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CHARACTERIZATION OF SILICA SAND DEPOSIT FROM RIVER DADIN-KOWA, NORTH EAST REGION OF NIGERIA FOR FOUNDRY USE.

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ABSTRACT

This study investigated the chemical characterization and sieve analysis of silica sand deposits at Dadin-kowa River for foundry use.Analytical techniques such as X – Ray Fluorescence Spectroscopy (XRF) and Atomic Absorption Spectroscopy (AAS) coupled with sieve analyses were employed to characterize silica sand deposit obtained from River Dadin-kowa, Gombe state North East Region of Nigeria. The results of the analyses revealed that silicon dioxide (SiO_2) forms the predominant metal oxide in the entire samples with a percentage mean concentration of 94.25, followed by (CaO; 1.955),(Al_2O_3;0.725),(MgO;0.765),(Fe_2O_3;0.325),(MnO;0.06),(PbO;0.085),(TiO_2;0.05),(Na_2O;0.025),(K_2O;0.08),(P2O5;0.375)Further beneficiation(using acid leaching method) of the silica sand samples reveal an increased silica (SiO_2) content from 94.25 to 96.350 with a corresponding decreased in content of Al_22O_3; 0.725 to 0.012, $Fe_2O_3$0.325 to 0.0530 andP2O5;0.375 to0.353 across samples. Physico-chemical analysis shows a moderate pH value of 7.83 signifying high basic oxides content in the silica sand samples. Acid Demand Value (ADV) test reveals the average value of 20.18 ADV in samples, signifying the presence of low soluble carbonates in the silica sand samples. Grain size distribution analysis revealed that a high percentage of the samples A & B grains size distribution fraction are 213 and 215 respectively, these are within the recommended screen sizes150 to 400 microns for foundry use. A correlation between the $SiO_2$and other elementsin the samples revealed a direct relationship between $SiO_2$and the elements found which implies that as theSiO_2increases that of other elements also increases and vice versa these shows that the silica sand samples from River Dadin-kowa can be used as a source of $SiO_2$for foundry use.

***Keywords**: Foundry, Silica sand, Grain size, Metal Oxides, Beneficiation, Acid demand values Dad*

1.0 INTRODUCTION

Silica sand is an industrial term used for sand or easily disaggregated sandstone with a very high percentage of quartz (silica) grains. Quartz is the most common silica crystal and the second most common mineral on the earth's surface. It is found in almost every type of rock: igneous, metamorphic, and sedimentary, while quartz deposits are abundant and available in some form in nearly all mining operations. High-purity and commercially viable deposits occur less frequently. The composition of silica sand is highly variable, depending on the source (river or rocks). Silica exists in nine different crystalline forms, or polymorphs, but the three main forms are quartz, which is by far the most common, tridymite, and cristobalite. It also occurs in a number of cryptocrystalline forms (Aliyu, 2013; Bourne, 1994; Press, 2001; Schrotenber, 2008; Tsoar, 2004).

The silica content in sand will normally be in the crystalline form of quartz. For industrial use, pure deposits of silica capable of yielding products of at least 90% SiO_2 are required. Silica sand may be produced from sandstones, quartzite, and loosely cemented or unconsolidated sand deposits. Silica sand deposits are mostly found in surface mines in open pit operations or on riverine surface deposits due to erosion, but in some cases, dredging and underground mining are also employed (Harold, 2014; Press, 2001; Schrotenber, 2008).

Large tonnages of silica sand are used in iron and steel foundries to make moulds and cores for metal castings. Molten metal is poured into a shaped cavity in a block of sand, where it cools and solidifies. The part of the cavity that forms the internal surface of the casting is called the mould. A core of moulded sand may be placed in the mould to form the internal shape and dimensions of the casting. In each application of sand, particles are held together by some material called a binder (Greer, 2002).

