PETROLOGY AND INDUSTRIAL POTENTIAL OF ALLUVIAL SAND DEPOSIT IN THE NANDO AND IYIOWA AREAS OF ANAMBRA STATE, SOUTHEASTERN NIGERIA

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ABSTRACT

Petrological evaluation of alluvial sand deposit in the Nando and Iyiowa areas of Anambra State, Southeastern Nigerian was carried out to determine the suitability for the manufacture of glass wares and solar panel. Forty samples (40) were collected from four localities in the study area and subjected to sieve analysis and X-Ray Fluorescence (XRF) spectrometry. Result of the textural analysis shows that the sand is medium to coarse grained, moderately well sorted, negatively to positively skewed and platykurtic to leptokurtic. These parameters are consistent with the size requirements for the manufacture of glass wares. Result of X-Ray Fluorescence (XRF) Spectrometry revealed that silicon dioxide (SiO_2) averages over 93.311%, with alumina Al_2O_3 averaging 2.17%. Oxides of potassium, sodium, calcium, magnesium, iron and titanium occur in subordinate amounts. The trace elemental oxide concentrations are as follows: V_2O_5 (0.01%); Cr_2O_3 (0.02%); NiO (0.01); MnO (0.01%); SrO (0.04%); BaO (0.09%); and CuO (0.02%). These results, when compared with the British standard for the manufacture of glass wares and solar panel, show that the sands are unsuitable for such industrial applications. However, with beneficiation (reduction of iron oxide and other impurities) the sands can be employed as raw material for the manufacture of glass wares and perhaps solar panel.

Keywords: Alluvial sand, grain size, XRF analysis, silicon dioxide, glass wares

1. INTRODUCTION

The surface geology of the Nando and Iyiowa areas of Anambra State is dominated by alluvial sand deposits of the Niger and Anambra Rivers respectively. The exploitation of these sand deposits has not attained the desired level possibly because of inadequate geological information and environmental challenges related to the optimal exploitation and utilization. Sand is a major source of commercial silica. Silica sand is a very stable mineral consisting of a very high percentage of quartz (SiO_2) usually more than 95% with minor impurities that are commonly clay minerals (kaolinite, illite), iron and titaniferous minerals and other heavy minerals (Pettijohn, 1987). It constitutes one of the most readily available geological materials used in glass manufacturing, foundry and chemical industries. Silica sand yields pure silicon widely used in the manufacture of solar panels for generation of solar energy (Platias, 2014). Silica sand is produced and consumed in many countries of world with USA being the highest producer followed by Italy, France and Germany (Marius, 2017). Singapore is currently the highest consumer followed by Canada and Belgium-Luxembourg (Marius, 2017). With the recent advent of solar as alternative source of cleaner, renewable and sustainable energy, it has become imperative for Anambra State and in deed Nigeria as whole, to key into the solar revolution by developing, exploiting, processing and utilizing our abundant silica sand resource. This study therefore aims at detailed textural and chemical characterization of the rich alluvial sand deposits in the Nando and Iyiowa areas of Anambra State in order to determine the suitability of the sand deposits for the manufacture of solar panels and glass wares.

2. Geomorphological setting

The study area is located in Anambra State of southeastern Nigeria between latitudes 6^0 05^1 N and $6^{\ 0}$ 25^1N and longitudes 06^0 45^1 E and 7^0 00^1E (Fig. 1). It extends from Iyiowa and Onitsha in the southeast to Otuocha and Nando in the north. Figure 2 shows that there are two major ridges that dominate the area. The upper one runs from Ifite-Ukpo to Otucha where it tapers into the alluvial plain sediments of Anambra River. It trends in NW-SE direction with a strike of about 315^0 and attains a maximum height of 600m in the vicinity of Ifite-Ukpo. The ridge is truncated by a river that flows in southwesterly direction between Aguleri and Nteje.

The Lower one passes through Abatete – Onitsha areas and flattens out into alluvial plain deposits of River Niger. The ridge trends roughly in E-W direction with a strike of about 280^0 and attains a maximum elevation of 700m around Umuoji. Both ridges are aligned sub-parallel to the present Nigerian coastline and may mark successive limits of the withdrawal of the sea from the Nigerian coastline during the Paleogene (Obi et al., 2001).

