2.42%. With an increased presence of Fe_2O_3, the quality of the concentrate is compromised, which is indicative that 200 g/L is the less effective pulp density in the separation of this gangue mineral. At 250 g/L, the Fe_2O_3 assay in the concentrate is 2.67%, the highest among the three conditions.

4.12.4. Effect of pulp density on assay of other oxides

From Table 11 & Figure 22, 23 & 24, the gangue mineral assays NiO (0.17%), CoO (0.04%), MnO (0.06%), Cr_2O_3 (0.04%), and Al_2O_3 (0.01%) on 150 g/L pulp density, it was 0.19%, 0.06%, 0.09%, 0.07%, and 0.11% on 200 g/L pulp density, respectively, while it was 0.40%, 0.10%, 0.16%, 0.10%, and 0.15% at 250 g/L, respectively. An increase in pulp density from 150 to 250 g/L for talc flotation tests was associated with a higher assay of gangue minerals such as NiO, CoO, Fe_2O_3, MnO, Cr_2O_3, and Al_2O_3, largely due to an improved settlement and aggregation of these minerals as pulp densities are increased. The process of flotation is more effective at lower pulp densities regarding talc assay, while at high density, increased solid content results in enhanced interaction among particles, leading to the entrapment of gangue minerals within the talc matrix. Also, talc and gangue minerals change their surface properties, increasing the hydrophilicity of some gangue components and their subsequent flotation, thus accounting for assays for such minerals rising with an increase in pulp density. Table 11 shows component assay value at different pulp density [10, 11, 46–48, 91, 125].

$$Assay\ concentrate = \frac{Mass\ of\ oxide\ in\ concentrate}{Mass\ of\ concentrate} * 100$$

$$Assay\ tailing = \frac{Mass\ of\ oxide\ in\ tailing}{Mass\ of\ tailing} * 100$$

4.13. Component & mass recovery at different pulp densities

Table 12: *Chemical analysis of the component recovery in the flotation products of experiments at different pulp densities*

Pulp density (g/L)	Concentrate Component Recovery Rc(c), %								Rm (c)	Tailing Component recovery Rc(t), %								Rm(t)
	NiO	CoO	Fe_2O_3	MnO	Cr_2O_3	Al_2O_3	SiO_2	MgO	%	NiO	CoO	Fe_2O_3	MnO	Cr_2O_3	Al_2O_3	SiO_2	MgO	%
150	9.27	11.44	3.01	11.80	2.38	3.02	87.87	71.90	69.20	90.67	88.70	96.99	88.50	97.62	96.53	12.13	28.10	30.80
200	10.82	19.31	12.49	19.17	4.46	36.20	92.26	75.56	74.15	88.87	79.40	87.49	81.12	95.54	63.35	7.74	24.44	25.80
250	20.09	27.44	12.11	30.68	5.71	43.44	80.54	65.57	65.08	80.06	72.04	87.89	69.62	94.29	56.11	19.46	34.43	34.92