In the United States, for instance, silica sand production increased from 2.5 to 28.5 metric tonnes from 1996 to 1997, and out of this, about 37% was used for glass making while 23% was used as foundry sand. Other uses were hydraulic fracturing (6%) and abrasives (5%) (Bourne, 1994; Wallace, 1997; Langer, 2003). The US produces 30% of the world's total silica sand from more than 150 operations, with about three-fourths of production coming from the central US alone in 1992 (Chang, 2002; Dolley, 2004a). In Africa, especially in Nigeria, however, the use of silica sand is limited on a domestic scale, as most of the teeming population only utilise it for road and building construction, while the vastly spread deposits are left unattended to, which has prevented their exploration and left them underutilised in spite of their valuable economic mineral content (Chang, 1991; Claude, 2002). Available evidence shows that this silica sand contains a high proportion of pure quartz (SiO2) and can be directly or indirectly used in the manufacture of various industrial products, especially glass and foundry sand products (Bajah, 1986; Malu and Bassey, 2003). It is therefore desirable to investigate the potentials of this vast silica sand deposit within the river Dadin-kowa, especially for the establishment of silica for foundry use and other allied industries

2.0 MATERIALS AND METHODS

2.1The study area

The study area covers Dadin-Kowa in the north-eastern part of Nigeria; it is one of the major tributaries of the River Benue in Nigeria and has a large deposit of silica sand along its shore. The Dadin-Kowa river is located 35km away from Gombe metropolis in Yamaltu-Deba local government of Gombe state, which lies on coordinates of 10^0 19’ 19N and 11^0 28’ 54E (Fig. 1). It covers a total land area of 1,981 km2, with a population of 255,248 according to the Uhrotu (2006). It has a capacity of 800 million cubic metres of water and a surface area of 300 square kilometres on the river Gongola, which has its source in the Bamenda highlands in Cameroon. It flows 200 miles (320km) northwest in Cameroon, passing through the eastern Nigerian-Cameroon border into Nigeria. Its length and size make them one of the largest tributaries of the Benue River. (Neba, 1999; Chisholm, 2010; Malu, 2015).

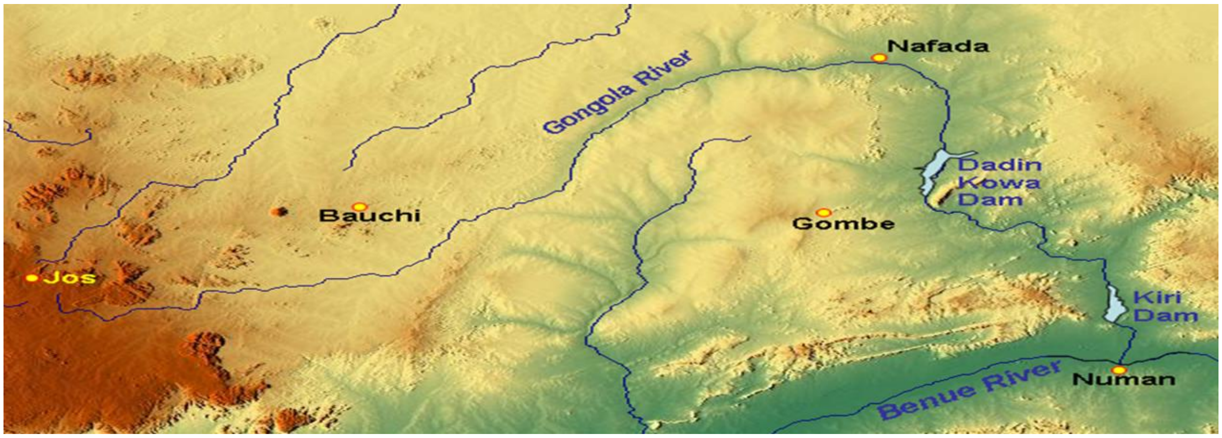

Fig. 1 (Google map of River Dadin-kowa, 2019)

