FUDMA Journal of Earth and Environmental Sciences (FUDJEES), Vol. 2, No. 1, 2025
Print ISSN: 1595-9686
EISSN: 1595-9708

ASSESSMENT OF GYPSUM QUALITY ON SETTING TIME ABOUT CEMENT PRODUCTION AND OTHER INDUSTRIAL APPLICATIONS IN NAFADA L.GA. GOMBE STATE, NORTHEASTERN NIGERIA

U.I Ashaka[1*], B.A. Abatcha[2], and M.A. Muhammad[1]

1 Department of Geology, Federal University Dutsinma, Katsina State.
2 Maiganga Coal Mines, Ashaka Cement Ltd, Ashaka, Gombe State.

*Corresponding author: ashaka14u@gmail.com; +234 8069798930
https://doi.org/10/33003/jees.2025.0201/09

ABSTRACT

The quality of gypsum is a critical factor in cement production, particularly in terms of its impact on setting time and the overall performance of the cement. This assessment examines the dual role of gypsum as both a retarder and a strength enhancer in Portland cement. Gypsum, primarily composed of calcium sulfate dihydrate ($CaSO_4{\cdot}2H_2O$), regulates the hydration process by controlling the reaction of tricalcium aluminate (C_3A), thus preventing flash setting and allowing for extended workability. The study highlights that optimal gypsum content typically ranges from 5% to 6%, which has been shown to enhance compressive and flexural strength while maintaining desirable setting times. Impurities in gypsum can adversely affect these properties, leading to inconsistent performance and potential structural issues. The findings underscore the importance of high-quality gypsum in achieving superior cement characteristics, emphasizing that excessive amounts or low-purity gypsum can lead to detrimental expansion and reduced strength. Overall, this research provides valuable insights into optimizing gypsum quality for improved cement production, with implications for both industry practices and future studies aimed at enhancing material performance. The purity of gypsum is crucial; lower purity levels (below 65%) can negatively impact the quality of cement. High-quality gypsum contributes positively to both the setting time and strength characteristics of cement, whereas impurities may compromise its performance.

Keywords: Assessment, Gypsum Quality, setting time, Nafada, Portland cement, Retarder

INTRODUCTION

Gypsum plays a crucial role in cement production, primarily as a setting regulator that influences both the setting time and the overall quality of the cement.

Gypsum mineralization is a pivotal factor in Nigeria's industrial revolution, fostering a self-reliant and durable economy, particularly in the building, agricultural, and construction industries. A.I. Haruna (2005). The cement, chemical, ceramic, pharmaceutical, and paint industries, among others, in Nigeria require gypsum as one of the most essential raw materials for their production. However, before the 1990s, gypsum mineral was imported from Spain and Morocco. Nigeria spent approximately N900 million annually on importing gypsum for its cement (Anonymous, 1996).

Gypsum, a mineral composed of hydrated calcium sulfate, is found globally and used in various industries, including construction, agriculture, and medicine. Major producers include China, Iran, Thailand, Spain, and the United States. Gypsum's versatility stems from its properties and is utilized in various products, including plaster, wallboard, and cement.

Global Market, Domestic Production, and Use: In 2012, domestic production of crude gypsum was estimated to be 9.9 million tons, with a value of approximately $69.3 million. The leading crude gypsum-producing States were, in descending order, Oklahoma, Texas, Iowa, Nevada, and California, which together accounted for 58% of total output. Overall, 47 companies produced gypsum in the United States at 54 mines and plants in 34 States. Approximately 90% of domestic consumption, which totaled approximately 22 million tons, was accounted for by manufacturers of wallboard and plaster products. Approximately 1.5 million tons were used for cement production and agricultural applications, with small amounts of high-purity gypsum serving a wide range of industrial processes, accounting for the remainder of the tonnage. Events, Trends, and Issues: U.S. gypsum production increased 11% compared with that of 2011 as the housing and construction markets increased in activity. Apparent consumption increased by 4% compared with that of 2011. The world's leading gypsum producer, China, produced more than five times the amount produced in the United States, the world's fourth-ranked producer. Iran is believed to rank second in global production and supplies much of the gypsum required for construction in the Middle East. Spain, the leading European producer, ranked third in the world and supplied crude gypsum and gypsum products to much of Western Europe. The increased use of wallboard in Asia, coupled with the construction of new gypsum product plants, led to increased production in that region. As more cultures recognize the economy and efficiency of wallboard use, worldwide production of gypsum is expected to increase. Demand for gypsum depends primarily on the strength of the construction industry, particularly in the United States, where approximately 95% of the consumed gypsum is used for building plasters, the manufacture of Portland cement, and wallboard products. If the construction of wallboard manufacturing plants designed to use synthetic gypsum from flue gas desulfurization (FGD) units as feedstock continues, this will result in less mining of natural gypsum. The availability of inexpensive natural gas, however, may limit the increase of future FGD units and, therefore, the production of synthetic gypsum. Gypsum imports increased slightly compared with those of 2011. Exports, although very low compared with imports and often subject to wide fluctuations, increased by 56%.