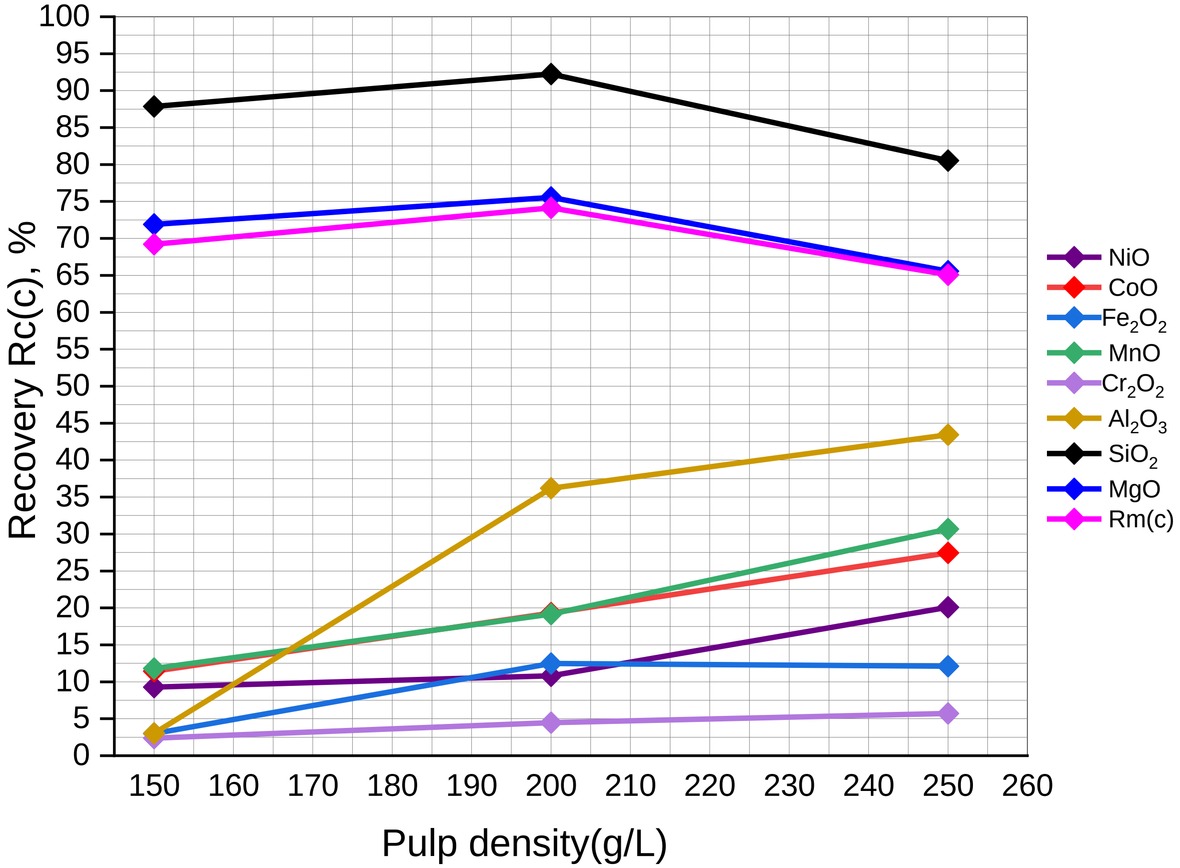

Figure 24: *component & mass recovery at different pulp densities*

In addition, the recovery of target oxides SiO_2 and MgO in pulp density 150 g/L is about 87.87% and 71.90%, respectively. This indicates that the flotation process concentrates the valuable components of talc. High recoveries mean good separations, implying that a majority of the main components of talc are thus recovered in the concentrate. However, gangue minerals show relatively low recoveries: NiO (9.27%), CoO (11.44%), Fe_2O_3 (3.01%), MnO (11.80%), Cr_2O_3 (2.38%), Al_2O_3 (3.02%). This is desirable because it shows that unwanted materials are effectively separated from the valuable minerals, making a purer concentrate.

For the pulp density of 200 g/L, the recovery rates for the target oxides SiO_2 (92.26%) and MgO (75.56%) are even higher than those at 150 g/L. This indicates an enhanced efficiency in concentrating the valuable components of talc. However, there is also a significant increase in the recovery rates of gangue minerals: NiO (10.82%), CoO (19.31%), Fe_2O_3 (12.49%), MnO (19.17%), Cr_2O_3 (4.46%), Al_2O_3 (36.20%).

At a pulp density of 250 g/L, target oxides such as SiO_2 (80.54%) and MgO (65.57%) have poor recovery rates with respect to all other conditions. In other words, the concentration of these valuable elements is not very effective. The recoveries of the gangue minerals are also fairly high: NiO (20.09%), CoO (27.44%), Fe_2O_3 (12.11%), MnO (30.68%), Cr_2O_3 (5.71%), and Al_2O_3 (43.44%). These elevated values indicate a considerable presence of impurities in the concentrate, suggesting a less efficient separation process at this higher pulp density. As shown in Table 12 and Figure 24 the component and mass recovery of talc at different pulp densities was agreed into in [1, 10, 11, 110, 127].

$$\mathit{Mass\ recovery\ of\ the\ concentrate} = Rm(c) = 100 * \frac{C}{F}$$

$$\mathit{Component\ recovery\ in\ concentrate} = Rc(c) = 100 * \frac{C * c}{F * f}$$

$$\mathit{Component\ recovery\ in\ tailing} = Rc(t) = 100 * \frac{T * t}{F * f}$$

Where:

