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# Quality Characterization Of Silica Sandsfrom River Mayo-Wandu, Kuburshoshoand Kwadzale For Glass Production And Sustainable Economic Development In Adamawa, Nigeria.

A.E. Zira; Wadai J., And T. Cosmas
*Department of Mechanical Engineering, Federal Polytechnic, Mubi, Adamawa State, Nigeria.*
*Corresponding Author: A.E. Zira*

**--------------------------------------------------*ABSTRACT*--------------------------------------------------**
*The most essential raw material for glass production is silica sand, which is underutilized amongst the available engineering materials in Nigeria. Silica Sands used for glass production are desired for their suitability and availability at very low cost. Thus, silica sand sourced from River Mayo-wandu, Kuburshosho, and Kwadzale situated in Michika, Adamawa State, Nigeria have been analyzed for their suitability in glass production. Physical properties of grain morphology, Specific gravity, Grain fitness Number (GFN); and Chemical characteristics such as mineralogical constituents, and Loss on Ignition were determined and compared with standards required for glass production. Analysis of the physical properties indicates that sand from River Mayo-wandu, Kuburshosho, and Kwadzale has percentage silica (99.6%, 99.3%, 99.21%); GFN (17.01, 10.80 and 12.45); specific gravity average (2.45, 2.60 and 2.65); Iron III Oxide (2.58, 1.57, and 2.28); Loss on Ignition (0.21, 0.26, and 0.24) respectively; with their Grain morphology in all the three rivers angular. The result obtained from the investigation;revealed that allthe silica sand samplesare suitable for light, dark green bottles, and window-glass production.*

***Key Words:*** *Grain morphology, specific gravity, silica sand, iron-oxide and Glass.*
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## I. INTRODUCTION

The word “Glass” was said to have originated from the late –Latin term “Glesum” a Germanic word for a transparent, lustrous amorphous solid, brittle, durable to wet atmosphere and most chemicals (Dauglas, 1972). These properties made glass materials widely used in building, house ware, optical, bottles, electronics, communications, fiber optics, laboratory, vessels, jeweler, bangles etc. (Fleming, 1999; Greer et al., 2005).

The major part of the raw materials required for commercial glass manufacturing is Silica Sand (also known as quartz), comprising of about 70% and above by weight (either from river/sea deposition, mined, or weathered rocks) with Soda, lime and some minor additives (de Jong, 1989; Allen, 1998). Sometimes the Silica sand usually undergo beneficiation, to improve the quality of the sand (Taxiarchaou et al., 1997; Wills, 1998).

Considering the demands for glass raw material or finished product in the country, particularly in the North Eastern region of the County; regional industrialization and diversification is important. This is motivated because major consumer of glass products such as breweries, bottling companies, local food preservation, window glasses, laboratory, mirror, automobile, buildings etc.;presently meet their needs mainly through importation with limited supply coming from both the western and eastern parts of the country. Currently, this practice limits production schedule of firms that use glass products as feedstock in their production; thus resulting in high production cost and ultimately adding a premium to the cost at which the consumer obtains such products.

The Northern part constitutes about two-third of the land mass of the country (Shafiu, 2013) as such, should ordinarily attracts consideration for the setting up of glass production facilities since it is presumed to have silica sand in abundance inclusive of other economic and social factors, rather there is virtually no such facility in this part of the country. This is attributed to lack of technological information on the equality and proven reserve of the terrestrial silica sand deposits in the region. This may be attractive to pursue this option in sourcing for silica for glass production in the North Eastern part of the country. Michika, one of the far north local government areas of Adamawa state in North East Nigeria has several rivers traversing its length and breath, and this may be exploited for glass production. The success of this effort will reduce or eliminate importation of glass products, increase production schedule and ultimately improve the profitability of firms in related economic activity. This will also contribute to improving employment rate as well as the well-being of the state and region. However, there is no information in literature or anywhere else on the suitability of silica sand sourced from Rivers in Michika Local Governmentof Adamawa state for glass production. Therefore, in the

present work, the suitability of silica sand sourced from River Mayo-wandu,Kuburshosho and Kwadzale for glass production was evaluated. This is to unveil the untapped and unexplored silica sand in MichikaLocal Government of Adamawa State for wealth creation and industrialization. Such efforts will serve as feedback for packaging, automobile part, fiber optics, electrical insulations and fiber reinforcement plastics (Ibhadode, 1997)
Some major oxides and elements associated with glass production as revealed by the Energy Dispersive X-ray Fluorescence Spectrometer (ED $XRF_s$) were Silica sand ($SiO_2$), Soda ash ($NaO_2$), Lime stone (CaO), Salt cake or Gypsum ($SO_3$), Lead Oxide (PbO), Iron (III) Oxide ($Fe_2O_3$) and associated Oxides (Mills, 1993).

