

Study of the Chemical and Mineralogical Composition of Kindia Bauxite in the Republic of Guinea: The Case of the Saföfö Site

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Abstract

The chemical and mineralogical composition of bauxite deposits is a key factor in the profitability of refining processes. The study of bauxites from the Saföfö site has assessed variations in chemical and mineralogical composition under various conditions, as well as the optimum conditions for their exploitation. The methodologies used in this study include experimental methods for determining moisture content, chemical composition, mineralogical composition, and specific density of bauxite. The results show significant variation in moisture content among the bauxite samples, with values ranging from 2.90% to 17.80%. The silica percentages in the samples range from 1.69% to 8.14%, while alumina percentages vary from 36.81% to 54.03%. After calcination, alumina oxide percentages range from 40% to 75%. After chemical activation, alumina oxides Al_2O_3 range from 40% to over 50%. Gibbsite is the most abundant mineral, accounting for about 60% - 70% of the total composition of the bauxite samples. Samples A to F have bulk densities varying between approximately 3.6 and 3.9. Sample B has the highest density, around 3.9, while sample C has the lowest, at around 3.5. Bauxite mining at the Saföfö site offers significant potential for the alumina industry, provided appropriate processing methods are selected to maximize quality and profitability while minimizing environmental impact.

Keywords

Bauxite, Chemical Composition, Guinea, Mineralogy and Saföfö

1. Introduction

On a global scale, the bauxite issue involves several aspects. The quality of bauxite deposits varies considerably based on their chemical and mineralogical composition [1]. The composition of bauxite deposits affects the profitability of refining processes. Deposits rich in gibbsite are generally preferred because extracting aluminum from them is easier [2]. Deposits with high levels of iron (hematite, goethite) or silica (quartz, kaolinite) present additional challenges, particularly in terms of processing cost and complexity [3].

Bauxite mining has a significant environmental impact, including deforestation, soil erosion, and water pollution from processing residues known as “red mud” [4]. The authors highlight the challenges related to resource depletion, environmental impacts, and the technological innovations essential for more sustainable extraction. The chemical treatment of bauxite to extract alumina, notably via the Bayer process, generates caustic waste that is difficult to manage [5].

The authors emphasize the importance of mineralogical composition in the efficiency of the Bayer process. Growing global demand for aluminum is exerting increasing pressure on bauxite resources. Some deposits are being mined at a rate that could lead to rapid depletion, requiring sustainable management strategies and more efficient extraction technologies [2]. The authors note that large-scale bauxite mining leads to massive deforestation, destruction of natural habitats, and contamination of waterways by red mud, alkaline residues generated by processing bauxite and alumina.

Africa has some of the world’s largest undeveloped bauxite deposits, notably in Guinea, Ghana, Sierra Leone, and Cameroon [6]. The authors discuss the specific challenges of bauxite mining in Ghana, including governance, infrastructure, and regulatory issues. They propose strategies for maximizing economic benefits while minimizing negative impacts.

Many African countries lack the infrastructure needed to fully exploit their bauxite resources. Transport, mining technology, and processing are often underdeveloped, limiting production capacity [7]. Technological innovations in bauxite mining and processing are essential to reduce costs and minimize environmental impacts. However, the adoption of these technologies remains limited by economic constraints and inadequate infrastructure in developing regions.

Governance of natural resources, including bauxite, varies considerably across Africa. Transparency, corruption, and conflicts of interest can hinder the responsible and sustainable development of these resources. Bauxite mining in Africa significantly impacts local communities, including displacement, loss of agricultural land, and pollution. Bypassing these impacts can lead to conflict and community resistance [8].

Guinea is a key player in the global bauxite market, possessing the world’s largest reserves of high-quality bauxite. Guinean bauxite is mainly of the gibbsite type, which is favorable for alumina extraction due to its generally lower reactive silica content [9]. This property makes it very attractive for global mining. Despite its

potential, Guinea faces infrastructure challenges in transporting bauxite from mines to ports. The lack of well-developed roads and railroads hampers large-scale export [10] [11]. The environmental impact of bauxite mining in Guinea is concerning, affecting biodiversity and the livelihoods of local populations. Companies need to implement responsible mining practices to minimize environmental damage [8] [12]. The authors examine the environmental and social challenges of bauxite mining in Guinea. They address mining waste management and impacts on local communities, suggesting approaches to improve the industry's sustainability.

Bauxite mining in Guinea could offer significant economic development opportunities, but it requires a robust regulatory framework to ensure that revenues benefit the Guinean population and improve local living conditions.

