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ASSESSMENT OF MAJOR OXIDE GEOCHEMISTRY AND FERTILIZER PRODUCTION POTENTIAL OF MAGNESITE MINERALIZATION IN SAKASIMTA, NORTHEASTERN NIGERIA

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Abstract

Magnesium deficiency in agricultural soils has become an increasing challenge affecting crop productivity, particularly in tropical regions where intense weathering, nutrient leaching, and continuous cultivation contribute to depletion of essential nutrients. This study evaluates the geochemical characteristics, resource potential, and suitability of the Sakasimta magnesite deposit in Gombi Local Government Area, Adamawa State, Nigeria, as a potential raw material for magnesium fertilizer production. The deposit occurs within a weathered basaltic environment and is associated with magnesium-bearing minerals such as olivine and serpentine, suggesting formation through alteration and carbonation processes of magnesium-rich silicate minerals. Representative magnesite samples were subjected to X-ray Fluorescence (XRF) analysis to determine major oxide compositions, including SiO₂, Al₂O₃, Fe₂O₃, MgO, CaO, Na₂O, K₂O, TiO₂, MnO, Cr₂O₃, BaO, and loss on ignition (LOI). The results revealed significant magnesium enrichment, with MgO concentrations ranging from 29.19 to 39.09 wt.%, with an average value of 34.04 wt.%, confirming the magnesitic nature of the deposit. The samples recorded moderate SiO₂ contents ranging from 6.60 to 20.84 wt.% (average 13.14 wt.%), while Fe₂O₃ and Al₂O₃ showed relatively low concentrations with average values of 1.22 wt.% and 2.90 wt.%, respectively. The high LOI values (39.1–48.0 wt.%; average 43.81 wt.%) indicate significant carbonate content associated with magnesium carbonate decomposition. Resource evaluation of the deposit estimated approximately 53,460 metric tonnes, indicating potential for small-scale mineral development. The high MgO content, favourable impurity levels, and available resource volume suggest that Sakasimta magnesite has potential as a raw material for magnesium fertilizer production. However, beneficiation studies, fertilizer formulation trials, and agronomic evaluations are recommended to optimize magnesium recovery and confirm its effectiveness as an agricultural input.

Keywords: Magnesite; Magnesite fertilizer; Geochemical characterization; X-ray fluorescence; MgO enrichment; Adamawa State; Nigeria

I. INTRODUCTION

Magnesium is an essential element in agricultural systems because it plays a significant role in plant metabolism, particularly in chlorophyll formation, photosynthesis, enzyme activation, and carbohydrate transportation. The availability of magnesium in soils directly influences crop productivity and plant health. In many tropical agricultural regions, continuous cultivation, intense weathering, and nutrient leaching have contributed to magnesium depletion in soils, creating a need for alternative sources of magnesium fertilizers. The use of mineral-based magnesium resources as fertilizer raw materials provides an opportunity for sustainable soil nutrient management and reduction of dependence on imported fertilizer products (Marschner, 2012).

Magnesite (MgCO₃) is one of the most important magnesium-bearing minerals and represents a major natural source of magnesium compounds. It belongs to the carbonate mineral group and occurs in a variety of geological environments, including ultramafic rock terrains, hydrothermal systems, sedimentary basins, and weathering zones. Magnesite formation commonly involves the interaction between magnesium-rich minerals such as olivine and serpentine with carbon-bearing fluids during carbonation processes. In ultramafic and mafic environments, magnesium released from the

alteration of silicate minerals reacts with carbonate-rich solutions, resulting in the precipitation of magnesium carbonate minerals (Kelemen & Matter, 2008; Quesnel *et al.*, 2016).

The importance of magnesite extends beyond industrial applications, as it serves as a potential source of magnesium for agricultural purposes. Magnesium carbonate can be processed through calcination and chemical conversion to produce magnesium oxide (MgO), magnesium sulphate, and other magnesium compounds suitable for fertilizer production. The quality and suitability of magnesite as a fertilizer raw material depend on its magnesium content, mineralogical composition, impurity levels, and the availability of economically recoverable resources (Liu *et al.*, 2020). High magnesium oxide content combined with low concentrations of undesirable elements such as silica, iron oxide, and aluminium oxide enhances the suitability of magnesite for magnesium-based agricultural products.

