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Comparative study of shaking table and dense medium separation for improved lithium recovery from Udawa ore, Kaduna state, Nigeria

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ABSTRACT

This study aims to optimize lithium recovery from Udawa Pegmatite using two beneficiation techniques: gravity separation with a Wilfley shaking table and dense medium separation (DMS). The ore, containing 3.03% Li_2O, was processed across three particle size ranges: -500 +250 µm, -250 +125 µm, and -125 +90 µm. The results from the Shaking Table tests indicated that the -250 +125 µm range provided the best recovery, with the concentrate assay improving to 4.25% Li_2O from 3.03% in the feed. The -500 +250 µm range showed a moderate recovery with a concentrate assay of 3.61% Li_2O, and the -125 +90 µm range produced a higher concentrate weight, but the assay dropped to 3.75% Li_2O, with a greater lithium loss in the tailings (2.05% Li_2O). For DMS, the -250 +125 µm range again yielded the best recovery with a concentrate assay of 3.70% Li_2O and minimal lithium in the tailings (1.04% Li_2O). The -500 +250 µm range produced a moderate concentrate assay of 3.63% Li_2O, while the -125 +90 µm range showed a 3.68% Li_2O concentrate, with higher lithium content in the tailings (1.14% Li_2O). This research highlights the -250 +125 µm sieve range as the optimal range for both methods, offering the best trade-off between lithium recovery, concentrate grade, and particle size. Shaking table performed slightly better for coarser materials, while DMS showed better performance with finer particles. The study provides essential insights for developing a more efficient and sustainable lithium beneficiation process in Nigeria, contributing to the country's economic growth and the global transition to renewable energy solutions.

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1.0 Introduction

The global demand for lithium has surged dramatically, primarily due to its pivotal role in energy storage systems, especially in electric vehicles, mobile devices, and renewable energy technologies. As one of the most critical minerals of the 21st century, lithium has garnered significant attention for its application in high-tech industries, particularly in the production of lithium-ion batteries [1]. Nigeria, with its vast geological resources, is poised to capitalize on its rich lithium deposits, particularly those found in pegmatites across various states, including Kaduna. Among the numerous pegmatite bodies in Nigeria, the Udawa Pegmatite in Kaduna State has been identified as a significant source of lithium-bearing minerals, including spodumene, lepidolite, and petalite [2].

Despite Nigeria's vast lithium potential, the extraction and processing of this mineral remain underdeveloped, with the country largely exporting its crude lithium ore. This not only leads to a loss of potential value-added revenue but also limits the opportunities for local economic growth. The lack of sustainable and efficient processing methods for lithium in the country calls for innovative approaches to beneficiation and processing. One such promising approach involves optimizing the concentration of lithium ores from Udawa Pegmatite using modern and effective separation techniques such as gravity separation (using shaking tables) and dense medium separation (DMS).

The main challenge in mineral processing lies in achieving high recovery rates with minimal energy consumption and environmental impact. Various studies have shown that gravity separation methods, such as the shaking table, have proven to be effective for ores that require physical separation based on density differences, making them suitable for lithium-bearing pegmatites [3]. On the other hand, dense medium separation (DMS) has emerged as a method that can significantly enhance recovery while also reducing environmental costs by using a dense medium to separate the ore based on density differences [1].

The aim of this study is to conduct a comparative analysis of these two beneficiation techniques to determine which provides the most efficient and cost-effective route for lithium recovery from Udawa's pegmatite ores. The study will explore the ore's mineralogical composition, liberation size, and textural properties, followed by laboratory tests to assess the effectiveness of both gravity separation and dense medium separation methods. By evaluating the performance, energy consumption, and environmental impacts of these methods, this research aims to develop an optimal processing route that maximizes lithium recovery, reduces energy costs, and ensures a more sustainable approach to mineral processing.

This research will not only contribute to Nigeria's mining sector but also support the country's broader economic diversification goals by enabling the local beneficiation of lithium, thereby contributing to the global shift towards renewable energy solutions.

2.0 Materials and Methods

The gravity concentration method using a Wilfley shaking table and dense medium separation (DMS) were both employed to enhance lithium recovery from Udawa Lithium Ore (spodumene) containing 3.03% Li_2O. In the shaking table process, the ore was crushed and ground to a particle size range of -63 +45 microns, mixed with water to form a slurry, and then fed onto a riffled deck inclined at 4°. The deck's oscillations, combined with a controlled water flow, allowed the denser spodumene particles to concentrate at the discharge zone while lighter gangue minerals were washed towards the tailings. The lithium content in both the concentrate and tailings was analyzed using Atomic Absorption Spectroscopy (AAS) to calculate lithium recovery, and the procedure was repeated for accuracy.