**Scope Of Study**

River Mayo-wandu, Kuburshosho, and Kwadzaleof Michika Local Government, Adamawa State were selected for investigation of the suitability of their property for Glass production.

## II. METHODOLOGY

Silica Sand Samples from River Mayo-wandu, Kuburshosho, and Kwadzale of Michika Local Government, Adamawa State were collected for analysis. The silica sand samples were mined from the surface, to about one and half meters deep at the river banks to obtain each sample; and Table1 shows the Global location of the sites where the samples were obtained. It is clear from the table that the samples have different height above sea levels while mining was done to the same depth for the purpose of ensuring similar profile in the samples.

The representative fraction of the samples was obtained by pouring the silica sand samples on a flat surface so that it formed a cone which were then cleaned, coned and quartered using a straight edge (Head, 1992). The two alternate quartered samples were mixed again for further quartering. The representative fractions for each sample were later crushed, and grounded separately to fine particle size producing 120 mesh B.S sieve (Head, 1992). The crushed and grounded samples were kept for chemical analysis, specific gravity test, particle size/ sieve analysis, loss on ignition, and morphology examination.

**Table 1:** Global location of soil samples obtained for the test/analyses from Michika local government, Adamawa State. (Source: Google Earth, and GPRS)

| Samples | Co-ordinate | Heights above sea level |
|---|---|---|
| **River Mayo-wandu** | $8^0$23´08.48´´N;$10^0$30´12.72´´E | 118.57 meters above sea level |
| **River Kuburshosho** | $8^0$ 59´43.75´´N;$11^0$40´50.61´´E | 555.35meters above sea level |
| **River Kwadzale** | $8^0$ 54′45.76″ N: $11^0$ 38′50.58″E | 554.56 meters above sea level |

**Chemical Analysis**

An Energy Dispersive X-Ray Florescence Spectrometer (Minipal 4, ED-XRFs), a non-destructive analytical technique of identifying/determining the concentration of elements present in a solid, powdered, and liquid samples were used. The ED-XRFs is capable of ascertaining the presence of elements in traces levels, from below one part per million (ppm) up to 100%

The previous quartered, crushed, and grounded silica sand samples were further re-grounded and sieved to 75µm particle size for homogeneity. 4g each of the homogeneous silica sand samples were mixed with 1g of Lithium tetra-borate binder ($Li_2B_4O_7$), and under a pressure of 10 tones/$m^2$, the samples were pressed into pellet. The pellet was then dried in an oven at about $110^oC$ to rid of absorbed moisture to about 98% and then stored in desiccators for analysis. The calibrated ED-XRFs machine was switched on and each sample were then tested. The elements and their concentration in each sample were automatically calculated and digitally displayed, printed and recorded (NMDC, 2003).

**Loss on Ignition**

The primary purpose of Loss on Ignition (LOI) is to determine the amount of possible organic materials that might be present in the raw material samples for glass production. The weight of glass material that is charged into the kiln will not be the same with that which comes out of the kiln, since there will be lost of weight. To compensate for any lost during firing therefore, the knowledge of LOI is important. (Hansen, 2008; Baxter et al, 2006).

The loss on ignition was carried out to determine the possible amount of chemically/physically bonded water present in each of the silica sand samples. The following steps were taken to determine the loss on ignition:

Sample of the quartered, crushed and grounded fine silica sand samples were each carefully mixed. A prepared crucible (without lid) was weighed and recorded 'Wc', 5g of each of the samples (not more than ¾ of the crucible volume) were placed into a crucible and carefully taped, and the weight of each "crucible with sample" was noted and recorded 'Ws' to precision of ±0.1mg. The crucible with samples was carefully placed in the muffle furnace (when the furnace was still cold) to avoid air turbulence in the porcelain (fine silica sand particle). The samples were then heated gently up to 1000$^{o}$C in the furnace, and then hold at thattemperature for two hours. The samples were removed, the crucibles covered with their lids and stored in adesiccator where it was allowed to cool for one hour. The crucibles with the samples were each weighed (without the lid) and recorded 'Wa' (Osarenmwinda, et'al, 2012). The loss on ignition was then calculated from Equation 1below: -

$$L.O.I = \frac{Ws - Wa}{Ws - Wc} * 100\% \qquad (1)$$

where:

Ws = weight of crucible with sample
Wc = weight of empty crucible
Wa = weight of crucible with sample after heating

Each test was carried out four times for each sample and the average loss on ignition obtained and recorded.