The area is drained by Niger-Anambra-Ezu Rivers Drainage Basin Complex (Fig. 2). The Anambra River rises from the northwest flowing through the northwestern low plains where it meanders heavily developing abandoned meandering channels. The major tributary of the Anambra River in the study area is the Oyi River. Nkisi and Idemili Rivers which flow in a southwesterly direction into the River Niger (Fig. 2). There is a number of east-flowing, dendritic streams that drains the flanks of the upper ridge around Nteje and Abube-Nando. These streams ultimately empties its load into the Anambra River through the Ezu River (Figs. 2) at the northern part of the study area.

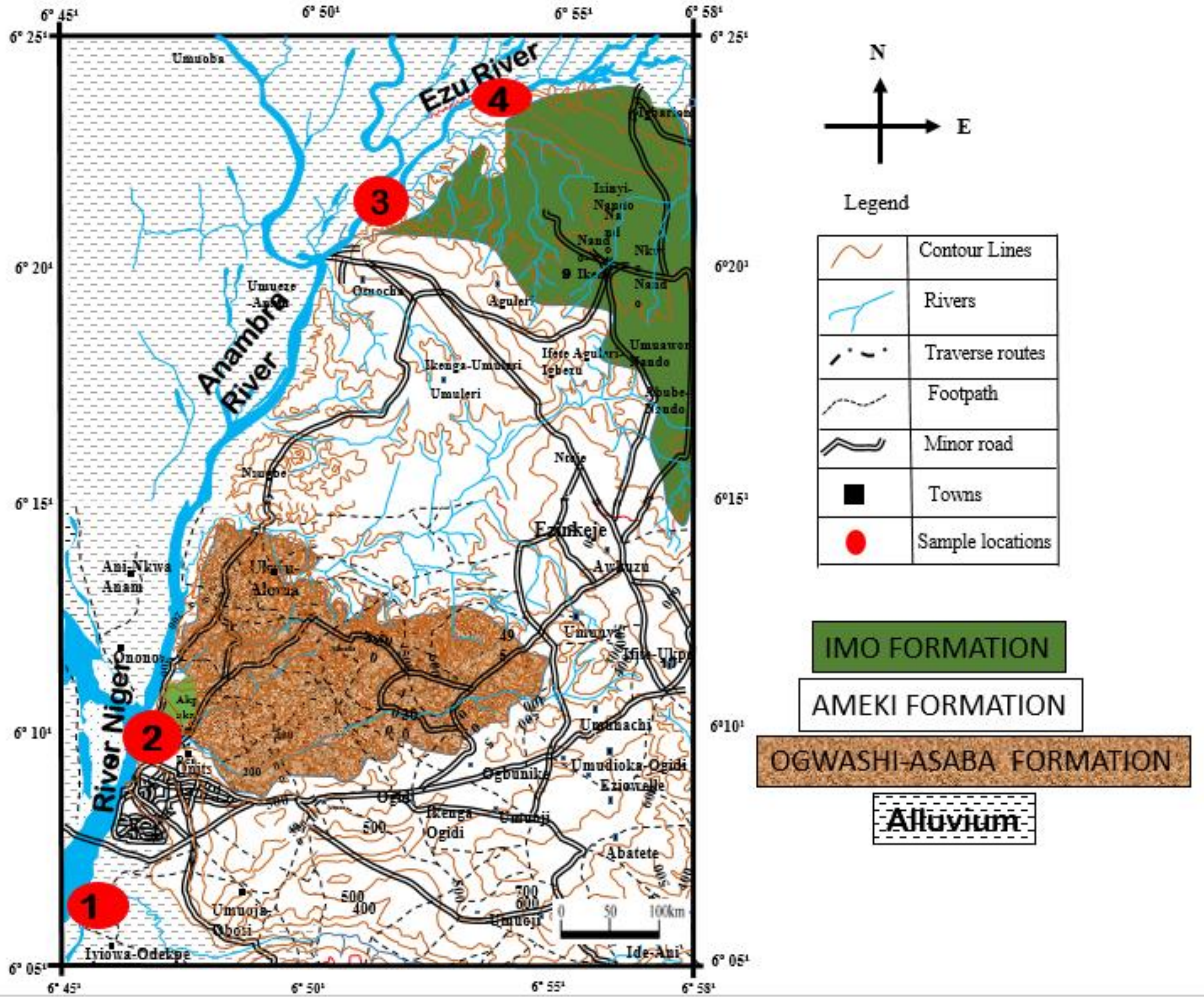

Fig. 1: Geological map of the study area showing sample locations and aerial distribution of the major lithostratigraphic units.