Gypsum is a hydrous calcium sulfate. Its chemical composition is expressed by the formula $CaSO4 \cdot 2H2O$, which can be interpreted as calcium united with sulfuric acid and holding water of crystallization. The percentage of these materials by weight is as follows: calcium, 32.5%; sulfuric acid, 46.6%; and water, 20.9%. The mineral is not infrequently impure, as a result of other substances present during its formation or deposited subsequently in intimate relation with it. These impurities are usually organic matter, iron compounds, clayey material, and the carbonates of lime and magnesia. The color of gypsum when reduced to powder is white. In its natural form, when pure, it is usually white when massive and pearly or glistening when crystallized. The crystalline form is transparent, sometimes to a remarkable degree. Gypsum is often gray, flesh-red, honey-yellow, ocher-yellow, or blue. As a result of impurities, it may appear brown, red, or reddish-brown, and sometimes black. The hardness of gypsum ranges from 1.5 to 2.0, with the crystalline form serving as the standard for the second degree on the scale of mineral hardness. It can be scratched with the fingernail, which is the standard test applied to distinguish it from other minerals that have a similar appearance. The specific gravity of gypsum, i.e., its weight as compared with pure water, is 2.3. At a temperature of 26° C., which is practically the ordinary temperature, one part of gypsum is soluble in 372 parts of water. Compared to 40 parts of common salt that would dissolve in 100 parts of water. The presence of other salts in solution, such as common salt and especially potassium salts, increases the amount of gypsum that may be dissolved. When heated sufficiently, gypsum releases its water of crystallization and becomes opaque, transforming into anhydrite. It does not dissolve in sulfuric acid, and when acted on by other acids, it does not effervesce or gelatinize. Instead, it fuses, coloring the flame reddish yellow. When ignited at a temperature not exceeding 260° C, it will again combine with water and set. The assessment of gypsum quality is vital for optimizing setting time in cement production. Maintaining optimal gypsum content between 5% and 6%, alongside ensuring high purity levels, is crucial for enhancing both the setting characteristics and strength of cement. Future research may focus on exploring alternative sources and formulations of gypsum to improve cement performance further while addressing environmental sustainability in the industry. Studies have shown that different types of gypsum affect the setting time and strength of Portland cement in varying ways. For instance, mineral gypsum has been found to optimize setting times when used at around 7%, while chemical gypsum shows peak performance at 5%.

Study Area

Location and Accessibility

Nafada and environs are located between latitudes 11 ° 00 ' N to 10 ° 30 ' N and longitudes 11 ° 00 ' E to 10 ° 30 ' E within the Gongola Arm of the Upper Benue Trough, northeastern Nigeria. The study areas include Barwo Winde, located about 4 km southwest of Nafada, Shole, Gadi, Sudingo, located about 10km south of Nafada, Mada, and Papa mines, located about 6 km northwest of Nafada town (Fig. 1). These areas are generally flat-lying terrain and undulating in some areas. A sandstone ridge generally surrounds the area, the Dumbulwa Bage High (Zarboski *et al.,* *1997).*

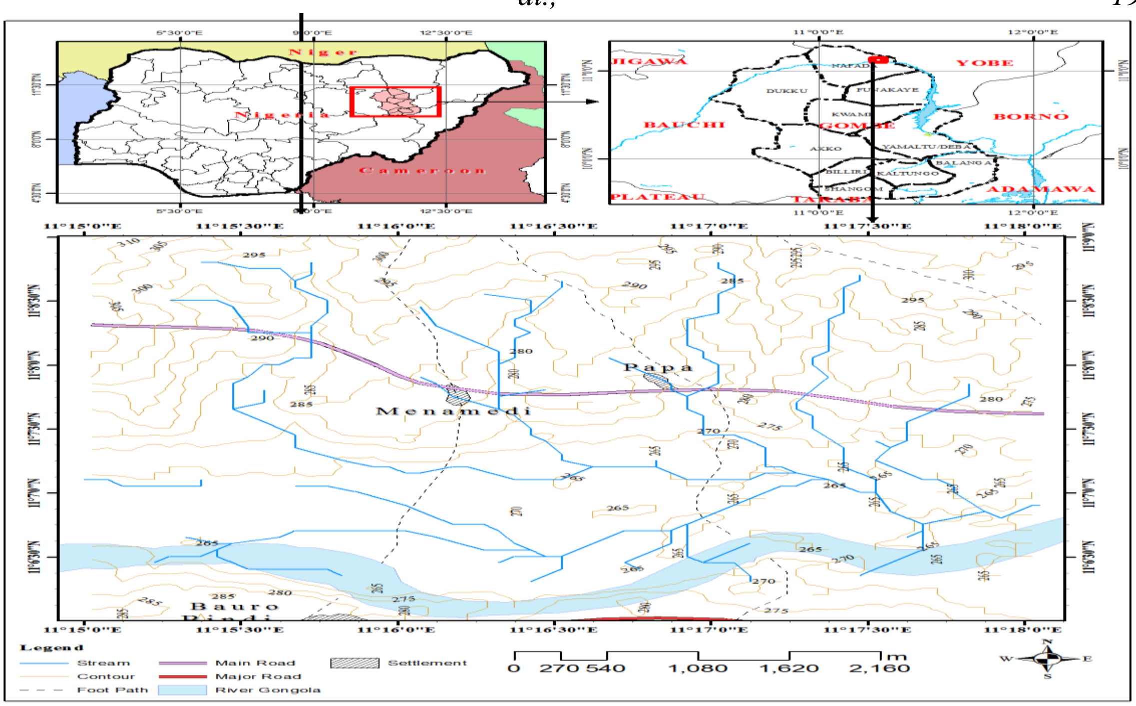

Figure 1. Map of the study area. Source: Umar Ashaka (2017)

Gypsum Occurrences in Nigeria

The occurrence of gypsum within the Fika Shale in the Gongola arm of the Upper Benue Trough was first reported by Carter *et al* (1963) and later confirmed by Reyment (1965). Orazulike (1988) reported the occurrence of gypsum in the Nafada and Bajoga areas. Barka (2011) also reported the occurrence of gypsum in the Nafada area of Gombe State, northeastern Nigeria. Ntekim (1999) and Mamman *et al*. (2007) also reported the occurrence of gypsum deposits in Guyuk and Cham in the Yola Arm of the Upper Benue Trough. The earliest work on evaporites in the Northeastern region was conducted by Vischer (1910) in a geographical account of an early expedition to the Chad Basin and its immediate environment. The author described two classes of evaporite mineral deposits, namely;

(a) The magma salt (an admixture of sodium carbonate and bicarbonate, sodium sulphate and sodium chloride in concentrations of approximately equal magnitude)

