NIGERIAN
MINING JOURNAL
ISSN 1117 - 4307

A Publication of
NIGERIAN SOCIETY OF MINING ENGINEERS

NIGERIAN MINING JOURNAL

Volume 10 - Number 1 - November 2012

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NIGERIAN MINING JOURNAL

INFORMATION FOR AUTHORS

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Unpublished work: Umoru, E.E. (1996) Re-appraisal of mining methods of Ameka Lead/zinc deposit. Unpublished HND project, Kaduna Polytechnic Kaduna, Nigeria.

Proceedings: Bello,S.B. (1996) Optimisation of mning parameters of sub-basalt underground mine development of solid mineral for national self-reliance and economic growth. Edited by E.O.A. Damisa, Engineering Conference Series, pp 202-215

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Upgrading of Obi Coal to Coking Grade by Inoculation Process

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Abstract

In this work the possibility of upgrading a sample from Obi coal deposit to coking grade for iron making process using the blast furnace route by inoculation process was investigated. The sample used in this project was sourced from Kwagshiri in Obi local government area of Nassarawa state with estimated reserve of 22 million tones. The chemical composition of the as-received Obi coal sample was determined using proximate analysis method with the following percentages: carbon content (52.64%), ash content (10.73%), volatile matter (24.62%), moisture content (7.99%), sulphur content (4.01%) and phosphorus content (0.0081%). The as-received coal specimens was calcined at a temperature of 1200^0C for 1hour and inoculated by quenching in various medium with a soaking time of 30 minutes in kerosene, water, black oil and the last specimen was allowed to cool in the furnace as a controlled specimen. Before inoculation, some physical tests were carried out on the as-received coal specimens. The drop number values of the as-received coal specimens inoculated in kerosene, water, black oil was found to be 4 while the controlled specimen has a drop number of 2. The drop resistance values of the as-received coal specimens inoculated in kerosene, water was found to be 3, 4 for the black oil and 0 for the controlled as-received coal specimen. The microporosity values of the various as-received coal specimens inoculated in various medium was 19.53% for kerosene, 7.23% for water, 3.66% for black oil and 14.57% for the controlled. The percentage of the absorbed medium into the matrix of the as-received coal specimens is 22.49% using black oil, 13.91% for using kerosene and 7.33% using water. It is on this basis that the coal sample inoculated in black oil was pulverized and sieved into -40+63µm and -90+125µm and grouped as fine and semi coarse respectively. The two particle sizes were used to form pellets using black oil as a binder. The pellets formed were dried in electric furnace at 34^0C for 1 hour and subsequently increased to 40^0C and dried for 1 hour. Some physical test was carried out on the pellets formed and the micro porosity value of the pellets formed from fine and semi-coarse particle size was determined as 7.83% and 9.59% with drop numbers of 4 respectively. These values obtained for the inoculated Obi coal specimens met the literature value requirement of 4 for the drop number and 7 to 10% porosity value for a good metallurgical coke.

Significance: This work has shown that the Obi coal caking problem can be eliminated by inoculation process using black-oil to meet the metallurgical requirement of coke for iron and steel making.

Keywords: Upgrading, Obi coal, coking grade, inoculation process.

IIntroduction

Many industrialized economic depend on iron and steel for modern technological and infrastructural development. To achieve high productivity the blast requires high quality coke as a resource of energy, reducing agent and a support material for furnace burden. In the blast furnace process of iron making, the most expensive material used as coke, which is a brittle porous, grayish solid fuel obtained from the carbonization of coking coal. Despite the general decline in the coal industry worldwide over the last twenty-five years, the demand for coking coal in the metallurgical industry has remained on the high side due to the predominance of the blast furnace process in melting the increasing demand for steel (Damisa, 2001).

In Nigeria, only the Lafia-Obi coal has proved to be slightly coking, although it has high sulphur and ash content which tend to limit it use for the production of metallurgical coke. With this limitation it cannot be used directly

except blended to achieve good quality coke (Damisa, 2001).

At present, due to non availability of coking coal, the iron and steel company will have to spend billions of naira to import coking coals, which are not yet discovered in the country. The scenario is difficult to sustain. Therefore effort to develop processes or techniques to produce coke from locally available coal is imperative (Oyedeji, 1994). Effort in this direction resulted in the topic "upgrading of obi coal to coking grade by inoculation process.

In the past five and a half decades, there have been researches on the characteristics of Nigerian coals. The study of the chemical and physical properties of Nigerian coal was made by Powell Duffrym technical service limited between 1947 and 1951. The obtained result was untenable and therefore further investigation was called for (Deseward and Casey, 1983 in Damisa 2001).

In an analysis by the steel development department through some foreign consultants on the ultimate and proximate analysis of Nigerian coals, a recommendation of blending ratio 3 and 4% to 97 and 96% local imported coal was made for Ajaokuta steel company. Their recommendation was economically not suitable for a developing nation like Nigeria because of the huge cost of import duties (Uwaidiale and Adahama, 1995). At laboratory scale, National Metallurgical Development Center Jos, took a giant step forward in producing a coking blend from Nigeria coals. Employing the foreign gully eagles prime coking coal for maximum ash content of 10% specification for metallurgical coke, only 13% local (Lafia) and 28% (Enugu) coal could go into the blend with the prime economically good considering the heavy charges place on import duties (Uwaidiale and Adahama, 1995). In a research, Oyedeji (1994) in Mathias (2008), Lafia coal was blended with Australian coal at different percentages of imported local coal, a recommendation of 60 – 40% was made. Based on the result of the analysis, the ash content of the blend was too high and thus falls short of the specification of the blast furnace coke. Although, the sulphur content was reduced to the required percentage used

in the blast furnace specification. Analysis of the blend of imported Agro-allied coal done by Tyoden, 1997 gives a recommendation of 70-30% imported local coal, but real coking properties was not achieved.

The software developed for optimization of Nigerian coal blend for making coke used in the blast furnace process by Damisa (2001) was an on line one. The result of the input program in Fortran 77 environment shows that 20% of the blend of Nigerian coals could be blended with 70% of foreign coals (prime coking coal). A ratio of this sort is not economically good considering the charges on importation.

All these deficiencies open ways for further researches on the possible way of upgrading the coking property of Lafia coal. Recently, it has been reported that the problem of obi coal is not with its properties but the inability of the coal to cake. Caking is a property associated with good metallurgical coking coal that gives coal ability to carry other burden materials without shattering into fine grains. The study indicated that Lafia-Obi coal could be blended to improve it coking and caking ability. The processes used to achieve these are yet to be exhausted, therefore new innovation like inoculating obi coal using local fuels at certain temperature to enhance the diffusion and adsorption of carbon and other elements of fuels into the Obi coal microstructure in order to improve its physical and chemical properties is necessary and then the utilization of inoculated Lafia-Obi coal by Ajaokuta and other metallurgical based industries will promote the development of industries through effective supply of products to priority sector such as mining/metallurgical engineering, energy, chemical, construction, transportation, communication, agriculture and agro-allied industries. It will also diversify the source of income of the nation economy, conserve scarce foreign earnings, create employment opportunities as well as encourage development of appropriate indigenous technology.

This prompts the research of upgrading the Lafia-Obi local coal to coking grade coke by inoculation process.

2

Inoculation Process

Inoculation is a process of increasing the strength of a material. This is usually achieved by either injecting fluid into the material or placing the material where it is being soaked and by so doing strengthens the material matrix. Inoculation as a process of upgrading coal is aimed at increasing the molecular strength of the coal. This is accomplished by injecting the coal with a hydrocarbon fuel such as black oil which diffuses into the coal and increase the strength of the micro structure of the coal on cooling. Hence diffusion plays a very important role in inoculation process.

Theoretical Consideration of Inoculation Process

Diffusion plays an important role in inoculation process. For example, oxygen diffuses across capillary walls into the micro structure of a material and cause changes in the structure of the material.

All particles in a solution are in continual motion due to the thermal energy of the system. This motion is called Brownian movement. Solute molecules in a solution are constantly colliding with the solvent molecules and the kinetic energy transferred to the solutes particles causes them to under a random "walk" through the solution. If there is a difference in solute concentration between two parts of solution, there will be a net migration i.e. diffusion of solute molecules from the region of high solute concentration to the region of low solute concentration. This net movement will continue until the two regions have equal solute concentration. At equilibrium the movement stops (Brown, 1972) in (Eugene, 2008).

The rate at which solute particles migrate through the solvent depends on the particle size and shape. The parameter that describes a particles case of movement through solvent is called the diffusion coefficient and expressed in units of cm^2/sec.

Albert Einstein showed that: $D \alpha 1/r^2$

Diffusion is an extremely slow process. A lump of sugar added to a cup of coffee will require days to uniformly diffuse throughout the coffee in the cup. When solutes diffuse through membranes, it is necessary to consider how the membrane influences migration. Hence, we have to introduce a new term called permeability (P) which includes the diffusion coefficient for the solute. Membrane permeability to a solute reflects the ease with which the solute passes through the membrane therefore the degree of porosity of a material provide the avenue to which this phenomenon could be achieved in strengthening the microstructure of the Obi coal to improve it carrying capacity (caking property) in the blast furnace.

Coals and its Formation

According to Chung and Geer (1997) in Damisa (2001), coal consists of a complex mixture of organic chemical substance with small amount of nitrogen and sulphur. The organic materials and designed mainly from plant remains, which have undergone various degree of decomposition, physical and chemical alteration after burial in the peat and swamps. Coal is not formed from a single material but many and it did not form all by itself but in the presence of a great many other geometrical, mechanical, thermal and chemical processes. According to Chung and Geer (1997) in Eugene (2008) coal formation may have been influenced by bacteria, temperature, time and pressure. The stage of carbonization reached by a coal determines its rank. Rank of a coal can therefore be defined as the degree of its alteration starting from decomposition and proximity value for mineral matter free coal (Tyoden, 1997). Due to geological processes based on apply pressure to dead matter over time, under suitable conditions. It is transformed successively into the following types of coal:

i.   Pent
ii. Lignite
iii. Sub bituminous
iv. Bituminous
v.   Anthracite (Mathias, 2008)

The Coal deposits of Nigeria

Coal exploration in Nigeria started as far back as 1916; available data show that coal (mainly sub-bituminous seam coals except for the Lafia-Obi bituminous coking coal) occurrences in Nigeria have been indicated in

more than 22 coal fields spread over 13 states of the federation. The proven coal reserves so far in Nigeria total about 629 million metric tones while the inferred reserves sum up to 2.75 billion metric tones.

There are five economically important seams of sub-bituminous coal so far recognized in Nigeria of which most are located in the south – east and middle belt of the country.

Table 1.0: give the summary of coal deposits in Nigeria and shows that Nigeria has over 2.5 billion tones of coal with proven reserve of about 661 million tones out of which about 25million tones have been mined.

Characteristics and selection of coking coal

Coke is a solid carbonaceous residue derived from low ash, low sulphur bituminous coal from which the volatile constituents are driven off by baking in an oven without oxygen at temperatures as high as $1,000^0$C ($1,832^0$F) so that the fixed carbon and residual ash are fused together. Metallurgic coke is used as a fuel and as a reducing agent in smelting iron ore in blast furnace. Coke from coal is grey, hard and porous and has a heating value of 24.8million btu/ton (29.6mj/kg) (Tastsch, 1980).

The primary essentials in the selection of coking coals are chemical analysis. They are also required at frequent intervals in order to ensure maintenance of quality once the coal has been selected. In the American standard for testing and measurements (ASTM) classification, the ranks of most coking coals are defined by their proximate analysis and the heating value determination. A proximate analysis including moisture, ash, sulphur and sometimes phosphorus also shows the grade of a coal (see Tables 2.0 and 3.0). A good coking coal or blend must possess the correct combination of swelling, coking and plastic properties so that during heating would cause the coal particles to fuse together to form a strong coherent mass, which fractures a long planes of weakness to leave a preponderance of pieces in the 20mm size range on cooling (Damisa, 2001).

Individually, the above coking data serve only

to indicate the coals potential for coke manufacture. A confident prediction of coals performance in the coke oven can only be made after more extensive testing. Prime coking coals would exhibit properties in the upper part of the ranges mentioned. The best metallurgical coke would be found from gray king types G4 – G9. The coke pieces must be resistant to further abrasion and size degradation, be un-reactive and contain less than 10% ash, 1% sulphur and only traces of phosphorus or complete elimination of it. Coals outside this range can be blended with high range coking coal (Damisa, 2001).

Caking Power

The behaviour of coal on heating is of special importance and many methods have been suggested for its definition and measurement. One of these is the Gray king method. Coal (20g passing a 72 B.S. sieve) is carbonized under standard conditions to 600^0C. If the carbonized residue is pulverulent with no sign of coherence, the term "non caking type A" is assigned. Coal which gives a hard, compact, non fissured coke of the same volume as the original coal is termed A, while the intermediate letters designated coals whose coke friability decreases within this range, coals of higher caking power are blended with 72 mesh carbon to give a coke corresponding to type a and termed A1 to G10 respectively, the subscript members indicating the corresponding to type G and termed G1 to G10 respectively, the subscript members indicating the number of grains of coke necessary in the 20g blend. Figure 1.0: shows types of coke from Gray King Assay (Damisa, 2001, Mathias, 2008).

A, B	Non-caking
C, D	Very weakly caking
E, F, G (G_1, G_2, G_3, G_4)	Medium caking
G_5 – G_8	Strongly caking
G_9 and over	Very strongly caking

correlation of swelling index with gray-king coke

Gray King	A	B	C	D	E	F	G	G_1	G_2	G_3	G_4	G_5	G_6	G_7	G_8	G_9
Swelling Index	1	½	2		3	4	5	6	7	8	8	9				

Figure 1.0: Types of coke from Gray-King Assay (Mathias, 2008, Damisa, 2001)

Coke Testing Methods

The properties of a coke are evaluated by chemical and physical test. Frequent testing is necessary in order to ensure uniform quality and to note the effect of any changes in the coal mixture and to note the effect of any changes in the coal mixture or coking conditions. Case in securing a representatives sample of the coke under examination is a primary and essential requisite of successful testing. This is important because the average size of the coke pieces is usually large, a condition which materially increases the difficulty in securing a representatives sample. In order to evaluate the size and other qualities of the coke used in metallurgical operations, a large member of physical test have been developed. Most of them provide for subjecting the coke to a standard set of empirical conditions designed to reproduce those to which the coke is subjected in practice. The comparative value of such tools depends primarily on how closely the prescribed conditions are followed. The methods described in this section of the project are those commonly used in international practice (150) and most of them are covered by ASTM specification. Example of such test includes microporosity, drop number and drop resistance test in which the coal must have a minimum drop value of 4 (Weiss, 1985).

Beneficiation

Coal preparation, like the beneficiation of ores, is also aimed at the separation of values from the associated waste. Even though the unit operations involved when enriching coal and ores are similar. There are certain characteristics unique to coal preparation. It should also be noted that, mineral matter is to a great extent discretely distributed in coal; hence concentration is mainly achieved by taking advantage of differences in specific gravity between clean coal and associated waste. In general 90% of coal is concentrated using specific gravity separation and about 10% by froth flotation. In contrast, there operations are frequently reverse in the beneficiation of ore. In coal preparation almost all fractions separated during the various stages are made use of while large amounts of gangue material are rejected in the concentration of ore. Hence, coal generally has a much lower ratio of concentration than ore. Hence beneficiation is a variety of processes whereby resource extracted from mining is reduced to particles that can be separated into valuables and gangue, the former suitable for further processing or direct use. Sometimes in the course of this process coal fines are produced and hence the need to form them into larger lump size is important (Damisa, 2001, Dungka, 2008).