**Particle Size/Sieve Analysis**

Using the "+GF+DIM (England) octagonal" digital sieve vibrating machine, these procedures were followed in carrying out the test.

A portion of the quartered sand for each samples were first dried in an oven at 110$^{o}$C to get rid of moisture. Ten standard sieves and the Pan were arranged vertically on the vibrating machine with the most coarse screen on top and the pan at the bottom. 200g of each sample was made to passed through the sieves by operating the mechanical vibrating machine for 15minutes. After sieving the samples, the amount of sample retained on each sieve was emptied on to sheet of paper and weighed in turn, per sample. Cumulative percentage by weight of the Samples passing through each sieve was calculated. The test was repeated four times and the average of each sample calculated.

**Specific Gravity Test**

Using digital weighing balance (Model METLLER PM200; tolerance RE-zero, 1000g/0.09g) the specific gravity for each of the three silica sand samples were determined using density bottles (Pycnometer) method (Krishna, 2002). These procedures were followed:

The density bottles were cleaned and weighed on a standard digital balance and recorded $M_1$. From each samples, 50g was weighed and poured into marked density bottles which were weighed and recorded $M_2$ for each sample. The density bottle with 50g sand samples each were filled with water and air bubbles expelled using a vacuum pump. The density bottles and their contents were then weighed and recorded $M_3$. Emptied and properly cleaned with distilled water, the density bottles were filled with water and weighed M4. Rudolph and Lubos Equation (2) were used to determine the specific gravity of each sample.

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

$M_1$=weight of empty density bottle.
$M_2$=weight of density bottle with silica sand sample before heating.
$M_3$=weight of cooled density bottle with silica sand sample after heating.
$M_4$=weight of density bottle filled with water.

**Grain Morphology**

AA.3000 Scanning Electron/Probe Microscope (SEM) machine was used, revealing the grain morphology or size of each of the three silica sand samples. These procedures were followed in carrying out the analysis.

Ceramic slides and spatula were cleaned and stored in a sterilized box. From each of the three samples, small amount was placed on slide using spatula. The slide containing the sample was positioned under the SEM focus lens and the objective lens of the SEM adjusted for good focus. The shape/grain morphology of each sample was transformed into computer codes which were interpreted automatically, and were recorded as Angular, Sub-Angular or Round and printed. The test was repeated for four times and their average obtained (NMDC, 2003).

## III. RESULTS AND DISCUSSION

The results of the test and analysis carried out to determine the suitability of the silica sand samples for glass production are summarized as below:

**Particle size Analysis.**

The result of the particle size/sieve analysis results are presented in Table 2.

**Table 2:** Particle Size/Sieve Analysis Result.

| Sieve aperture | Mesh number | Weight of grains retained on each sieve per sample | | |
|---|---|---|---|---|
| | | River Mayo-wandu sample | River Kuburshosho sample | River Kwadzale sample |
| 1.4 | 14 | 29.50 | 51.10 | 46.48 |
| 1.00 | 18 | 21.60 | 20.70 | 24.27 |
| 0.71 | 25 | 19.00 | 13.80 | 14.18 |
| 0.50 | 35 | 15.30 | 7.30 | 8.13 |
| 0.355 | 45 | 6.80 | 3.10 | 3.21 |
| 0.25 | 60 | 6.60 | 2.70 | 2.03 |
| 0.18 | 80 | 0.80 | 0.60 | 0.91 |
| 0.125 | 120 | 0.30 | 0.40 | 0.54 |
| 0.09 | 170 | 0.10 | 0.10 | 0.15 |
| 0.063 | 230 | | | 0.10 |
| Pan | | | 0.10 | |

The table above represents the quantity of sand samples retained on each sieve after being vibrated for 15 minutes. The total sum of samples retained on each sieve and pan must be equal to the total weight before the test was carried out. This will later be used for some analysis like percentage weight, and Grain Fitness Number