(b) Magma natron (mainly sodium carbonate with a subordinate amount of sodium sulphate and sodium chloride). The earliest reconnaissance traverse of the area was made by Falconer (1911) during the mineral survey of northern Nigeria. Gypsum occurrence in Northeastern Nigeria was first reported by Carter *et al*. (1963) as occurring within a sequence of blue-black shales, containing few, thin, and impersistent limestone beds, and occasional interbedding with thin siltstone beds and lava flows. Reyment (1965) confirmed this by reporting the Fika Formation as consisting of blue-black shales, occasionally gypsiferous, with a thickness exceeding 430 meters. Maglione (1981) also confirmed the presence of gypsum mineralization in well-drained, well-aerated environments within the Nigerian sector of the Chad Basin (part of which is the research area). Gypsum occurrence at Nafada and Bajoga areas was reported by Orazulike (1988). All these workers confirmed that the Fika shales are gypsiferous. Since then, little work has been done in this area to determine the economic viability of gypsum mineralization at various depths and locations within the Chad Basin. Only the illegal miners patronize the gysiferous areas. These areas are generally flat-lying terrain, with undulating sections in some areas. A sandstone ridge generally surrounds the area, the Dumbulwa Bage High (Zarboski *et al*., 1997). Gypsiferous shales are reported from the upper Cretaceous Dukamaje Formation and the Paleocene Dange Formation in the Sokoto area. Small-scale miners are currently mining the 1.46-million-tonne gypsum deposit at Wurno in Sokoto State to supply the Sokoto cement plant. Other gypsum prospects are reported from Nafada and Bajoga in Gombe State, at Fika in Yobe State, and in the Guyuk/Gwalura areas of Adamawa State (Ministry of Solid Minerals Development, 2000). The field occurrence of gypsum bodies in the Nafada area shows discontinuous and displacive patterns of vertical to sub-vertical cross-cutting minor fractures within the Senonian Fika shale, evident as thin laminae (1-6 cm) of diagenetic (secondary) origin.

The geochemistry of gypsum deposits within the Senonian Fika shale in Nafada and its environs reveals that the gypsum in the study area has a high percentage purity of 90.6-95.8 wt%. These results concur with the British Industrial Standard, Raw Material Research Development Council (BIS: 1290 -1973, RMRDC 2005) and Umeshwar 2005) indicating high grade gypsum form that is suitability for different industrial usage (Cement, Agriculture, Medical, Pottery and Ceramic, Pharmaceutical, Chemical, Paints, Building and Construction etc.).

Role of Gypsum in Cement Setting

Gypsum is added to Portland cement to prevent early hardening, known as "flash setting," which allows for extended working time. It achieves this by slowing down the hydration reaction of tricalcium aluminate (C_3A), forming ettringite, which regulates the setting process.

Optimal Gypsum Content

Research indicates that the optimal gypsum content for cement production typically lies between 5% and 6%. This range has been shown to enhance both flexural and compressive strengths at various curing ages (7, 14, 21, and 28 days) while preventing excessive expansion and deterioration of the cement paste. Excessive gypsum can lead to adverse effects, including abnormal expansion and reduced strength.

Quality and Purity of Gypsum

The purity of gypsum is crucial; lower purity levels (below 65%) can negatively impact the quality of cement. High-quality gypsum contributes positively to both the setting time and strength characteristics of cement, whereas impurities may compromise its performance.

Microstructural Considerations

Scanning electron microscopy (SEM) analyses have demonstrated that optimal gypsum content enhances microstructural features, which correlate with improved strength properties. The development of silicate-rich regions within the microstructure indicates effective hydration processes facilitated by appropriate gypsum levels.

Chemical Composition of Gypsum

The chemical composition of gypsum plays a crucial role in determining its performance in the cement production process. Gypsum, primarily composed of calcium sulfate dihydrate ($CaSO_4 \cdot 2H_2O$), influences various properties of cement, including setting time, strength development, and overall durability. Here is a detailed assessment of how these factors interact:

Main Components

Gypsum consists mainly of calcium oxide (CaO), sulfur trioxide (SO_3), and water. A typical composition may include approximately 32.5% CaO, 46.6% SO_3, and 20.9% H_2O. The presence of these components is vital for the hydration reactions that occur during cement setting.

Impurities

Natural gypsum often contains impurities such as clay, organic matter, and other minerals (e.g., SiO_2, Al_2O_3, Fe_2O_3). These impurities can adversely affect the performance of gypsum in cement applications by altering its reactivity and hydration characteristics.

Impact on Setting Time

Retarding Effect:

The primary function of gypsum in cement is to regulate setting time by slowing down the hydration of tricalcium aluminate (C_3A). When gypsum is added to cement, it reacts with C_3A to form ettringite ($C_3A \cdot 3CaSO_4 \cdot 32H_2O$), which coats C_3A particles and delays further hydration. This retarding effect is crucial for allowing adequate time for mixing, transporting, and placing concrete.

Materials and Methods

Materials

The materials used for the research work include;

i. GPS, ii. Tape, iii. Sample Bag, iv. Field Note Book, v. Biro, vi. Hammer, vi. Hammer, vii. Masking Tape, viii. Analytical balance, ix. Weighing boat, x. Aluminium press cups, xi. Herzog swing mill, xii. Herzog press machine, xiii. Stearic acid

Field Methods

The fieldwork was conducted in March 2016. Two mining sites were visited: Barwo Wind and Mada, around Menamedi and Papa. Twenty mining pits were sampled (Fig. 2). The mode of mining in all the mining sites was pitting (ranging from 12m to 18m depth). While in the field, careful observation of different gypsum forms was done by examining the various carrier beds and the structural and textural characteristics of the collected samples. The carrier beds are primarily composed of fika shale and mudstone. The following are the findings based on the fieldwork:

(i) The gypsum changes in form with depth
(ii) The thickness and deformation of the gypsum forms increase with depth
(iii) All the different gypsum forms at any depth have peculiar carrier Beds.