Chemical and mineralogical studies of Guinean bauxite deposits are crucial for determining the concentrations of alumina (Al_2O_3), silica (SiO_2), iron (Fe_2O_3), titanium (TiO_2), and other elements.

2. Materials and Methods

2.1. Geography and Demographics of the Kindia Region

The Kindia region is an administrative subdivision of Guinea. It covers a total area of 28,873 km² and comprises five prefectures: Coyah (3215 km²), Dubreka (5672 km²), Forecariah (4250 km²), Kindia (8850 km²), and Telimele (9000 km²). It is located at an average altitude of 458.18 meters between 12°30 and 13°30 West longitude and 9°5 and 11°15 North latitude.

It is bounded by:

- The Mamou region to the east
- The Atlantic Ocean and the Conakry region to the west
- The Boké and Labé regions to the north and northeast
- The Republic of Sierra Leone and the Atlantic Ocean to the south

The total population of the region, updated in 2015, is 1,607,520 inhabitants, with a density of 51.88 inhabitants per km² (presentation of the administrative map of the Kindia region).

2.2. Determination of Humidity

1) Principle: The moisture content of bauxite is determined by measuring the weight loss when the material is heated to a specific temperature to evaporate any free water.

2) Procedure: We took representative samples of bauxite and ground them to homogeneous particle sizes. We then weighed the samples (around 5 to 10 grams) and recorded the initial mass. The samples were placed in an oven at 105 °C for 24 hours, or until the mass remained constant. Afterward, the samples were removed from the oven, allowed to cool in a desiccator to prevent moisture absorption, and weighed again. The moisture percentage is calculated as follows:

$$H (\%) = \frac{M_{\text{init}} - M_{\text{apres sech}}}{M_{\text{init}}} \times 100 \quad (1)$$

where H stands for Sample moisture in (%);

M_{init} stands for Initial sample mass in grams;

$M_{\text{apres sech}}$ stands for Sample mass after drying in grams.

2.3. Determination of Chemical Composition

1) Principle: The chemical composition of bauxite is determined by X-ray fluorescence (XRF) analysis methods.

2) Procedure (by XRF): We dried and ground the bauxite samples to obtain a fine, homogeneous powder. We then mixed the powder with a lithium tetraborate binder and compressed the mixture under high pressure (1000°C) to form solid pellets. These pellets were placed in the X-ray fluorescence spectrometer for analysis to determine the concentration of elements present in bauxite, such as Al, Si, Fe, and Ti.

2.4. Determination of Mineralogical Composition

1) Principle: Mineralogical composition is determined using X-ray diffraction to identify and quantify the minerals in the samples.

2) Procedure: We ground the bauxite samples into a very fine powder. The powder was placed on sample holders, ensuring the surface was smooth and uniform. We then placed the sample holders in the X-ray diffractometer and scanned to obtain a diffraction pattern. We used X-ray diffraction databases to identify characteristic peaks of the various minerals present in the samples, such as gibbsite, boehmite, and hematite. Lastly, we performed a quantitative analysis using the Rietveld method to determine the relative proportions of each mineral.

2.5. Determination of Volumetric Density

1) Principle: The volumetric density of bauxite was determined using the pycnometry method.

2) Procedure: We dried the bauxite samples by reducing them to powder and then weighing them. Empty pycnometers were filled with 5 g of bauxite powder and distilled water to a marked level. We weighed the pycnometers filled with water and bauxite powder. Lastly, we calculated the volumetric density using the difference between the mass and volume of the pycnometer to determine the density of the samples.

$$\text{Dente volumetrique} = \frac{M_{\text{echant.bauxite}}}{V_{\text{pycnom}} - V_{\text{liqui.ajout}}} \quad (2)$$

where $M_{\text{echant.bauxite}}$ stands for Mass of bauxite sample;

V_{pycnom} stands for Volume of pycnometer;

$V_{\text{liqui.ajout}}$ stands for Volume of liquid added in (cm³)

3. Results and Discussion

Results of Physico-Chemical Analysis of Saföfö Bauxite

1) Moisture content of bauxite samples from the Saföfö site

The moisture content of bauxite samples is an important parameter in the aluminum industry. It influences the transport, storage, and processing of bauxite and alumina. Bauxite samples from the Saföfö site, like those from other regions, can vary in moisture content depending on climatic conditions, extraction depth, and storage. **Figure 1** shows the moisture content of bauxite samples from the Saföfö site.