In contrast, the DMS method involved preparing an aqueous sodium carbonate solution with a specific gravity of 1.5–1.6, in which the ore was separated based on density. Spodumene, being denser, sank to form the sink fraction, while the gangue floated. Both fractions were then analyzed for lithium content, and the results were repeated for consistency. This comparative study aims to evaluate the efficiency of both methods in terms of lithium recovery, with the goal of identifying the most effective and sustainable method for concentrating lithium from Udawa pegmatite ores.

The shaking table offers simplicity with lower energy costs, while DMS may be more efficient for finer particles, making it crucial to determine which method provides the best trade-off between cost-effectiveness and sustainability for Nigeria's lithium processing.

In this study, the effectiveness of the lithium beneficiation processes was quantified using key performance indicators. Recovery (%) was calculated as the percentage of lithium in the concentrate relative to the lithium in the feed, using the formula:

$$\text{Recovery (\%)} = \left(\frac{Li_2O \text{ in Concentrate}}{Li_2O \text{ in Feed}}\right) \times 100 \qquad (1)$$

Yield (%) represents the percentage of the total mass of concentrate produced relative to the initial feed mass, calculated by:

$$\text{Yield (\%)} = \left(\frac{\text{Weight of Concentrate}}{\text{Weight of Feed}}\right) \times 100 \qquad (2)$$

Finally, Grade Improvement (%) indicates the increase in lithium content in the concentrate compared to the feed, calculated as:

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$$\text{Grade Improvement (\%)} = \left(\frac{\text{Concentrate Assay} - \text{Feed Assay}}{\text{Feed Assay}}\right) \times 100 \qquad (3)$$

These formulas enabled a detailed analysis of the recovery efficiency, material yield, and grade enhancement during the beneficiation processes, providing essential insights into the performance of both the Shaking Table and Dense Medium Separation (DMS) methods

3.0 Results and Discussion

The **Table 1: Yields in Mass and Assay for Tabling (Shaking Table Test)**

Test Size Range	Product	Weight (g)	Assay (%) Li_2O
-500 +250 µm	Feed	1000	3.03
	Concentrate	115.975	3.61
	Tailings	873.197	0.85
-250 +125 µm	Feed	1000	3.03
	Concentrate	170.875	4.25
	Tailings	820.125	0.9
-125 +90 µm	Feed	1000	3.03
	Concentrate	203.175	3.75
	Tailings	720.125	2.05

Table 2: Yields in Mass and Assay for Dense Medium Separation (DMS Test)

Test Size Range	Product	Weight (g)	Assay (%) Li_2O
-500 +250 µm	Feed	1000	3.03
	Concentrate	155.75	3.63
	Tailings	753.17	1.20
-250 +125 µm	Feed	1000	3.03
	Concentrate	190.59	3.70
	Tailings	793.92	1.04
-125 +90 µm	Feed	1000	3.03
	Concentrate	223.17	3.68
	Tailings	620.12	1.14

