BENEFICIATION OF SPODUMENIC ROCK FROM LADE , KWARA STATE , FOR RECOVERY OF LITHIUM AND SOME OTHER CRITICAL MINERALS

BY

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HND/23/MNE/FT/0003

SUBMITTED TO

THE DEPARTMENT OF MINERAL AND PETROLEUM RESOURCES ENGINEERING TECHNOLOGY, INSTITUTE OF TECHNOLOGY, KWARA STATE POLYTECHNIC, ILORIN

IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF HIGHER NATIONAL DIPLOMA (HND) IN MINING ENGINEERING TECHNOLOGY

JULY 2025

CERTIFICATION

This is to certify that this project was written by Soliu Monsurat Bisola with Matriculation Number HND/23/MNE/FT/0003and submitted to the Department Of Minerals and Petroleum Resources Engineering Technology, Kwara State Polytechnic Ilorin, In Partial Fulfillment of The requirement Of Higher National Diploma in Mining Engineering Technology.

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DEDICATION

I dedicate this project work to almighty God for his sufficient mercy over me throughout the course of the project

ACKNOWLEDGEMENT

My profound gratitude goes to Almighty Allah, who has been the source of our strength and breath since these years.

I want to appreciate my supervisor Dr. Engr Olatunji K.J, for his assistance he rendered to me during my project. I want to say a big thanks to you, may God bless you abundantly.

To my loving parents, Mr & Mrs Soliu, I would forever be grateful to you for your love, care, moral, financial and spiritual support. May Almighty Allah bless you. I would also love to appreciate for all his love, care and support. I say a very big thank you Adebayo Abdulrasaq my bestie may Almighty Allah bless you abundantly Amin.

My acknowledgement would not be completed without appreciating Hon. Mohammed Jamiu Issa and all lecturers of Mineral and Petroleum Engineering Technology for impacting so much in me in knowledge, attitude and characters. am very grateful.

ABSTRACT

This research explores the mineral processing potential of spodumenic rock sourced from the Lade region in Kwara State, Nigeria, with an emphasis on extracting critical industrial minerals. A series of beneficiation experiments were carried out utilizing froth flotation techniques. The flotation protocol employed sodium oleate as the primary collector, calcium chloride as an activating agent, and sodium silicate as a selective depressant. Despite the target mineral lithium not being identified in the ore body during analytical testing, post-flotation chemical assessments showed significant enrichment in silicate-based minerals.

The upgraded concentrates were predominantly composed of silicon dioxide (SiOz), aluminum oxide (AlzO3), and ferric oxide (FezO3), with minor traces of additional oxides. These findings suggest a promising application of the processed materials in various industrial sectors such as ceramics, metallurgy, and glass manufacturing. Although lithium recovery was unachievable in this specific context, the study confirms the economic relevance of the Lade deposit and encourages continued research into its broader mineral potential and utilization.

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CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

In the modern world, the demand for lithium and other critical minerals has surged significantly due to their indispensable roles in renewable energy, electric vehicles (EVs), electronics, and battery technologies. Lithium, in particular, is often referred to as the "white gold" of the 21st century because of its extensive application in lithium-ion batteries that power most modern electronics and EVs. As the global economy gradually transitions to low-carbon energy systems, the importance of developing sustainable sources of lithium and critical minerals has never been more paramount (Grosjean *et al.,* 2012).

Spodumene ($LiAlSi_2O_6$) is the most commercially important lithium-bearing mineral and occurs primarily in pegmatite ores. It contains one of the highest concentrations of lithium among available minerals, making it a vital source for lithium extraction. However, the direct use of raw spodumene ore is economically and technically infeasible due to the presence of gangue minerals such as quartz, feldspar, and mica. Therefore, beneficiation—a process that improves the economic value of ore by removing impurities—is necessary to increase the lithium content before metallurgical processing (Abaka-Wood *et al*., 2017).

Beneficiation methods commonly used for spodumene include gravity separation, magnetic separation, dense media separation (DMS), and most effectively, froth flotation. Among these, froth flotation is widely recognized for its efficiency in selectively separating spodumene from associated gangue minerals such as quartz, feldspar, and mica (Moon & Fuerstenau, 2021; Zhu *et al.,* 2020). This makes the process suitable for industrial application in lithium extraction from hard rock sources like pegmatite.