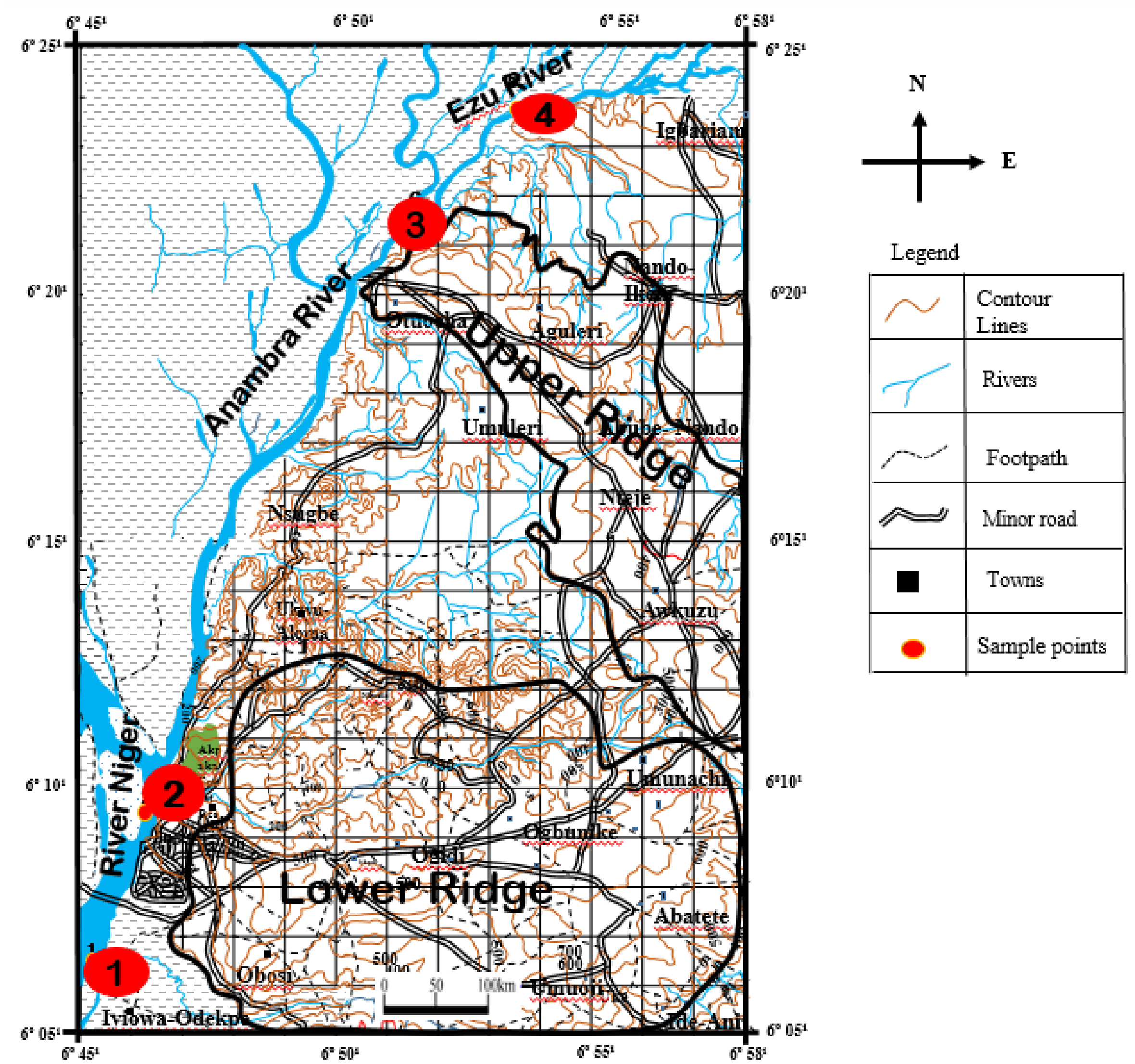

Fig. 2: Geomorphological map of the study showing topographic and drainage features.