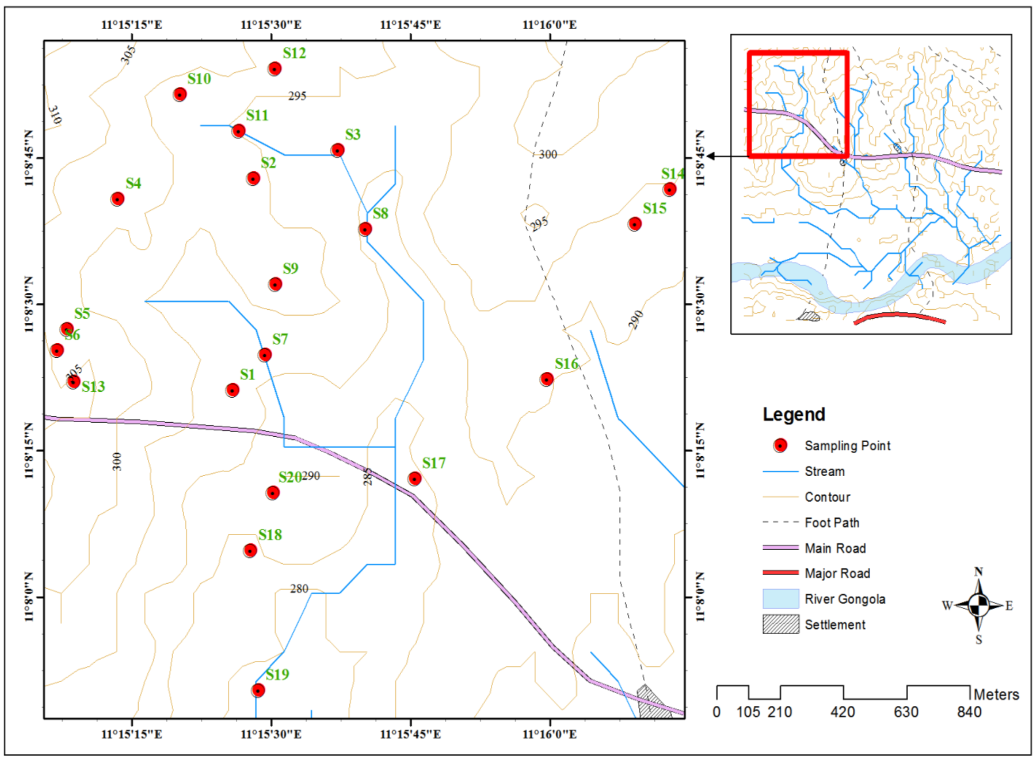

Figure 2: Sampling Location of the Study Area
Source: Umar Ashaka (2017)

Laboratory Methods

Twenty samples were analyzed using the X-ray fluorescence analytical technique at the laboratory of the AshakaCem PLC quality section. This was done to determine the chemistry and assess the quality of the gypsum.

Sample Preparation for XRF Analysis

The following steps are taken to prepare the samples for XRF analysis

I. Cleaning up the samples (remove mud and shale particles)
ii. Crushing the sample into powder
iii. Sieving the crushed sample into the required mesh
iv. Weighing the representative sample (20g)

Procedures for XRF Analysis

To carry out an XRF analysis after sample preparation, I took the following procedures
i) I weigh 0.4 g of stearic acid into a weighing pan and add 20 g of the sample.
ii) I transfer the mixture into the grinding vessel completely.
iii) I place the vessel in position inside the swing mill machine and press down the clamp.
iv) I then selected the appropriate program for the sample.
v) I pressed the start button and allowed the program to run to completion.
vi) I removed the vessel and poured the sample onto a clean sheet of paper.
vii) I filled an aluminum cup to about 1/3 of its volume with stearic acid.
viii) I filled the cup to the brim with the ground sample and carefully leveled the surface with a spatula.
ix) Press the start button of the press machine, and the plunger will rise. Place the cup on it when it is in the up position, and allow the plunger to lower the cup.
x) Then I inserted the die head on the sample and used the screw fastener to hold it in position.
xi) Press the start button and wait one minute after the pressing action is concluded.
xii) Lose the fastener, press the start button, and the die-head, together with the press pellet, will be lifted out.
xiii) Remove the die head and the pellet, and carefully label them.
xiv) Place the pellet face down in the XRF computer machine and then insert it in the loading position.
xv) From the measure and analyze window of the XRF computer (superQ software), select the appropriate program for the sample and click 'measure'
xvi) Wait for the analysis to be completed and print out the result.

Petrographic Analysis

Four different gypsum forms (alabaster, selenite, satin spar, and balatino) were studied in hand and thin section to assess their textures and textural evolution

Sample Preparation for Thin Section

The following steps are taken for the preparation of the thin section in the geology laboratory of Abubakar Tafawa Balewa University, Bauchi;
i) Gypsum samples were brought from the field
ii) The Samples were washed, dried, and cleaned
iii) The Samples are polished using a polishing machine
iv) The Samples are then mounted on a polished glass surface using Canada Balsam
v) The Samples were polished to 3mm
vi) The Samples are ground with Carborundum of 0.6mm size
vii) Samples were ground with powdered caborundum of 0.4mm size
viii) The Polished gypsum surface is covered with gum (Canada balsam) and thin glass
ix) The slide is then placed on a heater to expel air bubbles and dried up
x) The Gypsum slide is then allowed to cool, which yields a thin section that can be used for the study.

RESULTS AND DISCUSSION

Geochemical Analysis

The results of the XRF studies are summarized in Tables 1 and 2; all the information and findings in Tables 1- 4 are plotted in the Figures. 3-6:

Table 1. Oxide Composition of Gypsum in Nafada (in wt%)