The efficiency of beneficiation techniques, especially flotation, depends on several critical parameters such as reagent type and dosage, particle size distribution, pulp temperature, and pH level. These parameters affect the surface chemistry and hydrophobicity of spodumene particles, thereby influencing flotation selectivity and recovery (Zhou et al., 2022; Xie *et al.,* 2024).

In Nigeria and across Africa, many spodumene-bearing pegmatites remain underexplored and underutilized. Recent geological surveys have confirmed lithium occurrences in pegmatite belts in Kwara, Nasarawa, Kogi, Ekiti, and Oyo states, with Li_2O grades ranging from 1% to over 3% (Olade, 2025). A more strategic and science-based approach to beneficiation could unlock these mineral resources, reduce Nigeria's dependence on imported lithium, and contribute meaningfully to the global lithium supply chain (Oladipo *et al.* 2024).

1.2 Aims and Objectives

The aim of this research is to explore the beneficiation of spodumene-rich rock with the goal of maximizing lithium recovery and identifying any associated critical minerals of economic importance.

Specific Objectives:

- To investigate the occurrence and distribution of lithium and other critical minerals in the rock.

- To apply froth flotation techniques for the beneficiation of spodumene ore for The efficiency of beneficiation based on lithium grade and recovery.

1.3 Statement of the Problem

Despite the growing global demand for lithium, many spodumene-rich deposits remain underutilized due to technical, infrastructural, and economic limitations. In Nigeria, although pegmatite bodies containing spodumene are found in regions such as Oyo, Nasarawa, and Kwara states, their exploitation remains minimal. A major bottleneck is the lack of efficient and sustainable beneficiation technologies that can recover lithium in high purity and concentration.

Another pressing issue is the lack of comprehensive data on the mineralogical and chemical characteristics of Nigerian spodumene ores.This work will help to overcome it is difficulty in design and optimization of effective beneficiation flowsheets. Additionally, the presence of other valuable critical minerals such as beryllium, tantalum, and niobium, is often overlooked in spodumene beneficiation, though they may offer added value if properly identified and recovered.

1.4 Justification

This study is timely and relevant for several reasons:

- Strategic Mineral Development: With the Nigerian government's focus on mineral diversification away from petroleum, lithium and other critical minerals offer promising revenue streams. This study supports National Mineral Development policies.

- Global Demand: As lithium demand continues to surge, Nigeria can position itself as a significant player in the global lithium market if proper beneficiation and recovery processes are implemented.

- Technological Advancement: The beneficiation techniques assessed in this study—especially froth flotation—are aligned with global best practices and will serve as a benchmark for future mineral processing studies in the region.

- Environmental and Economic Benefits: Proper beneficiation minimizes environmental waste and maximizes economic returns by enabling the efficient recovery of lithium and other valuable minerals.

1.5 Scope of the Study

This study focuses on the beneficiation of spodumenic rocks obtained from a designated pegmatite-rich area in Nigeria. The study covers, sample collection and geological characterization, chemical and mineralogical analysis of spodumenic ore, froth flotation beneficiation to improve lithium concentration, assessment of composition grade before and after beneficiation and identification of other associated critical minerals.

1.6. **Limitation Of Study**

This study is limited to the beneficiation of spodumenic rock from LADE ,for recovery of lithium and some other critical minerals.The Froth Flotation method will be adopted

CHAPTER TWO

LITERATURE REVIEW

2.1 Physical and Chemical Properties of Lithium and Other Critical Minerals

Lithium is an alkali metal with the symbol Li and atomic number 3. It is the lightest metal and exhibits high electrochemical potential, low density, and excellent thermal and electrical conductivity. These properties make lithium ideal for use in high-energy-density rechargeable batteries, which are crucial to electric vehicles (EVs), mobile devices, and grid storage systems (Kesler *et al.,* 2012).

Lithium is typically extracted from two major sources: brines and hard rock ores. Among the latter, spodumene ($LiAlSi_2O_6$), a pyroxene mineral, is the most significant. Spodumene has a lithium content of around 3.73% in its pure form. It is usually found alongside other silicate minerals like quartz, feldspar, and mica (Jaskula, 2021).

