Characterization and Beneficiation of the Glass Making Potentials of Silica Sand Deposit from River Benue North Central Nigeria

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Abstract

Analytical techniques such as X – Ray Fluorescence Spectroscopy (XRF) and Atomic Absorption Spectroscopy (AAS) were employed to characterize the glass making potentials of silica sand obtained from River Benue, North Central Region of Nigeria. The results of analyses reveal that silicon dioxide (SiO_2) forms the predominant metal oxide in the entire samples with a percentage mean concentration of $93.946 \pm 0.4775\%$, followed by (Fe_2O_3; $0.7116 \pm 0.0829\%$) (P_2O_5; $0.1160\pm 0.1746\%$), (MnO; $0.0692 \pm 0.0851\%$), (Na_2O; $0.0460 \pm 0.0047\%$), (BaO; $0.0494 \pm 0.0183\%$), (PbO;$0.0342\pm 0.0319\%$) (NiO; $0.0280\pm 0.0178\%$), (TiO_2; $0.0240\pm 0.0021\%$), (Al_2O_3;$0.0142 \pm 0.0035\%$),and trace amounts of CaO, MgO,K_2O ZnO and CuO. Further beneficiation(using acid leaching method) of the silica sand samples reveal an increased silica (SiO_2) content from $93.946 \pm 0.4775\%$ to $96.1590 \pm 0.0683\%$, with a corresponding decrease in Fe_2O_3 content ($0.7116 \pm 0.0829\%$ to $0.4150 \pm 0.0014\%$ across samples. Physico-chemical analysis shows a moderate pH value of 7.03 signifying high basic oxides content in the silica sand samples. Acid Demand Value (ADV) test reveals a moderately low ADV in samples of 20.09, signifying the presence of low soluble carbonates in the silica sand samples. Grain size distribution analysis reveals that a high percentage of the samples grains size distribution fraction are within the recommended screen sizes (40-100 mesh). Heavy liquid separation test reveals a significant trace amount of principal minerals such as ilminite, magnetite, mica, calcite and kaolinite. A correlation between the mean values of SiO_2 and Fe_2O_3 in all the samples reveals an inverse relationship between SiO_2 and Fe_2O_3 which implies that as the values of SiO_2 increases that of Fe_2O_3. Furthermore, comparison of observed mean of SiO_2, Fe_2O_3, CaO, Al_2O_3 and TiO_2 with their observed minimum standard (95.00%; 0.005%; 0.1000% and 0.0120%) shows that the silica sand samples from River Benue can be used as a source of SiO_2 for glass making.

Key Words: Silica sand, Grain size, Chemical composition, Metal Oxides, Beneficiation, Acid demand values, Characterization.

1.0 Introduction

Silica sand is one of the mast commonest mineral in the Earth Crust. It is made up of from broken quartz crystals which has been broken down into tiny granules over years through the action of water and wind(Weathering).Silica sand granules can be used for different purpose and it is found deposited in most non-tropical region of the world (Carr,1971;Hecketal,2002;Freestone,2005) In Africa especially in Nigeria silica sand deposit are mostly found deposited in most parts of the country particularly in riverine ,estuaries and beaches(Chang, 1991; Claude, 2002;Malu and Bassey,2003).

In the United States for instance due to its vast deposits, its production increased from 2.5 to 28.5 metric tons from 1996 to 1997 and out of this about 37% is used for glass making while 23% was used as foundry sand. Other uses were hydraulics fracturing (6%) and abrasive (5%) (Bourne, 1994; Wallace, 1997; Langer, 2003).The US produces 30% of the world total silica sand from more than 150 operations and about three-fourths of production coming from the central US alone in 1992(Chang,2002;Dolley, 2004a).In Nigeria however, the used of silica sand is limited as it is only used in the construction of road and building while the vast deposit is left un exploited inspite of their valuable economic mineral content(Bajah, 1986; Malu and Bassey, 2003). Available evidence shows that this silica sand contain a high proportion of pure quartz (SiO_2) and can be directly or indirectly used in the manufactured of various industrial products .