3. Literature Review

Sand is used in a great variety of products and the term 'quartz sand' is used as essential raw material for the glass and foundry casting industries, as well as in other industries such as ceramics, solar, chemical manufacture and for water filtration purposes (Platias et al., 2014). Silica sand has also been used in reference to quartz sand of which both terms refer to a very stable mineral consisting of very high percentage of quartz (SiO_2) usually more than 95% with minor impurities that are commonly clay minerals (kaolinite, illite), iron and titaniferous minerals and other heavy minerals (Pettijohn et al., 1987). Silica sand is defined as a high purity industrial mineral in which the sand grains are made entirely of quartz (Ketner, 1973). According to Shaffer (2006), silica sand is the final product of rock weathering which is an important part of the rock cycle. Silica sand deposits are usually mature or super-mature. Super mature sands often contain more than 95% quartz with some natural deposits containing 98% quartz (Platias et al., 2014). These high purity sands are termed 'silica sand'.

They have a wide range of industrial applications particularly in solar and glass manufacture. Its suitability for the different industrial applications is determined by the grain size distribution, chemical composition, colour and durability. Silica sand must conform to a closely specified standard for it to be considered as essential raw material for different industrial applications. The specifications applicable in glass and solar industries have been recommended by the British standard BS2975 (Tab. 1). Aluminum, magnesium, calcium and potassium levels that affect the melting properties have to be kept at low levels. Grain size and grading is another very important aspect by the glass manufacturers. Finer grains are more likely to carry iron oxide and refractory minerals grains, while larger grains will melt slower than the smaller grains and will remain un-melted leading to poor finishing. A typical grading of silica sands for optical glass is between 0.25mm and 0.325mm (i.e. fine to medium) of grain size (Fig. 2.).

Table 1: British Standard recommended limits for the composition of silica sand for seven different grades of glass (Platias et al, 2014)

Grade	Product	SiO_2%	Fe_2O_3%	Al_2O_3%	Cr_2O_3%
A	Optical glass	99.7	0.013	0.2	0.00015
B	Tableware glass	99.6	0.01	0.2	0.0002
C	Borosilicate glass	99.6	0.01	0.2	0.0002
D	Colourless container	98.8	0.03	0.1	0.0005
E	Flat glass	99.0	0.1	0.5	-
F	Coloured container	97.0	0.25	0.1	-
G	Insulating fibres	94.5	0.3	3.0	-

