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Evaluation of Physical and Chemical Characterization of Kazaure Iron Ore: Implications for Metallurgical Processing and Beneficiation Techniques

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ABSTRACT
This study presents the physical and chemical characterization of Kazaure iron ore, located in Jigawa State, Northwestern Nigeria, to assess its industrial potential and beneficiation prospects. The ore was subjected to several characterization techniques, including specific gravity and bulk density determination, chemical analysis via X-ray Fluorescence (XRF), and calculation of the Concentration Criterion (CC) for gravity concentration. The results revealed a significant iron content of 41.78%Fe_2O_3**,** indicating that it is a medium-grade ore suitable for metallurgical applications. The mineral composition identified includes gangue minerals like silica and alumina, which may affect beneficiation efficiency. The CC value of 4.17**,** which is greater than 2, suggests that gravity concentration is an effective method for separating iron from gangue minerals like silica. Based on these findings, the study recommends the application of magnetic separation, gravity concentration, and froth flotation to enhance the ore's quality. The research highlights the potential of Kazaure iron ore to contribute to Nigeria's steel production, reduce reliance on imported raw materials, and support industrial growth.

Keywords: Kazaure Iron Ore, Beneficiation, X-ray Fluorescence (XRF), Gravity Concentration, Steel Production

I. INTRODUCTION

Iron ore plays a pivotal role in the global economy, particularly in the steel industry, which is essential for infrastructure development, transportation, manufacturing, and technological advancements. The demand for steel has surged globally, heightening the need for high-quality iron ore deposits. Iron ore deposits vary in grade and mineralogy, from high-grade hematite ores that can be directly used in blast furnaces to lower-grade ores such as magnetite or goethite, which require beneficiation before use (Abdel-Hakeem, 2023). A deposit's value is determined not only by its abundance but also by its physical and chemical properties, which affect its suitability for direct application or the extent of beneficiation necessary. The characterization of iron ore involves assessing its mineral composition, particle size, density, loss on ignition, and harmful elements like phosphorus and sulfur. Such characterization is critical, as it influences the efficiency of beneficiation processes, energy consumption, and the quality of steel produced (Abdullahi, 2023).

In Nigeria, although the country is rich in iron ore deposits, the steel industry has been constrained by over-reliance on imported raw materials. Nigeria's iron ore deposits, including those in Kogi, Kaduna, Katsina, and Jigawa states, remain underexploited, with the Kazaure iron ore deposit in Jigawa State being particularly under-researched. The Kazaure deposit is located within the Kazaure Schist Belt, part of the Nigerian Basement Complex, and hosts ferruginized metapelites and banded iron-formation-like rocks rich in hematite, magnetite, and goethite, often interbedded with quartz and clays (Abubakar, 2023). These mineralogical variations make it crucial to perform a detailed characterization of the ore to determine its quality, mineral phases, and beneficiation potential. Previous studies on Nigerian deposits have shown variability in grades, with iron contents ranging from 15% to 82%, further highlighting the need for detailed investigations (Abdullahi, 2023).

The lack of comprehensive data on Kazaure iron ore's physical and chemical properties is a significant barrier to its industrial use. Current reports on Kazaure's ore are either limited or generalized, making it difficult to assess its suitability for large-scale industrial application. This knowledge gap inhibits effective beneficiation, creating uncertainty about the ore's quality and the best processing methods to apply. Consequently, the absence of reliable data hampers Nigeria's efforts to reduce its dependence on imported steel, despite the potential of its local resources. Given the importance of iron ore for the steel industry and the significant economic opportunity presented by the Kazaure deposit, this study aims to fill this knowledge gap by providing detailed physical and chemical characterization of the ore. This research will not only enhance the understanding of the ore's potential but also support the development of Nigeria's metallurgical industry, reducing reliance on imported steel materials (Abdel-Hakeem, 2023).

Iron ore characterization is vital for improving Nigeria's steel sector, as it can guide the selection of the most appropriate beneficiation techniques and processing routes. The results from this study will provide important insights into the mineralogy and chemical composition of Kazaure iron ore, thus facilitating its integration into the national steel industry. Additionally, the findings will contribute to the broader understanding of the geological controls of mineralization within the Kazaure Schist Belt, promoting more effective resource utilization and fostering economic growth in Nigeria. The characterization will also provide a foundation for future studies and industrial exploitation of the ore, helping policymakers, investors, and engineers make informed decisions regarding the local iron ore industry (Abubakar, 2023).