In the United States of America for instance, there are about 350 to 400 established full automated glass plants, producing from the simpler to the most complex glass wares and equipment for domestic, scientific and industrial uses (Sell, 1981; Fwatmwol, 1992; Fox, 1994). Since every individual makes use of one form of glass or the other, there is an increasing demand for the number of glass plants and industries around the world, especially in the developed countries (Fox, 1994).Most of these Glass Plants are either located near or around the vicinity of major rivers in the United States where there is abundant deposit of sand (quartz), a major glass making raw material (Fox, 1994). In the developing countries of the world, especially in Nigeria, these Glass Plants are mostly located in the southern parts of the country with very few ones in the northern   part (Akomolafe, 1990;Bajah, 1986; Malu and Bassey, 2003).

1.1 Silica sand processing

Nature separates and purifies silica sand to a great degree but further processing is needed to produce sand sufficiently pure for modern uses. Current processing technology can upgrade sand deposits that are not naturally pure enough for glass making. Consistency is of paramount importance for most silica sand users. Chemical purity and particle size are the most important parameters. Main contaminants are iron (Fe_2O_3), alumina (Al_2O_3), and titanium dioxide (TiO_2).Others include lime (CaO), soda (Na_2O) and potash (K_2O) (Andrew *et al.*, 1989; Schurlz and Kohl, 1991; Zdunczyk, 1994). Rare heavy minerals can be deleterious even when present in only very low levels. Iron is a strong colorant and must be carefully controlled. Alumina affects the viscosity and density of glass. Alkalis affect melting temperatures; certain refractory heavy minerals (usually silicates or oxides) in parts per million levels are counted as number of grains. Even one or two grains of chromate in 500 grams of material can eliminate silica sand from glass making. Thus raw materials are usually processed to remove minerals that contain contaminants (Schurlz and Kohl, 1991; Zdunczyk, 1994; Goldman, 1994).

The most common and easiest processing technique is simple washing. Water is added to the sand then the slurry is pumped to a cyclone separator. Movement of the slurry and grain-to-grain rubbing is enough to loosen clays and fine contaminants. Scrubbing with specialized equipment can be used if clays or films are tightly bound to quartz grains. A process called desliming removes <100 micron materials. Such small minerals are generally clays. Cyclone separators are used if clays are low (<3%) and hydrosizers using kindred settling techniques are efficient if clay contents are >74% (Goldman, 1994; Chang, 2002).

Plate 1: An aerial out crop view of silica sand deposit on River Benue

Heavy minerals and iron oxides can be removed by gravity separation using spiral separators in which lighter particles are pushed to the outside of spiral pans. Flotation techniques can also remove undesirable minerals including micas. Strong rare-Earth magnets or electromagnetic cells remove certain slightly magnetic minerals and certain minerals can be separated based on their electrical charges by turboelectric methods (Schurlz and Kohl, 1991; Goldman, 1994; Chang, 2002; Dolley, 2003). Particle size is very critical for glass making. Sizing of larger grains is done by screening to remove oversize >1 mm grains assuming that most grains are about 0.5 microns. Screening is very efficient; one screen can separate 250 tons per hour. Screens are generally stacked for efficiency. Some applications require very fine sizes of quartz, thus grinding methods are used to produce ground silica. Grinding is accomplished in large mills that use flint or alumina ceramics as liners and grinding media. Strict size control is achieved using special air classifiers. All glass sand is dried prior to shipping. Drying can be the most expensive stage of sand processing. Simple beneficiation can enlarge already huge and growing sand resources (Schurlz and Kohl, 1991; Bolen, 1996; Harben, 1997).

The River Benue with its major tributaries has large deposit of silica sand along its shore. These deposits do not only cause obstruction to free flow of inland water way transportation of goods and services but also prevent the generation of revenue due to under utilization. Silica sand deposit, if properly utilized, would provide job opportunity as well as industrial development of the State, but unfortunately, it has been neglected for so long. (Akomolafe, 1990; David, 2005).It is therefore desirable to investigate the potentials of this vast silica sand deposit within the State for the establishment of Glass and other allied industries.