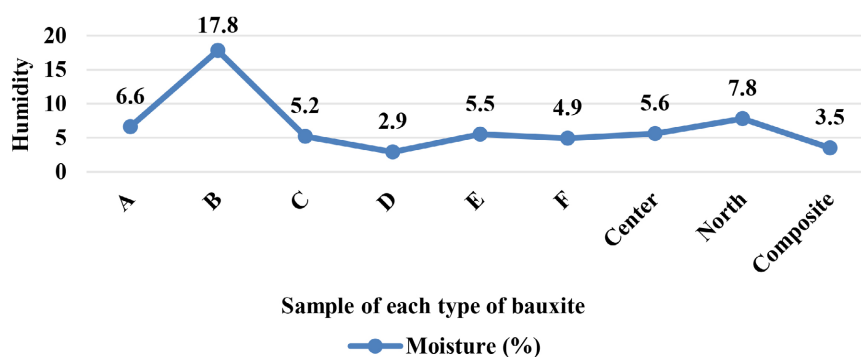


Figure 1. Moisture variation curve for bauxite from the Saföfö site.

Figure 1 shows the variations in moisture content of various bauxite samples from the Saföfö site. The increase in hygroscopic water content ranges from 2.9% to 17.8% for the Saföfö Block D and B bauxite samples, respectively. Except for the value of 17.8%, no other value exceeded 7.8%, while that of the composite was 3.5%. These values indicate that bauxite samples in this state remain natural adsorbents and have not reached their full adsorption capacity.

Our results show a moisture content of 17.80% for sample B, which is higher than the 10% reported by [13] under similar conditions. The significant variation observed in our study compared to [14] suggests that regional factors and sampling methods significantly impact bauxite moisture content. The analysis of bauxite samples reveals moisture content ranging from 2.90% to 17.80%. This variation indicates that factors such as geological source, climatic conditions, and storage or sampling methods can significantly influence bauxite moisture content.

2) Physical activation of natural-base bauxite samples

Figure 2 below shows the chemical composition of physically activated (natural-based) bauxite, detailing the percentages of four main oxides: SiO_2 , TiO_2 , Fe_2O_3 , and Al_2O_3 . The results of these observations are from Saföfö.

Figure 2 shows the oxide content of the bauxite samples. Silica percentages in the samples range from 1.69% to 8.14%, while alumina percentages range from 36.81% to 54.03%. Some bauxites require the addition of siliceous materials. The results also indicate that the ratio of alumina to silica varies inversely. Physical activation has enhanced porosity development in these materials. The differences

in chemical composition among bauxite samples suggest opportunities for optimizing their use in various industrial contexts and highlight the need for further research to understand the factors behind these variations.

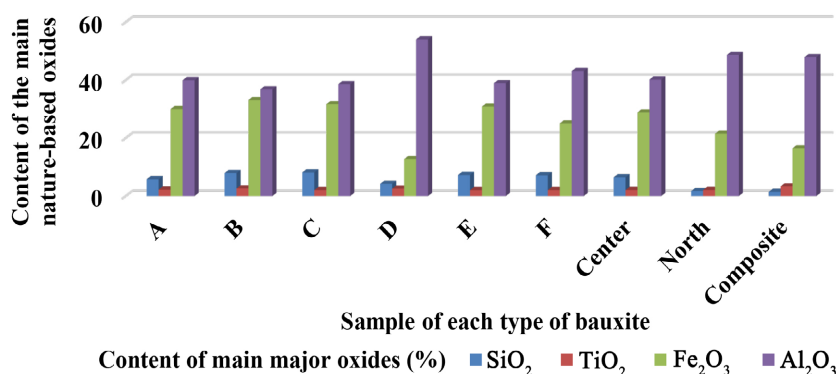


Figure 2. Bar graph of the chemical composition of naturally based, physically activated bauxite.

3) Physical activation of bauxite samples (calcined base)

Figure 3 shows the chemical composition of physically activated (calcined base) bauxite, indicating the percentages of four main oxides: Al₂O₃ (aluminum oxide), SiO₂ (silica), TiO₂ (titanium dioxide), and Fe₂O₃ (iron oxide) for various samples (A, B, C, D, E, F) and regions (central, northern), as well as for a composite sample.