**Percentage weights of the samples.**

The percentage weight is obtained from table 2 above, using the formula below.

$$\text{Percentage weight (\%weight)} = \frac{\text{weight at each mesh}}{\text{Total weight}} * 100 \qquad (3)$$

**Table 3**: Percentage weight of the samples.

| Silica Sand Samples | Percentage Weight (% weight). | |
|---|---|---|
| | Mesh No.10 to 100 (B.S) | Mesh No. 100 and above (B.S) |
| River Mayo-wandu | 99.6% | 0.4% |
| River Kuburshosho | 99.3% | 0.6% |
| River Kwadzale | 99.21% | 0.79% |

The percentage weight of the samples as revealed by `table 3´ above are: River Mayo-wandu (99.6%), River Kuburshosho (99.3%), and River Kwadzale (99.21%). The silica sand samples have their percentage weights well above the international standard value for silica sand for glass production 80% weight, for 10-100 mesh, B.S. sieve number. Silica sand samples from these rivers can therefore be justified for glass making. This trend for each of the samples is presented in Fig.1

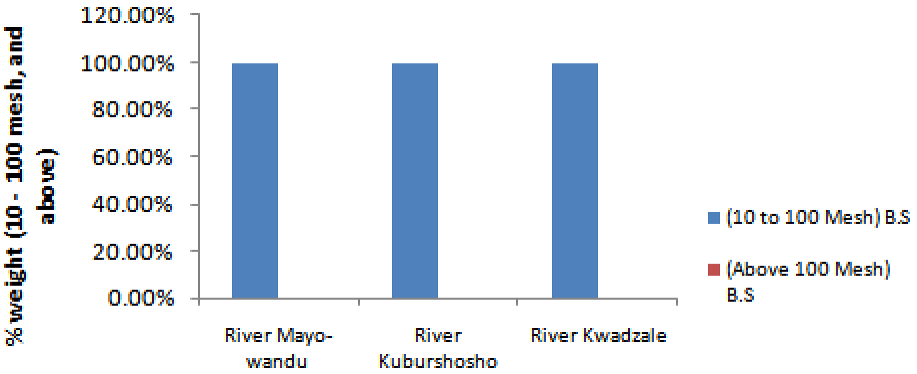


**Fig. 1: Percentage weight of silica sand samples from Mayo-wandu, Kuburshosho, and Kwadzale of michika, Adamawa state.**

**Grain Fitness Number (G.F.N.).**

The grain fitness number was obtained from the sample' sieve analysis test results. The Grain Fitness Number of the samples were calculated Using Equation 4; and the result presented in Figure 2.

$$\text{GFN} = \frac{\sum(\text{previous Mesh No.} * \text{\% Weight retained per sieve})}{\sum(\text{\% Weight retained per sample})} \qquad (4)$$

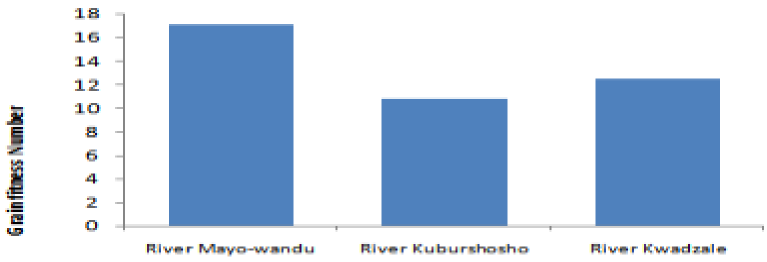


**Fig. 2: Grain fitness Number of the sand samples from River Mayo-wandu, Kubiushosho, and Kwadzale, Michika, Adamawa stste**

The GFN of the sand sample explains the average distribution of the sand grains on the screens, as whether the sample is too fine or too coarse for glass production. Since too fine sand sample will trap air bubbles, and coarse sample will possess solid inclusion during glass production, the GFN becomes a factor to be considered in glass production. All the samples lay within the standard GFN for glass production, whose value ranges between 10 – 50 which is averagely obtained on mesh number 10-100, B.S.

**Specific Gravity Results**

The specific gravity of the silica sand samples wascalculated and obtained using equation 2. Fig.3 represents the values of the specific gravity of the samples.