Other critical minerals often associated with spodumene-rich pegmatites include:

- Tantalum (Ta): Used in electronics and aerospace.
- Niobium (Nb): Applied in steel and superalloys.
- Beryllium (Be): Valued for its stiffness and thermal stability.
- Cesium (Cs) and Rubidium (Rb): Found in trace amounts and used in specialty glasses and drilling fluids.

These associated elements, including feldspar, mica, quartz, tantalum, and iron oxides, can significantly influence the beneficiation process. While some may enrich the concentrate and increase the economic value of the ore, others can complicate the separation process due to overlapping physical and chemical properties (Fuerstenau et al., 2018; Zhang *et al.,* 2020). The presence of iron-bearing minerals, for instance, can interfere with spodumene flotation due to similar surface chemistry under certain pH conditions.

Proper reagent selection and process optimization are therefore crucial in ensuring effective separation of spodumene from its gangue and associated minerals. If not adequately addressed, these elements can either lead to dilution of the final concentrate or increased reagent consumption, making the process less efficient (Liu *et al.,* 2022).

2.2 Formation and Occurrence of Lithium and Other Critical Minerals

Spodumene, one of the principal lithium-bearing minerals, typically forms under high-temperature conditions within granitic pegmatites — coarse-grained igneous rocks that crystallize in the late stages of magma cooling (Černý, 1991; Bradley et al., 2017). These pegmatites belong to the Lithium-Cesium-Tantalum (LCT) family and are often enriched in rare elements like beryllium, niobium, tin, and rubidium.

LCT pegmatites serve as economically important sources of multiple critical minerals and are globally distributed in regions like Australia, Canada, Brazil, and parts of Africa, including Nigeria (Evans, 2023). Their geological complexity offers a unique opportunity for multi-mineral beneficiation, provided that separation technologies are adapted to the diverse mineral assemblage present.

In Nigeria, known lithium-bearing pegmatite belts in Kwara, Kogi, Nasarawa, and Ekiti states have been found to contain not only spodumene but also economically significant quantities of feldspar, quartz, mica, and columbite, among others (Oladipo et al., 2024). These occurrences highlight the need for integrated beneficiation approaches that can recover multiple products efficiently.

2.3 Industrial Applications of Lithium and Other Critical Minerals

Lithium has become one of the most strategic critical minerals in the 21st century due to its central role in the global energy transition. It is essential for decarbonization technologies, especially in energy storage and electric mobility (USGS, 2023; IEA, 2022). The primary industrial applications of lithium include:

- Rechargeable Lithium-ion Batteries: This is currently the largest and fastest-growing use of lithium. Li-ion batteries are widely used in electric vehicles (EVs), laptops, smartphones, power tools, and renewable energy storage systems (Global Battery Alliance, 2023). Demand from the battery sector accounts for over 70% of total lithium consumption globally.

- Glass and Ceramics: Lithium compounds (especially lithium carbonate and lithium oxide) improve thermal shock resistance, mechanical strength, and melting behavior in ceramics and specialty glassware. These properties are valuable in products such as ovenware, cooktops, mobile device screens, and glazed tiles (Evans, 2020).

- Lubricating Greases: Lithium hydroxide is used to produce lithium-based greases, which offer high water resistance, oxidation stability, and superior performance at high temperatures. These greases are extensively used in automotive, aerospace, and industrial machinery applications (Roskill, 2021).

- Aluminum-Lithium Alloys: Lithium is alloyed with aluminum to create stronger, lighter materials used in aircraft, spacecraft, and military applications. These alloys reduce the density of materials while improving fatigue resistance and stiffness, which is essential for the aerospace sector (Nazari *et al.,* 2018).

- Beryllium: Used in X-ray windows, nuclear reactors, and aerospace applications.

Recognizing the multi-functional uses of these minerals highlights the importance of effective beneficiation processes that maximize their recovery (USGS, 2021).

2.4 Froth Flotation of Lithium Ore

Froth flotation is a widely used method for beneficiating lithium-bearing minerals, especially spodumene. The principle of flotation involves selectively altering the surface properties of minerals to render them hydrophobic (water-repelling) or hydrophilic (water-attracting), enabling separation based on differences in wettability.

In spodumene flotation, collectors, depressants, activators, and frothers are used:

- Collectors: Fatty acids (e.g., oleic acid) or hydroxamic acids are used to selectively float spodumene.