2.2 Sample Collection

Two silica sand samples were collected along the river bank of the River Dadin-kowa, as indicated on the map of the study area (Figure 1). The samples were collected at different points at an interval of 100m from each other between the months of April and May to reflect the late dry season periods when water depth is low. The samples were each separately prepared by thoroughly blending using the "centre displacement method, where the homogenous material was obtained. 20kg of each silica sand sample was heaped at one point, and then the entire material was shovelled and heaped on a second point (displacing the center). This process was repeated about 10 times (four heaps at one point of the river), where the homogenous mixture was adequately obtained. The samples were then put into sample bags (Ashaka cement bags) and labelled A and B to distinguish them from each other. The labelled silica sand samples were taken to the laboratory for pre-treatment and preparation. This is consistent with the studies of Abinfarin (2004), Malu (2015), Paul (2011), and Uhrotu (2006).

2.3 Sample pre-treatment and preparation

The collected samples were each poured on a 200-mesh screen and placed in a plastic container, scrubbed and de-limed (thoroughly washed with water to remove impurities such as clay and soluble materials), and finally rinsed with distilled water (Malu, 2015). After washing, the samples were dried in the air-dried machine at a temperature of 100 °C for 12 hours. After drying, about 100g were taken from each sample, weighed, and homogenised into fine grain using a Mangan Model BB200 crusher. The crushed fine grain particles were further sieved using a 100-mm mesh screen to ensure homogeneity of particle size. To avoid contamination of samples, the crusher and mesh were repeatedly washed and rinsed with distilled water each time a new sample was to be crushed and sieved. Each of the pulverised samples was poured into clean, dried bottles and set for chemical analysis, while the other remaining parts of the uncrushed samples were preserved for physicochemical analysis.

2.4 Sample digestion

The digestion of the pre-treated samples for metallic oxide analysis was carried out using 10 mL of concentrated hydrochloric acid (HCl) and perchloric acid (HClO4) to release metal oxide content into solution (Allen, 1974; Rantalla and Lorring, 1992; Ademoroti, 1996; Malu, 2015). For each of the representative pretreated samples, 0.2g was carefully weighed and placed in a clean-dried crucible. A 5 mL mixture of nitric and perchloric acid in the ratio of 3:2 was added, followed by 10 mL of hydrofluoric acid (HF), and refluxed for one hour (1 h). The mixture was then heated to dryness on a hot plate in a fumed cupboard at a temperature of 90–1000 °C.The mixture was then cooled to room temperature, and 5 mL of concentrated hydrochloric acid (HCl) was added and allowed to settle. It was then filtered into a 100 mL plastic flask, made up to mark with de-ionised water, and allowed to stay for three days before analysis using an atomic absorption spectrophotometer (AAS). All glassware and specimen bottles used were initially washed thoroughly with HN03 and rinsed with distilled water (Harries, 1975; Sinex et al., 1980; Asuquo, 1999).

2.5 Determination of metal oxide concentration

This experiment was carried out using an atomic absorption spectrophotometer (AAS), Shimadzu model AA 6800, and an X-ray fluorescence spectrophotometer (XRF), Mini Pal Model 4 version PW430. The atomic absorption spectrophotometer was used for the determination of MnO, MgO, PbO, and K_2O. The working standard solution for each element was prepared, and the standard solutions and aliquots of the diluted clear digest were used to determine this. A standard curve was used to establish the relationship between absorption intensity and concentration of each element (Malu, 2015; Nuhu, 2008; Shaffer, 2006). The detection limit of the AAS was < 0.00lmg/L. The X-ray fluorescence spectrophotometer was used to determine SiO_2, Fe_2O_3, CaO, Al_2O_3, Na_2O, TiO_2, and CaO. To a specific amount of each of the pulverised samples, a binder (PVC dissolved in toluene) was added, mixed, and pressed in a hydraulic chamber to form a pellet. The pellet of not more than 30 kV was then loaded into the sample chamber (analyzer) of the spectrophotometer, and a current of 1 amp maximum was applied to produce the x-rays. The analyzer was then calibrated using the software attached to it and run for about 30–60 seconds; the result was automatically printed out. This process was repeated until all the samples were analysed.