Agglomeration Process

Coal processing produces fine grain of coal which cannot be charge directly into the furnace due to inability to withstand the weigh of the subsequent iron ore in the furnace. The coal produced are usually converted into larger lump materials of controlled physical and chemical properties, this process is called agglomeration. Agglomeration process can be broadly classified into four types namely: sintering and nodulising conducted at elevated temperature, and pelletization and briquetting conducted at room temperature usually at elevated temperature to improve their metallurgical properties (Moore, 1989, Yaro and Dungka, 2007).

Materials and Methods
Source of Sample

The coal sample weighing 50kg used in this work was sourced from Kwaghshiri village in the Obi Local Government Area of Nasarawa State.

Equipment

The following equipment was used in this research work: Hammer, laboratory Jaw crusher, Ball mill grinding machine, pulverizing machine, sieve shaker, Muffle dryer oven, electronic sensitive weighing balance, electric muffle heating furnace.

Procedure

A total of 10kg of coal sample was used of which 50 pieces as-received coal specimens 3x3x3cm were cut and each weighing 200g. The as-received coal specimens was calcined

using an electric muffle furnace to a temperature of 1200^{0}C for one hour this done to eliminate the volatile matter and other impurities that is associated with the coal specimens. The calcined as-received specimens were inoculated by quenching in water, kerosene, black-oil and some allowed to cool in the furnace as a controlled respectively. To determine the effect of the various inoculated medium on the coal sample, drop number, drop resistance and micro porosity tests were all carried out on the specimens. Furthermore based on the result of the findings the as-received coal specimens inoculated in black-oil was pulverized and sieved into two different particle size of -40+63um as fine and -90+125um as coarse these particle sizes were agglomerated into pellets using black-oil as binder and dried using electric muffle oven at 30^{0}C for 1hour and the temperature was further increased to 40^{0}C for 1hour and allowed to cool in the furnace. The inoculated different particle sizes agglomerated coal pellets specimens were subjected to drop number, drop resistance and microporosity tests to ascertain their metallurgical properties.

Discussion and Results
Chemical, drop number, drop resistance and porosity tests analysis

This was carried out to ascertain the chemical composition of the as-received Obi coal specimen. From the analysis using proximate method the following percentage of elements was estimated: 52.64% carbon, 4.01% sulphur, 0.0081% phosphorus, 7.99% moisture content, 24.62% volatile matter content and ash content of 10.7319% as shown in Table 4.0 the values obtained compared favourably with other Nigeria coal deposits. Table 2.0 is the result of loss of weight test of the as-received specimen calcined at 1200^{0}C, the result showed that 28.00% by weight of the coal specimen was lost to calcination process an indication that the volatile matter of the as-received coal specimen are eliminated at 1200^{0}C for 1 hour. This process reduced the initial weight of the specimen from 200 to 144g and thus increased the porosity of the calcined specimen from

9.09 to 14.54%. The increased in the porosity value could be attributed to the elimination of the volatile matters on calcination and the micro-pores formed created an avenue to which fluid can be capillary-rated or diffused into the matrix of the calcined as-received coal specimens and on cooling strengthened the matrix or the structural frame of the as-received coal specimens. The strength of any material achieved by this process depends on the type of inoculated substances used and the number of available pores contained in the material to be inoculated (Weiss, 1985). Table 5.0 is the result of the percentage of absorption of the various quenching mediums into the matrix of the as-received specimens calcined at 1200^{0}C with the as-received coal specimen inoculated in black oil having 22.49%, in kerosene having 13.91%, water having 7.33% and the specimen that is allowed to cool in the furnace has 0.00%. From the result in Table 3.0 the specimen inoculated in black oil has the highest percentage absorption then followed by kerosene, water then the specimen cooled in the furnace. This could be attributed to that more of the black-oil which has high viscosity compared to other fluid may be the least to evaporate went in contact with calcined as-received coal specimen at 1200^{0}C and hence much of the fluid diffused into the matrix of the as-received calcined coal specimen compared to kerosene and water. The weighed of the calcined as-received inoculated coal specimen in black-oil is higher compared to that of water and kerosene this could be attributed to amount of the black-oil absorbed partly by diffusion and capillary action into the matrix and crystallized on cooling and hence increased the weight of the specimen.

Table 6.0 is the results of drop number test of the as-received specimens inoculated at 1200^{0}C, from Table 4.0 the drop number values of the four specimens inoculated in kerosene, water and black-oil was found to be 4 this could be due to the partly capillaration and diffusion of the mediums into the matrix of the as-received calcined coal specimens while the as-received calcined coal specimen allowed to cool in the furnace has a drop

number of 2 an indication that inoculation of the as-received calcined coal specimens with various medium do strengthen their matrixes and increased their resistance to shattering. The drop number of 4 obtained for the as-received calcined coal specimens inoculated in black-oil, kerosene and water met the literature value of 4. The low drop number value for the specimen allowed to cool in the furnace could be as a result of lost of volatile matter which left the specimen with more pores than before and hence reduction in its strength. Table 5.0 is the results of drop resistance test of the as-received inoculated coal specimens; the drop resistance value of 3 was obtained for specimens inoculated with kerosene and water, 4 for black-oil and 0 for the controlled as-received calcined specimen. From the result in Table 4 only the as-received calcined specimen inoculated in black-oil met the literature value of 4 followed closely by water and kerosene this could attributed to the earlier reasons mentioned in this work (the crystallization of the absorbed fluid by the specimen which closed the some pores and strengthens the microstructure of the coal specimens). The controlled has 0 drop resistance value an attribute coursed by the lost of volatile matter which create voids and weakens the microstructure of the specimen. Table 7.0 is the results of the porosity test of the as-received specimens after inoculation at $1200^{0}C$, from result the micro porosity value of specimens inoculated in kerosene was 19.53%, water 7.23%, black-oil 3.66% and controlled 14.57%. The result shows that the as-received calcined specimen inoculated in black-oil has the lowest porosity value compared to others. This could probably be as a result of the absorption and crystallization of the carbon of the black oil in the matrix of the calcined coal specimen which resulted in reduction of pores and thus reduced the porosity to 3.66% compared to that which others. The low porosity of the specimen inoculated in black-oil resulted in strengthening the microstructure of the coal specimen and as a result of this the specimen inoculated with black-oil was able to meet the literature value of 4 for both the drop number and drop resistance tests.

Table 8.0 is the results of the drop number and drop resistance tests for the Pellets produced using the as-received coal specimen inoculated in black-oil and using the black-oil as binder. The result of drop number and drop resistance tests of the pellets formed with the fine particle size (-60+40µm) and that formed with coarse particle size (-125+90µm) all has both drop and drop resistance of 4 and porosity values of 7.83% and 9.59% respectively (see Tables 9.0,10.0 and 11.0) and these values met the literature value of 4 for both the drop number and drop resistance tests and the porosity value of between 7 to 10% for a good metallurgical coke.

Conclusion

In conclusion the Obi coal can be upgraded to metallurgical grade coking coal by inoculation process using black-oil as the inoculation medium and at the same time binder to produce coke that would be used in Ajaokuta and other iron and steel making shops.

Recommendation

It is recommended that the inoculated Obi coal should be used to reduce some Nigerian iron ores so as ascertained the quality of the iron metal produced using the inoculated Obi coal.

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Table 1.0: Coal deposits in Nigeria and their reserves

State	Location	Indicated in-situ (million tonnes)	Inferred reserves (million tonnes)	Overall reserve (million tonnes)
Enugu	Enugu	54	200	254
	Ezimo	56	60	116
	Inyi	20	Unknown	20
Kogi	Okaba	73	250	323
	Ogboyoga	107	320	427
Benue	Otukpo	57	75	132
	Ogboyoga	107	320	427
Delta	Asaba	250	Unknown	250
Nassarawa	Obi	22	Unknown	22
Gombe	Maiganga	22	Unknown	-
		661	905	1544

Source: (Aderibigbe, 1989)

Table 2.0: Summary of characteristics of good coking coal

Parameter	Desire	Typical limit	Comments
Total moisture %	5 – 10	12	Limited for easy handling and grinding
Volatile matter various dmmf (%)	Various	16 – 21 21 – 26 26 – 31	Low volatile coals Medium volatile coals High volatile coals
Total sulphur (air dry)	Low %	0.6 – 0.8	Sulphur content of coke should be low to limit take- Zip of sulphur by pig iron in blast furnace.
Free swelling index	7.9	Min. 6	
Roga index	60 – 90	Min. 50	
Gray king coke	G6 – G14	Min. G4 – G5	
Dilatometry	25 – 70 80 – 140 150 – 350	Min. 20 Min. 60 Min. 100	Low volatile coals Medium volatile coals High volatile coals
Plastometry Fluidity range	Min. 80 Min. 100 Min. 130	Min. 70 Min 80 Min. 100	Low volatile coals Medium volatile coals High volatile coals

Source: Aderibigbe, (1989)

Table 3.0: Specifications for blast furnace coke

Volatile matter	0.75 – 2% by weight
Ash	7.0 – 9.0% by weight
Sulphur	0.65 – 1% by weight
Shatter test (on 5cm)	70 – 78% by weight
Drop number	4
Drop resistance	4
Porosity	7-10%
Size	7 – 12cm
Fixed carbon	48.91 – 90%
Moisture content	Below 5%
Calorific value kcal/kg	7,652
Phosphorus	0.007
Total Reactive	97.6%

Source: Weiss, (1985), Eugene, (2008)

Table 4.0: The result of the chemical analysis carried out on as-received Obi coal using proximate method

Fixed Carbon	52.64%
% sulphur	4.01%
% phosphorus	0.0081%
% moisture	7.99%
% volatile matter	24.62%
% ash	10.73%

Table 5.0: The result of loss of weight test of the as-received coal specimen calcined at 1200^0C

	Initial weight of specimen before calcination (g)	Final weight of specimen after calcination (g)	Percentage lost of weight initial weight – final weight X 100/ Initial weight
Cooled in the furnace	200.00	144.00	28.00

Table 6.0: The result of the percentage of absorption of the inoculated mediums into the matrix of the as-received specimens calcined at 1200^0C

Quenching mediums	Initial weight of specimen before calcination (g)	Final weight of specimen after calcination and inoculation (g)	Amount of inoculated mediums absorbed (g)	Percent Absorption of medium into the matrix of the as-received specimens (%)
1. Kerosene	144.00	164.04	20.04	13.91
2. Water	144.00	154.56	10.56	7.33
3. Black oil	144.00	176.38	32.38	22.49
4. Furnace cooled	144.00	144.00	nil	0.00

Table 7.0: The results of drop number test of the as-received specimens inoculated at 1200^0C

Quenching Mediums	Drop Number Test Result
1. Kerosene	4
2. Water	4
3. Black oil	4
4.Furnace cooled	2

Table 8.0: The results of drop resistance test of the as-received specimens inoculated at 1200^0C

Quenching Mediums	Drop Number Test Result
1. Kerosene	3
2. Water	3
3. Black oil	4
4. Furnace cooled	0

Table 9.0: The results of porosity test of the as-received specimens after inoculation at 1200^0C

Quenching mediums	Initial weight d_1 (g)	Final weight d_2 (g)	Porosity (%) $\frac{d_2 - d_1}{d_2}$ x 100
1. Kerosene	34	42.25	19.53
2. Water	34	36.65	7.23
3. Black oil	34	35.29	3.66
4.Furnace cooled after calcination	34	39.80	14.57
5.As-received coal specimen (uncalcined)	34	37.40	9.09

Table 10.0: The results of the drop number and drop resistance tests for the Pellets after inoculation at 1200^0C using black oil as binder

Pellet	Drop Number Test Result	Drop Resistance Test
1. Fine (40-63μm)	4	4
2.Coarse(90-125μm)	4	4

Table 11.0: The result of micro porosity test of the Pellets after inoculation at 1200^0C using black oil as binder

Pellet	Initial Weight d_1 (g)	Final Weight d_2 (g)	Porosity (%) $\frac{d_2 - d_1}{d_2}$ X 100
1. Fine (40-63μm)	80.77	89.63	7.83
2. Coarse (90-125μm)	80,77	87.34	9.59

Assessment of Potential of Coal for Power Generation in Nigeria

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Abstract

The potential of vast coal deposit for power generation in Nigeria was investigated to ascertain amount of electrical energy, this fossil fuel could contribute to the national grid. This was achieved by gathering data on estimated reserves of coal deposit in Nigeria. The result obtained shows that Nigeria has estimated proven coal reserve of about 639 million tons and this is capable of contributing more than 1, 095.88MW annually to the national grid when effectively utilized for generation electrical energy. The life span of these mines varies from between 33-170 years. Hence, there is need for utilization of coal for power generation because of its abundance in Nigeria and is capable of transforming the socio-economic frontiers and improve power supply in Nigeria.

Keywords: Coal, Power, Utilization, Potential, Life span, Grid

Introduction

Just like any of the developed countries of the world, Nigeria will achieve development when its idle coal reserves are tapped and transformed into energy, this is to due to the fact energy plays a dominant role in the socio-economic industrialization of any country. The level of power generation in Nigeria is 3,000-3,200 MW instead of 10,000 MW needed, the per capita consumption in Nigeria is 100 kWh as against 4,500 kWh, 1,934 kWh and 1,379 kWh for South Africa, Brazil and China respectively (M2M workshop-Nigeria, 2005)). Despite the unfair distribution of world's coal reserve, Nigeria is richly endowed with coal. The estimated proven coal reserve of Nigeria is 639 million tones (M2M workshop-Nigeria, 2005).

Bell (1992) defined coal as a sedimentary rock of organic origin. Thomas (1992) said it is sediment, organoclastic in nature, composed of lithified plant remains which have the important distinction of having a combustible material. Coal is a readily combustible rock containing more than 50 percent by weight and more than 70 percent by volume of carbonaceous materials including inherent moisture formed from compaction and induration of variously altered plant remains similar to those in peat. Coal is a carbonaceous mineral made primarily of carbon but also contains sulphur, oxygen and hydrogen (Isife and Ajayi, 1999). Coal is mostly associated with sedimentary environment and has various types ranging from lignite, anthracite, bituminous to sub-bituminous. World Bank (1998) reported that underground and surface coal production potential is 200,000 to 600,000 tones per year and 400,000 to 800,000 tones per year respectively.

The process of converting coal to electrical system is carried out in a generating station called power station, it converts out the heat energy of coal combustion into electrical energy, almost all coal are steam-electric. A steam-electric power plant is a power plant in which the prime mover is steam, water is heated to turn into steam and spins a turbine. After it passes through the turbine, the steam is cooled and condenses. The conversion of heat energy to electrical energy generates electricity (David, 1984). There has been an outcry of the harmfulness of coal burning in the past years due to the emission of carbon dioxide (CO_2) which is as a result of reaction between coal and the surrounding air in a complete combustion, also production of oxides of sulphur mainly sulphur dioxide (SO_2) and various oxides of nitrogen are experienced during coal burning. These are not enough to

neglect the use of coal for power generation as there are now modern power plants that utilize variety of techniques to limit the harmfulness of their waste products and improve the efficiency of burning. To eliminate CO_2 emissions from coal plants, carbon capture and storage has been proposed but has yet to be commercially used. The thermodynamics efficiency of this process has been improved over time, the thermodynamic efficiency for standard steam plant is about 30% which means 70% of the coal energy is rejected as waste heat (EIA, 2005).

Coal is a readily combustible rock containing more than 50 percent by weight and more than 70 percent by volume of carbonaceous materials including inherent moisture formed from compaction and induration of variously altered plant remains similar to those in peat. Differences in the kind of plant materials (type), degree of metamorphism (rank) and the range of impurity (grade) are characteristics of coal used in classification. It is in fact, a fossil or an organic sedimentary rock formed mainly by the action of temperature and pressure on plant debris and always has associated with its various amount of moisture (Robert, 1993).