- Depressants: Sodium silicate or starch can suppress the flotation of quartz and feldspar.

- pH Control: Typically, alkaline conditions (pH ~7–9) enhance the flotation of spodumene.

- Temperature: Higher temperatures (above 80°C) are often required to convert spodumene from α-phase to β-phase to improve floatability.

Flotation has proven successful in pilot and industrial plants. For example, the Greenbushes mine in Australia and some facilities in China rely extensively on flotation for spodumene concentration (Zhang *et al.,* 2020).

CHAPTER THREE

MATERIALS AND METHOD

3.1 Description of Study Area

Lithium ore samples was collected from deposit at Lade , Pategi Local Government Area of Kwara state . Lade is a rural community located in the Pategi Local Government Area of kwara state, Nigeria. The area is predominantly inhabited by the Nupe speaking people, who have traditionally England in farming as their primary occupation. In recent years, Lade has experienced a significant shift in its economic activities due to the discovery of lithium deposits in the region, this has led many residents to transit from farming to artisanal mining.

This transformation has turned Lade into a notable site for lithium extraction, attracting attention from various stake holders interested in the minerals potential. The climate of the area Lade; located in the Guinea Savannah zone of Nigeria, experiences a tropical Savanah climate characterized by two main seasons which are rainy season : April to October and dry season : November to March , average annual rainfall is around 1000 to 1500mm. The natural vegetation is that of the Guinea Savannah, featuring tall grasses and scattered trees, during the rainy season, the area becomes lush and green, while the dry season brings browner, sparser vegetation due to moisture loss .

However, recent Mining in Lade have started to impact the natural landscape and may lead to gradual vegetation degradation if not managed sustainably. Geographically it lies at approximately on 8.7589%N latitude and 5.616 longitude, with an elevation of about 83 meters (272 feet) above sea level(Geonames,2024).