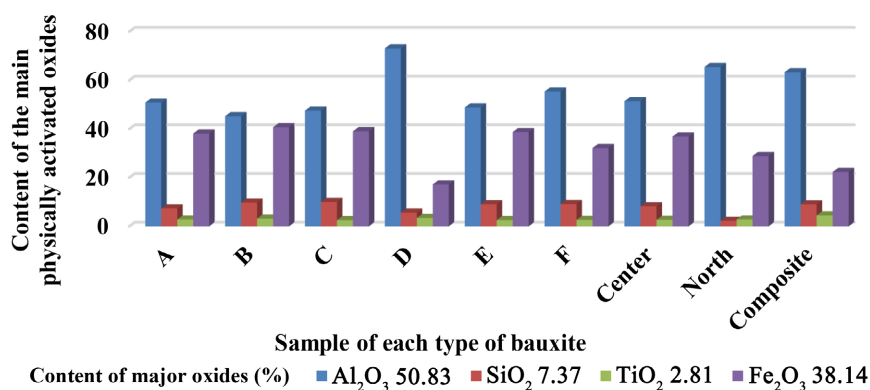


Figure 3. Bar graph of the chemical composition of physically activated bauxite.

Figure 3 shows the most abundant component in all samples after calcination, with percentages ranging from 40% to 75%. Samples D, north, and composite show the highest values, reaching around 70% or more. Fe₂O₃ content varies considerably between 10% and 35%, with samples A, B, and north showing relatively high contents. SiO₂ percentages remain low in all samples, generally below 10%. TiO₂ content is also low, at less than 5% for all samples.

4) Chemical activation of bauxite samples

Figure 4 shows the chemical composition of chemically activated bauxite,

indicating the percentages of four major oxides: SiO₂ (silica), TiO₂ (titanium dioxide), Fe₂O₃ (iron oxide), and Al₂O₃ (aluminum oxide) for various samples (A, B, C, D, E, and F) and regions (central, northern, composite).

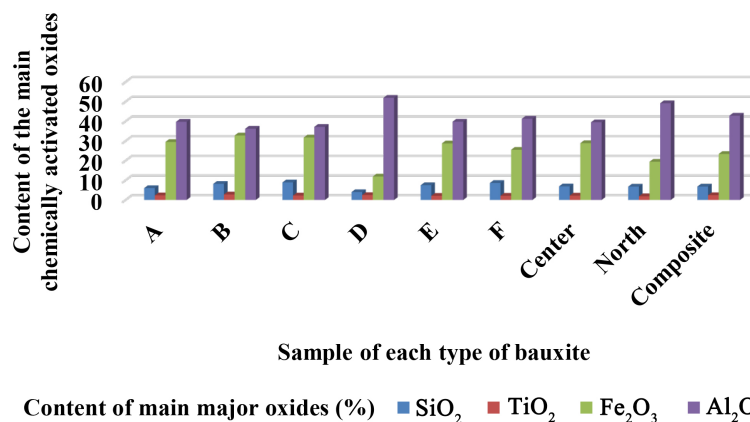


Figure 4. Bar graph of the chemical composition of chemically activated bauxites.

In **Figure 4**, we show that Al₂O₃ is the main component in all samples after chemical activation, with percentages ranging from 40% to over 50%. Samples D, North, and Composite show the highest percentages, exceeding 50%. Fe₂O₃ percentages are also significant, generally ranging between 30% and 45%. Samples A, B, D, North, and Composite show high Fe₂O₃ contents, reaching around 40% or more in some cases. SiO₂ percentages are low in all samples, below 10%, indicating a low presence of silica after chemical activation. TiO₂ is present in minimal quantities in all samples, also below 5%, suggesting that chemically activated bauxite contains little titanium dioxide.

5) Results of the mineralogical composition of the various Bauxite samples.

To determine the mineralogical composition of the bauxite samples, we need to identify the main minerals present and their relative proportions in each sample. Bauxite is primarily composed of aluminum minerals but may also contain various impurities. Graph 5 shows the results of a mineralogical analysis.

Figure 5 shows the mineralogical composition of bauxite from the Saföfö site. Gibbsite is the most abundant mineral, accounting for about 60% - 70% of the total composition. This dominance indicates that the Saföfö site bauxite is rich in hydrated aluminum, favorable for alumina production via the Bayer process. Hematite constitutes about 15% - 20% of the composition. As an iron oxide, its presence may require additional steps to reduce iron content during alumina extraction. Boehmite and diasporite are present in small quantities (less than 5%), suggesting that extreme processing conditions are unnecessary, thus reducing energy costs. Other minerals, such as corundum, rutile, kaolinite, quartz, and carbonate, are each present in minimal proportions, generally below 5%. This suggests that the bauxite from the Saföfö site is relatively pure, with few impurities that would complicate processing.