2.6 Determination of phosphorous

About 5g of each sample was weighed into a 250-mL plastic beaker, and 100 mL of 0.1M HCl was added, cooked, shaken for 30 minutes, and allowed to settle. The mixture was then filtered using filter paper; 10 mL of each filtrate was introduced into a curvetted cell and another 10 mL of distilled water into a separate curvetted bottle to produce a blank. 1 mL of phosphate reagent was then added to each of the filtrate and the blank.

The UV spectrophotometer was then calibrated using the blank to mark zero, and the filtrate was inserted into the curved hole and read at a wave length of 690nm. Standard solutions of phosphate reagents were prepared and a calibration curve constructed, and with the help of the curve, the concentration of phosphorous in the samples was determined in mg/L. (Harries, 1975; Christian, 1980; Malu, 2015).

2.6 Beneficiation and upgradation of samples

The beneficiation of the silica sand samples was done according to the method of Veglio et al. (1999). 10g of the representative samples were weighed and placed in a 250-mL flask, and 100 mL of oxalic acid was added. The mixture was placed on a heating plate and agitated (870 rpm) at a temperature of 800 °C to 900 °C for 2 hours. To ensure uniformity, the agitation was kept constant for all the experiments. A watch glass was fitted to the flask to prevent evaporation during each experiment. The samples were filtered and the residue washed with distilled water, then dried in an electric oven, and the percentage concentration of metal oxides in each sample was determined using the XRF method.

2.7 Determination of loss on ignition (LOI) and pH

10g of each sample was taken, carefully poured into a clean crucible, and weighed using an analytical balance. The weighed samples were then placed in an electric muffle furnace and heated for 1 hour at 950 ^oC to determine the loss of ignition.

The pH of the samples was determined electronically using a pH metre of 0.1 percent sensitivity (WTW pH 422). (Krist and Rump, 1988; Malu, 2015).

2.8 Grain size distribution analysis

200g of the river sand from Dadin-kowa was weighed using an electric digital weighing balance and dried to a constant temperature using an Armfield tray drier mild field model at 10 oC for 1 hour. 200g of the material sand was weighed and dispensed into the topmost sieve of the nest of sieves arranged from the largest aperture to the smallest. The nest of sieves was mounted on a sieve shaker and agitated for 15 minutes. The sieves had the largest sieve with an aperture of 1000 microns and the smallest with an aperture of 45 microns. The process was repeated until all the samples were analyzed. The results were tabulated and used in calculating the average grain size of the river sand deposits at Dadin-kowa.

2.9 Determination of acid demand values in samples

Acid Demand Values (ADV) are a measure of the soluble carbonates present in a given silica sand sample. Its value determines a low or higher concentration of alkali or carbonate-reacting materials present in a given silica sand sample. Their presence is an indicator of whether a given silica sand sample can be used for foundry work, ceramics, or glass making. It is therefore important that the presence of these reacting materials be measured so that uniformity and formulation control may be achieved. The ADV was therefore carried out according to the methods of Sundeen (1978).

3.0 RESULTS AND DISCUSSION

The chemical characterization of silica sand samples obtained from the River Dadin-kowa has been analysed using some analytical methods. The results are presented in Table 1.

Table 1: Chemical Analysis of Samples A,& B,

Samples **Constituent**	**A** **Values (%)**	**B** **Values (%)**	**Average of A&B Values (%)**	**Average of A&B After Beneficiation (%)**
SiO_2	**94.60**	**93.90**	**94.25**	**96.35**
Al_2O_3	**0.72**	**0.73**	**0.725**	**0.012**
Fe_2O_3	**0.30**	**0.35**	**0.325**	**0.053**
TiO_2	**0.10**	**ND**	**0.05**	**ND**
CaO	**1.90**	**2.01**	**1.955**	**1.92**
MgO	**0.60**	**0.93**	**0.765**	**0.75**
LOI	**0.28**	**0.60**	**0.44**	**0.40**
Na_2O	**0.03**	**0.02**	**0.025**	**0.023**
MnO	**0.04**	**0.08**	**0.06**	**0.05**
PbO	**0.13**	**0.04**	**0.085**	**0.085**
K_2O	**0.04**	**0.12**	**0.08**	**0.08**
P2O5	**0.32**	**0.43**	**0.375**	**0.353**