Coal is one of the world's most plentiful energy resources. It occurs in a wide range of forms and qualities; but there are two broad categories namely: hard coal, which includes coking coal, used to produce steel and other bituminous and anthracite colas used for steam and power generation; brown coal (sub bituminous and lignite), which is used mostly as on-site fuel. Coal has a range of moisture content: 2-40%, and ash content: 5-40% (World Bank, 1998); In addition, coal could be classified according to their carbon content and thus classified coal as: lignite; containing 25-35% carbon and a heating value of about 4000-8300 British thermal unit (Btu) per pound; sub-bituminous; containing 35-45% carbon and a heating value of about 8300-13000 Btu per pound; bituminous; containing 45-86% carbon and a heating value of about 11000-15500 Btu per pound; and anthracite; containing 86-97% carbon and a heating value near to 15000 Btu per pound. The objectives of this paper therefore are to assess the proven reserves of coal and estimate the quantity of electrical energy that could obtained from the coal deposit.

Table 1 shows Nigeria's coal mine, their reserves and method of mining respectively. The proven reserves of coal deposit in Nigeria ranges from 20 million tones for Inyi to 107 million tones for Ogboyoga mine. Table 2 shows Nigheria's coal characteristics in terms of moisture content, % ash, volatile matter, caloric value, total sulphur and gas content. The moisture content ranges from 7.5 for Okpara coal to 37.5 for Ogwashi Azagba Lignite, % ash ranges from 4.2 for Ogwashi Azagba lignite to 14.7 for Lafia Obi bituminous, volatile matter ranges from 31.7 for Lafia Obi bituminous to 39.9 for Ezimo coal, calorific value ranges from 5,098 for Ogwashi Azagba lignite to 7,637 for Lafia Obi bituminous and total sulphur % form 0.55 for Ezimo to 1.0-3.5 for Lafia Obi bituminous.

Materials and Method

In order to determine the potential of coal for power generation in Nigeria, data on power generation were obtained as well as coal reserves in the country that could be transferred into energy. Also literatures on coal efficiency and carbon cost were reviewed. The total quantity of energy that could be generated from each mine were determined.

Efficiency Factor of Coal for Power Generation

The energy density of coal is measured in kilowatt-hours (kWh), the standard energy density of coal is 6.67 kWh/kg and the typical thermodynamic efficiency of coal power plant is 30% of the 6.67 kWh/kg of coal, only 30% of it is successfully turned into electricity (EIA, 2005). The efficiency of coal power plant is calculated using Equation 1.

$$\varepsilon = \frac{30}{100} \quad ....1$$

Where ε = thermodynamic efficiency of coal power plant
ρ = energy density of coal i.e. 6.67 kWh/kg
The energy density of coal is calculated using Equation 2.

$$P = \frac{L \times \varepsilon}{24h \times 365(day \text{ in a year})} \quad ...2$$

where P = Amount of power generation

   ε = Thermodynamic efficiency of coal power plant

Relative Carbon Cost

Since coal has at least 50% carbon (by mass), then 1 kg of coal contains at least 0.5 kg.

$$M = \frac{m}{mm} \quad ...3$$

Where m = Molarity

   mm = Mass of Coal

$$Ms = M \times W \quad ...4$$

Where Ms = Mass of CO_2 in 1 Kg of coal

   M = Molarity of coal

   W = Atomic weight of CO_2

The carbon (IV) oxide production rate is calculated using Equation 5.

$$Pr = \frac{Ms}{\varepsilon} \quad ...5$$

Where Pr = CO production rate

ε = thermodynamic efficiency of coal power plant

The life span of each mine is calculated by dividing its proven reserve by its annual production while the total potential power generation is calculated by multiplying the potential annual power generation from each mine by its life span.

for Ogboyoga mine and the total potentialpower generation during mine life ranges from 4,566.33MW for Inyi to 23,508.56MW for Ogboyoga mine. Table 4 highlighted the comparison between various types of power plant. A total of 1,095.88MW annually is expected to be contributed to the national grid if the nation's coal reserves are effectively utilized, this can help improve power supply in Nigeria.

Conclusion

The potential of coal for power generation in Nigeria were studied by estimating the country's coal proven reserves. Investigation showed a total proven reserve of 639 million tonnes. Essentially, the sum of 1,095.88 MW/year and a total of 104,752.32 MW will be generated over the years if the coal reserves are properly harnessed and since power plant using coal as raw materials has low initial cost, low transmission and distribution cost. It is therefore capable of boosting power generation in the country.

Recommendation

The private business enterprises and

Results and Discussion

Table 3: Potential Power Generation from Coal Mines

Coal Mine	Proven Reserve (Million Tons)	Potential Power Generation (MW/year)	Life span of Mine (Years)	Total Potential Power Generation during Mine life (MW)
Okpara	24	91.32	60	5,479.20
Onyeama	40	91.32	100	9,132.00
Ogboyoga	107	136.99	173.8	23,808.86
Ogwashi Azagba	63	136.99	105	14,393.95
Ezimo	56	136.99	93.33	12,812.67
Inyi	20	136.99	33.33	4,566.33
Lafia/Obi	21.42	91.32	53.55	4,890.19
Okaba	73	136.99	121.67	16,666.57
Owukpa	57	136.99	95	13,753.82
Total		1,095.88		104,753.82

Table 3 shows potential power generation from each mine, life span of mine and total potential power generation during mine life. 91.32 MW/year for all underground mines and 136.98MW/year for all surface mines, life span (years) ranges from 33.33 for Inyi mine to 173.8

government of Nigeria should brace up by citing steam power plants in those places where there are coal deposits to complement the existing hydro-electricity in the country, then Nigeria will be a veritable place for all.

Table 4: Comparison of Various Types of Power Plants

	Steam power Plant	Hydro-electric Power Plant	Diesel-power Plant	Nuclear Power Plant
Site	Need ample supply of water, coal and adequate transportation facilities	Only where large reservoir can be obtained by constructing a dam as hilly areas	Any place because they require less space and small quantity of water	Away from thickly populated areas to avoid potential radiation dangers
Initial cost	Lower than those of hydroelectric and nuclear power plants	Very high because of dam construction and excavation work	Less as compared to other plants	Highest because of huge investment on building a nuclear reactor
Running cost	Higher than hydro-electric and nuclear plants because of requirement of huge amount of coal	Practically nil because no fuel is required	Highest amount of all plants because of high price of diesel	It has low running cost because small amount of fuel can produce relatively large amount of powers
Availability of source of power	Coal is the source of power and abundantly available in Nigeria	Water is the source and is not dependable because of wide variation in annual rainfall	Diesel is the power source and not available in huge quantities	Nuclear fuel is the source of power and is not readily available
Cost of fuel transportation	Maximum because huge amount of coal is transported to the plants site	Practically nil	Higher than hydro and nuclear power plants	Maximum because small quantity of fuel is required
Cleanness and simplicity	Least clean	Most simple and clean	More clean than steam and nuclear power plants	Less cleaner than hydro-electric and diesel power plants
Maintenance cost	High operating skilled staff is required	Quite low	Less	Very high as highly trained personnel are required
Starting	Requires a lot of time for starting	Can be started instantly	Can be started quickly	Can be started easily
Space required	These plants need sufficient space because of boiler and other auxiliaries	Require very large areas because of the reservoir	Require less space	These require maximum space as compared to any other plants of equivalent capacity
Transmission and distribution cost	Quite low as these are generally located near the load centres	Quite high as these are generally located away from the load centres	Least as they are generally located at the center of gravity of the plant	Quite low as these are located near to load centers

Source: EIA (2005)

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Environmental Safety and Health Challenges of Artisanal Mining in Nigeria: Review of Regulatory Strategies

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Abstract

The artisanal mining sector in Nigeria has long been associated with smuggling of minerals, criminal activities, and environmental degradation and health diseases. This sector is burdened and plagued with issues ranging from child labour, the spread of HIV/AIDS, environmental devastation, poor health and safety, migrant workers and conflict with the large-scale mining sector. This study discusses the regulatory strategies and frameworks put in place by the Nigerian government to address these challenges. It identified some contradictions in government policies, weak enforcement of sanction and neglect of the activities and plight of artisanal miners as major impediments towards integration of artisanal mining into the real sector. Suggestions offered include enforcement of the environmental impact assessments requirements for all mining projects by the authorities.

Keywords: artisanal mining, environment, degradation, environmental impact assessment (EIA).

Introduction

Artisanal mining is mineral exploitation using manual techniques and tools with minimal capital and labour requirements. Small-scale mining (SSM) encompasses all small, medium, informal, legal and illegal miners who use rudimentary processes to extract minerals from secondary and primary ores (Telmer, 2006). Artisanal miners are generally unskilled and use simple implements such as diggers, shovels, head pans and spades to win and transport ore minerals (Amoka and Ogunbanjo, 2003).

Although this sector has employed large number of people thereby reducing the number of unemployed youths, the emanating environmental, safety and health challenges have raised serious concerns globally. Despite the identification of artisanal and small scale mining as a means of reducing poverty among rural dwellers (Akande and Adebimpe, 2004), such activities have been largely associated with deaths, spread of diseases (HIV/AIDS, silicosis, tuberculosis), flooded pits, child labour, criminality and environmental pollution, just to mention but a few. Fig. 1 shows a typical artisanal mining scene.

Moreover, the regulatory agencies charged with the enforcement of laws and coordinating these activities (Mines Inspectorate Department, Ministry of Environment) are facing increasing challenges in the discharge of their duties. Such obstacles are further compounded by lack of funding and poor implementation of some existing government policies.

More disturbing is the fact that most artisanal mining activities are not supported by the government and other stakeholders in the mining industry. Yet, they are the foot soldiers as far as mineral production in Nigeria is concerned (Nashuni, 2003). Their unsupported and uncoordinated activities have therefore resulted to more environmental and health problems such as destruction of arable farmlands, pit flooding and release of harmful substances into stream as identified by Chaanda, et.Al, (2010) and Mallo (2007).

Thus, this paper seeks to examine the environmental, health and safety challenges in Nigeria's artisanal mining terrain with a view to improving the proper implementation of relevant laws and policies of the government with respect to minerals development. It will also assist the government to review its regulatory strategies in terms of boosting

mineral production, integrating the artisanal mining into formal mining sector for employment generation and protection of environmental and health interests of residents in the mining communities.

Artisanal and Small Scale Mining In Nigeria

Artisanal and small scale mining constitutes over 90% of mining activities in Nigeria. This sector is under-developed and has long been neglected. The importance of artisanal and small scale mining (ASM) has been overlooked with most mining activities unregulated which resulted in the country's large-scale illegal mining activities. For decades, artisanal mining was ignored due to Nigeria's dependence on oil and consideration for the mining sector was predominately focused on state-run large-scale mining (Damisa, 2007; Lawal , 2004).

The nationalization policy coupled with the drop in tin price of 1985, which caused so many job losses in the mine fields, as well as the introduction of the Structural Adjustment Programme(SAP) in Nigeria in the 1980s resulted in the re-emergence of artisanal and small scale mining (ASM) in the area of metal and gemstones production (NEITI, 2011). Presently, the artisanal and small scale mining operations have dominated the Nigerian mineral sector. They are mainly informal working with rudimentary methods, limited technical training and inadequate social provision for environmental considerations (Fig. 2). It is only in quarrying that large scale operations exist with construction companies (stone aggregates and laterite) and cement manufacturers (limestone or marl) andcoal production dominating.

Fig. 1: Miners working along AzaraBarytevein Orientation in Nasarawa State

Fig. 2: Local Miners working in a pit

Although global report on ASM (Hentschel, 2002) estimated that 13 million people are engaged directly in artisanal and small-scale mining activities throughout the world, mainly in developing countries, concerns for environmental and health hazards are on the increase. Combined effects of environmental degradation and twin-effects of water and air pollution through artisanal mining have recorded many human and animal diseases, and high degree of injuries, miners themselves being among the victims.

Artisanal mining often creates economic and social tensions between the local community and outside groups drawn to artisanal mining activities as well as increased environmental, health and safety risks (free Report, 2010). However, a regulated ASM sector can play an important developmental role, through boosting employment, supporting communities, and alleviating poverty. According to Telmer (2006), at least 100 million people in over 55 countries depend on ASM, with 10 to 15 million miners including at least 4.5 million women and 1 million children also involved. But almost all the 100 million people involved are potentially exposed to risks associated with ASM. Nigerian situation is not different as it is believed that we lose billions of dollars annually to illegal miners who are responsible for 95 % of the activities in the mining sub-sector (Helen E. and et al 2012). Therefore, the development of ASM should conform to the following aspects of United Nations Millennium Development Goals:

(a) Eradicating extreme poverty and hunger;
(b) Promoting gender equality and empowering women;
(c) Reducing child mortality;
(d) Improving maternal health;
(e) Combating HIV/AIDS, malaria and other diseases ;
(f) Ensuring environmental sustainability;
(g) Achieving universal primary education; and
(h) Attaining global partnership for development.

All the above should form the guidelines upon which ASM programmes are anchored in order to attain balance between resource utilization and safe mining environment.

Case Studies

Zamfara Lead Poisoning

Over 400 children in Zamfara State died in 2010 due to lead poisoning (Fig. 3). According to Opafunso (2011), such crude method of mining gold that constituted environmental pollution and eventually led to lead poisoning, did not conform to the best practices in artisanal gold mining and greatly contributed to such enormous environmental and health hazards.

Fig. 3 Environmental Degradation and Water Pollution in Dareta, Zamfara State

Open-Pits in Azara Mining Fields

In Azara, Nasarawa State, indiscriminate mining of barytes deposits by artisanal miners has opened up large open pits which have become death traps and hindering free movement. Akande and Amos (2005) reported that such pits could be as deep as 200 meters and more than 2 kilometers in length. In rainy season the pits are flooded and filled to the brim with water, turning to deep inaccessible rivers and posing great dangers to residents and the miners.

Kafanchan Gemstones Mining Business and Drug Addiction

Salati (2000) reported the use of hard drugs by young men and women who are involved in gemstones mining around Kafanchan in Kaduna State. These youths take to hard drugs to make them withstand the rigours of gemstones mining which eventually makes them become aggressive towards mine officials and other law enforcement agents who confront them while trying to enforce the law. The zone is a 'no-go-area' for residents due to this act coupled with other criminal activities in

the area. The use of hard drugs also portends serious health problems for these young miners. The prevalence of HIV/AIDS and other sexually transmitted diseases has posed another health challenge.

Safety and Health Issues in Birnin-Gwari Gold Mining Sites in Kaduna State
Artisanal miners employ rudimentary mining method, including the use of loto mining (sub-surface) through which large pits holes are

created, thereby resulting to serious environmental hazards. Sidi-Baba (2008) reported that panning of gold in dirty water also exposes the miners to water-borne diseases (Fig. 4), while air-borne infections such as tuberculosis are rampant among the miners in the area due to air pollution and close contact with infected miners. Caving of hanging walls also occurs, where excavations are not properly supported or where there is no support at all. This sometimes results to miners' deaths.

Fig. 4: Artisanal Miners panning for Gold

Identified Challenges
The following are the challenges identified as far as environmental health and safety issues in ASM are concerned:
Causes of Poor ASM Practice (Telmer, 2006)
   (a) **D**isorganization and transience
   (b) Lack of general education
   (c) No technical assistance
   (d) Financial barriers
   (e) Rejection by mainstream society
   (f) Inadequate/inappropriate regulation
   (g) Poverty.

Environmental Problems Caused by Artisanal Mining (Telmer, 2006; Opafunso, 2011)
   (a) **W**ater pollution (mercury pollution)
   (b) Water filtration
   © Landscape degradation
   (d) Destruction of habitats
   (e) Loss of organic soil
   (f) Deforestation

Occupational Health and Safety in ASM (Hentschel, et al, 2002)
The five major health risks in ASM according to

ILO reports are:
(a) Exposure to dust (silicosis);
(b) Exposure to mercury and other chemicals;
(c) Effects of noise and vibration;
(d) Effects of poor ventilation (heat, humidity, lack of oxygen);
(e) Effects of over-assertion, inadequate work space and inappropriate equipment.