C	mass of concentrate, g
T	mass of tailings, g
F	mass of feed, g
c	assay of constituent in concentrate, %
t	assay of constituent in tailings, %
f	assay of constituent in feed, %
Rm(c)	mass recovery of concentrate, %
Rm(t)	mass recovery of tailings, %
Rc(c)	component recovery in concentrate, %
Rc(t)	component recovery in tailings, %

5. Conclusion

The project on talc beneficiation using flotation techniques in the Sidama Regional State of Ethiopia showed some prospects of improving the quality of talc sourced locally. In this study, determination of optimal parameters of flotation, such as pH, collector dosage, and depressant dosage, was aimed at improving recovery and purity of the talc concentrates. The laboratory experiments with the froth flotation process indeed proved quite enlightening in bringing into clear vision how different parameters vary with recovery of valuable oxides namely SiO_2 and MgO, and amounts of non-valuable oxides. The experiments showed that under optimum conditions, the pH was 11, the collector dosage was 1.2 kg/ton, and the depressant dosage was 1.0 kg/ton, maintaining the pulp density at 200 g/l and an impeller speed of 1100 rpm. Under these conditions, the talc recovery was 74.25% in the flotation process. The chemical analysis of the resulting talc concentrate showed significant improvements: SiO_2 increased from 58.2% to 73.01%, while MgO increased from 24.22% to 24.62%. The Fe_2O_3 content decreased remarkably from 14.37% to 1.66%, reflecting a successful removal of impurities and a substantial increase in the purity of the final product. The results showed that the collector dosage of 1.2 kg/t the best recovery rates, while the concentrate component recoveries of gauge mineral decreased, proving that the selected dosage had a good effect on enhancing the hydrophobicity of valuable minerals. Also the depressants were used to selectively depress the non-valuable oxides during flotation. A dosage of 1 kg/t significantly improved the recovery of valuable components and suppressed the unwanted minerals using depressants, demonstrating the effectiveness of depressants in enhancing mineral selectivity. Besides, the changes in pulp density looked quite promising; at a concentration of 200 g/L, the recovery rates for SiO_2 and MgO reached a maximum and allowed for an optimal balance in the mineral suspension and bubble attachment efficiency. Further control was given through the pH of the medium: the best recovery metrics could be obtained for a pH of 11 from all the tested parameters. By focusing on parameters such as pH, collector dosage, and depressant dosage, the study provides valuable information that can be utilized to improve the overall quality and performance of talc in industrial applications.

6. Recommendation

The talc flotation project in Ethiopia has enormous opportunities for further academic and industrial work. Further research work should be concentrated on the optimization of flotation parameters from the preliminary results obtained by trying different collectors and depressants to achieve higher purity and recovery values of talc. Further, a study on environmental impacts of mining and processing of talc should be done as the sustainability of industries is increasingly being required. It is also possible that collaborations could be made with local industries for the practical application of research output to assure regional economic development while the quality of talc meets international standards for various industrial uses.

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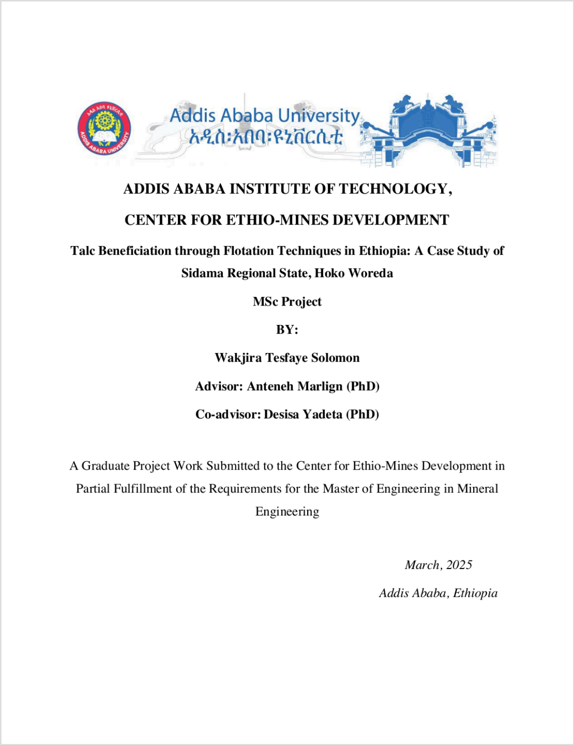

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Talc Beneficiation through Flotation Techniques in Ethiopia: A Case Study of Sidama Regional State, Hoko Woreda

MSc Project

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