ND Denote 'NOT DETECTABLE'

3.1 Metal Oxide Ooncentration

The average percentage metal oxide concentration (SiO2, Fe2O3, K2O, NaO, CaO, Al2O3, MgO, TiO2, ZnO, NiO, PbO, BaO, P2O5, MnO, and CuO) in the silica sand samples is presented in Table 1. The result revealed that the highest percentage concentration of SiO2 in the silica sand samples was 94.25, followed by CaO (1.955), Al2O3 (0.725), MgO (0.765), Fe2O3 (0.325), MnO (0.06), PbO (0.085), TiO2 (0.05), Na2O (0.025), and K2O (0.08). This high SiO2 content trend in the samples revealed that silica sand generally contains high SiO2 content (Sosman, 1954; Bajah, 1986; Siever, 1988; Malu, 2015). The concentration of SiO2 in silica sand samples in this study was found to be similar to those obtained by other research studies (Stocchi, 1973; Sundararatan*et al.*, 2009; Pisutti*et al.*, 2008; Babasaheb, 2010). Considering the percentages of SiO2 (Table 1) in the silica sand samples with its foundry sand making standard revealed that the concentration of SiO2 met the minimum standard, which implies that the entire silica sand sample requires further beneficiation to reduce the Fe2O3 content to a more acceptable standard level as stipulated by the American Foundry Society and the National Bureau of Standards (Ushie, 2005). The concentration of Fe2O3 in any silica sand deposit determines the quality of casting to be produced. A slight increase in Fe2O3 content will affect the colour of the result in this regard, which should not exceed 0.005 percent.

However, further beneficiation of the silica sand samples revealed an increase in SiO2 from 94.25 to 96.35 with a decrease in iron content of 0.053% from 0.325 (Table 1), which means that the samples can be used for foundries by the American Foundry Society. Comparison of the percentage concentration of SiO2 obtained in this study with those of other authors revealed that although most of the SiO2 concentrations were within the minimum standard, they could be upgraded after further beneficiation. Their SiO_2 content was upgraded to the average standard. The various concentrations of SiO2 observed may be attributed to some geological factors, such as type of weathering and distance travelled by particle size from the source rock of the individual river. Silica sand constitutes more than 60% of the material composition used in preparing foundry sand for casting. The quality of the sand is a primary factor in determining the quality of the metal casting product.

Table 1 showed that the relationship between SiO_2 and Fe_2O_3 in the samples is that if the value of SiO_2 increases, the value of Fe_2O_3 also increases, and vice versa. Most high-quality synthetic foundry sand needed to exceed 99.5% SiO_2 when processed and had an average close to the 99.80% level.

Table 2: Average Grain Size of Sample A

S/N	**ISO Aperture Size (μm)**	**Percentage Retained (sample A)**	**Multiplier**	**Product**
1	710	2.33	1180	419.40
2	500	3.13	600	1878
3	355	7.64	425	3247
4	250	29.66	300	8898
5	212	22.21	212	4708.50
6	180	68.26	212	14471.10
7	150	25.69	150	3853.50
8	125	19.26	150	2889
9	90	19.69	106	2087.10
10	63	0.26	75	19.5
11	45(pan)	1.07	38	40.70
	Total	199.10		42511.70

Average grain size = 42511.70/199.10
= 213.5

Table 3: Average grain size of Sample B

S/N	**ISO Aperture Size (μm)**	**Percentage Retained (sample B)**	**Multiplier**	**Product**
1	710	0.63	1180	743.40
2	500	1.66	600	996
3	355	5.22	425	2218.50
4	250	33.87	300	10161
5	212	24.04	212	5096.50
6	180	69.51	212	14736.10
7	150	29.84	150	4476
8	125	17.91	150	2686.50
9	90	15.68	106	1662.10
10	63	1.11	75	82.25
11	45(pan)	1.10	38	41.80
	Total	199.40		42900.20