Globally, magnesium resources are obtained mainly from magnesite, dolomite, brucite, olivine, and seawater deposits. Among these sources, magnesite remains one of the most economically important because of its relatively high magnesium content and wide distribution. Magnesium compounds derived from magnesite are used in agriculture, chemical industries, construction materials, and refractory applications (U.S. Geological Survey [USGS], 2024). The agricultural application of magnesium minerals is particularly important because magnesium is a central component of chlorophyll molecules and contributes to improved nutrient availability in deficient soils.

Nigeria is endowed with numerous solid mineral resources; however, many industrial minerals remain underexplored and underutilized due to inadequate geological characterization and limited evaluation of their industrial applications. Northeastern Nigeria contains diverse geological formations associated with volcanic and sedimentary activities, providing favourable conditions for the occurrence of magnesium-bearing minerals. The Sakasimta magnesite deposit located in Gombi Local Government Area of Adamawa State represents one of the identified magnesium mineral occurrences requiring detailed investigation to determine its quality, resource potential, and suitability for magnesium fertilizer production.

The Sakasimta area is situated approximately 20 km west of Garkida, within the northern part of Kufanta Marsh between Rivers Hawul and Jemba in Adamawa State, northeastern Nigeria. The area falls within the Shani NE topographic sheet (Sheet 154) and is accessible through Dangwala village along the Garkida–Biu road. The deposit can be reached through an untarred but motorable road linking Sakasimta and Gardamna villages. The accessibility of the area provides advantages for geological investigation, bulk sampling, mineral processing studies, and possible future small-scale exploitation of the deposit.

Previous geological investigations in the Sakasimta area indicate that the magnesite occurs within a weathering profile developed over basaltic rocks. Petrographic observations reveal the presence of olivine and serpentine minerals, suggesting that the magnesite mineralization may have resulted from the alteration and carbonation of magnesium-rich basaltic minerals. Similar geological processes have been documented in other magnesite-bearing environments where serpentinization and carbonation reactions contribute to the formation of magnesium carbonate minerals (Kelemen & Matter, 2008; Streit *et al.*, 2012).

Geochemical analysis of samples from the Sakasimta deposit indicates significant enrichment in magnesium oxide (MgO), with magnesian samples showing average MgO values of approximately 34%. The deposit also exhibits relatively low concentrations of some impurity elements compared with the associated basaltic rocks. These geochemical characteristics suggest that the deposit has potential as a magnesium-bearing raw material. However, detailed assessment is required to determine whether the mineral composition satisfies the requirements for fertilizer production.

The production of magnesium fertilizer from magnesite requires careful evaluation of chemical composition because impurities can influence processing efficiency, nutrient availability, and final product quality. Elements such as silica (SiO₂), iron oxide (Fe₂O₃), aluminium oxide (Al₂O₃), and calcium oxide (CaO) may affect beneficiation processes and determine the suitability of the mineral for agricultural applications. Therefore, detailed geochemical characterization is necessary to evaluate the potential of Sakasimta magnesite as a locally available source of magnesium fertilizer.

Resource evaluation of the Sakasimta deposit indicates an estimated resource of approximately 53,460 metric tonnes. Although the deposit morphology, characterized by pockets and lenses, may limit large-scale mining operations, the available resource may support small-scale mineral processing activities. The combination of adequate resource volume, favourable accessibility, and significant MgO concentration provides a basis for investigating the deposit as a potential source of magnesium fertilizer.

The Sakasimta magnesite deposit is located in the Gombi Local Government Area of Adamawa State, northeastern Nigeria. The area lies approximately 20 km west of Garkida and occurs within the northern part of the Kufanta Marsh, situated between River Hawul and River Jemba. Geographically, the deposit is located between latitudes 10°20'29"N and 10°20'43"N and longitudes 12°26'19"E and 12°26'36"E, covering part of the 1:50,000 topographic map Sheet 154 (Shani NE).