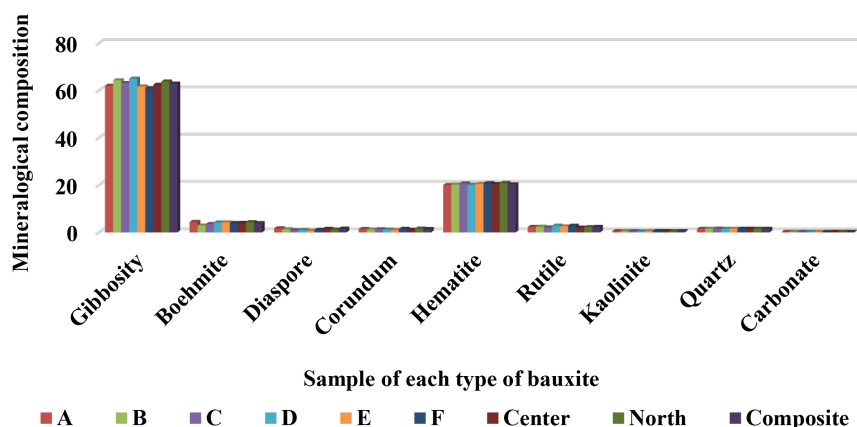


Figure 5. Bar graph of the mineralogical composition of Saföfö bauxite.

Studies of bauxite deposits in tropical regions, such as Guinea and Brazil, show a similar composition with a predominance of gibbsite. For example, studies by [15] [16] on bauxite deposits in Guinea noted a high gibbsite content (50% - 70%), with varying amounts of hematite and kaolinite. These similarities underline that tropical bauxite is typically alumina-rich and often associated with iron oxides. However, [17] have observed that bauxites from other regions, such as temperate zones, may contain a higher proportion of boehmite or diaspore, requiring more intense processing conditions (temperature and pressure range). In comparison, the low presence of these minerals in Saföfö site bauxite reduces energy requirements during refining. The study by [18] points out that impurities such as quartz and kaolinite, although present in small quantities in Saföfö site bauxite, can affect alumina yield if present in significant quantities. Fortunately, the levels of these impurities in Saföfö bauxite appear to be low enough not to pose any major problems.

6) Results of bauxite volumetric density analyses

Figure 6 shows the volumetric density of different samples. The following is a summary of the results observed:

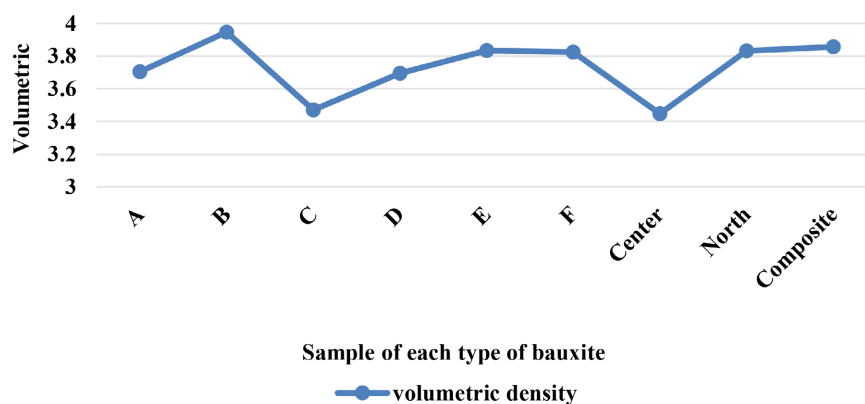


Figure 6. Gravimetric density curve for various bauxite samples from Kindia-Debele (Saföfö).

Samples A to F have volumetric densities ranging from 3.6 to 3.9. Sample B has the highest density at 3.9, while Sample C has the lowest at 3.5. The density values for Center, North, and Composite are also shown. North has a slightly lower density than the others, while Center and Composite have similar densities, around 3.8. These results are consistent with existing literature, which highlights the heterogeneous nature of bauxite deposits and the influence of various geological and environmental factors on their physical and chemical properties.

4. Conclusion

The study of bauxites from the Saföfö site has allowed us to assess variations in chemical and mineralogical composition after various treatments and determine the optimum conditions for their exploitation. The mineralogical composition is consistent with other bauxite deposits. Looking ahead, further studies could explore combined treatments using both physical and chemical methods on an industrial scale to assess their efficiency and cost-effectiveness. Finally, analyzing the environmental impact of different processes, particularly chemical treatments, is crucial for developing sustainable extraction methods.

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Conflicts of Interest

We, the authors of this study, declare no conflicts of interest in the publication of this work.

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