Parameterswt. %	SAMPLES									
	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
SiO_2	2.164	2.261	2.229	2.187	1.935	2.247	2.300	2.163	1.968	2.218
Al_2O_3	0.274	0.275	0.257	0.236	0.153	0.262	0.281	0.281	0.145	0.245
Fe_2O_3	0.095	0.132	0.115	0.110	0.092	0.119	0.132	0.100	0.100	0.116
CaO	32.313	32.057	30.936	31.916	32.950	31.826	32.014	33.371	32.011	30.881
MgO	1.108	1.131	1.136	1.128	1.101	1.126	1.132	1.108	1.103	1.132
SO_3	43.022	40.202	41.286	42.389	42.546	42.284	40.099	42.000	42.503	40.341
K_2O	0.045	0.050	0.048	0.052	0.041	0.048	0.054	0.048	0.046	0.048
Na_2O	0.070	0.073	0.071	0.072	0.071	0.073	0.072	0.074	0.072	0.072
P_2O_5	0.024	0.014	0.013	0.013	0.019	0.019	0.027	0.016	0.013	0.022
Mn_2O_3	0.036	0.035	0.032	0.034	0.032	0.032	0.037	0.033	0.034	0.027
TiO_2	0.023	0.024	0.016	0.030	0.024	0.033	0.023	0.021	0.035	0.021
Cl	0.012	0002	-0.006	-0.006	-0.006	0.003	0.009	-0.006	-0.005	-0.003
Cr_2O_3	0.008	-0.004	0.000	0.000	0.003	-0.002	-0.005	-0.006	0.006	0.007
SrO	0.042	0.039	0.035	0.041	0.041	0.039	0.041	0.039	0.039	0.043
Sum of Conc.	78.091	78.180	78.078	78.090	77.889	77.985	78.084	78.147	77.948	78.053
Purity	94.245	92.250	91.314	93.380	94.641	93.138	91.057	95.271	93.640	90.275
Combined water	18.910	19.991	19.092	19.075	19.145	19.028	18.944	19.900	19.126	19.053

Tabular Presentation of Results and Parameters

The table below (3 and 4) shows the four different gypsum forms identified in the field and the laboratory. There are various purities by weight. The percentage is determined from the XRF analysis, and the average weight of all the gypsum forms is known as follows: 94.135 for the Alabaster forms, 91.31 for the Selenite form, 90.065 for the Satin par form, and 91.575 for the Balatino forms. The average purity of the entire gypsum form from the study area is given as 91.775.

The moisture content is a key parameter in determining the purity of gypsum; the minimum water content for pure gypsum is 18, and the maximum is 20. The studied gypsum in the area has an average moisture content of 18.746 in wt. %

The studied Nafada gypsum has an average moisture content of 18.74% by weight (Table 3), which is slightly lower than that of pure gypsum. In contrast, the average purity of the Nafada gypsum is 91.78%. From this result, it can be deduced that the studied gypsum contains small amounts of other compounds, hence making it of good quality.

The purity of gypsum in Nafada ranges from 87% to 95%, which is suitable for both agricultural and industrial uses.

Comparison of the studied gypsum characteristics to the British Industrial Specification (BIS) reveals that the studied gypsum conforms to the BIS specification for various industries, except for the surgical and pharmaceutical industries, which require a minimum of 96.0% CaSO4 · 2H2O. The studied gypsum has an average composition of 91.78% CaSO4 · 2H2O.

Graphical Presentation of Results

Different gypsum forms and samples were presented in the figures below in the form of a Bar chart and a line graph. The bar chart represents various gypsum forms plotted against their purity. In contrast, the line graphs represent different samples plotted against various parameters, such as lime content (CaO), SO_3, and water content. All these parameters determined the purity of the gypsum in the study area.

Table 2. Oxide Composition of Gypsum in Nafada (in wt% %). Cont.

Parameters wt. %	SAMPLES									
	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20
SiO_2	2.256	2.329	2.254	2.209	1.974	2.258	2.338	2.336	2.189	1.987
Al_2O_3	0.267	0.302	0.268	0.287	0.154	0.270	0.290	0.296	0.292	0.149
Fe_2O_3	0.120	0.137	0.114	0.097	0.094	0.119	0.121	0.137	0.102	0.094
CaO	31.938	32.075	31.981	32.335	32.131	31.792	30.989	30.060	30.378	32.078
MgO	1.132	1.132	1.136	1.116	1.104	1.136	1.135	1.134	1.106	1.104
SO_3	40.292	42.084	42.316	41.981	41.478	40.279	41.180	40.097	38.999	42.502
K_2O	0.051	0.054	0.048	0.051	0.041	0.051	0.054	0.053	0.048	0.045
Na_2O	0.070	0.072	0.071	0.071	0.073	0.071	0.071	0.072	0.071	0.070
P_2O_5	0.015	0.025	0.017	0.024	0.013	0.011	0.030	0.017	0.021	0.018
Mn_2O_3	0.030	0.034	0.032	0.034	0.030	0.027	0.037	0.034	0.29	0.032
TiO_2	0.016	0.022	0.031	0.027	0.019	0.031	0.025	0.032	0.038	0.039
Cl	-0.006	0.009	-0.005	0.001	-0.005	-0.006	0.012	-0.006	0.003	-0.003
Cr_2O_3	0.002	-0.003	-0.002	0.004	0.010	0.004	0.005	-0.005	-0.007	-0.002
SrO	0.039	0.041	0.040	0.039	0.042	0.038	0.044	0.039	0.040	0.039
Sum of Conc.	78.126	78.184	78.188	78.148	78.050	77.976	78.177	78.185	78.184	78.028
Purity	90.261	89.097	92.339	93.207	90.724	91.096	90.150	88.101	87.276	93.706
Combined water	18.031	18.938	18.042	18.891	17.115	19.025	17.981	17.944	17.899	19.126

Table 3. Gypsum Forms and Their Average Moisture Content.

SAMPLE NO	GYPSUM FORM	MOISTURE CONTENT IN WT (%)	AVERAGE MOISTURE IN WT (%)
1	ALABASTER	18.910	19.212
4		19.075	
5		19.145	
6		19.028	
8		19.900	
2	SELENITE	19.991	18.864
9		19.126	
10		19.053	
12		18.938	
13		18.042	
11		18.031	
16	SATINSPAR	19.025	18.395
17		17.981	
19		17.899	
18		17.944	
20		19.126	
15	BALATINO	17.115	18.511
14		18.891	
7		18.944	
3		19.092	

Local and International Comparison of Gypsum Quality

A comparison is made between the gypsum in the study area and that from foreign countries (Morocco and Spain), as well as the local gypsum in other parts of the country (Yobe, Benue, and Sokoto). The data used to compare the results were sourced from Haruna A—I (2005). The result of the geochemistry of the gypsum in the study area, which has an average purity of 91.775, compares favorably with that of Morocco and Spain, at 95.90 and 94.70, respectively—also, compared to those of Yobe, Benue, and Sokoto, which have average purities of 93.40%, 89.30%, and 42.40%, respectively. The comparison is made in the form of the bar charts shown in Figures 5 and 6 below.