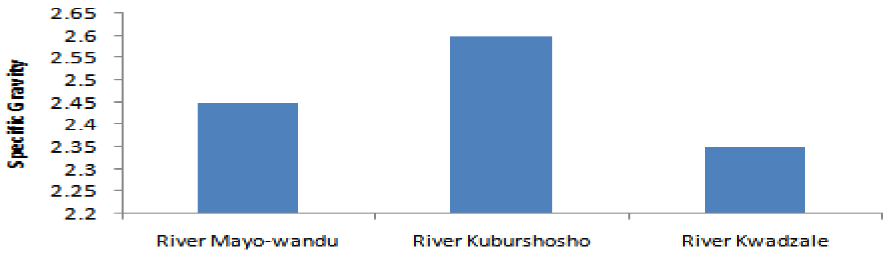


Fig.3: Specific Gravity results of the sand samples from River Mayo-wandu , Kuburshosho, and Kwadzale Respectively.

The Specific Gravity of the samples was obtained from the test and obtained using equation 2, and thus presented in Fig.3. the test revealed that samples from River: Mayo-wandu 2.45,Kuburshosho 2.60, and Kwadzale 2.35 are all below the standard specific gravity (2.65) required for glass production. As sand samples with specific gravity above 2.65 is said to possess heavy minerals which may require additional cost, of processingsample possessing heavy minerals can be minimized through any of the following methods: Washing, Floatation, Magnetic separation, Classification, Electrostatic separation and triboElectric separation (James et al, 2008).

**Grain Morphology/Grain Size Test Results.**

The Grain Morphology of the silica sand samples as obtained from the tests carried on each of the samples are presented in Table 4.

Table 4: Grain Morphology/Grain size Results.

| S/No. | River Mayo-wandu | River Kuburshosho | River Kwadzale |
|---|---|---|---|
| 1 | Angular | Angular | Angular |
| 2 | Angular | Angular | Angular |
| 3 | Angular | Angular | Angular |
| 4 | Angular | Angular | Angular |
| 5 | Angular | Angular | Angular |
| Average | Angular | Angular | Angular |

The Grain Morphology of silica sand samples from River Mayo-wandu, Kuburshosho, and Kwadzale are all angular in shape. Since the Grain Morphology of silica sand for glass production require silica sand that are angular in shape; silica sand sample from the three rivers are all suitable for glass production. Any silica sand that is not angular in shape may entrap air bubbles, causing interface crack due to larger voids between the sand samples at the course of glass production (Sintali et'al, 2007).

**Constituent Chemical Analysis Result.**
The Chemical Analysis results, revealed that the chemical composition (elements and compounds) of the sand sample's suitability for glass making are presented in Table 5(a), while table 5(b) indicates the standard chemical analysis requirement of sand for glass production.

**Table 5(a).: Constituent Chemical Analysis of Silica Sand of the samples from Michika, Adamawa State.**

| | **Mass in grams.** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Samples** | **$Al_2O_3$** | **$SiO_2$** | **$K_2O$** | **CaO** | **$TiO_2$** | **$Cr_2O_3$** | **MnO** | **$Fe_2O_3$** | **NiO** | **CuO** | **$As_2O_3$** |
| **River Mayo-wandu** | | 83.3 | 12.40 | | 0.28 | 0.10 | 0.14 | 2.58 | 0.008 | 0.072 | |
| **River Kuburshosho** | | 85.60 | 11.20 | | 0.38 | 0.10 | 0.040 | 1.57 | 0.009 | 0.070 | 0.003 |
| **River Kwadzale** | | 82,67 | 10.62 | | 0.35 | 0.12 | 0.05 | 2.28 | 0.01 | 0.06 | 0.002 |

**Table 5(a) (Continue) ……..**

| | **Mass in grams.** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Samples** | **$Rb_2O$** | **SrO** | **$Y_2O_3$** | **$ZrO_2$** | **$RuO_2$** | **BaO** | **$CeO_2$** | **$OsO_4$** | **Au** | **PbO** | **$V_2O_5$** |
| **River Mayo-wandu** | 0.066 | 0.54 | 0.023 | 0.037 | 0.436 | 0.46 | 0.02 | | 0.03 | | |
| **River Kuburshosho** | 0.058 | 0.045 | 0.023 | 0.059 | 0.433 | 0.31 | | | 0.02 7 | 0.04 | |
| **River Kwadzale** | 0.065 | 0.078 | 0.046 | 0.0041 | 0.452 | 0.086 | 0.02 | | | 0.042 | |

