

Investigation of the Properties of Makurdi, Buruku and Katsina-Ala Silica Sand Deposits For Glass Production

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ABSTRACT

In this study, the properties of silica sand deposits in Benue State, Nigeria from Rivers Benue (Makurdi) (A), Buruku (B) and Katsina – Ala (C) were examined. The aim was to determine whether these deposits could be used for glass production. The silica sand samples were taken at Makurdi, Buruku, and Katsina-Ala locations all in Benue State. Tests were carried out to determine the physical and chemical properties, such as grain morphology, particle size, shape and specific gravity using sieve analysis method with a mechanical shaker. An X-ray fluorescence spectrometer was used for chemical analysis and a scanning electron/probe microscope was used for grain morphology examination. Loss on ignition test was carried out with a muffle furnace at 1000 °C and held for two hours. The results for the test samples were then compared with the standard requirements for glass production. Sample B had the highest percentage silica content of 83.3 %, C 82.9% and A with 77.8%, which satisfies the silica requirement of 75%. The grain morphology was angular for samples A and B but sub-angular for C, while the average specific gravity for the samples were 2.60, 2.50 and 2.70 respectively. This shows that samples A and B can only be used for dark green bottle glass production while sample C is not suitable for glass production. The loss on ignition results were 0.34, 0.21 and 0.31 respectively which lies within the acceptable limits of 0.1 -10% by weight for normal silica and for glass production.

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Introduction

Glass is an amorphous (non-crystalline) solid material that is typically brittle, often optically transparent, and durable to wet atmospheres. The term glass includes a wide range of products characterized mainly by their desired rate of cooling from a desired state of fusion to solid state without crystallization (Agrawal et al, 1985). According to Oliver (1975), traditional and advanced application of glass are based on its physical and chemical properties of formability of the silica sand which is the main component or raw material for glass production. Therefore, the type and quality of glass to be produced depends greatly on the physical and chemical properties of the silica sand used.

The largest proportion of glass produced nowadays is done using soda lime in manufacturing process. The silica (SiO₂) sand is used as the forming agent, soda (Na₂O) as fluxing agent and lime (CaO) or (CaO + MgO) as stabilizing materials to provide chemical durability (Eric, 2007). The major part of the raw material required for commercial glass manufacturing is silica sand comprising of about 70% and above by weight, soda lime and some other minor additives (De Jong, 1989).

The suitability of silica sand for glass production must therefore certify certain requirements like the level of metallic iron oxides in silica sand, which will affect the color of the glass to be produced. According to Tooley (1987), window glass sand requires only 0.1 to 0.5% iron oxide, while dark green bottle glass requires as much as 2% to 3%. Colourless glass container will require less than 0.035% of Fe₂O₃ and for flat glass in the range of 0.040% to 0.1 % Fe₂O₃. The removal and control of iron

content in raw material is achieved by washing, scrubbing, classification, floating, magnetic separation, electronic separation, screening etc (James and Robert, 2008)

The grain morphology affects the performance of sand in the glass making. It is required that the silica sand must be angular and not rounded or spherical. Rounded grains may have larger voids between them thereby entrapping air bubbles during melting which may result in cracks. It is internationally accepted that a silica sand for glass making should be in the grain size range between 0.15 mm to 0.85 mm in diameter and between 10 -100 mesh (B.S. Sieve number) , with about 80% and above of grains (James et al , 2008) . The grain size must also be uniform.

According to Tooley (1989), silica sand with specific gravity greater than 2.65 is not suitable for glass making. Loss on Ignition (LOI) required for normal silica sand and silicate rocks for glass production is limited to 0.1 – 10% by weight of the material (Baxter et al, 2006). Harnessing the abundant silica sand deposits in Benue State as a result of this study will go a long way in helping investors who want to invest in the this area in the state.