Table 4. Quality Assessment Parameters in the studied Nafada Gypsum.

SAMPLE NO	COMBINED WATER	SO_3	CaO	PURITY
1	18.910	43.022	32.313	94.245
2	19.991	40.202	32.057	92.250
3	19.092	41.286	30.936	91.314
4	19.075	42.389	31.916	93.380
5	19.145	42.546	32.950	94.641
6	19.028	42.284	31.826	93.138
7	18.944	40.099	32.014	91.057
8	19.900	42.000	33.371	95.271
9	19.126	42.503	32.011	93.640
10	19.053	40.341	30.881	90.275
11	18.031	40.292	31.938	90.261
12	18.938	42.084	32.075	89.097
13	18.042	42.316	31.981	92.339
14	18.891	41.981	32.335	93.207
15	17.115	41.478	32.131	90.724
16	19.025	40.279	31.792	91.096
17	17.981	41.180	30.989	90.150
18	17.944	40.097	30.060	88.101
19	17.899	38.999	30.378	87.276
20	19.126	42.502	32.078	93.706

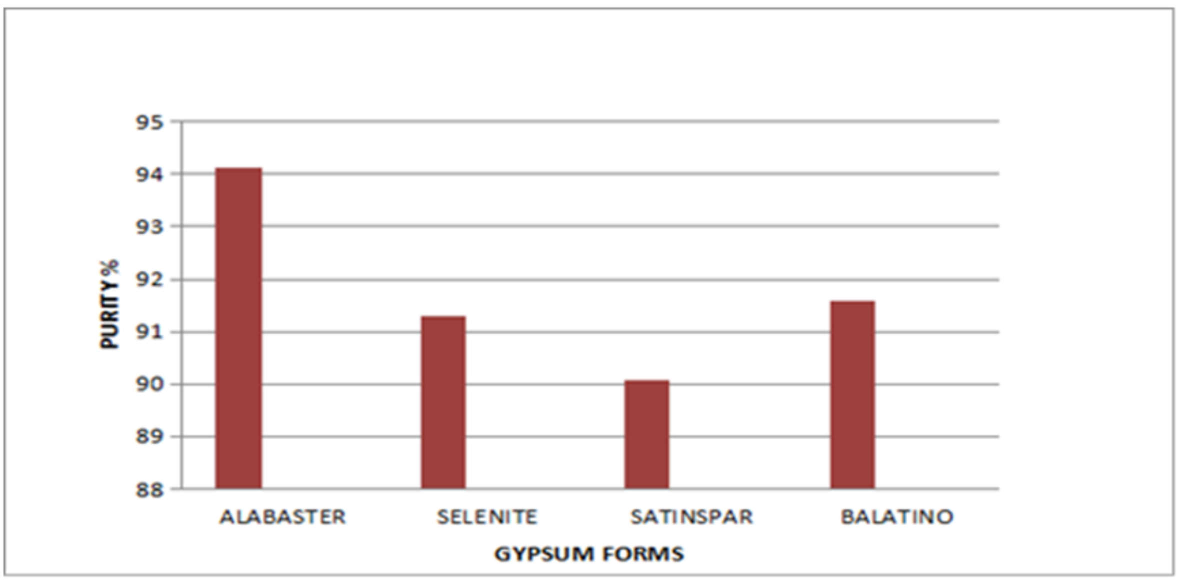

Figure 3: Graph of Average Purity Against Gypsum Forms.

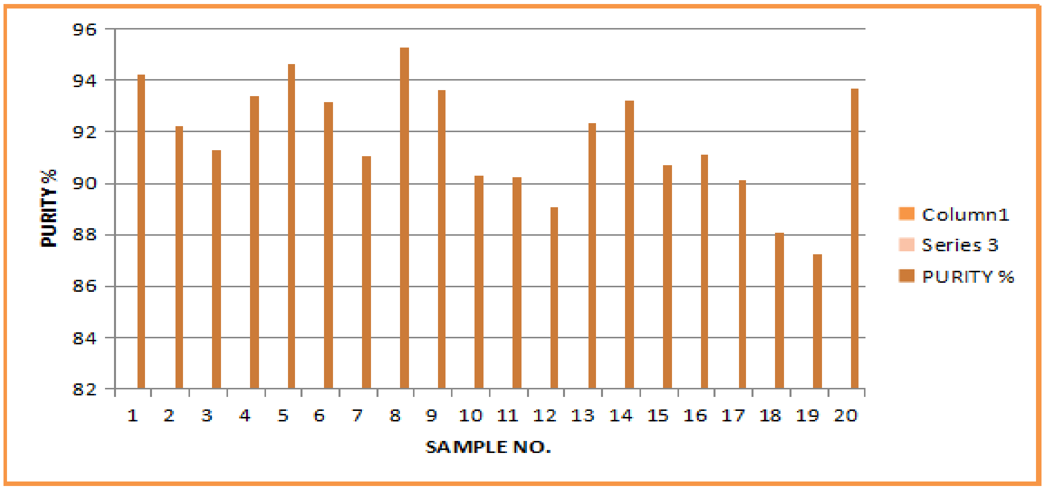

Figure 4. Graph of Purity of all Samples

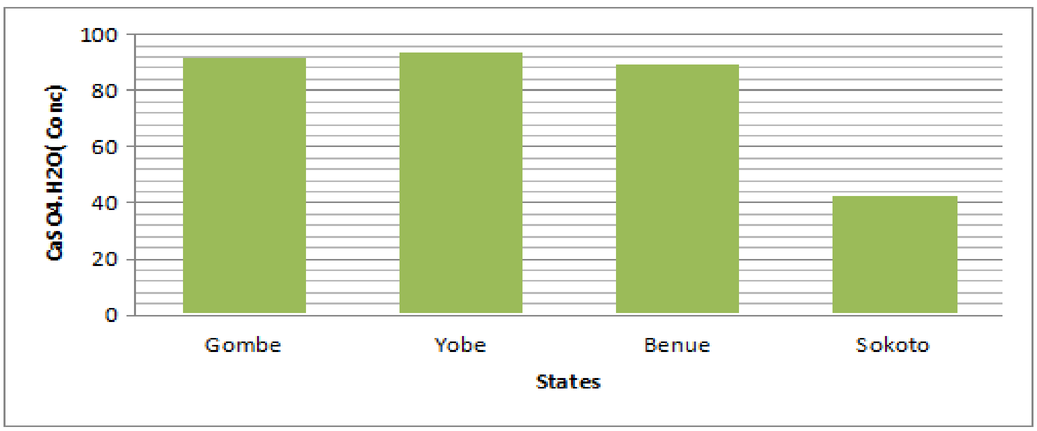

Figure 5. Graph of Comparison between Gypsum Locally and the Study Area
Note: Gombe Nafada