The study area is characterized by basaltic geological formations, which host the magnesite mineralization. The occurrence is associated with weathered basaltic rocks containing magnesium-bearing minerals such as olivine and serpentine. The location provides a suitable geological environment for investigating magnesite formation, geochemical characteristics, and resource potential for magnesium fertilizer production.

Accessibility to the Sakasimta deposit is relatively favourable for geological investigations and future mineral development. The area can be accessed through Dangwala village, which is located approximately 2 km from the Garkida–Biu major road. From Dangwala village, the deposit site is reached through an untarred but motorable access

road connecting the surrounding communities of Sakasimta and Gardamna villages. The existing road network allows transportation of geological equipment, movement of field personnel, collection of bulk samples, and potential movement of processed mineral products.

Research Gap

Although previous studies have established the geological occurrence, petrographic characteristics, and general geochemical composition of the Sakasimta magnesite deposit, limited research has focused on its application potential as a raw material for magnesium fertilizer production. Existing investigations have mainly emphasized geological mapping, mineral identification, and resource estimation, while the relationship between mineral chemistry and agricultural suitability remains insufficiently studied.

A major knowledge gap, therefore, exists in determining whether the MgO content and associated chemical characteristics of the Sakasimta magnesite are suitable for conversion into magnesium fertilizer products. Furthermore, limited information exists regarding beneficiation requirements, impurity control, processing methods, and the economic feasibility of utilizing the deposit for agricultural applications.

II. MATERIALS AND METHOD

Geochemical analysis was carried out to determine the major oxide composition of the Sakasimta magnesite deposit and evaluate its suitability as a raw material for magnesium fertilizer production. Representative magnesite samples collected from the mineralized zones were prepared for laboratory analysis by washing, air-drying, crushing, and pulverizing into fine powder to obtain homogeneous samples. The powdered samples were analysed using X-ray Fluorescence (XRF) spectrometry to determine the concentrations of major oxides present in the mineralized material.

The XRF analytical procedure involved the preparation of pressed powder pellets from the homogenized sample powders, which were then subjected to X-ray excitation. The intensity of emitted characteristic X-rays from each element was measured and converted into oxide concentrations using appropriate calibration standards. The major oxides analysed included silicon dioxide (SiO₂), aluminium oxide (Al₂O₃), iron oxide (Fe₂O₃), magnesium oxide (MgO), calcium oxide (CaO), sodium oxide (Na₂O), potassium oxide (K₂O), titanium dioxide (TiO₂), phosphorus pentoxide (P₂O₅), manganese oxide (MnO), chromium oxide (Cr₂O₃), barium oxide (BaO), and loss on ignition (LOI).

The geochemical results were evaluated based on the percentage abundance of each oxide, with particular emphasis on MgO concentration, which represents the principal component controlling the potential use of magnesite for magnesium fertilizer production. The levels of associated impurities, including SiO₂, Fe₂O₃, Al₂O₃, CaO, Na₂O, and K₂O, were also assessed because excessive amounts of these oxides may influence mineral processing requirements and fertilizer quality. The obtained chemical compositions were statistically analysed by calculating average oxide concentrations, variations among samples, and elemental relationships to determine the chemical homogeneity and quality of the deposit.

III. RESULTS AND DISCUSSION

The major oxide composition of the Sakasimta magnesite samples was determined using X-ray Fluorescence (XRF) analysis. The results show significant variation in the concentration of major oxides, reflecting differences in mineral composition and the degree of alteration within the deposit. The analytical results indicate that the samples are dominated by magnesium oxide (MgO), which represents the principal component of magnesite and determines its suitability as a source material for magnesium fertilizer production.