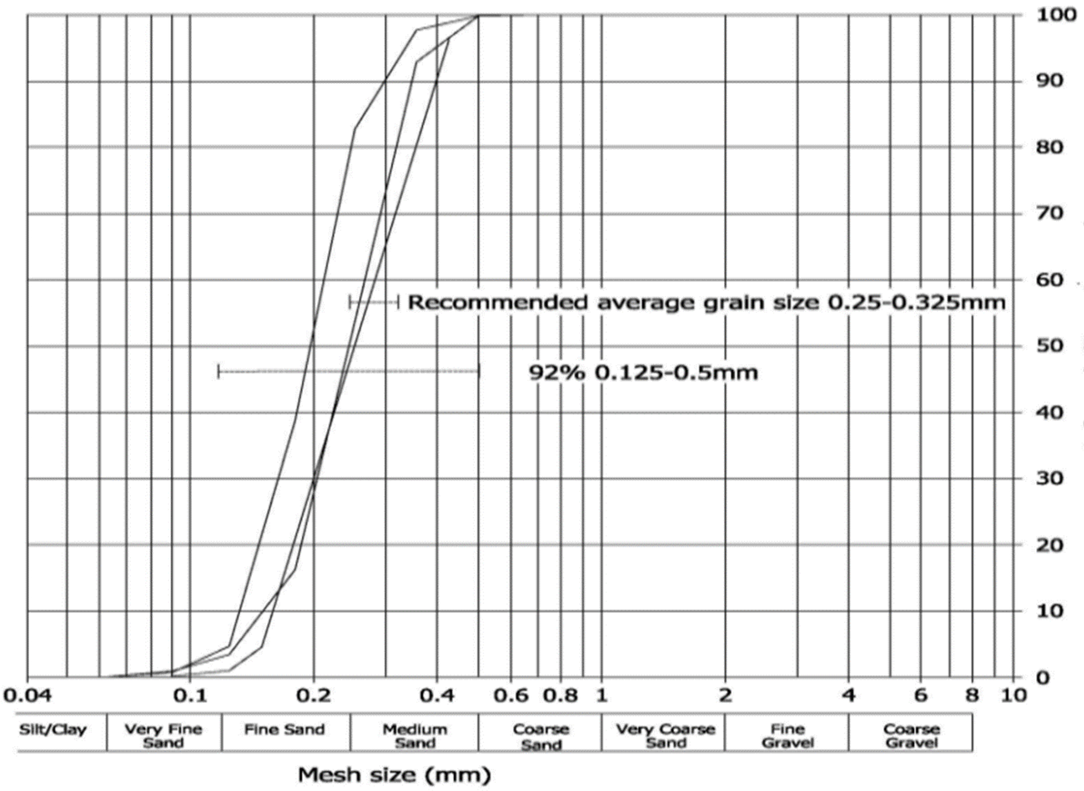

Fig. 3: Typical grading curves for processed glass silica sand (Platias et al., 2014).

Specification of silica sand for solar panels: Solar panels consist of solar cells, sometimes referred to as photovoltaic cells (Xakalashe and Tangstad, 2011). The panels convert solar energy into electricity. Solar cells produce renewable energy that is durable, portable with low maintenance. The most common material for the production of solar cells is silicon (either in mono- or polycrystalline form). The solar industry places its stringent standard on high purity silica with boron and phosphorus content in the sub-ppm range since these elements cannot be removed easily (Xakalashe and Tangstad, 2011). Table 2 presents recommended limits of elements for solar silicon used in the photovoltaic industry.

Table 2: Typical chemical analysis of silicon products for the photovoltaic industry (Xakalashe and Tangstad, 2011).				
Element	Metallurgical grade silicon (ppm)	Solar grade silicon (ppm)	Polycrystalline solar grade silicon (ppm)	Electronic grade silicon (ppm)
Si	99	99.9999	99.99999	99.999999999
Fe	2000-3000	<0.3	-	<0.1
Al	1500-4000	<0.1	-	<0.0008
Ca	500-600	<0.1	-	<0.003
B	40-600	<0.3	-	<0.0002
P	20-50	<0.1	-	<0.0008
C	600	<3	-	<0.5
O	3000	<10	-	-
Ti	160-200	<0.01	-	<0.003
Cr	50-200	<0.1	-	-

4. Methodology

The method of investigation employed for this research work involved field work and laboratory analyses. Forty samples (40) were collected from four localities in the study area. These samples were grouped into four and subjected to sieve analysis and X-Ray Fluorescence (XRF) spectrometry.

The grain size analysis were conducted at the Sedimentology Laboratory of the Geology Department, Chukwuemeka Odumegwu Ojukwu University. About 100g of the properly disaggregated sample were split into two parts using the Jones sample splitter. The 50-gram split of the sample is sieved or vibrated for 15 minutes in a Ro-tap/automatic sieve shaker using a set of U.S standard sieve at 1/2 phi sieve interval to provide maximum accuracy of the results as suggested by Folk (1980). The data obtained were represented graphically using the Ogive. From the cumulative plots, the critical percentiles (ϕ_{5}, ϕ_{16}, ϕ_{25}, ϕ_{50}, ϕ_{75}, ϕ_{84}, ϕ_{95}) were obtained and used to compute the mean size (M_z), standard deviation (σ_I), skewness (Ski), and kurtosis (K_G) using the formulae of Folk and Ward (1957).