Average grain size = 42900.2/199.40
= 215.1

3.2 Sieve Analysis

The particle size distribution of the sands could give rise to good permeability and strength (Heine, 1967). Tables 2 and 3 show the particle size distribution of the Dadin-kowa sands, which gives the average grain size of the samples A, 213.5 m, and B, 215.1µm. These values of the average grain sizes of the samples fall within the common foundry range of 150 to 400 m (McLaw, 1971; Heine, 1967). While average grain size is a useful parameter, the choice of sand should be based on particle size distribution. The size distribution of the sand affects the quality of the castings. Coarse-grained sands allow metal penetration into moulds and cores, giving a poor surface finish to the castings (Malu, 2015). Mclaw (1971) also agrees that the properties of moulding sand depend strongly upon the size distribution of the sand that is used, whether it is silica, olivine, chromite, or another aggregate.

3.3 Acid Demand Values (ADV)

The values of the acid demand value (ADV) of the silica sand samples are A = 20.0 and B = 20.36. The result revealed that the average acid demand value obtained from samples A and B was 20.18. This result is similar to those obtained by other researchers (Crockford, 1949; Robert *et al.*, 2002; Mclaws, 1971). The acid demand values measure the number of alkaline materials that should not be present in already processed, washed, and classified silica sand. Acid Demand Values (ADV) range from 1 to a maximum of 50. A low ADV (near zero) is an indication that either no acid was consumed, and so virtually no soluble carbonates are present in the sample, or low alkaline materials are present in the samples, while a high ADV (values in the upper 40s to 50) is an indication that nearly all the acid added in the test was consumed, or a high amount of soluble carbonate and salts that can be deleterious in the application of the silica sand for foundry and glass making (Sundeen, 1978; Hrdina, 1999; Pisutti, 2008). From the results, it was observed that the acid demand values of the silica sand samples fall within the moderately acceptable range of below 25.0, which is an indication of low soluble carbonate content present in the silica sand sample from the River Dadin-kowa. This low ADV may be attributed to the leaching and removal of soluble carbonate minerals (primarily calcite) by downward percolating oxidising surface waters (Sundeen, 1978; Hrdina, 1999; Pisutti, 2008).

3.4 Loss of ignition and pH

Table 1 also shows the results of the percentage weight loss on ignition (LOI) of the silica sand samples, which is 0.05%. Loss on ignition (LOI) is the combined loss of volatile matter, such as combined structural water (H_2O) and carbon dioxide from carbonates. It is used as a quality test, commonly carried out for solid mineral deposits, to ascertain the level of loss of volatile matter when a sample is subjected to a temperature of 950 oC or 1000 oC (Dean, 1974; Bengtsson, 1986; Velda, 1992; Ademoroti, 1996; Oliver, 2001). The average pH of the silica sand samples revealed the pH value to be 7.83. The pH of a given sample gives the water-soluble level of alkalinity or acidity of the silica sand (Doremus, 1973; Sell, 1981). A higher or lower pH value indicates the presence of acidic or basic oxide in a given silica sand sample. Sand with a pH close to neutral (7.00) is therefore the best for foundry use and glass (Doremus, 1973; Sell, 1981; Paul, 1982).

4.0 CONCLUSION AND RECOMMENDATION

4.1 Conclusion

(i) The silica sand samples generally contain a high percentage concentration of silicon dioxide (SiO_2) with a trace amount of Al_2O_3, K_2O, MgO, Fe_2O_3, CaO, TiO_2, NiO, ZnO, PbO, Na_2O, P_2O_5, and MnO.

(ii) The silica sand samples contain a moderate to low concentration of iron oxide (Fe_2O_3).

(iii) The grain size distribution of most of the silica sand samples falls within the recommended screen size (150–400 microns) for foundry use.