The analysed magnesite samples show MgO concentrations ranging from 29.19% to 39.09%, with an average value of approximately 34.04%. The high MgO content confirms the magnesitic nature of the deposit and indicates considerable potential for magnesium extraction. Other major oxides recorded include SiO₂, Al₂O₃, Fe₂O₃, CaO, Na₂O, K₂O, TiO₂, MnO, Cr₂O₃, BaO, and loss on ignition (LOI).

The high loss on ignition (LOI), ranging from 39.1% to 48.0%, is attributed mainly to the release of CO₂ during the decomposition of magnesium carbonate (MgCO₃) during heating. The relatively low concentrations of Fe₂O₃, Al₂O₃, Na₂O, K₂O, and TiO₂ suggest limited contamination from silicate minerals and indicate favourable chemical characteristics for further processing.

Table 1: Major Oxide Composition of Magnesite Samples from Sakasimta Deposit

Sample	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	MgO	CaO	Na ₂ O	K ₂ O	TiO ₂	P ₂ O ₅	MnO	Cr ₂ O ₃	BaO	LOI
11B	16.67	2.94	1.43	30.37	4.71	0.13	0.35	0.19	0.05	0.13	0.003	0.01	42.5
9B	12.01	2.91	1.21	35.64	2.70	0.07	0.42	0.17	0.04	0.02	0.003	0.05	44.2
16B	11.47	3.14	1.14	34.80	3.81	0.08	0.40	0.18	0.04	0.02	0.002	0.01	44.3
24B	6.60	1.67	0.73	39.09	2.85	0.04	0.18	0.10	0.02	0.02	<0.002	0.006	48.0
33B	14.72	3.50	1.59	32.46	3.59	0.07	0.42	0.20	0.03	0.05	0.003	0.01	42.8
39B	20.84	3.45	1.34	29.19	4.52	0.13	0.60	0.22	0.02	0.03	0.004	0.02	39.1
45B	9.65	2.70	1.09	36.70	2.90	0.04	0.32	0.14	0.03	0.01	0.003	0.01	45.8

Magnesium Oxide (MgO) Distribution

The distribution of MgO among the analysed samples shows consistent enrichment throughout the deposit. Sample 24B recorded the highest MgO concentration (39.09%), followed by sample 45B (36.70%) and sample 9B (35.64%), while sample 39B recorded the lowest MgO value (29.19%).

The average MgO content of 34.04% indicates that the Sakasimta deposit contains significant magnesium enrichment. The MgO values suggest that the deposit has potential as a source material for magnesium fertilizer production after suitable processing and beneficiation.