Fig 3.1 shows map of Kwara state showing the location of Lade

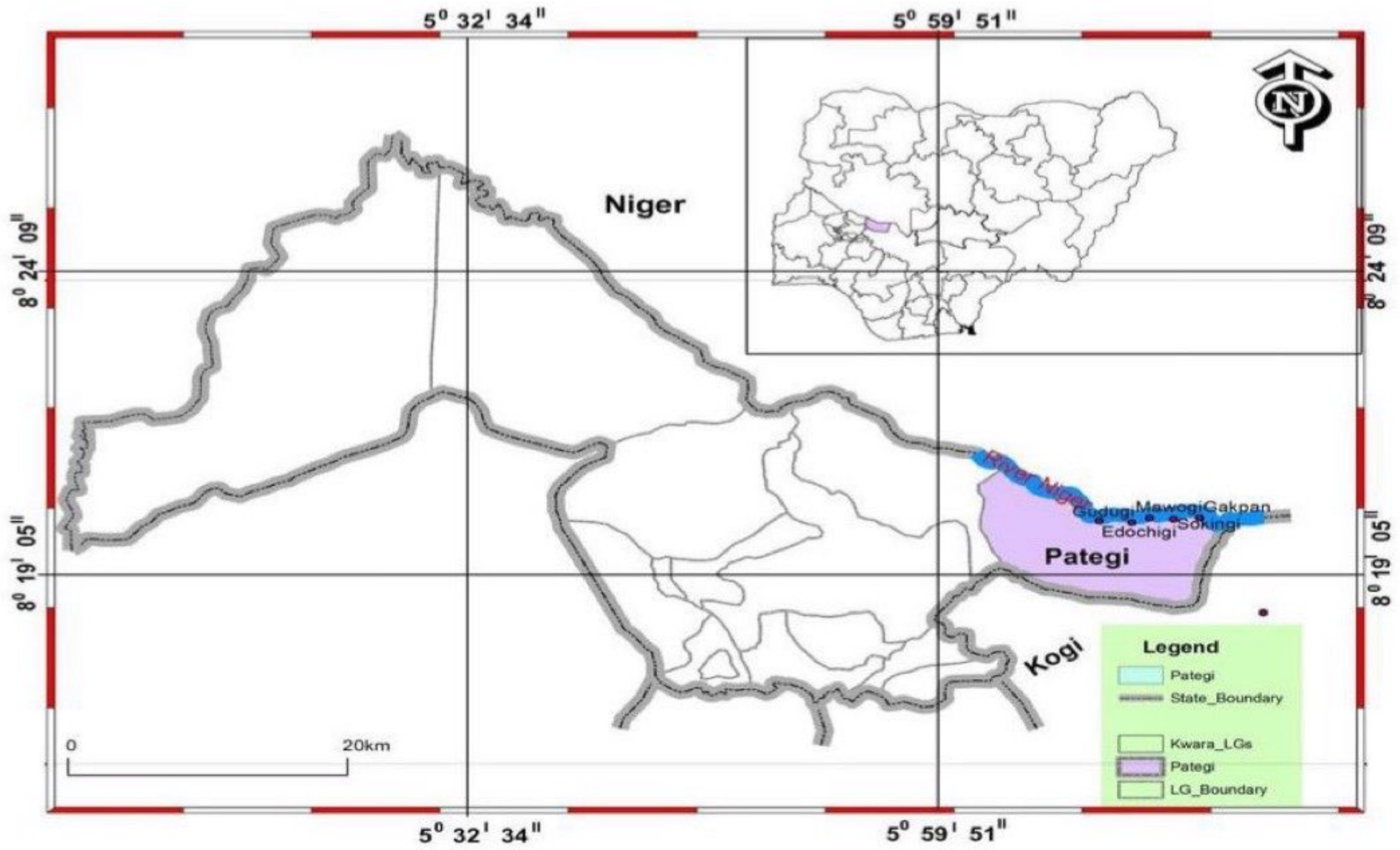

Fig. 3.1: map of Kwara state showing the location of Lade Pategi Local Government (Abiodun olabode,. 2011).

3.2 Sample Collection

Fifty kilogram (50kg) of lithium ore was collected from Lade , Pategi Locak Government Area of Kwara State Nigeria. The sizes of grains of ore sample was reduced to about 50mm using a geologic hammer, it was further reduced to 5mm using a Denver laboratory jaw crusher and subsequently, the sample was further reduce to a fine particle by a ball mill.

Fig 3.2 shows the photograph of Spodumenic rock collected from site

Fig. 3.2: Spodumenic rock

Fig 3.3 shows the equipment used to reduce the particle size

Fig 3.3: Geologic hammer

Fig 3.4: shows the equipment to ground the spodumenic rocks

Fig 3.4: Jaw crusher

Fig: 3.5: shows the Ball mill

Fig 3.5: Ball mill

3.3 sample preparation

After the particle were milled by the ball mill machine , the particle were sieved so that the mineral can be easier separation from the critical mineral , the fraction were sieved using fitter paper size 125mm diameter , After the lithium sample was ready for laboratory procedure

Fig 3.6 shows the Sieved mineral

Fig 3.6: Sieved mineral

3.4 Laboratory Procedure of Froth Flotation of the ores

The laboratory procedure begins with the sieving analysis . The fraction sieve technique was employed to determine particle size distributions of the grounded ore. Mainly oleic acid and sodium oxate were used as collector and the slurry was agitated for another 2 minutes before being transferred into the flotation cell, where it agitated for another 2 minutes. Methyl Isobuty Carbinol (MIBC) was added as a fr other and the mixture was agitated for a total of 10 minutes in the sun and sampled randomly for chemical analysis. The entire process was repeated for each particle sizes of 180um, 125um, 90um as specified.

Fig 3.7 shows the flotation cell

Fig 3.7: Flotation cell

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Grade of the Ore

Table 4.1 shows the elemental and oxides of critical minerals in crude

4.1 Table 4.1: Elemental and oxides of critical minerals in crude

Mineral	Oxide Formula	XRF (%)	Element	AAS (%)
Silicon	SiO_2	74.385	Si	34.791
Aluminum	Al_2O_3	11.930	Al	6.314
Potassium	K_2O	7.961	K	6.609
Manganese	MnO	0.801	Mn	0.620
Chromium	Cr_2O_3	0.04	Cr	0.037
Chlorine	Cl	1.053	Cl	1.053
Magnesium	MgO	0.00	Mg	0.00
Calcium	CaO	0.403	Ca	0.288
Titanium	TiO_2	0.027	Ti	0.016
Vanadium	V_2O_5	0.00	V	0.00
Iron (Ferrous)	Fe_2O_3	1.112	Fe	0.778
Phosphorus	P_2O_5	0.105	P	0.047
Sulphur	SO_3	0.076	S	0.031

Table 4.1 shows the chemical composition of spodumenic rock sample analyze as part of the beneficiation study for lithium and other critical minerals.Two different analytical techniques were used;X-ray fluorescence (XRF)and atomic absorption spectroscopy (AAS).