The major elemental concentrations of the sand samples were determined with X-ray fluorescence (XRF) spectrometry. Each sample was oven-dried at 100 ºC for 12 h to remove the adsorbed water and then crushed with a mortar and pestle to a fine powder. About 5.0g of dry rock sample powder was weighed in a silica crucible and then ignited in the furnace at 1000^0c for 2 to 3 hours for the calcinations of impurities in the rock powder. The samples were then removed from the furnace and allowed to cool to room temperature in desiccators. Each ignited rock powder was then weighed again to determine the weight of the calcinated impurities which were H_2O, H_2O^+ and CO_2. 1.0g of the stored ignited rock powder was weighed and exactly 5 times of flux (X-ray Flux-Type 66:34% (66.0% Lithium Tetraborate: 34% Lithium metaborate) was added to lower the vitrification temperature of the rock powder. The weighed mixture was mixed properly in a platform dish and ignited in the pre-set furnace (Eggon 2 Automatic fuse bead maker) at 1500^0c for 10 minutes to form glass bead. Each glass bead was labelled and slotted into the computerized XRF (Epilson 5 Panalytical model) for major elemental analysis.

5. Results and Discussion

Grain size analysis: Table 3 shows that all the samples are generally medium-grained, moderately well sorted. The mean sizes of grains are thus consistent with the size requirement for use in the manufacture of glass wares as shown in Figure 3 except for E4 that is coarse grained (Table 3). According to Edem et al., (2014), coarser grains during glass making are easily screened as they do not form homogeneous mixture thereby leading to poor finishing.

Table 3: Summarised result of grain size analysis

Sample code	Sample location	Mean Size (M_z)	Sorting (δ_1)	Skewness (SK_1)	Kurtosis (K_G)
E1	Iyiowa	1.09	0.89	-0.35	1.12
		Medium sand	Moderately sorted	Symmetrical	Leptokurtic
E2	Onitsha	1.88	0.46	0.82	0.77
		Medium sand	Well sorted	Very positively skewed	Platikurtic
E3	Otucha	1.01	0.64	-0.19	0.86
		Medium sand	Moderately sorted	Negatively skewed	Platikurtic
E4	Nando	0.59	0.99	0.08	1.23
		Coarse sand	Moderately sorted	Symmetrical	Leptokurtic

X-ray fluorescence analysis: The chemical composition of the alluvial sand deposits as determined by X-Ray Fluorescence (XRF) spectrometry, is displayed in Table 4. Samples from all the locations (E1 = 93.99%; E2 = 90.68%; E3 = 93.63% and E4 = 94.12%) do not meet the required silica (SiO_2) content standard for the different grades of glass. Similarly none of the samples met the required specification for Fe_2O_3, Al_2O_3, and Cr_2O_3, even though the MgO compositions of all the samples fall within the permissible limits recommended for all the grades (except for E2 = 0.18 which does not satisfy grade A).

Figure 5 is a comparison of essential chemical properties of analyzed sand samples against specific industrial standard. The solar industry places its stringer specification on high purity quartz (99.9999%). Based on the British recommended limits of SiO_2 (99.9999), Fe_2O_3 (< 0.3), and Al_2O_3 (< 0.1), it is evident that the alluvial sands analyzed in this study are all unsuitable, without beneficiation, for use in the manufacture of solar panels.

Table 4: Result of X-Ray Fluorescence spectrometry showing major element concentration in weight %

% Oxide concentration /sample location	E1 Iyiowa	E2 Onitsha	E3 Otucha	E4 Nando	Average
SiO_2	93.99	90.68	93.63	94.12	93.11
TiO_2	0.07	0.38	0.07	0.10	0.16
Al_2O_3	1.53	3.25	2.40	1.49	2.17
Fe_2O_3	0.99	0.66	1.03	0.72	0.85
SO_3	ND	ND	ND	ND	ND
MgO	0.08	0.18	0.07	0.02	0.09
Na_2O	0.77	1.37	0.73	0.91	0.95
V_2O_5	ND	ND	ND	ND	0.02
CaO	0.19	0.63	0.11	0.09	0.26
Cr_2O_3	0.02	0.02	0.03	0.02	0.02
NiO	0.01	ND	0.01	0.01	0.01
K_2O	1.54	2.05	1.35	1.98	1.73
MnO	ND	0.02	0.01	ND	0.01
Cl	ND	ND	ND	ND	ND
SrO	0.04	0.06	0.03	0.04	0.04
BaO	0.09	0.09	0.09	0.09	0.09
CuO	0.02	0.02	0.02	0.02	0.02
L.O.I	0.70	0.59	0.20	0.39	0.47