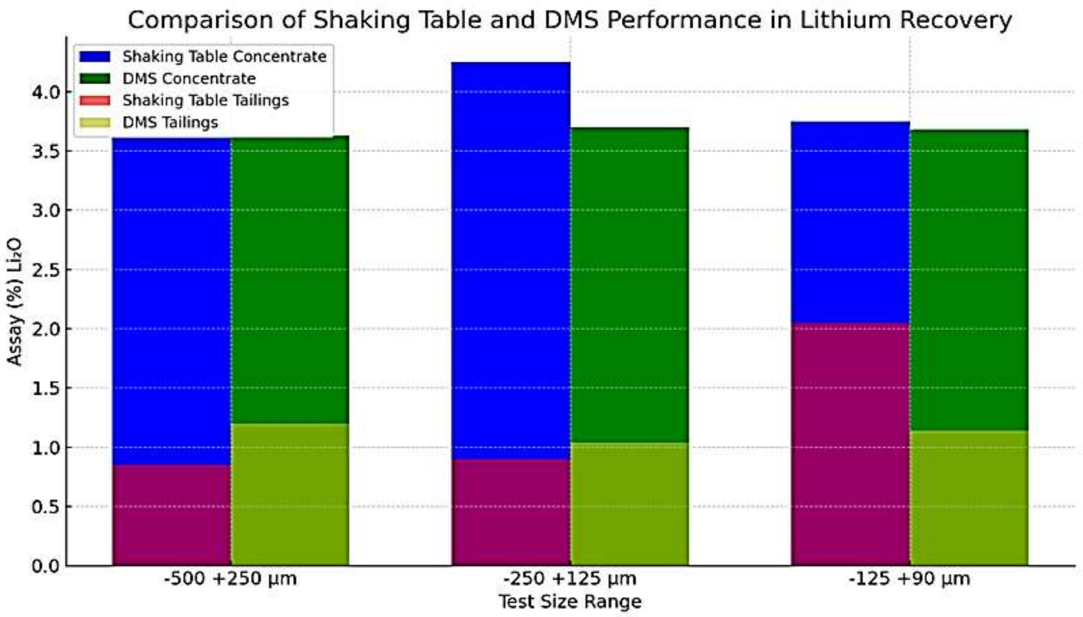

Figure 1. Bar Chat Showing the Comparison of Shaking Table and DMS Performance in Lithium Recovery

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Both Shaking Table and Dense Medium Separation (DMS) were evaluated for their effectiveness in recovering lithium from Udawa Lithium Ore across different sieve size ranges. The results of the tests are summarized in Table 1 and Table 2, showing the mass yields and Li_2O assay for each technique. In the Shaking Table test, the recovery efficiency varied with the particle size range. The -250 +125 μm range provided the best performance, with the concentrate assay increasing from 3.03% Li_2O in the feed to 4.25% Li_2O in the concentrate, yielding a total concentrate weight of 170.875 g and tailings with a low assay of 0.9% Li_2O. This indicated effective separation with minimal lithium loss, making this range the optimal size for lithium recovery. The -500 +250 μm range showed lower recovery, with a concentrate assay of 3.61% Li_2O and a larger quantity of material in the tailings (873.197 g), indicating less efficient separation. The -125 +90 μm range, although producing a higher concentrate weight (203.175 g), resulted in a moderate assay of 3.75% Li_2O, but with more lithium left in the tailings (2.05% Li_2O), reflecting lower recovery efficiency at smaller particle sizes.

In the DMS test, the -250 +125 μm sieve range again provided the best lithium recovery, with the concentrate assay improving to 3.70% Li_2O and a concentrate weight of 190.59 g, while the tailings assay dropped to 1.04% Li_2O, indicating efficient separation of lithium from gangue. The -500 +250 μm range showed a moderate concentrate assay of 3.63% Li_2O, and the -125 +90 μm range produced a concentrate assay of 3.68% Li_2O, with a slightly lower recovery compared to the -250 +125 μm range. The tailings in both finer ranges had lithium concentrations around 1.20% Li_2O and 1.14% Li_2O, showing that finer particles may not be as ideal for DMS, although the process still produced high-quality concentrates.

Both Shaking Table and DMS showed that the -250 +125 μm sieve range was optimal for lithium recovery, as it aligns with the ore's liberation size, ensuring effective separation of lithium-bearing minerals from gangue. The Shaking Table proved to be slightly more efficient in terms of lithium recovery at this range, with a higher concentrate assay (4.25% Li_2O) compared to DMS (3.70% Li_2O). However, DMS provided more efficient separation at the finer -125 +90 μm range, suggesting that DMS may be more suitable for handling finer particles and still providing high-quality concentrates. The comparative study shows that Shaking Table and DMS both have their advantages, with Shaking Table excelling for coarser material and DMS offering better results for finer ore. The -250 +125 μm sieve range was found to be the most effective for both methods, optimizing both recovery and concentrate quality.

Conclusion

The comparative study of Shaking Table and Dense Medium Separation (DMS) for lithium recovery from Udawa Lithium Ore revealed that the -250 +125 μm sieve range is optimal for both methods, aligning with the ore's liberation size. Shaking Table achieved the highest lithium recovery, with a concentrate assay of 4.25% Li_2O and minimal lithium in the tailings (0.9% Li_2O). While DMS also performed well in the same size range, it showed a slightly lower concentrate assay (3.70% Li_2O) but was more effective in handling finer particles (-125 +90 μm), where it still produced high-quality concentrates. For coarser particles, Shaking Table is recommended due to its superior recovery efficiency, while DMS is more effective for finer particles. Future research should focus on optimizing particle size and operational parameters to further enhance recovery and reduce environmental impact. This approach will help Nigeria improve its lithium beneficiation and support economic growth in the mining sector.

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