2.0 MATERIALS AND METHODS
2.1 The Study area

The study area covers River Benue and its environs, located on coordinates 8°00'N, 7°12'E, (Fig.1).The Benue River is the major tributary of the Niger River. It is located on coordinates 8°00'N, 7°12'E. The river is approximately 1,400 km long and is almost entirely navigable during the Raining season. As a result, it is an important transportation route in the regions through which it flows. It rises in the Adamawa Plateau of northern Cameroon, from where it flows west, and through the town of Garoua and Lagdo Reservoir, into Nigeria south

of the Mandara mountains, and through Jimeta, Ibi and Makurdi before meeting the River Niger at Lokoja. The river's largest tributary is the Mayo Kébbi, which connects it with the Logone River (part of the Lake Chad system) during floods. Other tributaries are Taraba River and River Katsina Ala. (Neba, 1999; Chisholm, 2010).

2.2 Sample collection

Five silica sand samples were collected along River Benue, as indicated on the map of the study area (Fig. 1). The samples were collected at different points at an interval of 100 meters apart from each other between the month of September and December to reflect the late dry season periods when water tidal influence is at low level. The collected samples were each separately prepared by thoroughly blending the material by "centre displacement method "so as to obtain a homogenous material. 100kg of each silica sand sample was heaped at one spot and then the entire material was shoveled and heaped on a second spot (thus displacing the center). This process was repeated for about 10 times (five heap at each spot), to obtained a homogenous mixture. The samples were then put into sample bags. (Calico bags) and labeled A, B, C, D and E to distinguish them from each other. The labeled silica sand samples were taken to the laboratory for pretreatment and preparation.
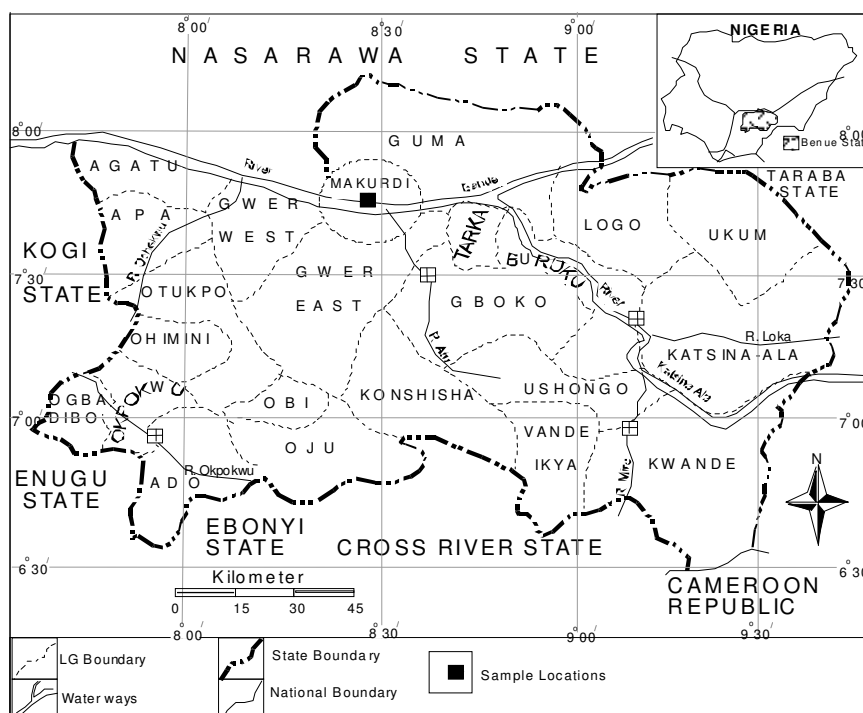
Figure 1: Map of Benue State showing sample location
Source: Ministry of Lands and Survey, Makurdi

2.3 Sample pretreatment 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 with distilled water (Allen,1974). After washing the samples were air-dried in the open for one week and finally dried in the oven at a temperature of 110°C for seven hours. After drying, about 100g were taken from each samples, weighed and homogenized into fine grain using a chrusher-Mangan Model BB200. The crushed fine grain particles were further sieved using a 100 mm mesh screen to ensure homogeneity of particle size (Plate 2) 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 pulverized samples was poured in a clean-dried universal bottles and sets 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 oxides analysis was carried out using 10mL concentrated hydrochloric acid (HCl) and Perchloric acid ($HClO_4$), to release metal oxides content into solution (Allen, 1974; Rantalla and Lorring, 1992 Ademoroti, 1996). For each of the representative pretreated samples, 0.2g was carefully weighed and placed in a clean-dried crucible. 5mL mixture of nitric and perchloric acid in the ratio of 3:2 was added followed by 10mL of hydrofluoric acid (HF) and refluxed for one hour (1h). The mixture was then heated to dryness on a hot plate in a fumed cupboard at a temperature of 90-100^{0}C. The mixture was then