Causes of Most Accidents in ASM (Hentschel, et al, 2002)

The five frequently causes of accidents most cited include:
(a) Rock falls and subsidence;
(b) Lack of ventilation;
(c) Misuse of explosive;
(d) Lack of knowledge; lack of training
(e)
(f) Violationof regulation (Fig. 5).

Table 1: Analysis of Water Samples from Azara, Wuse and Akiri Areas in Nasarawa State (Salati et al, 2011)

Parameters	Concentration (mg/l)			
	1	2	3	FMEHUD STANDARDS
pH	6.3	6.2	6.1	6.5 - 9.2
Pb	<0.001	< 0.001	< 0.001	0.05 max
Zn	0.032	0.04	0.037	5.00 max
Mg	0.02	0.04	0.025	100 (WHO)
Fe	0.05	0.27	0.18	20 (FEPA)
Na	1.25	0.76	0.89	250 (WHO)
Sb	0.0004	0.001	0.0006	-
K	0.001	0.001	0.002	10 (WHO)
Cd	< 0.001	< 0.001	< 0.001	5.00 max
TDS	135.00	130.50	132.40	1000 (WHO)

Fig. 5: Destroyed Lands by Artisanal Mining Activities in Azara areas of Nasarawa state

Review of Regulatory Strategies

The government's desire to regulate and monitor the activities of artisanal miners culminated in the enactment of relevant laws and regulations. The recent ones include:

(a) The Minerals and Mining Act, No 34 of 1999;

(b) The Nigerian Minerals and Mining Act of 2007;

(c) National Mineral and Metals Policy, 2008; and

(d) Nigerian Mineral and Mining Regulations of 2011.

The above laws and regulations are needed to regulate mineral exploration and exploitation in a transparent manner. However, it was believed that the Minerals and Mining Act, No 34 of 1999 was fraught with so many inconsistencies as it did not sufficiently sanction illegal mining activities and made little or no effort to develop the artisanal and small-scale mining(ASM) sector, among other weaknesses. It was therefore later replaced with the Nigerian Minerals and Mining Act of 2007 for better regulation and control of exploration and mining activities.

Ministry of Mines and Steel Development (MMSD) was established in 1985 as an attempt by the Nigeria Government to spur the rapid and beneficial development of the Nigeria's mineral resources. The ministry was set-up to unlock the economic potentials of the solid minerals sub-sector. It is the principal organ for information, policy and regulatory oversight in the solid mineral sector in Nigeria.

Prior to the enactment of the Minerals and Mining Act of 2007, many miners took advantage of the weaknesses of law to sabotage national economy and threaten national security. For instance, Salati (2004) reported that some illegal miners went about with their own "escorts" in order to harass mine officials who try to supervise their operations. The minimal fines and sanctions imposed by the previous laws have not deterred them from engaging in illegal mining, hence the need for the review mining laws and regulations now in place.

However, the coming of these latest policies has not improved the mining sectors beyond expectations, despite greater improvements over the previous laws. The greatest obstacles to the smooth operation of these laws and regulations are as follows, among other factors:

(a) Poor implementation of the law(weak

enforcement, poor logistics of the inspectorate division, inadequate personnel, lack of security personnel);

(b) Some contradictions in the Act and Regulations (e.g. clash of priorities with similar interests);

(c) Unnecessary bottlenecks caused by

bureaucracy in government work schedules;

(d) Corruption tendency by some government officials; and

(e) Lack of political will to develop the mineral sector.

Table 2: Type of Fees Empowered by the Minerals and Mining Act of 2007 and the Minerals and Mining Regulation 2011 collected by MID

S/No	Fees	Rate
1.	Royalty	Varies as attached in minerals Royalty Table, available in the Ministry.
2.	Permit to deposit tailings	-ditto-
3.	Permit to export minerals for commercial purpose	-ditto-
4.	Permit to export minerals Samples for analysis	-ditto-
5.	Permit to possess and purchase minerals	-ditto-
6.	Registration of accredited agent for movement minerals	-ditto-
7.	Permit to import explosive	-ditto-
8.	Blasting certificate	-ditto-
9.	License to manufacture explosive	-ditto-
10.	Permit to erect a magazine	-ditto-
11.	License to buy explosive	-ditto-
12.	License to sell explosive	-ditto-
13.	Explosives magazine license	-ditto-
14.	The access for storage of explosive	-ditto-
15.	Blasting certificate	-ditto-
16.	Penalties for contravening the provision of the explosives act of 1964 and explosives regulations of 1967.	-ditto-

If the obstacles highlighted above could be reduced or eliminated, the Ministry of Mines and Steel Development (MMSD), as presently constituted, has the capacity to adequately develop Nigeria's mineral resources for sustainable growth. However, the following strategies can help reposition the mining sector, if effectively applied:

(a) Value addition
(b) Research development
(c) Technological information
(d) Formalization
(e) Market-based policy instruments
(f) Sector-based solutions
(g) Supporting entrepreneurial development

(h) Community-based solutions (UNEP, 2011).

Discussion
There is no doubt that Nigeria has taken serious steps to develop effective environmental strategies by the promulgation of the Environmental Impact Assessment (EIA) Decree and all the procedural guidelines. Yet there are too many regulators with similar and identical responsibilities. Harmonization and clear allocation of responsibilities has become necessary. National Environmental Standards and Regulations Enforcement Agency (NESREA) is the apex regulator, and Department of

Petroleum Resources (DPR) in reliance on regulations cannot usurp the responsibilities of NESREA nor is the State Environmental Agency, when under our canon of legal interpretation, any Edict (law) in conflict with the Degree (Act) to the extent of the conflict void. Recognition of this, and an eschewing of rivalries among the administrators, will encourage co-operation among them. The EIA process is in transition in Nigeria, and may take years or even decades to develop and this depends on a strong and continuous political commitment at the highest levels within and among the administrators, on the active role of an informed and involved public and on some pragmatic programs of national action and sub-regional and regional co-operation.

Conclusion

Mining has evolved through the years and so have the applicable legal frameworks of the different jurisdictions where mining activities are developed. Among these legal developments, those related to environment, health and safety were adopted due to growing concerns about the potential collateral effects and dangers associated to mining activities. By developing such measures, mining is becoming a safer activity, not only thanks to legislations enacted by the governments of the different mining jurisdictions where mining activities are performed, but also to the standards self-imposed by the industry. Continuously improving the regulatory frameworks, control and compliance of mining activities will be beneficial to the different stakeholders involved in the mining industry, from employees, to the local communities, to the investors and mining companies.

Recommendations

The following recommendations would improve the level of environmental practice and enforcement of environmental laws in the study area and Nigeria in general:

(a) The regulators/administrators should be better supported and, for effective compliance monitoring and enforcement, stiffer sanctions and penalties should be prescribed and strictly adhered to. This way, environmental requirements will be met and maintained. Compliance should be tied to renewal of license and consents and proponents should ensure that staff is highly motivated with adequate equipment and capacity building programs vigorously pursued not only by the administrators but also the proponents.

(b) The administrators should invest more in capacity building, staff motivation and provision of conducive work environment together with the necessary facilities and timely availability of funds. Otherwise, they become exposed to monetary inducements leaving compliance in the hands of the proponents, and this is unhealthy. With basic knowledge of their responsibilities, they could become more efficient and effective in the implementation of environmental management.

(c) The administrators should set up a databank and provide baseline data.

Appendix I: Revenue collected by ASM Department 2010

Application	Rate (Naira)
Application For ASM Registration	5,000.00
Application for registration of mineral buying centre per mineral	50,000.00
Application for annual renewal of buying centre license	50,000.00
TOTAL revenue collected 2010	**105,000.00**

YEAR	TOTAL
2010	450,000 Naira

Source: Central Bank of Nigeria (CBN)

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Investigating the physical and chemical properties of Oreke dolomite deposit to be used as refractory ware

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Abstract
Oreke dolomite in Kwara State, Nigeria was investigated with a view to determine its suitability for use as a raw material for the manufacturing of refractory ware The dolomite samples were mixed with feldspar, clay, and quartz to form a blend. The fifteen (15) Blend samples were moulded and analyzed for their chemical compositions, physical and mechanical properties. The characterization was carried out in accordance with American Society of Testing and Material (ASTM). The blend samples were tested for various refractory properties such as bulk density, porosity, cold crushing strength, linear shrinkage, refractoriness and others like water absorption and compressive strength. The result of the chemical analysis shows that the clay samples contain aluminium oxide (Al_2O_3) and silica (SiO_2) as major constituents making them suitable as alumina-silicate refractory materials. The cold crushing strength has comparatively high values. Bulk density and porosity of all the five blend samples batches are high while the linear shrinkage values are low. The strength characterization of the selected samples shows that the Compressive Strength (mean value) of the blend samples varies from 1.2 N/m^2 – 10.1 N/m^2 with respect firing temperature. The strength classification varies between medium to high. The temperature of refractoriness for the blend were 850°C, 900°C and 1000°C respectively, the values were lower than the normal as a result of the high silica content in the blend. The implication of this is that its use is restricted to non-ferrous material processing/casting (refractory wares). The results of various analyses on Physical and Mechanical properties, and Chemical Composition of selected blend samples was found to satisfy the allowable standard values for the production of refractory wares.

Keywords: Dolomite, Clay, Feldspar, Refractory ware, Dolomite Blend, Cold Crushing Strength, Porosity, Bulk Density, Temperature, Linear Shrinkage, Refractoriness

Introduction

Dolomites are universally known for their scenic beauty and scientific interest. They make up a unique natural environment on our planet. The long and complex geological and geomorphological history of this region has created typical and spectacular landforms with huge vertical cliffs, whitish, silver or pink rock pinnacles and towers rising from green slopes made up of darker and brittle rocks, with woods, pastures and scattered hamlets (Birkeland, 1984).

Dolomite production in Nigeria was dated back to 1960, it was discovered in Lokoja (Kogi State) and Igbeti marble development in Oyo State followed. Also, dolomites deposits have been discovered in different areas among them are Alagutan dolomite field in Oyo State, Oreke in Ifelodun Local Government area of Kwara State and Ikepsi in Edo State (Adetoro, 1986).

Dolomites are of economic importance to man by virtue of its versatile physical, mineralogical and chemical properties that recommend them for numerous uses as building material. They are also used for making refractory furnaces lining and as a source of carbon dioxide (Read, 1979). Many industries like paint, chemical, pharmaceutical and cosmetics utilize dolomite as major raw materials.

Many researchers have examined the relationship between physical and chemical properties of various carbonate rocks (Jessica *et al.*, 2006).The attempts have not met with much success because of the homogenous nature of the rock.

Oyedeko and Olugbade (2009) show the importance of sourcing for industrial raw materials locally has often been stressed by stake holders in the industrial sector, not only as a means of reducing dependency on imports and conserving foreign exchange but also as a way of reducing production cost and the consequent price of commodity. As a result of

the abundant deposit of dolomite outcrop in Nigeria the desire of all the three tiers of government is to embark on infrastructural development like paint and refractory wares. Therefore, the knowledge of the reserve estimation of the deposit is important in order to be able to predict the quality of the in-suit rock mass and reserve estimate.

Refractories materials are all the materials that are principally incorporated into the final refractory product. It also often comprises of auxiliary materials as binders, which affect the intermediate properties of the product (Alsop, 1998). The basic raw materials for refractories ware are Dolomite, Ball (plastic) clay, Feldspar and Quartz. Other additional materials include Kaloin, Calcite and Talc. Raw materials can either be natural (clays, feldspar, and quartz) or artificial (frits, oxides, opacifiers, and pigments), (Alsop, 1998)

Akande *et al.* (2011) determined the properties of Olotu marine clay in order to verify its suitability as a pozzolana for the production of cement. The clay exhibits properties that qualify it as poz-zolanic material for cement production, having 66.5% of the oxides of silicon, aluminium and iron and 2.36% of Calcium oxide in line with the recommendations of the American Society for Testing and Materials, ASTM C323-56 10:02 (2010). The delay in the setting times of the lime pozzolana cements is as a result of its low fineness compared with Portland cement. Omotoyinbo and Oluwole (2008) investigated the working properties of the Ara – Awo – Isan clay deposits with the view to propose other possible uses of the clays apart from the local pottery making for which the deposits are known. The results of the investigation will be very useful and serve as a database for prospective investors and managers of metallurgical industries.

Location of Study Area

Oreke dolomite deposit is located on the co-ordinate (latitude 8^0 29' 25" N and longitude 5^0 12' 15" E). The deposit is situated in Ifelodun Local Government, Kwara State as shown in Figure 1.
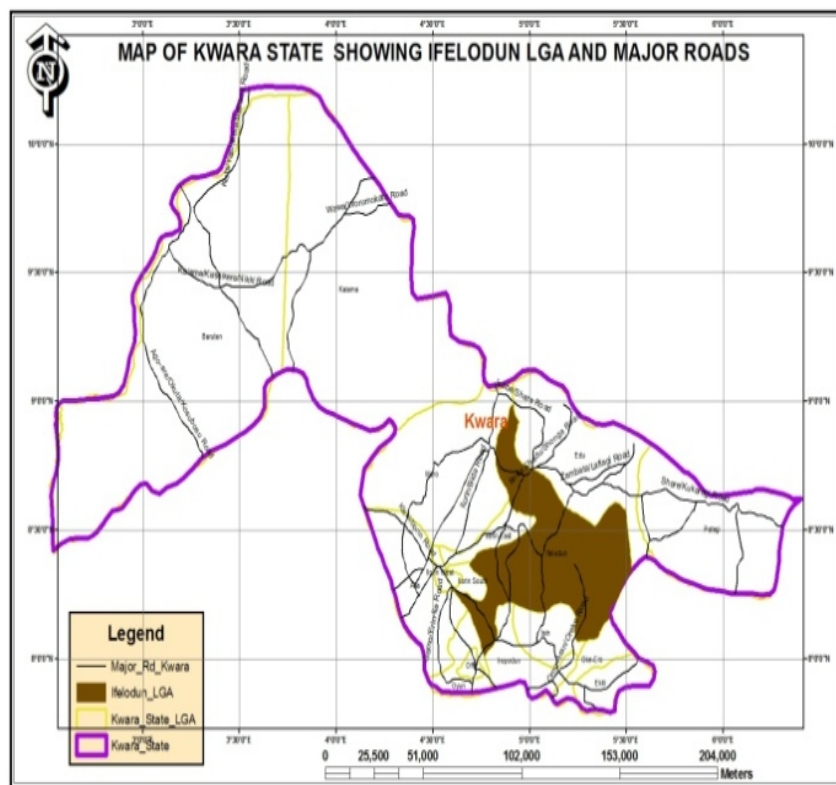

Figure 1: The Map of Kwara State showing the Location of Study Area

Materials and Method

Determination of Chemical Composition of the Blend

The results of the chemical composition of the blend (dolomite, clay, quartz and feldspar) samples are shown in Table 1

Table 1: Chemical Composition of the Blend
Determination of Linear Shrinkage of the Blends

Parameters	Level of Detected %
SiO_2	60
Al_2O_3	11.5
Fe_2O_3	0.48
CaO	10
MgO	6.4
$K_2O + Na_2O$	10.4
TiO_2, P_2O_5, SO_3 etc	Trace
LOI (H_2O)	15.28

The linear firing shrinkage determined as *FS* using Equation 1 the test was carried out in accordance with ASTM 15.02: C 326 (2001).

$$\text{Fired Shrinkage (FS)} = \frac{DL - FL}{DL} \times 100\% ......1$$

Where: FS is the Fired Shrinkage, DL is the Dried Length, m, and FL is the Fired Length, m
The results of the cylindrical blend sample tested for their compressive strength after firing are in Table 2