**Table 5(b): Certificate of Analysis: BCS-CRM No. 516 Standard Glass Sand 10.**

| **Element** | **$SiO_2$** | **$Al_2O_3$** | **$TiO_2$** | **$Fe_2O_3$** | **$Mn_3O_4$** | **CaO** | **MgO** |
|---|---|---|---|---|---|---|---|
| **%weight** | 98.73 | 0.513 | 0.172 | 0.0596 | 0.0012 | 0.0243 | 0.0387 |

**Table 5(b) (Continue)…………………**

| **Element** | **$Na_2O$** | **$K_2O$** | **BaO** | **PbO** | **$Cr_2O_3$** | **LOI** |
|---|---|---|---|---|---|---|
| **% weight** | 0.0195 | 0.127 | 0.0040 | 0.0127 | 0.0081 | 0.24 |

The percentage of Iron III Oxide ($Fe_2O_3$) content of the sample is one of the most important chemical compounds which determine the suitability of a sample for glass production. As revealed by the Energy Dispersive X-ray Florescence Spectrometer (E D X-RFs) test results in Table 5(a), the Iron III Oxide ($Fe_2O_3$) of samples from River: Mayo-wandu (2.58grams. = 0.0258%), River Kuburshosho, (1.57gram = 0.0157%) while River Kwadzale contains ( 2.28grams = 0,0228%). Table 5(b) is a standard requirement of sand for glass production, with maximum $Fe_2O_3$ requirement for Colorless glass production 0.0596%(Meeres et al, 2007). Looking at the $Fe_2O_3$ contents of the samples on table 5(a), it is clear that all samples are within the standard requirement for glass production. The color of the glass can be altered by careful enrichment of the sand sample with $Fe_2O_3$ depending on the type of glass product desired.

**Loss on Ignition Results**
The Loss on Ignition results revealed the amount of chemically and physically bonded water present in each of the silica sand samples as calculated using equation 1. Fig.4. Shows the test results chart for the Loss on Ignition.

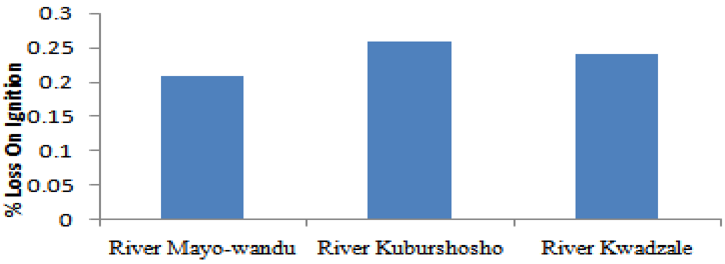


**fig.4: Loss on ignition chart for silica sand samples from river Mayo-wandu, Kuburshosho, and Kwadzale.**

The percentage Loss on Ignition results on Fig.4 for the sand samples from River: Mayo-wandu (0.21), Kuburshosho (0.26%), and Kwadzale (0.24%). This means, that sand sample from river Kuburshosho will lose 0.26% of its total weight when fired in a kiln during glass production. This indicates that there will be less or negligible loss on Ignition from the samples during glass production.

## IV. CONCLUSION

From analysis conducted on the three sand samples obtained from Michika Local Government of Adamawa state, sand samples from the rivers: Mayo-wandu,Kuburshosho, and Kwadzale are ranked; in terms of their suitability or non-suitability for glass production as summarized in Table 6.

**Table 6: Ranking of silica sand sample suitability for glass Production.**

| Silica Sand Samples | Suitability properties for Glass Production | Types of Glass product | Remark |
|---|---|---|---|
| River Mayo-wandu | Grain Fitness Number (17.01), Iron III Oxide (2.58), L.O.I. (0.21), Specific Gravity (2.50), and Grain Morphology (Angular). Percentage weight (99.6%) | Window glass, Dark and light green bottle glass | Very Good |
| River Kuburshosho | Grain Fitness Number (10.81), Percentage weight (99.3%), Iron III Oxide (1.57), L.O.I. (0.26), have Specific Gravity (2.60), and Grain Morphology (Angular). | Window glass | Excellent |
| River Kwadzale | Grain Fitness Number (12.45), Percentage weight (99.21%), Iron III Oxide (2.28), L.O.I. (0.24), have Specific Gravity (2.35), and Grain Morphology (Angular) | Window glass | Excellent |

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