Silica (SiO_2) dominates the ore sample, ranging from 74% to nearly 85%, which confirms that quartz and feldspar are major gangue phases. White-type silica complicates beneficiation and is typical for pegmatitic lithium ore (*Bridge et al.,* 2019).

Aluminum (Al_2O_3) and Potassium Oxide (K_2O) levels suggest the presence of spodumene and potassium-rich feldspar and mica. This necessitates careful froth flotation to selectively separate lithium-bearing minerals.

The trace presence of Fe_2O_3, TiO_2, P_2O_5, and SO_3 indicates minor impurity minerals. Though these do not occur in large quantities, their removal is essential to meet battery-grade lithium concentrate purity (Afolabi *et al.,*2017).

Calcium and Magnesium Oxide occur in negligible quantities, which is favourable for downstream lithium processing since they can hinder acid leaching and lithium concentration (Zhang *et.al.,* 2020).

4.2 Result of Froth Flotation Procedure

TABLE 4.2 Shows the result of beneficiated ores

TABLE 4.2: RESULT OF BENEFICIATION

MINERALS	XRF(%)		AAS (%)		0.25g of XRF		0.25g AAS		0.5g XRF		0.5g AAS		0.75g XRF		0.75g AAS		1.0g XRF		1.0g AAS	
					CONC.	TAILING	CONC.	TAILING	CONC.	TAILING	CONC.	TAILING	CONC.	TAILING	CONC.	TAILING	CONC.	TAILING	CONC.	TAILING
Silicone	Sio2	74.385	Si	34.791	70.099	70.22	52.768	34.695	69.865	70.942	32.658	33.161	69.070	69.26	32.29	32.38	34.78	66.95	31.57	31.30
alumininum	Al2o3	11.930	Al	6.314	16.447	11.51	8.71	6.11	13.78	17.12	9.30	9.06	16.43	15.92	8.69	8.43	6.31	12.36	8.26	6.55
pottasium	K2o	7.961	K	6.6.9	7.492	7.99	6.23	6.03	8.30	6.32	6.96	5.24	6.92	7.01	5.74	5.82	6.60	6.65	6.32	5.36
maganese	mno	0.801	Mn	0.620	0.882	0.65	0.68	0.50	0.78	0.51	0.61	0.59	0.65	0.60	0.50	0.47	0.62	0.07	0.56	0.40
crominum	Cr203	0.04	Cr	0.037	0.078	0.04	0.05	0.08	0..8	0.06	0.06	0.03	0.06	0.00	0.03	0.03	0.04	0.07	0.05	0.03
chlorine	cl	1.053	Cl	1.053	0.682	1.30	0.68	1.30	0.96	0.59	0.96	0.59	1.05	0.75	1.04	0.75	1.05	0.46	0.46	0.36
magnesium	mgo	0.000	Mg	0.000	0.000	0.00	0.00	0.00	0.00	0.82	0.00	0.49	0.00	2.22	0.00	1.33	0.00	2.08	1.25	5.94
calcum	cao	0.403	Ca	0.288	0.841	0.95	0.60	0.61	1.04	0.63	0.74	0.45	1.70	0.63	1.21	0.45	0.28	1.04	0.74	0.24

titanium	Tio2	0.027	Ti	0.016	0.000	0.06	0.00	0.03	0.01	0.02	0.01	0.01	0.09	0.00	0.05	0.00	0.01	0.04	0.02	0.02
Vanadium	V205	0.000	V	0.000	0.011	0.04	0.01	0.02	0.00	0.01	0.00	0.03	0.01	0.07	0.01	0.04	0.00	0.00	0.00	0.00
ferrous	Fe203	1.112	Fe	0.778	1.023	0.92	0.72	0.69	2.14	0.69	1.49	0.48	1.83	0.83	1.28	0.58	0.78	1.99	1.39	0.48
phosphorus	P203	0.105	P	0.047	0.042	0.42	0.12	0.18	0.00	0.13	0.00	0.05	0.10	0.00	0.04	0.00	0.42	0.00	0.00	0.69
sulphur	So3	0.076	S	0.031	0.098	0.00	0.04	0.03	0.17	0.49	0.08	0.19	0.00	0.57	0.00	0.23	0.03	0.84	0.34	0.15