Table 2: Linear Shrinkage of the Blends at varied Temperature

Temp. (ºC)	L_1	L_2	L_3	L_4	L_5	$L_{Ave.}$
850	1.66	2.00	1.66	1.00	2.00	1.67
900	1.66	2.00	2.33	2.66	1.00	1.93
1000	1.33	1.33	3.00	2.00	0.66	1.67

$$\text{Water Absorption (WA)} = \frac{S - D}{D} \times 100\% ....2$$

Where: WA is the Water Absorption, S is the Soaked Weight, g, and D is the Dry Weight, g
The results of the cylindrical blend sample tested for their water absorption after firing are in Table 3

Table 3: Water Absorption of the Blends at varied Temperatures

Temp. (ºC)	W_1	W_2	W_3	W_4	W_5	$W_{Average}$
850	60	50	50	40	50	50
900	60	40	40	60	40	48
1000 ºC	20	20.2	20	20.1	20.2	21

Determination of Porosity of the Blends

The test was carried out in accordance with ASTM C20 – 00 (2010). The porosity was calculated using Equation 3.

$$\text{Porositu (P)} = \frac{W - D}{W - S} .....3$$

Where: W is the Soaked Weight, g, D is the Dry Weight, g, and S is the Suspended weight, g
The results of the cylindrical blend sample tested for their porosity after firing are in Table 4

Table 4: Porosity of the Blends at varied Temperatures

Temp. (ºC)	P_1	P_2	P_3	P_4	P_5	$P_{Average}$
850	60	55.56	55.56	50	55.56	55.34
900	75	66.67	50	60	50	60.33
1000	25	25.1	25	25.2	25	25.06

Determination of Bulk Density of the Blends

The test was carried out in accordance with ASTM C134 – 95(2010). The bulk density of blend samples was calculated using Equation 4

$$\text{Bulk density} = \frac{Md}{V} ...4$$

When: Md is the dried mass (g), and V is the Volume (cm^3)
The results of the cylindrical blend sample tested for their bulk density after firing are in Table 5

Table 5: Bulk Density of the Blends at varied Temperatures

Temp. (ºC)	B_1	B_2	B_3	B_4	B_5	$B_{Average}$
850	2.50	2.50	2.50	2.50	2.60	2.52
900	1.25	1.25	1.67	1.67	1.67	1.50
1000	1.67	1.67	1.67	1.67	1.68	1.67

Determination of Cold Crushing Strength of the Blends

The test was carried out in accordance with ASTM C133 – 97 (2008). Cold Crushing Strength was then calculated using Equation 5

$$CCS = \frac{L}{A} \quad ...5$$

: L is the Maximum load, (kN), and A is the Cross – Sectional Area, m^2

The results of the cylindrical blend sample tested for their cold crushing strength after firing are in Table 6

Table 6: Cold Crushing Strength of the Blends at varied Temperatures

Temp.(ºC) S/N	850	900	1000
C_1	25,410	22,840	26,600
C_2	25,470	22,870	24,130
C_3	24,790	22,940	24,860
C_4	24,860	22,290	25,550
C_5	25,610	21,900	25,710
$C_{Ave.}$	25,228	22,568	25,370

Determination Compressive Strength of the Blends

This was carried in accordance with method suggested by International Society of Rock Mechanic Commission (ISRM, 1989). The uniaxial compressive strength was determined using Equation 6

$$Co = \frac{P}{A} = \frac{P}{W \times D} \quad ...6$$

Where: Co is the Uniaxial compressive strength (MPa), P is the applied peak load (kN), W is the Width of the sample (m), and D is the Height of the sample (m)

The results of the cylindrical blend sample tested for their compressive strength after firing are in Table 7

Table 7: Compressive Strength of the Blend at varied Temperatures

Temp.(ºC) S/N	850	900	1000
A_1	0.7374	4.7888	10.561
A_2	1.5334	4.2215	13.519
A_3	1.3403	5.8300	3.0054
A_4	1.2814	6.2304	10.316
A_5	1.1101	6.0592	12.870
$A_{Ave.}$	1.2005	5.4259	10.054

Results and Discussions

Mixture of Dolomite, Clay, Feldspar, and Quartz to form a Blend

Table 8 the average mass of the blends were same all through of the 15 blend samples characterised by varied temperatures. The percentage of Clay and Quartz was increased so as to have appreciable quantity of silica to improve the bond properties.

Table 8: Samples Mixture (Dolomite, Clay, Feldspar and Quartz)

Mineral Sample	Composition					
	1000ºC		900ºC		850ºC	
	A		B		C	
	(g)	(%)	(g)	(%)	(g)	(%)
Dolomite	625	25	550	22	500	20
Quartz	250	10	275	11	300	12
Feldspar	250	10	300	12	325	13
Clay	1275	55	1275	55	1275	55
Average	2,400	100	2,400	100	2,400	100

Firing Characterization of the Blend Sample

Linear Shrinkage Characterization of the Blend Sample

Table 9 present the average linear shrinkage for all the blends at varied temperatures was below the recommended values, 7-10%. In practice, shrinkage values lower than 7.0% may be suitable for production of low-tension porcelain and low-grade earthen-ware (Singer, 1979). Higher shrinkage values may result in wrapping and cracking of the dolomite blend and they may cause loss of heat in the furnace.

Table 9: Average values of Linear Shrinkage of the Selected Blend Sample

Temperature (ºC)	Average Linear Shrinkage (%)	Shrinkage Classification
850 ºC	1.67	Low Plasticity (Range: below7-10%)
900 ºC	1.93	Low Plasticity (Range: below7-10%)
1000 ºC	1.67	Low Plasticity (Range: below7-10%)

Porosity Characterization of the Blend Sample

Table 10 present the blend sample fired at 850^0C and 900^0C respectively have values in the range (65%) above standard value. The values of blend which was fired at 1000^0C fall within the standard values of 20-30% according to Chester (1973). This is an indication for use in open-hearth furnace. The value may be increased by addition of fine grain silica or other additives like polythene materials saw dust e.t.c. In general, blends with the low porosity levels have the high values for cold crushing strength, resistance to deformation under load at operating temperatures.

Table 10: Average Porosity value of the Selected Blends

Temp. (^{o}C)	Average Porosity (%)	Porosity Classification
850 ^{o}C	55.34	Good Porosity (Range: above 20-30%)
900 ^{o}C	60.33	Good Porosity (Range: above 20-30%)
1000 ^{o}C	25.06	Very Good Porosity (Range: within 20-30%)

Bulk Density Characterization of the Blend Sample

Table 11 Shows that the average bulk density of the blend samples at varied temperatures are within the range of 1.5 – 2.1g/cm^3 for dense fire bricks (at 900 to 1000^0C) and 2.2 – 2.8g/cm^3 for high alumina at 850^0C, Refractories as reported by Chesti (1986). This property indicates whether or not the refractory was well fired. Also, it signified an important property of a steel-work silica bricks.

Table 11: Average Bulk Density value of the Selected Blend Sample

Temp. (^{o}C)	Average Bulk Density (g/cm^3)	Bulk Density Classification
850 ^{o}C	2.52	For Bulk High Alumina Refractories (Range: above 2.2-2.8 g/cm^3)
900 ^{o}C	1.50	For Dense firebricks (Range: within 1.5-2.1 g/cm^3)
1000 ^{o}C	1.67	For Dense Firebricks (Range: within 1.5-2.1 g/cm^3)

Refractoriness Characterization of the Blend

The refractoriness for the blend were 850°C, 900°C and 1000°C respectively, the values were lower than the normal values of 1580°C - 1750°C according to Grimshaw (1971). This was as a result of the high silica content in the blend. The implication of this is that its use is restricted to non-ferrous material processing.

Firing Characterization of the Blend Sample

Cold Crush Strength Characterization of the Blend Sample

Table 12 present the average Cold Crush Strength for the blend sample at varied temperatures were above the standard value of 15,000kN/m^2 minimum as reported by De Bussy (1972). The values range from 22,568 - 25,370kN/m^2, deduced the ability of the blend to withstand the rigours handling (transporting). Cold crushing strength shows the effect of firing on blend bond and this may be affected by firing, sintering characteristic and pressing method.

Table 12: Average Cold Crushing Strength value of the Selected Blend Sample

Temp. (^{o}C)	Average Cold Crushing Strength (kN/m^2)	Cold Crushing Strength Classification
850 ^{o}C	25,228	Very High (Range: above 15,000 kN/m^2)
900 ^{o}C	22,568	Very High (Range: above 15,000 kN/m^2)
1000 ^{o}C	25,370	Very High (Range: above 15,000 kN/m^2)

Relationship between Physical, Mechanical and Fired Properties of the Blend Sample
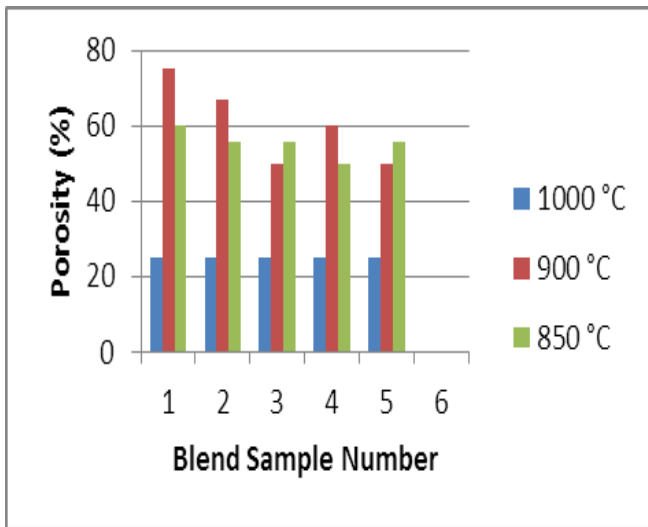

Figure 2: Porosity of Blend Sample

The result obtained in this study (Figure 2) show that most of the samples have high percentage porosity because of combustible materials in their composition which usually burn off on firing. The presence of pores in clay affects the strength by reducing the cross-sectional area expose to an applied load. They also act as stress raiser or concentrator especially in brittle clays according to Chukwuogo (1984). At 850°C, porosity of the batch samples show that sample number 4 has the least porosity values (50%), while sample number 1 has the highest value (60%). At 900°C, porosity of batch sample show that sample number 1, 2, and 3 has the least porosity values (25%) while sample number 2 and 4 has the highest value ranging (25.1 - 25.2) respectively. At 1000°C, porosity of batch sample show that all samples have same porosity values (25%) respectively. The porosity values falls within and above standardized values according to Chester (1973)

.Figure 3 shows the results obtained from cold crushing strength test after the blend samples have been fired between 850-1000°C. Grimshaw (1971) stated factors including composition, firing temperature, particle size and the amount of water content determine the strength developed by the blend materials. At

850°C, Sample number 5 has the highest compressive strength (25,610 kN/m^2), while sample number 3 has the lowest compressive strength (24,790 kN/m^2). At 900°C, sample number 5 has the lowest compressive strength (21,900 kN/m^2) and sample number 3 has the highest compressive strength (22,940 kN/m^2). At 1000°C sample number 1 has the highest compressive strength (26,600 kN/m^2) while sample number 2 has the lowest compressive strength (24,130 kN/m^2). The variation in the compressive strength values of the blend samples is very high which is attributed to the close range of the average grain fineness number of the batch samples, and amount of water content. The high silica content of samples together with the alkali metal presence results in glassy fusion which is responsible for the very high compressive strengths.
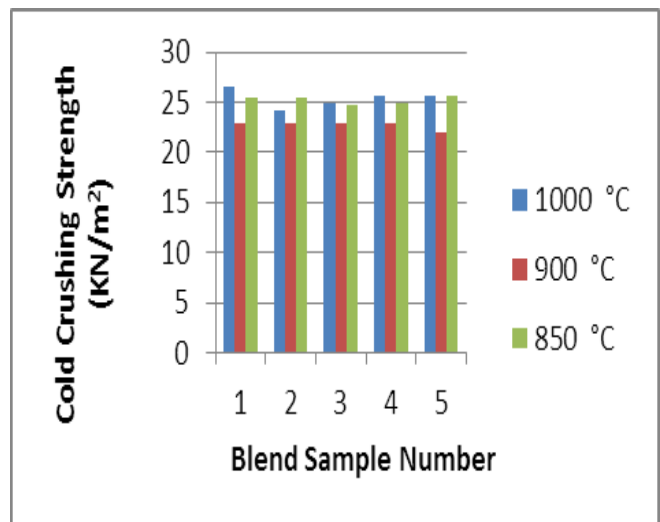
Figure 3: Cold Crushing Strength of Blend Sample

The result of the bulk density investigation of the blend sample is shown in Figure 4. It can be seen from Figure 4 that the bulk density values of the average samples varied between 1.67g/cm^3 and 2.52g/cm^3, which is characteristic of fireclays. These results are rather high and this may affect the cost of handling and transportation. This property is important in the transportation or handling of a refractory material. Some of the factors known to affect this property include particle size, treatment during manufacturing and the nature of the materials in the blend sample.
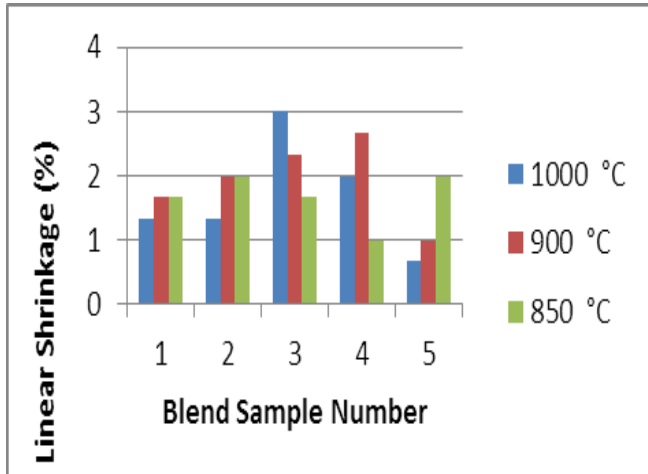
Figure 5: Linear Shrinkage of Blend Sample after firing

The linear shrinkage of the blend sample after firing is generally low as reflected in Figure 5 with the variations falling within a narrow range at $850^{\circ}C$, $900^{\circ}C$, and $1000^{\circ}C$. This is due to the fact that the variation in chemical composition, particle size, and porosity are not substantially large as to cause very large variation in shrinkage values. The shrinkage values obtained show that the blend samples are thermally stable and could be processed for use as low refractory furnace linings.

Conclusion

The results of various analyses on Physical and Mechanical properties, and Chemical Composition of selected samples of Oreke Dolomite Deposit in the blend (Dolomite, Quartz, Feldspar, and Clay) was found useful and serve as a database for prospective investors and managers of mineral extractive industries.

The tests on physical properties and chemical composition were carried out on all the fifteen (15) samples of the blend in accordance with American Society of Testing and Material (ASTM).

The result of the chemical analysis shows that the clay samples contain aluminium oxide (Al_2O_3) and silica (SiO_2) as major constituents making them suitable as alumina-silicate refractory materials. The cold crushing strength, bulk density, and porosity of all the five blend samples are high while the linear shrinkage values are low.