Materials and Method

Three samples of silica sand were collected for analysis from different rivers of Benue State. The silica sand samples were from Rivers Benue (Makurdi), Buruku and Kastina-Ala and were designated as samples A, B and C respectively. The samples were obtained from the river banks. The geographical locations of the sample sites were as follows River Benue (Makurdi

bridge), coordinates 7.73°N, 8.54°E; River Katsina-Ala at Buruku 7.47°N 9.2°E and Katsina-Ala 7.17°N 9.28°E.

Tests for physical and chemical properties of the samples were carried out at the Soil Science Department Laboratory of the University of Agriculture, Makurdi. The sand samples were cleaned, coned and quartered to obtain the representative fraction by following standard procedures. The representative fractions for each sample were later crushed and ground separately to fine particle size that could pass through 120 mesh (B.S) sieve (Head, 1992). The ground samples were then used for particle size/sieve analysis, chemical analysis, specific gravity test, loss on ignition, and grain morphology examination. This was carried out to determine the chemical composition of each of the three sand samples.

An-X-ray Florescence Spectrometer (XRF), a non-destructive analytical technique used to identify and determine the concentration of elements present in the sand was used. The earlier quartered, crushed ground silica sand samples were further re-ground and sieved to 75 µm particle size for homogeneity. 4 g of the sieved samples were mixed with 1 g of Lithium tetraborate binder (LiB₄O₇) and pressed in a mould under a pressure of 10-15 tons/m² into pellets. The pellets were then dried at 1000 °C for 30 minutes in an oven to remove any absorbed moisture and then stored in desiccators for analysis. The XRF machine was switched on and calibrated before the samples were introduced for test. The elements and their concentration in each sample were then automatically calculated and digitally displayed on the visual display unit and finally printed as given in Table 1.

The loss of ignition (L.O.I.) test was carried out following standard procedure at 1000 °C. The loss on ignition was calculated for each sample using equation 1.

$$L.O.I. = \frac{W_s - W_a}{W_s + W_c} \times 100\% \quad (1)$$

where, W_s = weight of crucible with sample before heating, W_c = weight of empty crucible and W_a = weight of crucible with sample after heating. The test for each sample test was carried out thrice and the average loss on ignition calculated and recorded in Table 3.

The specific gravity test for each of the three samples was determined using a digital weighing balance and density bottles (pycnometer) method (Krishna, 2002). Standard procedures were followed and Rudolph and Lubos equation was used to determine the specific gravity of each sample as shown in equation 2.

$$\text{Specific gravity} = \frac{M_2 - M_1}{(M_2 - M_1) + (M_4 - M_3)} \quad (2)$$

where, M₁ = weight of empty density bottle, M₂ = weight of density bottle with silica sand before heating, M₃ = weight of cooled density bottle with silica sand after heating, and M₄ = weight of density bottle filled with water.

The particle size/sieve analysis were carried out using an octagonal digital sieve vibrating Machine. The samples were taken from the quartered silica sand samples and dried in an oven to remove moisture. Ten standard sieves were arranged vertically on the vibrating machine with the coarsest on top. 100g of each sample was passed through the sieves by operating the mechanical vibrating machine for 15 minutes. After sieving, the amount of silica sand samples retained on each sieve were emptied onto sheets of paper and weighed accordingly; then the cumulative percentage by weight of the sand particles passing through each sieve was calculated and recorded in Table 2.

The silica sand samples were examined with the aid of a scanning electron probe Microscope (SEM) which revealed the shape of each silica sand sample following standard procedures. The shape/grain morphology of each sample were transformed into computer codes which were interpreted automatically and recorded as angular, sub-angular or round and printed. This test was repeated four times for each sample and average obtained.

Results and Discussion

The results of the tests carried out on the three silica sand samples are presented in Tables 1 and 2. These tables show the chemical composition and other parameters respectively. One of the main constituent for making glass is the (silicon oxide) which in effect could determine the types of glass that could be made. The chemical composition of all samples in Table 1 Shows that sample A has 77.80% silica, B has 83.3% SiO₂ and C has 82.9% SiO₂. This shows that all the samples have silica content enough for glass production. Another important element here is iron oxide which is also high with percentage of 2.27 in sample A, 2.58 in B, and 2.87 C. The high percentage of iron oxide therefore limits the usage of these silica sand samples to dark green bottle glass production which requires 2 – 3 % iron oxide (Santali and Egbo, 2007; Fleming, 1999).