cooled to room temperature and 5mL concentrated hydrochloric acid (HCl) was added and allowed to settle, and then filtered into a 100 mL plastic flask and made up to mark with de-ionized water and allowed to stay for three days before analysis using atomic absorption spectrophotometer (AAS). All glassware and specimen bottles used were initially washed thoroughly with HNO_3 and rinsed with distilled water (Harries, 1975; Sinex *el al.*, 1980; Asuquo, 1999).

2.5 Determination of metal oxides concentration

This was carried out using atomic absorption spectrophotometer (AAS), Shimadzu model AA 6800; x-ray fluorescence spectrophotometer (XRF) Mini Pal Model 4 version PW430 and UV-spectrophotometer model 2400 Hatch. The atomic absorption spectrophotometer was used for each determination of MnO, MgO, PbO and K_2O. Working standard solution for each element was prepared and the standard solutions and aliquots of the diluted clear digest were used for the determination. Standard curve was used to establish the relationship between absorption intensity and concentration of each element (Boyd, 1994; Underwood and Day, 1988; Emufurieta *et al.*, 1992). The detection limit of the AAS was < 0.00lmg /L.

The X-Ray fluorescence spectrophotometer was used for the determine SiO_2, Fe_2O_3, CaO, Al_2O_3, Na_2O, TiO_2, NiO, ZnO, BaO and CuO . To a specific amount of each of the pulverized samples, a binder (PVC dissolved in toluene) was added carefully, mixed and pressed in a hydraulic chamber to form a pellet. The pellet was then loaded into the sample chamber (Analyzer) of the spectrophotometer and a voltage (30 KV maximum) and a current (1mA 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 and the result automatically printed out. The process was repeated until all the samples were analyzed.

2.6 Determination of phosphorous

About 5g each sample was weighed into a 250mL plastic beaker and 100mL of 0.1M HCl added, corked and shaken for 30 minutes and allowed to settle. The mixture was then filtered using Whatman filter paper No. 42. 10mL of each filtrate was introduced into a curvette cell and another 10mL of distilled water into a separate curvette bottle to produce a blank. 1mL 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 inserted into the curvette hole and read at a wave length of 690nm. Standard solutions of phosphate reagents were prepared and calibration curve constructed and with the help of the curve the concentration of phosphorous in the samples were determined in mg/L. (Harries, 1975; Christian, 1980).

Plate 2: The mesh screen used for screening the silica sand samples

2.7 Beneficiation and up gradation of samples

The beneficiation of the silica sand samples was done according to the method of Veglio *et al.*, 1999 and Tarasova *et al.*, 2001.

Procedure:

20g of the representative samples were weighed and placed in a 250 mL flask and 100mL of oxalic acid added. The mixture was placed on a heating plate and agitated (870 rpm) at a temperature of 80^0C to 90^0C for 2hours.To ensures 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 and dried in an oven and the percentage concentration of metal oxides in each sample determined using XRF method.

2.8 Determination of loss on ignition (LOI) and pH

10_g of each sample were taken and carefully poured in a clean crucible and weighed using 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 on ignition.

The pH of the samples was determined electronically using a pH meter of ±0.1 percent sensitivity

model WTW pH 422. (The instrument was calibrated using a buffer solution) (Harries, 1975; krist and Rump, 1988).