II. METHODOLOGY

In this study, Kazaure Iron Ore samples were collected from Wawara Village in the Kazaure Schist Belt, Jigawa State, using a random sampling method to ensure representative samples. The coordinates for the sampling site were E 8° 11' 38" to 8° 12' 02" and N 12° 37' 42" to 12° 39' 13". The collected samples were split into two equal halves, with one portion passing through a 75µm sieve. One half was further analyzed for chemical composition using X-ray Fluorescence (XRF), while the other was retained as a reference. The physical characterization involved determining specific gravity, bulk density, streak, and hardness. Specific gravity was calculated using a pycnometer method, and bulk density was determined using the water displacement method. The streak was observed by crushing the sample and noting the color of the powder, while the hardness was tested using the Mohr's scale. The chemical analysis, performed with Genius IF Xenemetrix XRF equipment, identified major and trace elements such as Fe, Si, Al, Ca, Mg, Ti, Mn, and P, providing essential data for evaluating the ore's grade, beneficiation potential, and suitability for industrial use.

To calculate the gravity concentration criterion, the first step is to obtain the specific gravity of both the valuable mineral (iron ore) and the gangue mineral (silica). The specific gravity of iron (Fe) is approximately 7.87 g/cm³, while silica (SiO_2), a common gangue mineral, has a specific gravity of 2.65 g/cm³.

The Concentration Criterion (CC) is calculated using the formula:

$$CC = \frac{\text{Specific gravity of heavy mineral} - \text{fliud medium}}{\text{specifici gravity of light mienral} - \text{fliud medium}} \quad \text{(equation 1.)}$$

- Heavy Mineral refers to the valuable component of the ore (e.g., iron).
- Light Mineral refers to the gangue mineral (e.g., silica).
- Fluid Medium is typically water, with a specific gravity of 1.0.

This formula helps to assess whether gravity concentration is an effective method for separating the heavy mineral from the light mineral based on their respective densities. The greater the difference in specific gravity between the heavy and light minerals, the more effective the gravity concentration process will be (Wills, 2016).

Table 1: Specific Gravity of Kazaure Iron Ore

Test	Mass of Bottle (W1) g	Mass of Bottle + Specimen (W2) g	Mass of Bottle + Specimen + Water (W3) g	Mass of Bottle + Water (W4) g	Mass of Water (W4 – W1)	Mass of Water Added Bottle (W3 – W2) g
1	20.9	41.1	65.3	72.7	51.8	44.2
2	22.4	42.4	85.6	73.2	50.8	43.2
Average	21.65	41.75	75.45	72.95	51.3	43.7

The specific gravity of the Kazaure iron ore was calculated using the pycnometer method, resulting in an average value of 2.65**.** This value is typical for hematitic iron ores, which usually have specific gravities ranging from 2.5 to 5.0, depending on the mineral composition and porosity. This high specific gravity confirms that the ore is dense and metallic, with a significant concentration of iron-bearing minerals, such as hematite and goethite. The consistency of the readings (2.66 and 2.63) suggests homogeneity in the ore sample, indicating that it is compact and of good metallurgical quality. This finding, when combined with the chemical composition data, supports the classification of the Kazaure ore as a medium-grade hematitic iron ore**,** suitable for beneficiation and subsequent industrial use.

Table 2: Determination of Bulk Density of Kazaure Iron Ore

S/N	Parameters	Unit	Sample 1	Sample 2
1	Mass of Specimen (W1)	g	111.7	89.5
2	Mass of Empty Beaker (W_2)	g	33.0	33.1
3	Mass of Beaker + Displaced Water	g	76.5	67.8
4	Volume of Specimen (V)	cm³	43.5	34.7
5	Bulk Density (W_1/V)	g/cm³	2.57	2.58

The bulk density of the Kazaure iron ore was determined to be 2.58 g/cm³ on average. This represents the ratio of the mass of the specimen to its bulk volume, which includes both solid mineral matter and the pore spaces within the ore. The close agreement between the two samples (2.57 g/cm³ and 2.58 g/cm³) indicates uniformity in the physical composition of the ore. This bulk density value is consistent with the previously obtained specific gravity of 2.65**.** The relatively high bulk density reflects a compact grain structure, typical of iron-rich ores, and suggests that the Kazaure iron ore is well-suited for beneficiation processes, as it has minimal voids and porosity.