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Determination of the chemical composition and the work index of Rafin Gabas chalcopyrite ore

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Abstract

In this research, the chalcopyrite ore deposit used for this work was sourced from the vicinity of Rafin Gabas village of Kokona Local Government Area in Nasarawa state. The petrology of the Rafin Gabas chalcopyrite was carried out using metallographic technique and metallurgical microscope with in-built camera while the chemical analysis of the as-received chalcopyrite was carried out using XRF and gravity method of chemical analysis. The chemical analysis of the Rafin Gabas chalcopyrite ore sample indicated that the ore contains on the average 9.0% Al_2O, 21.1% SiO_2, 18.5% SO_3, 4.91% K_2O, 0.061% Cr_2O_3, 29.33% Fe_2O_3, 12.6% CuO, 0.818% ZnO, 1.5% Rb_2O, 2.0% MoO_3 and 0.05% $LaqO_3$ with iron, silica and copper minerals predominant in the matrix of the ore while other minerals associated with the ore are in minor percentages making the ore deposit another potential source for copper mineral. The work index of the as-received Rafin Gabas Chalcopyrite ore was also determined using the comparative method of determining work index known as the Berry and Bruce Method. The reference ore (granite) and the Rafin Gabas chalcopyrite ore samples were pulverized and ground for 1 hour respectively using the ball milling machine. The products were sieved for 20minutes using the sieve shaking machine and the work index of the chalcopyrite was determined and found to be 22.38Kwh/tonne. This work index value obtained for the Rafin Gabas chalcopyrite lies favourably within the work indexes of 18.3-23.38kwh/tonne for copper minerals sighted in the literatures.

Significance: The determination of the work index of Rafi Gabas chalcopyrite will give adequate information on the energy requirement for effective comminution in order to liberate the valuable minerals from the gangue and eliminate energy wastage.

Key word: Rafin-Gabas Chalcopyrite ore, Work index

Introduction

In view of the desire of Nigeria as country to attain the aim of becoming one of the leading 20 world economics, the power sector has become one of the critical area needing attentions. Therefore, the ability of the nation to conserve the energy use has become a very powerful tool in managing our limited power resources. In mining industry, this can be done by determining the energy requirement in the beneficiation of ore. In ore dressing, physical treatment is used to enrich effectively concentrate the valuable mineral in order to prepare it for the industrial use. This involves various processes: first, comminution to such a size to release all the valuable mineral particles; secondly, a sorting operation to separate particles of ore minerals from the gangue; thirdly, when necessary agglomeration (Gilchrist, 1989).

Due to the high demand of copper in the world today, it has become imperative that the production of copper is step up for it utilization locally and as a source for generating foreign exchange for the nation. Chalcopyrite is a copper-iron-sulphide mineral that crystallizes in the tetragonal system. It has the chemical composition $CuFeS_2$. It has a brassy to golden yellow colour and a hardness of 3.5 to 4 on the Moh's scale. Its streak is diagnostic as green tinged black. On exposure to air, chalcopyrite oxidizes to a variety of oxides, hydroxides and sulphates. Associated copper minerals include sulphide's bornite (Cu_5FeS_4), chalcocite (Cu_2S),

covellite(CuS), digenite(Cu_9S_5) carbonates such as malachite and azurite, and rarely oxides such as cuprite (Cu_2O). Chalcopyrite is rarely found in association with native copper, but occurs in a number of various ways: magmatic segregation, pneumatolytic veins, metasomatic veins, but more importantly as pyrometasomatic found in Canada, Australia, Japan, South Korea (Cornelius, 1985) and Nigeria (Ofor, 1997). The most commonly present source of copperore is chalcopyrite ($CuFeS_2$), which accounts for about 50% of copper production. Chalcopyrite ore is extensively mined in Chile, the United States, Canada, Zambia, and Poland. The world's largest copper mine is in Berkeley Pit, located in Butte, Montana (Wills, 2006).

Chalcopyrite is one of the principal ore of copper and is sometime polished into beads and pendant as jewellery. However, on extraction of copper from the ore, the copper is used for various things, such as the manufacture of electronics, electrical cables, jewels, alloying element, pharmaceutical drugs, construction materials and decors in homes and offices (Gilchrist, 1989).

Today there are cases of findings that indicated Nigeria is blessed with some reasonable amount of copper mineral deposits among which is the Rafin Gabas chalcopyrite ore of Kokona Local Government Area in Nasarawa state, the deposit is under development. To develop its process route flow sheet, mineral processing conceptual parameters like the work index, chemical composition, mineralogy and others must be determined to guide the process design for the Rafin Gabas chalcopyrite ore. Determining the energy needed to grind the newly discovered Rafin Gabas chalcopyrite ore means its comminution and hence, the energy requirement for comminution if known will minimised the energy wastage that will be used in grinding the Rafin Gabas chalcopyrite ore (Yaro and Thomas, 2001).

Comminution is a process whereby particular materials are reduced by blasting crushing, and grinding to product sizes required for downstream processing or end use. It ensures that valuable constituents are physically liberated from waste constituent before physical or chemical separations are attempted. In U.S.A, 15 billion Kwh per year is used for blasting, crushing and grinding materials of all types. Copper ore and iron ore consumed up to about 60% of the total energy (Fuerstenau and Han, 2003).

In the third world countries like ours where energy is a scare commodity, the greatest challenge facing mineral processing professional today is how to efficient design and operational maximised the available energy. Hence, application of energy is the driving force of grinding, it is natural that mineral processors would try to design a means of predicting the energy consumed during this process.

Theoretical consideration
Comminution theory focused on the relationship between energy input and particle size made from a given feed size. Various theories have been expounded such as Von Rittinger's law (1867), Kick's law and Bond's law in Weiss, 1985, however none had been entirely satisfactory as stated by Wills and Atkinson, 1993. Of recent Yaro and Thomas in 2009 conducted a grindability test on calcined sample of Koton Karfe iron ore to see if such phenomenon will reduce the amount of energy consumed in grinding the test ore, detailed analysis indicated that there is no much differences in the amount of energy consumed. Bond (1952) in Weiss 1985 developed an equation which is based on the theory that the work input is proportional to the new crack tip length produced in particle breakage and equals the work represented by the product minus that represented by the feed. In particle of similar shape, the surface area of unit volume of material is inversely proportional to the diameter. The crack length in unit volume is considered to be proportional to one side of the area and therefore inversely proportional to the square-root of the diameter. For practical calculations, we have

$$W = \frac{10W_i}{\sqrt{P_r}} - \frac{10W_i}{\sqrt{F_r}} \quad \text{...Equation 1}$$

Where W = work input in Kilowatt hour per tonne

P = diameter in microns which 80% of product passes

F = diameter in microns which 80% feed passes

W_i = work index

The Work index is the comminution parameter which expresses the resistance of material crushing and grinding; it is the kilowatt hour per tonne required to reduce the material from theoretically infinite feed size to 80% passing 100 (Wills, 2006).

From Berry and Bruce (1966) using Bond's law in Yaro and Thomas (2001) the work index of an ore can be determined by comparing the grindability:

$$W_r = W_t = W_{ir}\left[\frac{10}{\sqrt{P_r}} - \frac{10}{\sqrt{F_r}}\right] = \left[\frac{10}{\sqrt{P_t}} - \frac{10}{\sqrt{F_t}}\right] \quad ....\text{Equation 2}$$

$$\text{Hence, } W_{it} = W_{ir}\left[\frac{10}{\sqrt{P_r}} - \frac{10}{\sqrt{F_r}}\right] \Bigg/ \left[\frac{10}{\sqrt{P_t}} - \frac{10}{\sqrt{F_t}}\right] \quad ...\text{Equation 3}$$

Where W_r = work input of reference ore;

W_t = work input of test ore;

W_{ir} = work index of reference ore;

W_{it} = work index of test ore;

P_r = 80% of Product (reference ore) passes;

P_t = 80% of Product (test ore) passes;

F_r = 80% of feed (reference ore) passes

F_r = 80% of feed (test ore) passes

Denver Grindability Method

The grinding tests under this method for the determination of work index are performed for specific time intervals under uniform conditions. The amount (percentage by weight) of 75μm material produced is plotted against time in minutes, to produce a curve. The produced from the grinding of the material is then compared with five standard curves on the same scale which are designated as soft (A), medium soft (B), medium (C), medium hard (D), and hard (E) as shown in figure 1.0. Ores softer than "B" are considered to be soft and ones harder than "D" are considered to be hard. Having determined the relative hardness of the ore and for a given mill feed size, desired discharge sieved size fractions and tonnage,
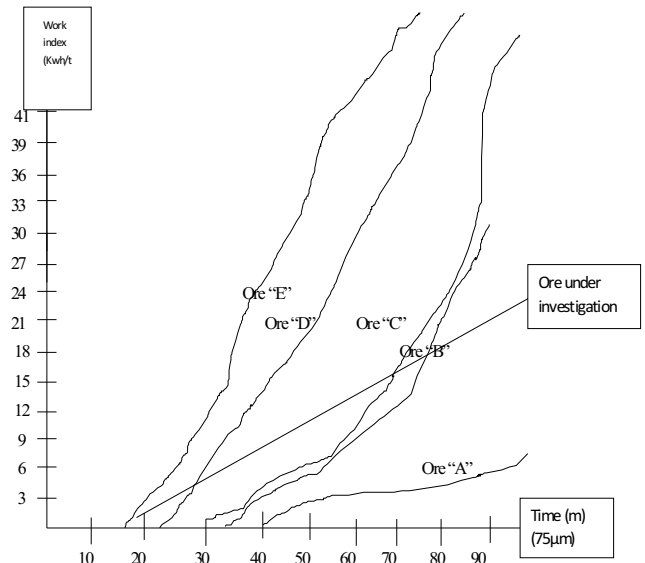
Figure 1.0: Denver grindability curves for classification ore types. Source (Mathur, 1985)

Denver Ball Mill size and horsepower required can be determined using Denver circular slide rule (Mathur, 1985).

Materials and Methods
Materials

(i)The Chalcopyrite samples used for this research work were obtained from Rafin – Gabas village of Kokona Local Government Area in Nasarawa state. 20 kilograms each of the samples totalling 60kilograms were collected from three different pits all in lump sizes.
(ii) Ore granite of known work index

Equipment

The equipment used in this research work is listed below:
1) Denver pulverizing machine
2) Denver sieve shaking machine
3) Denver jaw crushing machine
4) Denver ball milling machine
5) Denver polishing machine

Determination of the Petrology of Rafin Gabas chalcopyrite ore:

The as-received sample of the Rafin Gabas chalcopyrite was cut, ground, polished and observed under non polarize light using metallurgical microscope with an in-built camera. This was carried out to ascertain the distribution and association of the various

minerals in the matrix of the ore sample. The result is shown in plate 1 and 2.

Determination of the Chemical composition of Rafin Gabas chalcopyrite
The sample is weighed and grounded in an agate and a binder (PVC dissolved in Toluene) is added to the sample, then carefully mixed and pressed in a hydraulic press into a pellet. The pellet is loaded in the sample chamber of the spectrometer and voltage (30KV maximum) and current (IMA maximum) is applied to produce the X – ray to excite the sample is analyzed to determine the concentration of the elements in the sample.

Determination of the work index using Bond modified method (Berry and Bruce method)
The Modified Bond's method called Berry and Bruce method of determining the work index of an ore was used in this research work because of its simplicity, less time consuming and is called the comparative method of determining grindability parameter. This method requires the use of a reference ore of known work index (Ore granite of known work index 15.13kwh/tone). The procedure used in the determination Rafin Gabas chalcopyrite ore included: 200grams each of the test and reference ores were ground in the laboratory Ball Mill machine for an hour and sized for 20minutes using the automatic sieve shaker. Each size fraction was weighed and the value noted to be the "discharge or product".

(i) The ore under test and the reference ore were each crushed and pulverized.
(ii) An identical weight of the test and reference ores was each taken and sized by sieving into a number of size fraction using the automatic sieve shaker for 20minutes.
(iii) Each sieved fraction of the test and reference ores was weighed and the value noted as the "Feed".
(iv) The "Feed" test and reference ores were each gathered together and introduced into the laboratory ball mill machine and ground for a

specific time of one hour.
(v) The test and reference ores from the laboratory ball mill machine were sieved and each sieved fraction was weighed and the value noted as the product or discharge".

Then, if r is the reference ore and t the ore under test. From Bond's equation
The results of the tests are presented in Tables and Figures 1 and 2.

Discussion
Plate i shows the as-received Rafin Gabas chalcopyrite ore sample while Plate ii shows the non polarize light micrograph of the Rafin Gabas chalcopyrite ore sample with copper mineral in sky blue, silica in black and iron and other associated minerals in brown colours.
Table 2.0 shows the result of the chemical analysis of the Rafin Gabas chalcopyrite ore. From the table the Rafin Gabas chalcopyrite ore contains on the average 9.0% Al_2O, 21.1% SiO_2, 18.5% SO_3, 4.91% K_2O, 0.061% Cr_2O_3, 29.33% Fe_2O_3, 12.6%CuO, 0.818% ZnO, 1.5% Rb_2O, 2.0% MoO_3 and0.05% $LaqO_3$ with iron, silica and copper minerals predominant in the matrix of the ore while other minerals associated with the ore are in minor percentages making the ore deposit another potential source for copper mineral as copper minerals less than 12.6%Cu have been mined (Weiss, 1985). Table 3.0 to 6.0 shows the results of the particle sizes analysis of the reference and test ores 80% passing for both the feeds and products sieves size fractions for the reference and the Rafin Gabas chalcopyrite ores. The 80% passing particle size fraction for both feed and the product of the as-received Rafin Gabas chalcopyrite ore was found to be andthe work index of the as-received Rafin Gabas chalcopyrite was computed to be 22.38Kwh/tonne which went compared to the work index of other copper ores the result obtained lies favourably within the work indexes of 18.3-23.38kwh/tonne for copper minerals sighted in the literatures (Fuerstenau and Han, 2003). The 22.38kwh/tonne work index obtained for the Rafin Gabas chalcopyrite ore means that about 22.38kwh of energy is required to reduce

one tonne of the as-received Rafin Gabas chalcopyrite ore from 80% passing size of 288.02 to 80% passing size of , using the Denver grindability test curves the Rafin Gabas chalcopyrite is classified as a medium texture type ore, because the work index of the as-received Rafin Gabas chalcopyrite samples grind for one hour cut through the curve line of the ore type "C" of the Denver grindability curves (Mathur, 1985).

Conclusion

Based on the results obtained from this work, the Rafin Gabas chalcopyrite ore is another potential source of copper mineral deposit in the country as it is found to contains on the average 9.0% Al_2O, 21.1% SiO_2, 18.5% SO_3, 4.91% K_2O, 0.061% Cr_2O_3, 29.33% Fe_2O_3, 12.6%CuO, 0.818% ZnO, 1.5% Rb_2O, 2.0% MoO_3, 0.05% $LaqO_3$ with a work index of 22.38Kwh/tonne making it a medium texture type chalcopyrite ore.

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Copper Mineral
(light blue in colour)
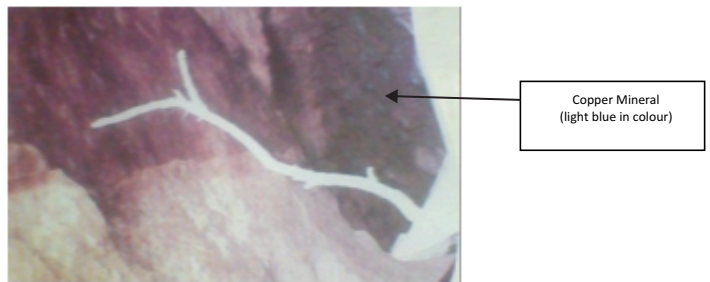
Plate 1: Rafin Gabas Chalcopyrite (in-situ) ore sample.

Silica
(black in colour)

Iron &other mineral
(brown in colour)
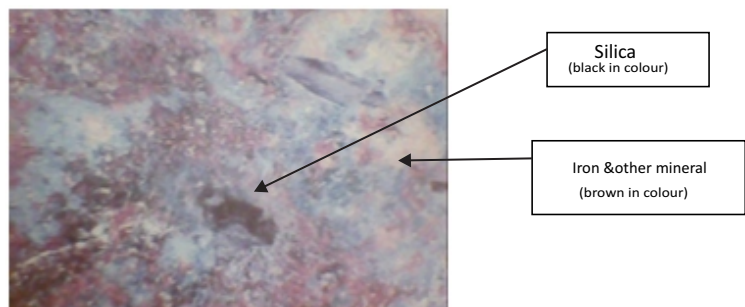
Plate 2: Microstructure of Chalcopyrite in the ore sample.