Table 4.2 presents the results obtained from flotation tests conducted on finely ground samples at a particle size of 90 μm and a pulp density of 30%. For each flotation run, 500 g of ore was processed. The collector used to enhance particle hydrophobicity was a mixture of oleic acid and sodium oleate, applied in varying dosages of 0.25 g, 0.5 g, 0.75 g, and 1.0 g

At a dosage of 0.25 g, flotation yielded no detectable lithium grade or recovery, likely due to insufficient collector to adequately hydrophobize the spodumene particles. Increasing the dosage to 0.5 g and 0.75 g resulted in a marked improvement in the concentration grades of associated minerals. However, at 1.0 g, although some critical mineral concentrations remained relatively high, the grades of certain minerals showed a slight decline. This suggests that excessive collector dosage may have promoted the recovery of some critical minerals that were not the primary target, thereby diluting the final concentrate.

These flotation trends are in agreement with previous studies, where sodium oleate/oleic acid has been reported as a highly effective collector for spodumene flotation under alkaline conditions. Its efficiency is attributed to strong adsorption on mineral surfaces. In this study, the optimum performance occurred at 0.75 g collector dosage, achieving high grades and recoveries for key critical minerals while minimizing the carryover of less desirable critical minerals. Similar outcomes have been reported by Meshram *et.al.* (2020) and Zhu *et.al.,* (2020), who observed significant improvements in spodumene recovery up to an optimal collector dosage, beyond which selectivity decreased

Table 4.3 below shows the result of changes in the concentration of the critical minerals and we explain the best minerals.

TABLE 4.3: CHANGE IN THE CONCENTRATION AFTER BENEFICIATION

TABLE 4.3 : RESULT OF BENEFICIATION

MINERALS	Crude XRF(%)		Crude AAS (%)		0.25g of XRF		0.25g AAS		0.5g XRF		0.5g AAS		0.75g XRF		0.75g AAS		1.0g XRF		1.0g AAS	
					CONC.	TAILING	CONC.	TAILING	CONC.	TAILING	CONC.	TAILING	CONC.	TAILING	CONC.	TAILING	CONC.	TAILING	CONC.	TAILING
silicone	Sio2	74.385	si	34.791	4.286	0.16	2.01	-0.09	4.52	3.44	2.11	1.16	5.31	5.12	2.48	2.39	6.87	7.43	3.19	3.47
alumininum	Al2o3	11.930	Al	6.314	-4.56	0.42	2.33	0.20	-2.35	-5.20	-0.98	-2.75	-4.51	-3.99	-2.38	-2.11	-3.69	-0.43	-1.95	-0.23
pottasium	K2o	7.961	k	6.6.9	0.47	-0.03	0.39	-0.02	-0.41	1.64	0.34	-1.36	1.03	0.95	0.86	0.78	0.35	1.50	0.28	1.25
maganese	mno	0.801	mn	0.620	0.15	0.15	-0.06	0.12	0.01	0.29	0.01	0.23	0.15	0.19	0.12	0.15	0.73	0.28	0.05	0.21
crominum	Cr203	0.04	cr	0.037	-0.03	0.001	-0.2	0.001	-0.04	-0.01	-0.02	-0.01	-0.03	0.05	-0.02	-0.01	0.02	0.05	-0.01	0.01
chlorine	cl	1.053	Cl	1.053	0.37	-0.25	0.37	-0.25	0.09	0.45	0.08	0.46	0.04	0.30	1.01	0.30	0.59	0.68	0.59	0.68
magnesium	mgo	0.000	Mg	0.000	0.000	0.00	0.00	0.00	0.00	0.83	0.00	0.49	0.00	-2.22	0.00	-1.34	-2.08	9.85	-1.25	-5.94
calcuim	cao	0.403	Ca	0.288	-0.44	-0.54	-0.31	0.39	-0.64	-0.23	-0.45	-0.16	-1.30	-0.23	-0.93	-0.16	-0.68	0.05	0.45	0.04
titanium	Tio2	0.027	Ti	0.016	0.003	0.03	0.02	-0.02	0.01	0.01	0.05	0.07	-0.07	0.02	-0.04	0.00	-0.01	-0.01	-0.01	-0.01
Vanadium	V205	0.000	v	0.000	-0.01	-0.04	-0.01	-0.02	0.00	-0.01	0.00	-0.03	-0.09	-0.07	-0.05	-0.01	0.00	0.00	0.00	0.06
ferrous	Fe203	1.112	Fe	0.778	0.09	0.19	0.06	0.08	-1.02	0.43	-0.72	0.39	-0.72	0.27	-0.52	0.19	-0.88	0.42	-0.62	0.29
phosphorus	P203	0.105	P	0.047	0.06	-0.31	0.02	-0.13	0.11	-0.02	0.05	-0.07	0.07	0.17	0.03	0.05	0.10	-0.05	0.05	-0.02
sulphur	So3	0.076	s	0.031	-0.02	0.07	0.001	-0.03	-0.09	-0.41	-0.04	-0.16	0.07	0.49	0.03	-0.19	-0.76	-0.28	-0.31	-0.12