Table 1: Percentage composition of silica sand samples from River Benue

Parameters	Percentage composition (%)
SIO_2	93.946±0.4775
Fe_2O_3	0.7116±0.0829
K_2O	0.0022±0.0008
Na_2O	0.0460±0.0047
CaO	0.0052±0.0008
Al_2O_3	0.0142±0.0035
MgO	0.0028±0.0008
TiO_2	0.0240±0.0021
ZnO	0.0059±0.0008
NiO	0.0280±0.0178
PbO	0.0342±0.0319
BaO	0.0494±0.0083
P_2O_5	0.0160±0.1763
MnO	0.0692±0.0851
CuO	0.0088±0.0050
LOI	2.110
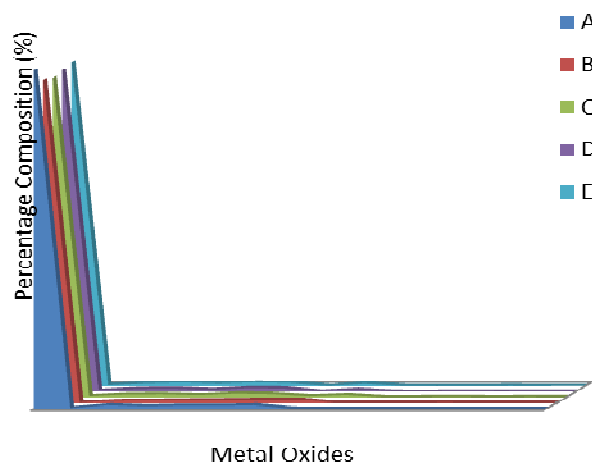
Figure 2: Percentage concentration of metal oxides in River Benue

2.9 Grain size distribution analysis

The grain-size analysis was carried out to determine the percentage ideal fraction of the silica sand samples using a standard set of sieves (from 20-140 mesh).100g of each of the dried sample was poured into an Endoctts sieving machine model EFL 2000/1 with standard mesh range of 20-140. The machine was electrically agitated for 30 minutes and the percentage retentions   of grain size of each sample on each sieve calculated. (Freestone, 2005; Ushie *et al.*, 2005; Sundararajan *et al.,* 2009). Further, the silica sand samples grains shape distribution patterns were observed using a magnifying machine, Suntex colony counter model 560 (Ushie *et al.*, 2005).

Table 2: Beneficiated percentages mean composition of metal oxides in the silica sand samples from River Benue

Metal Oxides	Percentage composition (%)
SiO_2	96.1590±0.0683
Fe_2O_3	0.4150±0.0014
K_2O	0.0010±0.0001
Na_2O	0.0240±0.0001
CaO	0.0040±0.0002
Al2O3	0.0006±0.0007
MgO	0.0400±0.0092

Table 3: Shows the Acid Demand Values/pH of the silica sand samples

S/N	Sample Code	ADV	pH
1	A	20.10	7.00
2	B	20.20	7.01
3	C	19.50	7.03
4	D	20.30	7.05
5	E	20.34	7.05
Mean		20.09	7.03

2.10 Determination of acid demand values of samples

Acid Demand Values (ADV), is a measure of soluble carbonates present in a given silica sand sample. It value determines a low or higher concentration of alkali or carbonates reacting materials present in given silica sand sample. Their presence is an indicator of whether given silica sand sample can be used for 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).

2.11 Heavy liquid separation of minerals/Beneficiation of samples.

Heavy liquid separation of minerals was carried out according to the wok of Muller and Burton, 1965; Robert *et al.*, 2002 and Sundararajan *et al.,* 2009 while the beneficiation and up gradation of samples was done according to the method of Veglio *et al.*, 1999 and Tarasova *et al.*, 2001. 20g of the representative samples were weighed and placed in a 250 mL flask and 100mL of oxalic acid added. The mixture was placed on a heating plate and agitated (870 rpm) at a temperature of 80^0C to 90^0C for 2hours.To ensures 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 and dried in an oven and the percentage concentration of metal oxides in each sample determined using XRF method as explained in (2.5) above.

Table 4: Grain size distribution analysis of silica sand samples from River Benue

Mesh no	Sieve size (mm)	A	B	C	D	E	Mean
20	0.840	0.45	0.01	0.00	0.04	0.05	0.110
30	0.600	1.40	1.51	1.39	1.42	1.43	1.430
40	0.425	18.60	18.05	17.88	17.78	18.76	18.76
50	0.300	36.50	37.42	37.05	39.62	38.66	37.864
70	0.212	32.60	33.24	32.58	32.07	31.02	32.302
100	0.150	8.50	9.06	8.74	8.28	9.01	8.718
140	0.100	1.95	0.71	2.36	0.79	1.03	1.368

Percentage silica sand retained (%)

Table 5: The principal minerals present in the silica sand samples

NAME OF RIVER	MINERAL S PRESENT	CHEMICAL COMPOSITION
River Benue	Quartz	SiO_2
	Mica	$H_2KAl_3(SiO_2)_3$
	Kaolinite	$Al_2O_3.2SiO_2.2H_2O$
	Ilminite	$Fe^{2+}TiO_3$
	Magnetite	Fe_3O_4
	Rutile	TiO_2
	Gypsum	$CaSO_4.2H_2O$
	Calcite	$CaCO_3$

Table 6: Pearson product moment correlation between mean values of SiO_2 and Fe_2O_3 from River Benue.

