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Physical and Geochemical Investigation of Cross River Sand at Ozizza, Ndibe, Kpoghirikpo and Unwana, Afikpo-North Ebonyi State, South-East Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

High strength, high hardness and very tough engineering material derived from geologically occurring minerals and processed into a tool that rubs or wears off by friction is regarded as an abrasive. Abrasives are produced in different forms and shapes and they afford good opportunities for precision scraping away or machining. In this empirical paper, effort is made in establishing a case for the production of abrasive tools that are formulated with silicon carbide and aluminium oxide as catalytic raw materials. These are locally found in the researchers' locality a place that

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has many geological deposits of solid minerals. At each of Ozizza, Ndibe, Kpoghirikpo and Unwana beaches, eleven samples of sand were collected at random locations from the Cross River that is flowing through Ozizza down to Unwana for physical and geochemical investigation to determine its suitability for abrasive making. Sand at the four locations were subjected to physical and geochemical investigation. Generally, the sand was physically characterized by bright colours of white, brown and yellow. Some samples at some locations contained dark specks of organic matter. From the distribution, the sand is generally of medium grade size as shown by the Scanning Electron Microscopy (SEM). Geochemically by X-ray fluorescence (XRF) analysis, the oxide contents are: SiO_2 (91.73%), CaO (0.045%), Al_2O_3 (4.24%), Fe_2O_3 (1.36%), TiO_2 (0.21%), K_2O (0.86%). The silica content (91.73%) of the sand is well above the industrial specification of 80% for sanitary ware making and suitable for the silica brick industry, for road dressing mixed with special asphalt. The physical and geochemical property results indicate that the sand is a good material for direct use in abrasive (sand paper and sand blasting).making, glass making and in the building and construction industries.

Keywords: River sand; physical properties; geochemical properties; abrasive.

1. INTRODUCTION

The much believed high quality naturally-occurring minerals can be processed into excellent raw materials for the making of high precision abrasives. But these abundant raw materials have remained grossly untapped. In line with the present political dispensations, attempts at diversifying the economy through the organised government and private sectors' participation in the extraction and processing of mineral resources, are already being made. It becomes necessary to focus on the use of local raw materials as this would impact largely on engineering technology and fabrication by creating functional products that can augment the increasing needs for imported finished goods like abrasives. Abrasives are high-strength, high hardness and very gritty surfaced materials which can be used to machine other materials of low strength and low hardness [1]. The removal of surfaces of another material through frictional rubbing, creates shapes and configurations that can be used as tools or components for agriculture or machine production. Abrasives could provide roughening and/or smoothening outlook depending on the nature and size of grits of teeth used. They are used in grinding, polishing, honing, broaching, cutting, drilling, sharpening, sanding and pressure blasting. Most of these operations are basic in the field of mechanical engineering and technology [2]. Odior and Oyawale [3] recorded that two types of abrasives are known: viz: naturally occurring abrasives and artificially occurring abrasives. The naturally occurring abrasives that are believed to be found in abundant quantities in Unwana-Nigeria include: Calcite, pure and impure Corundum, Diamond dust, Novaculite, Pumice, Sandstone, Garnet, Feldspr, Staurolite, Zirconia alumina. According to [4], the artificially occurring abrasives such as: Cubic Baron Nitride, Ceramic aluminium oxide, Ceramic Iron oxide, Aluminium oxide (Corundum), Glass powder, Steel abrasives, Silicon abrasives, Silicon carbide (Carborundum), Zirconia alumina, Baron carbide exists in Nigeria. These materials are, in the authors' opinion, available in large supplies but remain grossly untapped and managed. This is why this research focused on determining the suitability of the sand in the study area.

Sand generally is a sedimentary material ranging in size from 2.00 mm to (0.0625 mm), finer than gravel and coarser than slit and clay. It consists of small grains or particles of mineral and rock fragments. Sand grains as classified may be produced naturally from rocks (igneous, sedimentary and metamorphic) by mechanical, chemical and biological processes [5,6,7,8,9]. The grains may be of any mineral composition but the dominant component of natural sand is the mineral quartz, which is composed of silica (silicon IV, SiO_2),. Sand with particularly high silica levels that is used for glass or abrasive making and not for construction purposes is referred to as silica sand or industrial sand produced from unconsolidated sands and crushed sandstone rocks. The other mineral components of sands are feldspar, chromium, titanium, magnetite, and the carbonates. Sand can also be derived from other artificial or synthetic rocks such as slag, by crushing and used as fine aggregates. Sand derived from synthetic rocks has a mineral composition similar to that of cement clinkers composed majorly of silicate minerals like alite and belite; and the iron-rich ferrites [10,11,12]. Sand has found uses as

aggregates in the construction, building and transport industries, foundries, glassmaking, ceramics, water filtration, fluidized-bed furnaces, chemical manufacture, plastics, abrasives, cement and blasting industries based on either chemical purity or physical properties [13,9]. Sand in the Niger Delta of Nigeria, abundantly occurring along river or stream beds, on beaches and on land at shallow depths are, not investigated before use mostly in bulk rock form in the building and construction industries resulting sometimes in structural failure. In Nigeria, there is a continuous need of sand for the production of different types of glass, sanitary ware, construction and other industrial products which are in increasing demand. These should be readily made available at affordable cost to Nigerians with abundant availability of suitable sand [14]. This work therefore investigated the physical and geochemical properties of the Cross River sand at Ozizza, Ndibe, Kpoghirikpo and Unwana, the study areas, in order to deduce its potentials for use in the abrasive and glassmaking, building, construction and allied industries.