ND = Not detected

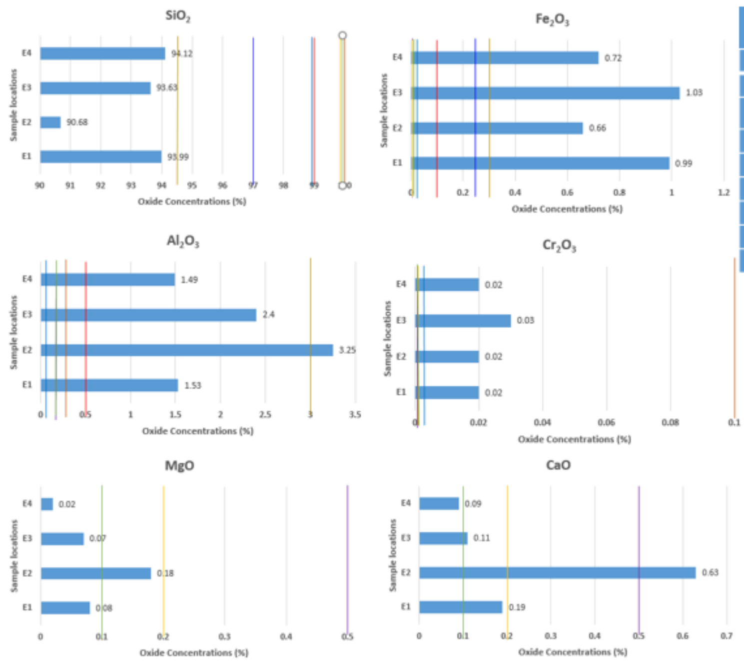

Table 1: British standard specification for the manufacture of glass and solar panel (modified after Platias et al, 2014).

Grades (BS2975:1988)		SiO_2	Fe_2O_3	Al_2O_3	Cr_2O_3	MgO	CaO
Optical and ophthalmic	A	99.7	0.013	0.2	0.00015	0.1	0.1
Tableware and lead crystal glass	B	99.6	0.01	0.2	0.0002	0.2	0.2
Borosilicate glass	C	99.6	0.01	0.2	0.0002	0.5	0.5
Colorless glass	D	98.8	0.03	0.1	0.0005	0.5	0.5
Clear flat glass	E	99.0	0.1	0.5		0.5	0.5
Colored glass	F	97.0	0.25	0.1		0.5	0.5
Insulating fibres	G	94.5	0.3	3.0		0.5	0.5
Solar		100	0.1	0.3	0.1	0.1	0.1

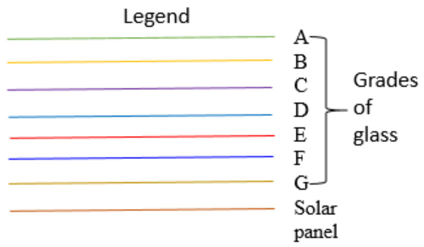

Fig. 5: Comparative chart of essential chemical properties of the analyzed sand samples against British standard for the manufacture of glass and solar panel.

6. Conclusion

Textural analysis has revealed that the alluvial sand deposits in the Nando and Iyiowa areas of Anambra State have characteristics suitable for use as raw material for the manufacture of various grades of glass wares. Chemical analysis, however, reveal that the samples contain only about 94% silica as well as uncomfortable amounts of the oxides of iron (Fe_2O_3), aluminum (Al_2O_3,) and chromium (Cr_2O_3). The sand deposits are therefore unsuitable in their natural state, for use in the manufacture of glass wares and the solar panel. Appropriate beneficiation processes can however, improve the SiO_2 content by reducing the impurities to render the sands suitable for the manufacture glass and perhaps solar panel.

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