The result of (L.O.I) test showed samples A (0.34), B (0.21) and C (0.31) respectively, which is in agreement with acceptable limits of 0.1-10 % by weight of the material (Baxter et al, 2006). The specific gravity for the three samples were A (2.60), B (2.50) and C (2.70). According to Tooley (1989), samples A and B have the required gravity of less than 2.65 but sample C has 2.70 which is not suitable. The particle size or sieve analysis shows that all the three samples are suitable for glass production since over 90% Of the particle size distribution lie within 10 to 100 mesh (BS sieve Number).

Table 1: Constituents chemical analysis of the three silica sand samples from Benue State

S/N	Composition	Makurdi % by weight	Buruku % by weight	K/Ala % by weight
1	Al ₂ O ₃	1.00	-	-
2	SiO ₂	77.80	83.30	82.90
3	K ₂ O	0.87	12.40	12.7
4	CaO	1.49	-	-
5	TiO ₂	0.36	0.28	0.25
6	Cr ₂ O ₃	0.071	0.10	0.15
7	MnO	0.051	0.14	0.037
8	Fe ₂ O ₃	2.27	2.58	2.87
9	NiO	0.006	0.08	-
10	CuO	0.058	0.072	0.071
11	As ₂ O ₃	0.004	-	-
12	Rb ₂ O	0.027	0.066	0.068
13	SrO	0.102	0.54	0.048
14	Y ₂ O ₃	0.017	0.023	0.026
15	ZrO ₂	0.054	0.037	0.12
16	RuO ₂	0.343	0.436	0.41
17	BaO	0.32	0.46	0.39
18	CeO ₂	0.03	0.02	0.009
19	OsO ₄	0.01	-	0.01
20	Au	0.023	0.03	0.026

Table 2: Particle size / sieve analysis result

S/N	Sieve aperture	B.S. Mesh number	Percentage weight per sample (% weight) Retained		
			River Benue (Makurdi)	River Buruku	River K/Ala
1	1.40	14	21.90	29.30	36.10
2	1.00	18	11.20	19.60	9.50
3	0.71	25	12.00	21.00	9.90
4	0.50	35	13.60	15.40	11.50
5	0.355	45	13.50	2.80	0.20
6	0.250	60	20.20	10.70	22.50
7	0.180	80	4.90	0.80	4.80
8	0.125	120	1.40	0.30	3.40
9	0.050	170	1.10	0.10	1.10
10	0.063	230	0.10		1.00
11	0.063	pan	0.10		

Table 3: Summary of physical parameters studied

Samples	Average Loss on Ignition (L.O.I.)	Average Specific gravity	Particle Size/Sieve 10-100 Mesh (cumulative % weight)	Grain Morphology /Grain shape
Sample A (Makurdi)	0.34	2.60	97.3%	Angular
Sample B (Buruku)	0.21	2.50	99.6%	Angular
Sample C (K/Ala)	0.31	2.70	94.5%	Sub- angular

Conclusion

The percentage of silica in the three samples was found to be adequate for glass making which requires a minimum of 70% silica. The sieve analysis also shows that all the three samples have the required grain size and homogeneity standard of over 80% which is internationally acceptable for glass making. Looking at all the parameters assessed, River Benue sample at Makurdi and River Buruku sample could be used for glass manufacturing purposes, while the sample from River Katsina-Ala is not suitable for glass production due to the high specific gravity above the acceptable limit of 2.65 and sub-angular grain morphology. Based on the iron III oxide contents of the sand samples, it can be concluded that Makurdi and Buruku samples are limited in application dark green bottle glass production. Investors wishing to produce this type of glass in Benue State can now confidently take advantage of the abundant silica sand deposits in the State as confirmed by this study.

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