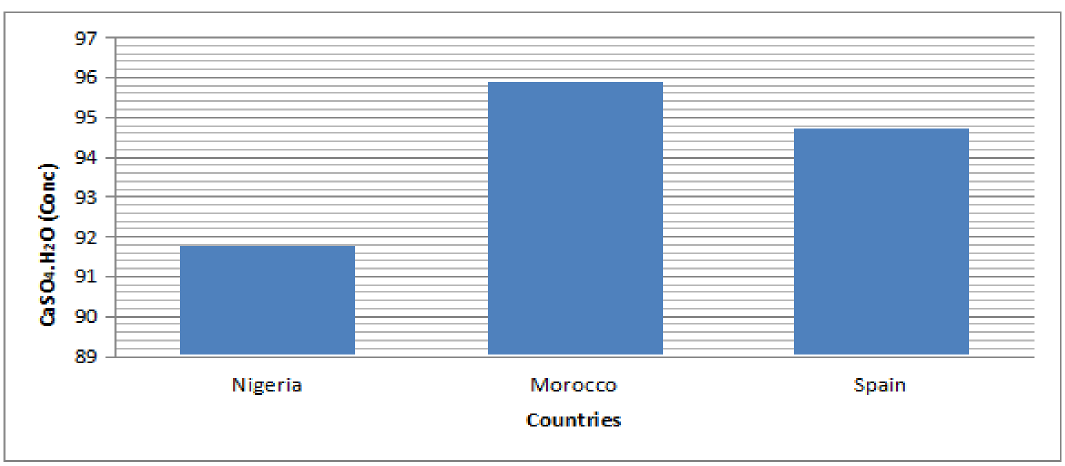

Figure 6: Graph of Comparison between Gypsum Internationally and the study area
Note: Nigeria Nafada

Table 5: Comparison of Local and Foreign Gypsum

FOREIGN GYPSUM	$CaSO_4.2H_20$ (Wt% %)	MOISTURE CONTENT	LOCAL GYPSUM	$CaSO_4.2H_20$ (Wt% %)	MOISTURE CONTENT
MOROCCO	93.40	15.67	YOBE	93.40	15.00
SPAIN	94.70	18.38	BENUE	89.30	18.52
			SOKOTO	42.40	9.78

Source: Haruna (2005)

Discussion

The result of the analyzed samples is presented in Table (1&2) The concentration of the various oxide composition of Nafada gypsum shows that, SiO_2 ranges from 1.9 to 2.3%, Al_2O_3 from 0.1 to 0.3%, Fe_2O_3 from 0.09 to 0.12%, CaO from 30.9 to 32.3%, MgO from 1.10 to 1.13%, SO_3 from 38.9 to 43.0%, K_2O from 0.04 to 0.05% and Na_2O from 0.070 to 0.074%. According to the BIS specification, gypsum with a moisture content of 20.9 weight percentage (wt. %) is regarded as pure gypsum. Those with low moisture content are regarded as impure, while those with no moisture content have been transformed from gypsum to anhydrite. The studied Nafada gypsum has an average moisture content of 18.75% by weight (Table 3), which is slightly lower than that of pure gypsum. In contrast, the average purity of the Nafada gypsum is 91.78%. From this result, it can be deduced that the studied gypsum contains small amounts of other compounds, hence making it of good quality.

According to British Industrial Standard, Raw Material Research Development Council (BIS: 1290 - 1973, RMRDC 2005), gypsum is graded into 4

- High grades (88%-100%)
- Medium grades (65%-87%)
- Low grades (50%-60%)
- Anhydrides (less than 50%)

Gypsum Purity and Its Impact on Cement Quality

The purity of gypsum directly correlates with the quality of cement produced. Higher purity levels result in better performance characteristics, including improved setting times and compressive strength. Research indicates that gypsum with a purity of less than 65% can lead to detrimental effects on cement properties, including flash setting and reduced moldability.

Industrial Application of Gypsum

The BIS specification for cement is 70-75% and 80-85 % $CaSO_4.2H_2O$ for export quality, 0.6 % (max) $K_2O + Na_2O$, and 3.0% (max) MgO. The studied gypsum, with an average of 91.78% (max) $CaSO4·2H2O$, 0.12% $K2O + Na2O$, and 1.12% MgO, meets the BIS required standard limit. The BIS specification for ammonium sulphate fertilizer is 85-90% (min) $CaSO4 \cdot 2H2O$, 6.0% (max) SiO2, 1.0% (max) Fe2O3/Al2O3, and 1.5% (max) MgO. With 91.78% (max) $CaSO_4.2H_2O$, 2.19 %

SiO_2, 0.45 % Fe_2O_3/Al_2O_3, and 1.12 % MgO, the studied gypsum is within the BIS required specification for ammonium sulphate fertilizer production. Pottery has a BIS specification of 85 % (min) CaSO4.2H2O, 1.0 % (max) Fe2O3/Al2O3, and 1.5 % (max) MgO, while the studied gypsum has 91.78 % CaSO4.2H2O, an average table4) 0.45 % Fe2O3/Al2O3, and 1.12 % MgO; hence, it is within the specified BIS requirement. Cosmetics manufacturing has a BIS specification of 75.25% (min) CaSO4·2H2O and 3.0% (max) SiO2. The studied gypsum, with a composition of 91.78% CaSO4 · 2H2O and 2.19% SiO2, can be utilized in cosmetic manufacturing. The studied gypsum, with 93.0% CaSO4 · $2H_2O$, is within the specified specifications for materials used in the building, chemical, and paint industries, as well as for soil amendment.
Similarly, according to the BIS specification, gypsum with a moisture content of 20.9 weight percentage (wt%) is regarded as pure gypsum. Those with low moisture content are regarded as impure, while those with no moisture content have been transformed from gypsum to anhydrite.