		SiO_2	Fe_2O_3
SiO_2	Pearson Correlation	1	-.983**
	Sig.(2-tailed)		.003
	N	5	5
Fe_2O_3	Pearson Correlation	-.983**	1
	Sig.(2-tailed)	.003	
	N	5	5

**Correlation is significant at the 0.01 level

Table 7: General specification of chemical composition of glass sand.

Glass quality	$SiO_2\%$	$Fe_2O_3\%$	$Al_2O_3\%$	CaO/MgO%	$TiO_2\%$
Optical glass	99.80	0.005	0.100	0.100	-
Borosilicate glass	98.50	0.05	0.50	0.20	0.012
Colourless container glass	98.50	0.150	0.50	0.50	0.100
Clear/Float glass	95.00	0.200	4.00	0.50	0.100
Insulating fibre	95.00	0.300	0.50	0.50	0.100
Amber glass	95.00	1.00	4.00	0.50	0.100
Green glass	95.00	1.00	4.00	0.50	0.100
Grain shape: Angular, Round and sub-angular melt easily					
Grain size : Higher % retention between 40-100 mesh screen					

Source: Crockford, 1949; Carr, 1971 Stocchi, 1974, Sell, 1981; Harben, 1999)

3.0   RESULTS AND DISCUSSION

The results concentration of silica sand samples obtained from River Benue have been analyzed using some analytical methods. The results are as presented in Table 1.

3.1 Metal oxides concentration

The mean percentage metal oxide concentration (SiO_2, Fe_2O_3, K_2O, NaO, CaO, Al_2O_3, MgO, TiO_2, ZnO, NiO, PbO, BaO, P_2O_5, MnO, and CuO) in the silica sand samples are presented in Table 1 and depicted in a three dimensional graph of Figures 1. The result revealed that the highest percentage mean concentration of SiO_2 in the silica sand samples was (93.946 ± 0.4775%), followed by Fe_2O_3 (0.7116±0.0829),P_2O_5(0.1160±0.1746), MnO (0.0692±0.0851) ,BaO (0.0494±0.0183),Na_2O (0.0460±0.0047), PbO(0.0342±0.0319) and significant amounts of, CaO, Al_2O_3, TiO_2, NiO,Al_2O_3,TiO_2, ZnO, CuO and MgO. This high SiO_2 content trend in all the samples revealed that silica sand generally consist of high SiO_2 content (quartz) (Sosman, 1954; Bajah, 1986, Siever, 1988).The concentration of SiO_2 in silica sand samples in this study is similar to those obtained by other research studies (Shakila *et al.,* 1999; Sundararatan *et al.,* 2009; Pisutti *et al.,* 2008; Babasaheb, 2010). Compararison of the observed mean values of SiO_2 ,Fe_2O_3,CaO,Al_2O_3,MgO and TiO_2 (Table 7) in the silica sand samples with their glass making standard revealed the concentration of SiO_2 (93.946 ±0.4775%) ,CaO,Al_2O_3 and MgO was below the minimum standard ,while those of Fe_2O_3 and TiO_2 were above the minimum standard which imply that the entire silica sand sample require further beneficiation to reduce the Fe_2O_3 content to a more acceptable standard level as stipulated by the American ceramic society and the National Bureau of standards (Frank, 1972; Enuvie, 2003; James, 2007). The concentration of Fe_2O_3 in any silica sand deposit determines the quality of glass to be produced. A slight increased in Fe_2O_3 content gives the glass a green, yellow or red colour as a result should not exceed 0.005 percent. This colouration to a certain extent can be neutralized by the addition of manganese resulting to a faint shade or purple colour (Host, 1991; Goldman, 1994; Heck, 2002). However further beneficiation of the obtained silica sand samples revealed an increased in SiO_2 from 93.946±0.4775% to 96.159±0.0683 % with a decrease in iron(Fe_2O_3)content of 0.4150±0.0014 % from 0.7116±0.0829% which means that the samples can be used for glass making (Ushie *et al.,* 2005; Marson, 1978). The various concentration of SiO_2 observed though may be attributed to some geological factors such as type of weathering and distance travelled by particle size from source rock of the individual rivers.
Stocchi; 1975)