(iv) The silica sand deposit from River Dadin-kowa is suitable for foundry work due to its high SiO_2 content and low Fe_2O_3, Acid Demand Values (ADV), coupled with a suitable grain size distribution fraction.

4.2 Recommendations

This silica sand deposit can be used for synthetic foundry sand production, which has subsequently enhanced the manufacture of silica brick for the lining of furnaces and asbestos pavement, and it can also use as engine sand to give traction to locomotives, filter sand to remove foreign matter from water reservoirs.

REFERENCES

Abinfarin, M. S., Olugboji, O.A. & Ugwuoke, I.C. (2004). *Experimental Investigation On Local Refractory Material for Furnace Construction.* Paper presented at the Proceeding of Fifth Annual Engineering Conference, Federal University of Technology, Minna, Nigeria.

Ademoroti, C. M. A. (1996). *Standard methods for water and effluents analysis.* Ibadan: Foludex Press, 121-214.

Aliyu, S., Garba, B., Danshehu & Isah, A.D. (2013). Chemical and Physical Characteristics of Selected Clay Samples. *Journal of Engineering Research and Technology, 7*, 171-183.

Allen, S. E. (1974). *Chemical analysis of ecological materials*. Oxford: Black Well, 241-245.

Asuquo, F. E., Ogri, R. O. & Bassey, E. E. (1999). Distribution of heavy metals and total hydrocarbon in coastal waters and sediments of Cross River State, South Eastern Nigeria. *International Journal of Tropical Environment*, *2*, 229-242.

Babasaheb, A. B. (2010). *Geological exploration of friable quartzite (glass sand) deposit of Jiajuri District (phase I and II)*. Nagpur: Nagaon, Assam Mineral Exploration Cooperation, 1-8.

Bajah, T. (1986). *Chemistry science teachers' association of Nigeria (STAN).* Ibadan: Heinemann, 78-89.

Bengtsson, L. & Enell, M. (1986). Chemical analysis. In B. E. Berglund (Ed.), *Handbook of holocene palaeoecology and palaeohydrology*. Chichester: John Wiley & Sons, 423–451.

Bourne, H. L. (1994). *Glass Raw Materials in D. D. Carr (Eds).* Littleton CO: Society for Mining, Metallurgy and Exploration: Industrial Minerals and Rock.

Chang, R. (1991). *Chemistry*. London: McGraw – Hill, 252.

Chisholm, H. (2010). Benue. *Encyclopædia Britannica* (11th ed.). Cambridge: Cambridge University Press, 411-455.

Christian, G. R. (1980). *Analytical chemistry* (3rd ed.). New York: John Willey, 56-78.

Crockford, M. B. B. (1949). Geology of the Peace River glass sand deposit. *Research Council of Alberta, Mimeographed Circular, 7,* 1-20.

Claude, E. B. (2002). Properties of liming materials. *Journal of Fisheries and Aquaculture, 3,* 70-74.

Dean, W. E. Jr. (1974). Determination of carbonate and organic matter in calcareous sediments and sedimentary rocks by loss on Ignition: Comparison with other methods. *Journal of Sedimentary Petroleum, 44,* 242–248.

Doremus, R. H. (1973). *Glass science.* New York: John Wiley, 78-90.

Greer, B. A., Venderracek, J.E., Ham, R.K & Oman, D.E. (2002). The Natural and Characteristics of Foundry Waste and its Constructive Use: A review of the Literatue and Current Practice. (R. f. t. U. S. F. m. o. Wisconsin., Trans.). U.S.

Harold, J. B. (2014). Silica in Sediments of the Upper Paleozoic of the Cordilleran Area: Brigham Young University, Provo, Utah.

Harries, P. (1975). *Association of official analytic chemistry handbook.* England: Philip Harries Holding, 85-105.

Hrdina, K. (1999). Production and properties of ULE glass with regards to EUV Masks, Proceeding at the international workshop on extreme ultra-violet lithography, Corning, New York.

McLaws, A. (1971). Uses and specification of silica sand. *Research Council of Alberta Report, 64,* 71-74.