Conclusion and Recommendation

This research reveals that the study area features four distinct forms of gypsum: Balatino, Alabaster, selenite, and satin spar, which differ in their characteristics. These gypsum forms vary in their depth, ranging from 13 m to 18 m. The geochemistry of these gypsum forms reveals that the gypsum in the study area is pure and can be recommended for various industrial applications, including pharmaceuticals, ceramics, cement manufacture, agricultural purposes, and the production of plaster of Paris.
The quality of gypsum used in cement production is paramount for achieving desired performance characteristics. Ongoing research continues to refine our understanding of how different types and purities of gypsum influence the quality of cement, guiding best practices in the industry. Future studies may focus on long-term effects and alternative sources of gypsum to enhance sustainability in cement manufacturing.
The presence of impurities in gypsum has a multifaceted impact on its performance in the cement production process. While some impurities may enhance specific properties, excessive or incompatible impurities generally lead to adverse outcomes such as inconsistent setting times, reduced strength, and compromised durability. Therefore, selecting high-quality gypsum with minimal impurities is crucial for optimizing cement performance and ensuring the reliability of construction materials.

Acknowledgment

I want to express my sincere appreciation to Abubakar Tafawa Balewa University and the individuals whose contributions and support have greatly enhanced the quality and rigour of this research. First and foremost, I am grateful to my primary advisor and supervisor, Prof. Ahmed Isa Haruna, for his unwavering guidance, insightful suggestions, and constant encouragement throughout the research period. His expertise and wisdom were an invaluable asset to this project.
I am grateful to Ashaka Cement Ltd for providing the facilities and support for this project. Their support facilitated the smooth execution of the research.
I extend my appreciation to my friends and colleagues, who have been supportive throughout and provided a stimulating academic environment. Their encouragement was immensely motivating during my challenging research journey.
Lastly, I am thankful to my family for their understanding, encouragement, and support.

References

Anonymous (1996). Minister for Solid Minerals. The Guardian, October 26th, 1996.

Benkhelil, J. (1989). The Origin and Evolution of the Cretaceous Benue Trough, Nigeria. Journal of African Earth Sciences 8(4): 251–282.

Braide, S.P. (1992). Studies on Sedimentary and Tectonics of the Yola Arm of the Upper Benue Trough; Facies Architecture and Their Tectonic Significance. Journal of Mining and Geology, 28 (2): 23–32.

BIS (1997). British Industrial Specification for Gypsum Uses (IS: 1929 – 1973).

Burke, K.C., Dessauvagie, T. F. J., & Whiteman, A.J. (1971). Opening of the Gulf of Guinea and Geological History of the Benue Depression and Niger Delta. Nature Phys. Sci . 233, 51-55.

Carter, J.D., Barber, W., Tait, E.A., J. P. (1963). The Geology of Part of Adamawa, Bauchi, and Bornu Provinces of Nigeria. GSN Bull. 30: 109p.

Dike, E.F., (1993). Stratigraphy and Structures of Kerri-Kerri Basin, Northeastern Nigeria. Journal of African Earth Sciences, 8, pp. 251-262.

Evans, G. E., Schmidt, V., Bush, P., & Nelson, H. (1969). Stratigraphy and Geologic History of the Sabka Abu Dhabi, Persian Gulf. Sedimentology 12, pp. 145–159.

Falconer, J.D. (1911). The Geology and Geography of Northern Nigeria. Macmillan Publishers, London. Pp. 33 – 36.

Haruna, A.I. (2005). Review of Geology, Geochemistry, and Origin of Gypsum Mineralization in Chad Basin (North Eastern Nigeria)

Maglione, G. 1981. An Example of Recent Continental Evaporitic Sedimentation: The Chadian Basin (Africa), in Evaporite Deposits, Gulf Publishing Company, Houston, Texas, 5 – 9.

Mamman, Y. D., Orazulike, D.M., & Ndaye, S.T. (2007). The Occurrence and Chemical Composition of Gypsum at Cham in the Yola Arm of the Upper Benue Trough, N.E. Nigeria. Global Journal of Pure and Applied Sciences. Vol. 13 No. 4 Pp 563 – 569.

Murray, R.C. (1964). Origin and Diagenesis of Gypsum and Anhydrite. Journal of Sedimentary Petrology 34: 512–523.

Ntekim E.E (1999). Preliminary Report on Gypsum Occurrence in Guyuk Area, Northeastern Nigeria. Global Journal of Pure and Applied Science. Vol. 5. No.1.

Obaje, N. G. Ulu, O. K. Petters, S.W., (1999). Biostratigraphic and Geochemical Control of Hydrocarbon Prospect in the Benue Trough and Anambra Basin, Nigeria. NAPE Bull. V. 14(1) P. 18-5.

Offodile M. E., (2006). Appraising the Geology, Structure, and Environment of Deposition as Indicators of Mineral Occurrences in the Gongola Basin of the Upper Benue Trough of Nigeria. A Paper Presented at the NMGS Annual Conference, Kaduna, Pp 64–91.

Orazulike, D.M., (1988). The Prospect of Gypsum as an Ore in Pindiga, Bauchi State, Unpublished Interim Technical Report for Detailed Prospecting of the Commodity. Submitted to Ashaka Cement Company, Bauchi State 3p.

Petters, S.W. (1978). Stratigraphic Evolution of the Benue Trough and Its Implications for the Upper Cretaceous Paleogeography of West Africa. Journal of Mining and Geology. 86 p.311–321.