Table 1.0: Average work indexes of some minerals

Minerals	Specific gravity	Work index(kwh/tonne)
Bauxite	2.38	9.45
Cement clinker	3.15	13.49
Cement raw materials	2.67	10.57
Clay	2.23	7.10
Coke	1.51	20.70
Coal	1.63	11.37
Copper ores	3.02	13.3 and 18.3-23.38
Gravel	2.70	25.17
Granite	2.68	15.14
Pyrite ore	3.48	8.90

Source: Weiss (1985), Society for Mining, Metallurgy and Exploration, Inc. (2003)

Table 2.0: Chemical Analysis of the Rafin Gabas Chalcopyrite ore sample

Comp.	Al_2O	SiO_2	SO_3	K_2O	Cr_2O_3	Fe_2O_3	CuO	ZnO	Rb_2O	MoO_3	$LaqO_3$
%	9.0	21.1	18.5	4.91	0.061	29.33	12.6	0.818	1.5	2.0	0.05

Table 3.0: Result of Particle Size Analysis (feed to Ball Mill for Granite Sample)

Sieve size (	Weight(g) Retained	Weight (%) Retained	Nominal Aperture	Cumulative Wt (%) Retained	Cumulative Wt(%) passing
+355	27.02	13.54	355	13.54	86.46
355+250	24.22	12.14	250	25.68	74.32
250+180	32.36	16.22	180	41.90	58.10
180125	34.98	17.53	125	59.43	40.57
12590	23.70	11.88	90	71.31	28.69
90+50	26.86	13.46	50	84.77	15.23
- 50	30.36	15.21	-	100	0
	199.5				

From table 3.0, to calculate the 80% passing of granite feed to Ball Mill Machine

if $250\mu m$ gives 74.32% passing, then $x\mu m(F_r)$ will give 80%

$$\Rightarrow x = 250 \times \frac{80}{74.32} = 269.11\mu m$$

Table 4.0: Result of Particle Size Analysis (feed to Ball Mill for Chalcopyrite Sample)

Sieve size (	Weight(g) Retained	Weight (%) Retained	Nominal Aperture	Cumulative Wt (%) Retained	Cumulative Wt(%) passing
+355	28.00	14.01	355	14.01	85.99
355+250	33.07	16.55	250	30.56	69.44
250+180	33.02	16.53	180	43.29	56.71
180+125	39.06	19.55	125	62.84	37.16
125+90	37.80	18.92	90	81.76	18.24
90+50	26.54	13.28	50	95.04	4.96
- 50	2.31	1.17	-	100	0
	199.8				

From table 4.0, to calculate the 80% passing of chalcopyrite feed to Ball Mill Machine

if $250\mu m$ gives 69.44% passing, then $x\mu m (F_t)$ will give 80%

$$\Rightarrow x = 250 \times \frac{80}{69.44} = 288.02 \mu m$$

Table 5.0: Result of Particle Size Analysis (Product of Ball Mill for Granite Sample)

Sieve size (	Weight(g) Retained	Weight (%) Retained	Nominal Aperture	Cumulative Wt (%) Retained	Cumulative Wt(%) passing
+355	7.12	3.57	355	3.57	96.43
355+250	35.91	18.00	250	21.57	78.43
250+180	29.68	14.88	180	36.45	63.55
180+125	30.88	15.48	125	51.93	48.07
125+90	16.96	8.50	90	60.43	39.59
90+50	23.88	11.97	50	72.40	27.60
- 50	55.07	27.60	-	100	0
	199.5				

From table 5.0, to calculate the 80% passing of granite (product) to Ball Mill Machine discharge

if $250\mu m$ gives 78.43% passing, then $x\mu m (P_t)$ will give 80%

$$\Rightarrow x = 250 \times \frac{80}{78.43} = 255 \mu m$$

Table 6.0: Result of Particle Size Analysis (Product of Ball Mill for Chalcopyrite Sample)

Sieve size (	Weight(g) Retained	Weight (%) Retained	Nominal Aperture	Cumulative Wt (%) Retained	Cumulative Wt(%) passing
+355	7.63	3.83	355	3.83	96.97
355+250	47.86	24.00	250	27.83	72.17
250+180	22.04	11.05	180	38.88	61.12
180+125	25.24	12.66	125	51.54	48.46
125+90	18.79	9.42	90	60.96	39.04
90+50	24.87	12.47	50	73.43	26.57
- 50	52.79	26.56	-	100	0
	199.4				

From table 6.0, to calculate the 80% passing of chalcopyrite (product) to Ball Mill Machine discharge;

if $250\mu m$ gives 72.17% passing, then $x\mu m(P_t)$ will give 80%

$$\Rightarrow x = 250 \times \frac{80}{72.17} = 277.12\mu m$$

Computations

To compute the work index using Modified Bond's equation

$$W_{it} = W_{ir} \frac{\left[\dfrac{1}{\sqrt{P_r}} - \dfrac{1}{\sqrt{F_r}}\right]}{\left[\dfrac{1}{\sqrt{P_t}} - \dfrac{1}{\sqrt{F_t}}\right]}$$

where $W_{ir} = 15.44, P_r = 255, F_r = 269.11, P_t = 277.12, F_t = 288.02$

$$W_{it} = 15.44 \frac{\left[\dfrac{1}{\sqrt{255}} - \dfrac{1}{\sqrt{269.11}}\right]}{\left[\dfrac{1}{\sqrt{277.12}} - \dfrac{1}{\sqrt{288.02}}\right]} = 22.38 kwh/tonne$$

Analysis of borehole water samples for public consumption in selected local government areas of Kwara state

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Abstract
Samples of borehole water from selected local government areas of the State were collected for analysis and testing. Ground water quality was tested, while physical, chemical and bacteriological characteristics of water samples were determined in the laboratory. Having compared the results of the analysis with World Health Organization (WHO) Standards and those of the Standard Organization of Nigeria (SON) for conformity in terms of consumption, it was established that the analyzed water samples were portable and fit for consumption within the expected limits World Health Organization(WHO, 1971), Environmental Protection Agency(EPA, 2007). This established the fact that the analyzed water is good for the users (students, residents of the immediate communities and the entire populace using the borehole water). It was also established within allowable limits(allowable limits of WHO /NIS for Drinking water) that the water is clean and disease- free, thereby making it fit not only for consumption but also for other domestic uses. However, continuous routine checks of the boreholes have been recommended, especially after construction works have been carried out near them to prevent possible underground contamination and other sources of pollution. It was also recommended that the position of a well should be at a higher altitude and farther distance from pit latrines and public toilet.

Keywords: Borehole, Water, Wells, Consumption, Domestic uses

Introduction
The importance of water in our daily life makes it imperative for thorough examination to be conducted on it before drinking. Ground-water provides a significant percentage of water supplies for domestic use by both rural and urban dwellers. In Kwara State, it is evident that ground water use is about 80% of the total water consumption (mainly through boreholes and wells) (UNICEF/ WHO,2011). Although, water as one of the remarkable substances and most abundant compound on Earth's surface covering about 70% of this surface in nature, it exists in any of the three phases (solid, liquid and gaseous states). It is in dynamic equilibrium between the liquid and gas states at standard temperature and pressure. At room temperature it is a tasteless and odourless liquid, nearly colourless with a blue limit. Many substances dissolve in water to form solution and so, it is commonly referred to as the 'universal solvent'. Water in nature is rarely pure and some of its properties may vary slightly from those of its pure state. Hence, water is the only common substance found naturally in all three common states of matter. It plays a vital role in the life of plants, animals and man, and as such could be regarded as matrix of life. It usually makes up to 55 – 78% volume of the total body fluid. (Michael, 2006)

Water occurs in all types of rocks, sedimentary, igneous and metamorphic, though the water-bearing structures differ with rock – type. While it occurs in the porous and permeable primary bodies in sedimentary rocks (aquifers), it occurs in weathered and or fracture portions of igneous and metamorphic rocks. Despite the favourable, large ground water occurrence reported the world over, the Nigerian situation appears to be restricted by the fact that more than half of the country is underlain by hard crystalline impervious rocks which are either igneous or metamorphic in origin (Offodile, 2002). The rocks underlie

most parts of eastern Sokoto and Zamfara States, most parts of Kano, Kwara, Bauchi, Plateau and Kaduna States; substantial areas of Cross River, Ondo, Ogun, Oyo, Edo, Niger, Benue Adamawa States. In these areas, therefore, a serious hydro-geological situation presents itself and water has to be found to meet the domestic, agricultural and industrial needs of the population.

In developing countries including Nigeria, majority of the people live in rural and urban areas, and so depend on rivers, streams, wells and more recently, borehole wells (shallow or deep) as their sources of water supply for consumption, and other domestic uses. A borehole well is constructed by installing a vertical pipe (casing), and well screened to keep the borehole from caving. The annulus space between the pipe and wall of the borehole is gravel- packed to hold the pipe firmly and to filter the water entering the pipe (casing). Among all these sources, borehole well which is from deep ground is considered safest, provided it is properly located, constructed and operated.

According to Ibe and Okplenye (2005), main origins of pollution of wells and boreholes are industrial, domestic and agricultural, and can be continuous or accidental. Industrial pollution may involve seepage of used water containing chemicals such as metals and radioactive compounds, or contaminated water from damaged pipelines infiltrating into the borehole. Domestic pollution may involve seepage from broken septic tanks, pit latrines, cesspools and rivers.   Domestic wastes, industrial activities are the major sources of water pollution. Though, other pollutions do enter water through air and oil. Generally, the nature of polluted water will depend very much on the locality in which it is located. The effects of pollutions in water include colour change, alteration of pH and alteration of the amount of free solids and in the level of biochemical and chemical oxygen demands. Consequently, the above changes have critical effects on life process (Kolo and Baba, 2004).

According to reports (WHO, 1973), water once polluted becomes poisonous to animals and aquatic plants and successive ecosystem either directly or as a result of the food chain whereby they ingest the pollutants and gradually accumulate some in their bodies to the point of toxicity, which in extreme case, may cause death. Extensive research works conducted in various parts of the world (Akinniyi and Ogugbuaja, 1996) have documented a large body of inorganic elements which are so far considered essential in human nutrition and play vital roles as structural and functional components of metalloproteinase and enzymes in cellular processes (Kolo and Baba, 2004).

According to WHO's report (1971), though ground water (through borehole supplies) is usually considered safe, contamination of the water may arise from sewage entering the borehole, through corroded casings and weathering of the filter materials; hence, the need to regularly test the water quality for domestic consumption. Nigerian Standard for drinking water quality relates to mandatory limits concerning constituents and contaminants of water that are known to be hazardous to health and/or give rise to complaints from consumers. The standard includes a set of procedures and good practices required to meet the mandatory limits.

The National Council in Water Resources (NCWR, 2005) recognized the need to urgently establish acceptable Nigerian standard for drinking water quality. This is against the background that the Nigerian Industrial Standard for Portable Water (NISPW) developed by the Federal Ministry of Environment did not receive a wide acceptance by all stakeholders in the country. This paper, therefore, focuses on the analysis of borehole water for domestic consumption in the sampled local government areas of Kwara State.

Materials and Method

Water samples were collected from Eight (8) different bore hole locations being in used as source of domestic water supply for students in some schools and other communities in Kwara State in clean bottles and securely covered. The bottles were labeled accordingly. The

Map of Kwara State

samples were tested for physical, chemical and bacteriological characteristics. Also, conductivity of the water samples were also tested. The test was carried out at the Kwara State Rural Supply and Sanitation Agency Laboratory (formerly UNICEF Laboratory).
The sampled areas are as listed below:

I.   Barakat LGEA Primary School, Ilorin (Ilorin West)
ii.   St. Andrews LGEA Primary School, Oro (Irepodun)
iii.   Baptist LGEA School, Ipee
iv.   LGEA Alapa, (Asa)
v.   Alla LGEA Primary School, Alla (Isin)
vi.   Etsu Abdullahi Primary school, Tsaragi (Patigi)
vii.   Central Primary School, Lafiagi (Edu).
viii. Sapati Oko LGEA School, Sapati (Asa)

This paper focuses on the analysis of the parameters of properties of the water samples collected. The parameters are grouped into physical, chemical and bacteriological categories. Conductivity of the water samples was also conducted. The physical tests indicate properties detectable by the senses, while the chemical tests determine the amount of mineral and organic substances that affect water quality, while the bacteriological tests show the presence of bacterial and characteristic of faucal pollution. Approach to data analysis was done based on the following tests:

Physical Test
Parameters for physical tests include colour, turbidity, total solids, dissolves solids, suspended solids, odours and taste.

Colour
Colour in water may be caused by the presence of minerals such as iron and manganese or by substances of vegetables origin such as alagae and weeds. Colour tests indicate the efficiency of the water treatment system.

Turbidity
Turbidity in water is because of suspended solids and colloidal matter. It may be due to eroded soil caused by dredging or due to the growth of micro – organism. High turbidity makes filtration expensive. If sewage solids are present, pathogens may be encased in the particles and escape the action of chlorine during disinfection.

Odours and Taste
These are associated with the presence of living microscopic organisms or decaying organic matter including weeds, algae, or industrial wastes containing ammonia, phenols, halogens and hydrocarbons. While chlorination dilutes odour and taste caused by some contaminants, it generates a foul odour itself when added to water polluted with detergents, algae and some other wastes.

Chemical Tests
These include tests for pH, hardness,

presence of a selected group of chemical parameters, biocides and high toxic chemicals.

pH

pH is a measure of hydrogen ion concentration. It is an indicator of relative acidity or alkalinity of water. Drinking water should have a pH between 6.5 and 8.5. Among the constituent elements always under test are aluminum (Al), Iron (Fe), Manganese (Mn), Chloride (Cl) Fluoride (Fl), Nitrate (NO_3), Sulphate (SO_3) and Boron (B). All the aforementioned elements have specific limits to which they could be consumed by human. The absence could sometime be dangerous, while their excesses could be highly damaging to the body system. Therefore, the need to check and balance their presence in our drinking water is essential.

Bacteriological Tests

For technical and economical reasons, analytical procedures for the detection of harmful organisms are impractical for routine water quality surveillance. In a bacteriological analysis, any evidence, at the time of examination, is mostly an indication of contamination of bacteria in a given sample of water using specific cultural methods. In addition, the results of routine bacteriological examination must always be interpreted in the light of a thorough knowledge of the water supplies, including their sources, treatment and distribution.

Discussion of Results

The water samples collected were put to physical, chemical and bacteriological test. Various elements as recommended by WHO (1990) and NIS (2003) were put to test to counter check the quality of water from the boreholes.

All the water samples tested were odourless which conform to NIS (2004) and WHO (2012) specifications for portable water. The colour of the water samples tested ranges from not clear to colourless, which conform to the NIS and WHO standards. Also, the pH, turbidity and conductivity of the water samples tested conform with the NIS (2004) and WHO (2004) standards. The chemical characteristics of the

water samples tested also conform to these standards. The total hardness of water samples tested were within the NIS (2003) and WHO (2011) recommendations. As for total dissolved solids, all water samples were in conformity with these international standards.