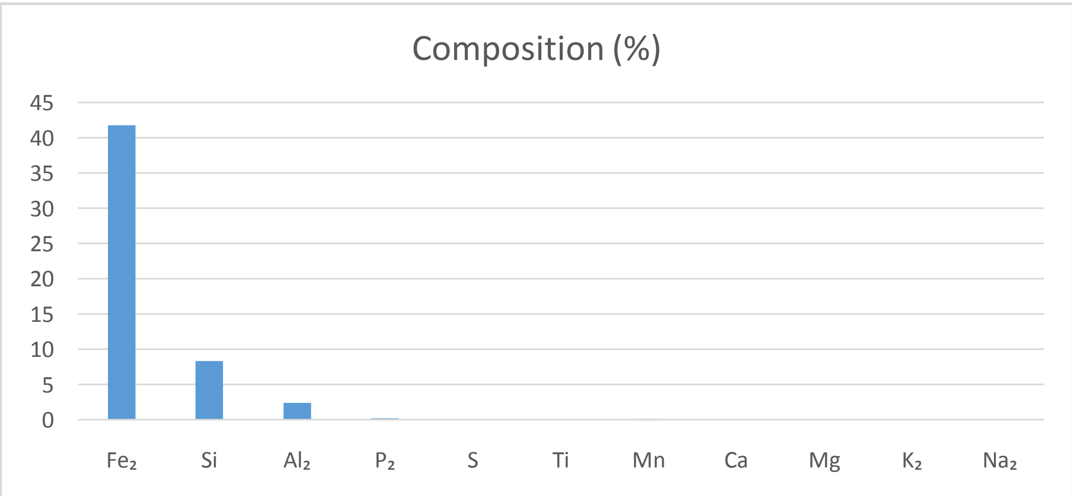

Figure 1: Chemical Composition of Kazaure Iron Ore (XRF Analysis)

The chemical analysis of Kazaure iron ore, conducted via X-ray Fluorescence (XRF) at the National Geosciences Research Laboratory (NGRL), revealed a significant iron content of 41.78% Fe_2O_3, categorizing it as a medium-grade iron ore. The presence of gangue minerals, including silica (8.28%) and alumina (2.36%), indicates that the ore contains significant impurities that could affect beneficiation efficiency. However, the levels of phosphorus (0.16%), sulfur (0.02%), and manganese (0.09%) are low, suggesting minimal negative impact on smelting operations. The loss on ignition (16.68%) indicates the presence of hydrated minerals, such as goethite and clays, which release volatiles and combined water during processing.

The Concentration Criterion (CC) for Kazaure iron ore was calculated using the formula from equation 1. Substituting the specific gravities of the iron ore (Fe) and silica (SiO_2) with values of 7.87 g/cm³ and 2.65 g/cm³, respectively, and considering the fluid medium (water) with a specific gravity of 1.0 g/cm³, the calculation yielded a CC of 4.17. This result, being greater than 2, indicates that gravity concentration is a highly effective method for separating the iron ore from the gangue mineral, silica. The high concentration criterion suggests that gravity-based beneficiation techniques, such as magnetic separation and density-based methods, will be efficient in upgrading the ore by removing impurities like silica, thus improving its suitability for industrial use in steel production.

III. CONCLUSION AND RECOMMENDATIONS:

Based on the results of the physical and chemical characterization, the Kazaure iron ore is suitable for metallurgical use after appropriate beneficiation to improve its iron content. The Concentration Criterion (CC) of 4.17, which is greater than 2, indicates that gravity concentration is a highly effective method for separating the valuable iron ore from the gangue minerals like silica. Methods such as magnetic separation, gravity concentration, and froth flotation should be considered to effectively upgrade the ore by reducing impurities such as silica and alumina. Magnetic separation is particularly recommended due to the presence of magnetite and hematite, which are ferrimagnetic. Further research and pilot-scale testing should focus on refining the beneficiation methods and assessing the ore's full potential for use in the steel industry. The findings suggest that with proper processing, the Kazaure iron ore can contribute significantly to Nigeria's steel production, reducing reliance on imported raw materials.

REFERENCE

[1]. Abdel-Hakeem, M. (2023). Textural complexity in banded iron formations and beneficiation implications. Scientific Reports.
[2]. Abdullahi, M. D. (2023). Chemical and mineralogical properties of the Lejja-Nsukka iron ore. Nigerian Journal of Technology.
[3]. Abubakar, F., Chukwu, L., & Ukpata, J. O. (2023). Geochemistry and occurrence of iron ore in north-central Nigeria. Mineral Resources Engineering.
[4]. Abdel-Hakeem, M. (2023). Textural complexity in banded iron formations and beneficiation implications. Scientific Reports.
[5]. Oladipo, B. I. (2024). Industrial potential of Agbada-Okudu iron deposits: Mineralogical and chemical appraisal. Journal of Mining and Geology.
[6]. Ogbezode, J. E., Ekine, B., & Okoro, S. (2024). Kinetic modeling of isothermal reduction of Nigerian iron ores. Metallurgical and Materials Transactions B.