Table 4.3 above shows the change in the improvement of the result of the beneficiation which show that the element such as oxide of iron (Fe_2O_3) , oxides of magnesium (MgO), oxides o

The results presented in Section 4.3 indicate notable changes in the elemental composition of the concentrate after beneficiation. Elements such as iron oxide (Fe_2O_3), magnesium oxide (MgO), calcium oxide (CaO), and titanium oxide (TiO_2) exhibited a reduction in concentration within the final concentrate, suggesting that these components were effectively rejected as part of the gangue material. This trend points to the selective flotation of silicate-rich minerals from the spodumenic ore.

The notable increase in silicon dioxide (SiO_2) concentration across the concentrate samples suggests a preferential recovery of light silicate minerals such as quartz, feldspar, and mica. This behavior may be attributed to the inherent floatability of these minerals or to surface modifications facilitated by reagents such as calcium chloride (activator) and sodium oleate (collector), which enhance the hydrophobicity of silicate particles. The response of SiO_2 during flotation serves as a practical indicator of how efficiently light acidic minerals were recovered.

Furthermore, the enrichment of SiO_2, Al_2O_3, Na_2O, and K_2O at a collector dosage of 1.0 g implies that the flotation process was optimized to recover valuable silicate phases. In contrast, the reduction of Fe_2O_3, CaO, MgO, and TiO_2—especially evident at the 0.75 g collector dosage—confirms that the process selectively floated light silicates while suppressing or rejecting denser gangue minerals such as iron oxides, carbonates, and amphiboles.

Although lithium was not detected in the ore samples, the effective concentration of associated acidic silicate minerals indicates the potential for future recovery of lithium-bearing phases, especially if they occur in trace amounts or cryptocrystalline forms. Thus, the beneficiation procedure employed not only improved overall concentrate quality but also validated the suitability of froth flotation for upgrading pegmatitic ores.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusions

Although lithium was not detected in the ore samples, the beneficiation process using froth flotation yielded a significant concentration of silicon dioxide (SiO_2), indicating an efficient recovery of silicate minerals—particularly quartz, feldspar, and mica. The consistent improvement in SiO_2 content across concentrates suggests successful removal of gangue materials and effective operation of the flotation parameters, even in the absence of lithium-bearing phases. These outcomes highlight the process selectivity and underscore the potential of repurposing flotation techniques for the enrichment of industrial minerals from spodumene-bearing pegmatites. Overall, the beneficiation trials confirmed the ability of the applied conditions to concentrate light silicates, thereby presenting a promising pathway for future mineral recovery and enhanced geochemical evaluation in similar rock types.

5.2 Recommendations

1. Further geochemical beneficiation techniques, including gravity separation, should be conducted to confirm results.

2. Pilot scale beneficiation should be done to test the commercial viability of the study .

3.More detailed mineralogical study of more sample should be done to improve the understanding of mineralogy of the crude.

4.Environmental impact assessment should be carried out prior to large scale mining.

5. Government should involve local stakeholders and mining professionals.

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