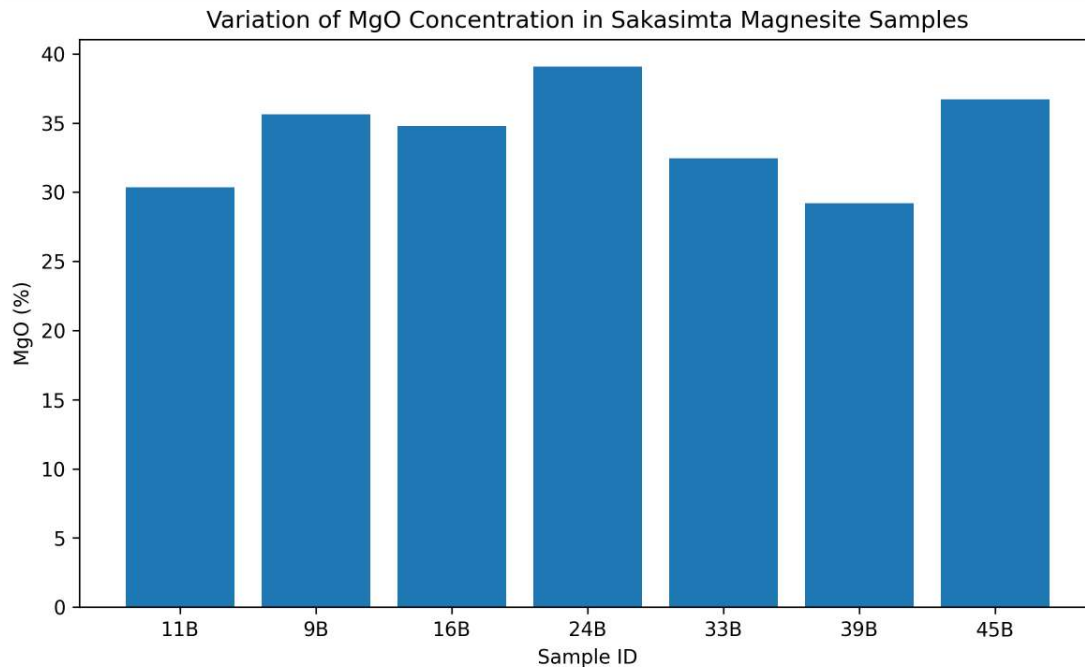


Figure 1. Variation of MgO Concentration in Sakasimta Magnesite Samples

Distribution of Impurity Oxides

The major impurity oxides affecting magnesite quality include SiO_2 , Al_2O_3 , and Fe_2O_3 . The silica content varies between 6.60% and 20.84%, with an average value of 13.14%. Aluminium oxide ranges from 1.67% to 3.50%, while Fe_2O_3 varies between 0.73% and 1.59%.

The relatively low Fe_2O_3 and Al_2O_3 concentrations indicate limited clay and iron mineral contamination. However, the moderate SiO_2 values suggest the presence of residual silicate minerals, possibly derived from the alteration of basaltic parent rocks containing olivine and serpentine.

Table 2: Average Geochemical Composition of Sakasimta Magnesite Compared with Major Fertilizer-Related Parameters

Parameter	Average Value (%)	Significance
MgO	34.04	Main nutrient component
SiO_2	13.14	Indicates silicate impurities
Fe_2O_3	1.22	Low iron contamination
Al_2O_3	2.90	Low clay contamination
CaO	3.58	Associated carbonate component
LOI	43.81	Indicates carbonate content

Geochemical Suitability for Magnesium Fertilizer Production

The chemical composition of the Sakasimta magnesite deposit indicates favourable characteristics for magnesium fertilizer production. The high MgO concentration confirms that the mineral can serve as a magnesium source, while the relatively low levels of Fe_2O_3 and Al_2O_3 reduce potential processing challenges.

The high LOI values indicate significant carbonate content, confirming that the samples are dominated by magnesium carbonate minerals. During thermal processing, the carbonate component can be converted into magnesium oxide, which is an important intermediate product for magnesium-based fertilizers.

IV. CONCLUSION AND RECOMMENDATION

This study assessed the geochemical characteristics, resource potential, and suitability of the Sakasimta magnesite deposit in Gombi Local Government Area, Adamawa State, Nigeria, for magnesium fertilizer production. The results indicate that the deposit occurs within a weathered basaltic environment and is associated with magnesium-bearing minerals such as olivine and serpentine, suggesting formation through alteration and carbonation processes. Geochemical analysis using X-ray Fluorescence (XRF) revealed that the magnesite samples contain high magnesium oxide (MgO) concentrations ranging from 29.19% to 39.09% with an average value of 34.04%, accompanied by relatively low concentrations of Fe₂O₃ and Al₂O₃, although moderate SiO₂ content indicates the presence of silicate impurities. The high MgO content and significant loss on ignition values confirm the dominance of magnesium carbonate minerals and demonstrate the potential of the deposit as a source material for magnesium fertilizer production. The estimated resource of approximately 53,460 metric tonnes, together with the favourable accessibility of the deposit, indicates that the occurrence has potential for small-scale mineral development and processing. However, further studies are recommended, including beneficiation tests to improve MgO concentration and reduce impurities, laboratory-scale fertilizer production trials, mineralogical investigations using advanced techniques such as XRD and SEM, agricultural performance evaluation of the produced magnesium fertilizer, and detailed economic and environmental assessments to determine the commercial viability of exploiting the Sakasimta magnesite deposit for agricultural applications.

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