3.2   Grain size distribution analysis

The mean grain size distribution analysis of the silica sand samples is presented in Tables 4. The result shows the mean grain size distribution among the silica sand samples to be 0.110-37.864 . The result revealed that the highest percentage retention fraction of the silica sand sample was between mesh number 40 to 70 (98%), This implies that silica sand samples met the requirement of sieve size retention fraction at different significant percentage levels of between 40 – 100 sieve size. Grain size distribution plays an important part in silica sand requirement. Large grain do not mixed proper with the other grains in the batch while too fine grain create air bubble in the glass final product. (Crockford, 1949; Corning Glass Works, 1967; Robert, 2002), as a result the grain size distribution should falls within the 40-100 screens mesh size. From the analysis so far carried out the grain size distribution fraction from River Benue, falls within the recommended size range of 40 to 100 screen mesh (Crockford, 1949; Sundeen, 1978; Robert, 2002).

3.3   Mineralogy

The principal minerals present in the silica sand samples is presented in Table 5. The result shows the principal minerals present in silica sand from River Benue to be Quartz, mica, Kaolinite, ilminite, magnetite, Rutile, gypsum and calcite. The results revealed that quartz in form of silica (SiO_2) form the predominant mineral in all the silica sand samples The grain shape of the silica sand samples observed ranges from angular to sub-angular with an average diameter range of 0.05mm to 0.125mm. However, most of the grain shapes would be classified as sub-angular. (Thomas, 2001; Robert, 2002; Sundararantan *et al.,* 2009)

3.4   Acid demand values (ADV)

The mean values of the acid demand values (ADV) of the silica sand samples are presented in Table 3. The result revealed that the highest Acid Demand Value is obtained from samples (20.09) this result is similar to those obtained by other researchers (Crockford, 1949; Robert *et al*., 2002; Mclaws, 1971). The acid demand values measures the amount 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 of either no acid was consumed ,and so virtually no soluble carbonates are present in the sample or low alkaline materials in the samples while a high ADV(values in upper 40's to 50) is an indication of nearly all acid added in the test was consumed or a high soluble carbonate and salts that can be deleterious in the application of the silica sand for glass making (Sundeen, 1978; Hrdina, 1999; Pisutti, 2008).From Table3,it was observe that the Acid Demand Values of the silica sand samples falls within the moderately acceptable range of 20.10 to 20.34,which is an indication of low soluble carbonates content present in the silica sand sample from the five Rivers. This low ADV may be attributed to the leaching and removal of soluble carbonate minerals

(primarily calcite) by downward percolating oxidizing surface waters (Sundeen, 1978; Hrdina, 1999; Pisutti, 2008).

3.5 Loss on ignition and pH

Table 1also shows the results of the mean percentage weight loss on ignition (LOI) of the silica sand samples to be 2.10% .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 pH of the silica sand samples is presented in Table 1. The results revealed the pH value to be 7.03. 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 values signify the present of acidic or basic oxide in given silica sand sample. Sand with a pH close to neutral (7.00) is therefore the best for glass making (Doremus, 1973; Sell, 1981; Paul, 1982).

4.0   Conclusion

Physico-chemical evaluation of silica sand deposit from River Benue was carried out in this research study. The results revealed that the silica sand samples generally contain a high percentage concentration of silicon dioxide (SiO_2) content with significant amount of Al_2O_3, K_2O, MgO, Fe_2O_3 and trace amount of CaO, TiO_2,NiO, ZnO, PbO, Na_2O, BaO, P_2O_5, MnO and CuO. The grain size distribution of the silica sand samples falls within the recommended screen size (40-100 mesh). The highest grade of silica sand sample obtained after beneficiation was 96.159±0.0683% SiO2 and 0.4150±0.0014% Fe_2O_3 which shows that the silica sand from River Benue is suitable for glass making due to their high SiO_2 content and low Fe_2O_3, Acid demand values (ADV) coupled with suitable grain size distribution fraction.

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