Conclusion and Recommendation

From the result of this study, it is shown that water samples collected from boreholes of all the schools tested conforms to the NIS (2004) and WHO (2011) standards, and are within the permissible level for household consumption. Having analyzed the water samples from Barakat LGEA Primary School, Ilorin (Ilorin West), St. Andrews LGEA Primary School, Oro (Irepodun), Baptist LGEA School, Ipee, LGEA Alapa, (Asa), Alla LGEA Primary School, Alla (Isin), Etsu Abdullahi Primary school, Tsaragi (Patigi), Central Primary School, Lafiagi (Edu), Sapati Oko LGEA School, Sapati (Asa) in Kwara State, the following recommendations are hereby suggested:

1. The students and populace using the boreholes within the scope of the study area should continue to use the water as the water is clean and disease free.

2. Periodic routine checks should be carried out on our boreholes at least biannually or annually as some contaminants such as feaces, pesticides, insecticide, etc, and other poisonous chemicals which could penetrate into the hole can be checked and removed.

3. The study suggests a collaborative work between chemists and geologists with a view to finding out the exact sources of the contaminants in boreholes within the study areas and easily treating such in order to make the borehole water completely fit for drinking.

4. After construction, the position of a borehole should be at higher attitude and at a far distance from toilets and waste disposal.

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Table 1: Results of the Tested Areas.

S/N	Parameters	Location and Results	Location and Result	Location and Result	Location and Result	Location and Results	Location and Result	Location and Result	Location and Result
		Barakat LGEA School (IL/West)	St. Andrews LGEA School, Oro (Irepodun)	Baptist LGEA School (Ipee)	LGEA Alapa (Asa)	Alla LGEA School (Isin)	Etsu Abdullahi Pry. Schl. Tsaragi	Center Pry. Schl. Lafiagi (Edu)	Sapati Oko LGEA Schl. (Asa)
1	Colour	Not Clear	Colourless	Colourless	Colourless	Colourless	Colourless	Colourless	Colourless
2	Turbidity	1.79	18.1	18.6	16.2 NTU	23.0	34.5NTU	20.3	187
3	Odour	Odourless	Odourlesss	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless
4	Ph	6.85	6.62	6.52	7.56	6.79	6.58	6.14	6.62
5	Conductivity	341us/cm	329 us/cm	343 us/cm	267us/cm	269 us/cm	242us/cm	137 us/cm	174 us/cm
6	Sulphate	45mg/L	162 mg/L	92mg/L	25mg/L	146 mg/L	28mg/L	67mg/L	NIL
7	Nitrate	0.05mg/L	12.4mg/L	17.4 mg/L	18.0mg/L	43mg/L	21.4mg/L	22mg/L	0.263 mg/L
8	Manganese	0.01mg/L	0.1mg/L	0.12mg/L	0.01mg/L	0.032 mg/L	0.12mg/L	0.1 mg/L	
9	Boron	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
10	Iron	0.2mg/L	0.19mg/L	0.91mg/L	0.02mg/L	0.15mg/L	0.20mg/L	0.35 mg/L	0.20 mg/L
11	Chloride	4mg/L	142mg/L	105 mg/L	175mg/L	230mg/L	197mg/L	186 mg/L	194 mg/L
12	Dissolved Gases (Carbondioxide)	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
13	Total Hardness	80 mg/L	136 mg/L	160mg/L	142mg/L	160mg/L	60mg/L	46mg/L	28 mg/L
14	Total Dissolved Solids	287 mg/L	194mg/L	189 mg/L	287 mg/L	342 mg/L	220mg/L	356 mg/L	240 mg/L
15	Silica	NIL	NIL	NIL	NIL	NIL	NIL	NIL	NIL
16	Flouride	0.3 mg/L	1.12mg/L	1.1mg/L	1.1 mg/L	0.085mg/L	1.1mg/L	1.1 mg/L	
17	Bacteriological Analysis (Coliform count/100ML of Water)	NIL	NIL	Nil	Nil	NIL	NIL	NIL	NIL
18	Chloride	2.50 mg/L	-	-	-	-	-	-	-

Table 2:   WHO Drinking Water Standards.

S/N	Parameters	Units	Maximum Permitted Level
1	Colour	TCU	12
2	Turbidity	NTU	5
3	Odour		Subjective limit of acceptance
4	pH		7.0 – 8.5
5	Conductivity	Us/Cm	1000
6	Sulphate	Mg/L	400
7	Nitrate	Mg/L	
8	Manganese	Mg/L	0.1
9	Boron	Mg/L	-
10	Iron	Mg/L	0.3
11	Chloride	Mg/L	250.0
12	Dissolve Gases		
13	Total hardness	Mg/L	500
14	Total Dissolve Solids	Mg/L	1500
15	Silica		
16	Flouride	Mg/L	1.5
17	Bacteriological Analysis (Coliform Count/ 100ml of waters)		

Source: WHO Drinking Water Standards (2011)

Table 3: Parameters and Maximum allowable Limits for Physical/ Organoleptic Parameters

S/N	Units	Parameters	Maximum Permitted Levels	Health Impact	Note
1	TCU	15	None		
2		Unobjectionable	None		
3	NTU	5	None		

Source: Nigerian Industrial Standard (NIS, 2007)

Table 4: Parameters and Maximum Allowable for Inorganic Constituent

Parameter	Unit	Maximum Permitted Levels	Health Impact	Notes
Chloride	Mg/L	2,500	None	
Conductivity	US/CM	1,000	None	
Flouride	Mg/L	1.5	Fluorosis, skeletal tissue (bones and teeth) morbidity	
Hardness (as Caco₃)	Mg/L	150	None	
Iron Manganese	Mg/L	0.3	None	
Nitrate	Mg/L	0.2	Neurological disorder	
pH	Mg/L	50	Cyanosis, and asphyxia "Blue baby syndrome") in infants under 3 months (syndrome)	
Sulphate		6.5 – 8.5	None	
Total Dissolved	Mg/L	100	None	
Solids	Mg/L	500	None	

Source: NIS (2007)

Table 5: Parameters and Maximum Microbiological Requirement Limits

Parameter	Unit	Maximum Permitted Levels	Health Impact	Notes
Total coliform count	Cfu /Ml	10	Indicating contaminant (Faecal)	

Source: Nigerian Industrial Standard (NIS, 2007)

Evaluation of the processing method of Keana salt deposit, Nasarawa State, North Central Nigeria

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Abstract
The evaluation of the processing method of Keana salt deposit was done by analyzing the salt deposit and the refined salt which was compared with the laboratory refined product obtained by dissolution, filtration, recrystallization and oven drying processes. In the laboratory process, filter paper was used for the filtration and the residue washed with distilled water before recrystallization. The major elements, sodium (Na) and Chloride (Cl) were determined by flame emission spectrophotometry and mohr's method of titration respectively. Trace elements in the various samples were determined by X-ray fluorescence spectroscopy. The result revealed 32.05%, 3.42% and 33.00% Na in the local processed salt, the deposit and the laboratory refined salt respectively. The chloride content was determined to be 58.70%, 1.42% and 61.40% Cl in the local refined salt, the deposit and the laboratory refined salt respectively. These gave 90.75%, 4.84% and 94.40% NaCl in the local refined salt, the deposit and the laboratory refined salt respectively. X-ray fluorescence showed that the following elements are present in the salt deposit. Fe, Zn, Rb, Sr, Zr and Nb. The end-product contained K, Ca, Ti, Cr, Fe, Ni, Cu, Zn, Rb. Sr and Br. The laboratory refined salt contained only Cu, and Cr as trace elements in lower proportion (3.05×10^{-6} and 2.5×10^{-6} respectively) compared to their concentrations in the local refined salt (7.93×10^{-6} and 6.54×10^{-6} respectively). Other trace elements associated with the local refined product were totally removed which shows that if modern filtration and evaporation equipment/techniques are used as in industries, it will enhance the quality of the refined product.

Keywords: Keana, process, salt deposit, filtration, evaporation

Introduction
The mineralogical name for salt (halite) originated from the Greek word hals meaning salts. Due to its simple crystal structure, it was the first to be analyzed by X – ray (Donald, 1994). Its chemical formula is NaCl commonly referred as table salt. According to Ronald (1991), the primary sources of salt production are either from brine (from the oceans, salt lakes and brine stream) or from rock salt deposit. Salt can be mined from rock salt either by traditional mining practices using heavy equipment underground or by pumping hot water in pipes into the salt deposit where the hot water dissolve the halite and the resulting salt water is then pumped to the surface and evaporated to yield salts. This is called solution mining.

The earliest method of production of salt was the evaporation of sea water by heat of the sun. This method was physically suited for hot arid regions near the ocean or near salt lakes and still in use in those areas where solar evaporation soon followed by quarrying of exposed rock salt, which quickly developed into mining of underground deposit of salt, some of which were more than 0.6 miles (1.0 km) deep. In an area where the climate did not allow solar evaporation salt water was poured on burning wood or heated rocks to boil it and the salt left behind was then scraped off (Microsoft Encarta 2009). During the time of the Roman Empire shallow leads where used to boil salt water over open fire. In the middle ages these were replaced with iron pans which were heated with coal. In the 1860's, a process called Machigani process was invented in which salt water is heated by steam running through pipes immersed in the water. This process is still used to produce certain types of salt. By the late 1880's, open pan were replaced by a series of closed pans in a device known as multiple effect vacuum evaporator which had been used in the sugar industry for about 50 years ago (Microsoft Encarta, 2009)

Ronald (1991) reported that, in UK practically all salt is obtained by solution mining, i.e. pumping water into the ground rock salt beds and collecting the brine so formed which is then concentrated by vacuum evaporation. Pure dried vacuum salt is a fine oven grained salt of high purity in the form of crystals mostly 0.2 – 0.5 mm size and consist typically of the dry base as Sodium carbonate, and 5 ppm of anticaking-agent (Sodium ferrocyanide) with a moisture content of 0.005 - 0.001 percent. Undried vacuum salt is slight less pure and contain 2.5 – 4 percent moisture.

After rock salt is mined, the material undergoes some basic mechanical processes that usually consist of crushing and screening to reduce and separate the particles into different size fraction. The processing of brines usually consists of removing impurities dissolved with the salt in the solution. Calcium and Magnesium are two common ions associated with salt that are removed during brine's purification treatment. Soda ash (Sodium carbonate) is used to remove calcium ion which precipitates as calcium carbonate. Magnesium ions are removed by adding caustic soda or lime. Barium carbonate is used to remove calcium sulphate from brines (Donald, 1994).

According to Oyarore (2007), keana salt is processed by filtration and evaporation methods. The deposit is mixed with the river water in a clay pot and transfer into another pot perforated at the bottom which is used for the filtration. This is left for days after which clear filtered salt water (brine) is collected and heated in another pot using firewood. The solution is evaporated leaving the crystallized salt behind.

Sood et. Al, (1973) reported that additives perform a wide variety of useful functions including those that are often taken for granted. In salt, additives are used for two purposes: to enhance the flow property of salt by preventing the dumping of fine crystal and to fortify salt with iodine in order to prevent iodine deficiency diseases. A method of fortifying salt with iron has been developed to control anemia in countries where anemia and goiter coexist and for anemia control in countries where iodization of salt is mandated by law (Narasinga and Vijayasarath, 1975). The double fortification of salt with both iodine and iron would be an ideal way to eliminate iron deficiency as well (Nadiger et. al, 1980).

Food grade salt accounts for only a small part of salt production in industrialized countries worldwide. Food uses accounts for 17.5% of salt production. The majority is sold for industrial use (Ronald, 1991). He also reported that salt has great commercial value because it is a necessary ingredient in the manufacture of pulp and paper settings, dyes in textiles and fabrics. Unrefined sea salt is also used as ingredients in bathing additives and cosmetics products.

This work is aimed at assessing the method of processing of Keana salt deposit by evaluating the quality of the end product and to suggest way(s) of improving its quality.

Methodology

Samples of locally refined salt and the salt deposits were obtained from the deposit site at Keana, Nasarawa state, North Central Nigeria. They were both taken in a polythene bag to the laboratory for the analysis. For the laboratory recovery of the salt, the deposit was dissolved in the river water collected from the site and was poured into a perforated container for filtration, the filtrate was further filtered using filter paper and evaporated on a hot plate to near dryness. This was re-dissolved in distilled water and filtered again using filter paper. It was again evaporated on a hot plate to near dryness and was oven dried at $105^{\circ}C$ to total dryness. This was cooled in a dessicator and poured into a polythene bag for the analysis. The Sodium in the samples were determined using flame emission spectroscopy (Basselt, et. al., 1978). X-ray fluorescence technique was used to determine the trace elements in all the samples (Brouwer, 2003). The Chloride in the samples were determined using Mohr's method of titrimetric analysis also called argentometric determination of chloride (Skoog, et. al., 1996).

Results and Discussion

Table 1: Result of analysis of the salt deposit

S/No.	Element	Composition (%)
1.	Sodium (Na)	3.42
2.	Chloride (Cl)	1.570
3.	Iron (Fe)	1.04
4.	Rubidium (Rb)	8.2×10^{-3}
5.	Strontium (Sr)	4.27×10^{-2}
6.	Zirconium (Zr)	2.54×10^{-2}
7.	Niobium (Nb)	4.5×10^{-2}
8.	Zinc (Zn)	2.57×10^{-2}

Table 2: Result of analysis of the end-product (locally refined salt)

S/No.	Element	Composition (%)
1.	Sodium (Na)	32.05
2.	Chloride (Cl)	58.70
3.	Calcium (Ca)	5.50×10^{-4}
4.	Titanium (Ti)	2.6×10^{-6}
5.	Chromium (Cr)	6.54×10^{-6}
6.	Iron (Fe)	1.2×10^{-6}
7.	Nickel (Ni)	1.17×10^{-6}
8.	Rubidium (Rb)	2.40×10^{-6}
9.	Bromine (Br)	1.99×10^{-6}
10.	Potassium (k)	1.50×10^{-4}
11.	Copper (Cu)	7.93×10^{-6}
12.	Zinc (Zn)	2.51×10^{-6}
13.	Strontium (Sr)	5.11×10^{-6}

Table 3: Result of analysis of the laboratory refined salt

S/No	Element	Composition (%)
1	Sodium (Na)	33.0
2	Chloride (Cl)	61.40
3	Copper (Cu)	3.05×10^{-6}
4	Chromium (Cr)	2.50×10^{-6}

The result of chemical analysis on the samples revealed that the deposit contained 3.42% Na and 1.57% Cl. The local refined salt contained 32.05% Na and 58.70% Cl while their amounts in the laboratory refined salt where slightly increased to 33.0% Na and 61.40% Cl. The XRF result revealed the presence of Fe, Rb. Sr, Zr, Nb and Zn in the deposit while the amount of Fe, Rb, Sr, and Zn were reduced in the local refined salt, Zr and Nb were completely removed during the refining process and thus were not found in then end product. K, Ca, Cr, Ni, Cu, Br and Ti though not present in the deposit were detected in the local refined salt. They are suspected to be from the river water used too dissolve the salt deposits or/ and from the local equipment and materials used for the filtration and evaporation. Analysis on the laboratory refined salt revealed that these trace elements were completely removed with exception of Cu and Cr which were reduced from 7.93×10^{-6} to 3.05×10^{-6} and 6.54×10^{-6} to 2.50×10^{-6} respectively.

Conclusion

From the results of the analysis obtained from this work and the discussions carried on the results, the following conclusion could be drawn: - though the local refining method of processing keana salt is able to reduce the amount of some of the trace elements in the refined product, it is only Zr and Nb that could be removed completely. The complete removal of other trace elements (Fe, Ca, K, Cr, Ni, Br, Ti, Rb, Sr and Zn), during the laboratory process shows that the improvement of the processing methods of this deposits by using modern equipments for filtration and evaporation will improve the quality of the end product. Also, reduction/ removal of these trace elements will upgrade the salt by increasing the NaCl content in the end product as evident in this work (32.05% Na to 33.0% Na and 58.70% Cl to 61.40% Cl). Also there should be a way of fortifying the salt with Iodine and other additives as in other products in the market.

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