Malu, S. P., Edem, C.A & Ita, B.I (2015). Chemical Characterization of Silica Sand Deposit from River Katsina-Ala, North central region of Nigeria. *Global Journal of Pure Chemistry Research, 3,* 26-37.

Malu, S. P. & Bassey, G. A. (2003*)*. Periwinkle (*T. fuscatus*) shell as alternative source of lime for glass industry. *Global Journal of Pure and Applied Sciences*, *9* (4), 491 -494.

Neba, A. (1999). *Modern geography of the Republic of Cameroon* (3rd ed.). Bamenda: Neba Publishers, 1-76.

Paul, A. (1982). *Chemistry of glass*. Oxford: Chapman and Hall, 56-65.

Paul, A. I., Johnson, A., Emmanuel,E.O. & Joy,O. (2011). Effects of Moisture on the Foundry Properties of Yola Natural Sand. *Leonardo Electronics Journal of Practices and Technologies.*, 85-95.

Pisutti, D., Prukswan, C., Pornsawat, W. & Narin, S. (2008). Investigation on local quarts sand for application in glass industry. *Advances in Geosciences*, *13*, 23-29.

Press, F. S., R. (2001). *Understanding earth*. W.H. Freeman. New York.

Rantala, D. H. & Loring, R. T. (1992). Manual for the geochemical analysis of marine sediment and suspended particular matter. *Earth Science Review*, *32*, 24 – 26.

Robert, M. B., Jeffry, C. R. & William, M. (2002). Suitability of the pine formation as a glass, Richmand Country, North Carolina. Unpublished PhD thesis, Department of Environmental Studies. CPO 2330, UMC- Asheville, Ashiville, NC 28804-8511.

Schrotenber, B. R. (2008). *Location Alternative Sand Sources for Michigan's Foundry Industry: A Geological Approach.* (M.Tech thesis), University of Michigan State University, America. (137)

Sell, N. (1981). *Industrial pollution, control issues and techniques*. New York: Van Nostrand Reinhold, 118-143.

Siever, R. (1988). *Sand*. New York: Scientific American Library, 1-19.

Sundeen, S. P. (1978). *Geologic study of sand deposits in the state of Michigan-Phase I*. Michigan: Institute of Mineral Research, 1-7.

Sinex, S. A., Cantillo, A. Y. & Helz, G. R. (1980). Accuracy of acid extraction methods for trace metals in sediments. *Analytical Chemistry, 52* (14), 2342-2346.

Sosman, R. B. (1954*)*. *The properties of silica.* London: Rein Holding, 7-11.

Stocchi, E. (1975). *Industrial chemistry*. New York: Wiley, 117-125.

Sundararajan, M., Ramaswany, S. & Raghavan, P. (2009). Evaluation for beneficiability of yellow silica sand from the overburden of lignite mine situated in Rajpardi District of Gujarate. *India Journal of Mineral and Material Characterization and Engineering*, *8* (7), 569-581.

Tsoar, H., Blumberg, D.G. & Stoler, Y. (2004). *Elongation and Migration of Sand dunes*. (57).

Ushie, F. A., Esu, E. & Udom, G. J. (2005). A preliminary evaluation of Otamiri River sands for the production of plain glass. *Journal of Applied Science Environmental Management, 9* (1), 65-68.

Uhrotu, M. S. (2006). Determination o Uhrotu, M. S. (2006). Determination of the Moulding Properties of Dindima River Sand using Alkaleri clay as a Binder *International Journal of Tropical Environment, 2,* 229-242.

Velda, B. (1992). *Introduction to clay minerals: Chemistry, origin, uses and environmental significance*. New York: Chapman Hall, 118-125.

Veglio, F., Passariello, B. & Abbruzzese, C. (1999). Iron removal process for high purity silica sand production by oxalic acid leaching. *Industrial and Engineering Chemical Research, 38,* 4443-4448. Global Journal of Pure and Applied Chemistry Research Vol.3, No.1, pp.26