Despite the abundance of abrasive and bonding materials, they remain very much untapped especially within the researchers' community where they can be processed to produce finished abrasive tools needed for fabrications.

1.1 The Studied Area

The study area comprising of Ozizza, Ndibe, Kpoghirikpo and Unwana, south-eastern Nigeria, falls within the South Eastern Region. The area is located at latitude 50 781 N and longitude 70 931 E of the Greenwich meridian, and altitude 354 feet (107m), lat.(DMS) 5' 46', long. (DMS) 7' 55' 60 E [15]. The area has a flat terrain. It is accessible directly by road off the Okigwe-Abakaliki road and water through the Cross River, a distributary of the Niger River. The Cross River, flows by Ozizza, Ndibe, Kpoghirikpo and Unwana villages of Afikpo Local Government Area. The area is located within the Tropics and experiences a high humidity which is lessened by an accompanying but increasingly shorter dry season. The longer rainy season, which occurs from the months of April to October is heaviest in the month of July and sometimes in September. The break in rainfall in August is often referred to as the August break. The dry season from about November to March, is characterized by a good amount of sunshine, with a mean daily temperatures of 30°C and maximum temperature of about 40°C. A cold spell particularly during December to January, called the harmattan coincides with the dry season. [16] indicated the following as the characteristics of these beach sand: they have ivory colour, are medium coarse in size (based on the 30 mesh sieve), have specific gravity of 2.0, a loss-on-ignition value of 1.5 while their chemical analysis show they are made up of the following elements: silicon (IV) oxide (SiO_2), Aluminium (III) oxide (Al_2O_3), Iron (III) oxide (Fe_2O_3), Calcium oxide (CaO), Magnesium oxide (MgO), Manganese (II) oxide (MnO), Potassium oxide (K_2O), Sodium oxide (Na_2O) and Sulphur trioxide (SO_3). Sand in the study area is never exhausted as it is being always brought and deposited annually, by the high volume rivers and streams during the flood from September to early few days of November. The thickness and volume of sand available in the streams cannot be exactly quoted but can be estimated to be trillions of tons.

2. MATERIALS AND METHODS

2.1 Field Method Sampling

Eleven samples from sand dumps in the study areas that had been dredged from the Cross River bed and from the sides of the River were collected. One kilogram (1 kg) each of eleven spot samples, (at half a kilometre intervals) were carefully collected with a shovel and a trowel into polythene samples bags after the macroscopic observations (colour, texture, hand feel and eye sizing) had been made. The quartering method of disturbed sample collection was used in order to get representative samples. The sample bags were taped and labelled accordingly and taken for laboratory analysis.

2.2 Laboratory Analysis

The laboratory analysis is in accordance with British Standard (BS 2975: 1958/1988) and Glass Making Raw Materials, Sand Reference: 48/340, 1974 standard specifications for the Glass Manufacturers' Association, included physical determination of moisture content, and Geochemical analysis using the X-ray Fluorescence spectrometry (XRF) analysis method [17].

3. RESULTS AND DISCUSSION

The results of the physical analysis of the sand are shown on Table 1(Moisture content), Table 2 (Geochemical analysis).

3.1 Colour, Texture and Shape

From the field macroscopic observation of the sand, the colour is characterized by white, brown and yellow with specks of organic matter in some places. The sand is medium sized and the grains are majorly sub-angular and rounded. Based on colour and texture the sand is suitable for use in the coloured glassmaking, building and construction industries.

3.2 Moisture Content

The results of the moisture content of all randomly collected sand samples and that of the mean for the Cross River sand at the four different locations are presented on Table 1.

From Table 1, the moisture content results of all sand samples mixed together, range between 0.4% (minimum) and 6.2% (maximum) and mean values of 3.24%, 3.12%, 2.77% and 2.95% for sand samples at the four locations. Except for samples I and K of Kpoghirikpo and Unwana with moisture contents of 5.8% and 6.2%, all other sample values fall within sand standard industrial use (SSIU) specifications. The mean values between 2.77% and 3.24% indicate that the 5.8% and 6.2% isolated values, are overshadowed by the general results and would not have an adverse effect on application of the sand for glass and abrasive making. The sand is therefore suitable for use particularly in the building, construction, abrasive and glassmaking industries based on moisture content (BS 2975: V 1988, Glass Making Raw Materials: Sand, Reference: 48/340, 1974), judging with [17].

3.3 Geochemical Analysis

The geochemical analysis result (element and elemental oxide composition) of all samples of the Cross River sand at the four locations and that of the mean of eleven (11) samples from each location, by X-ray Fluorescence Spectroscopy (XRF) in per cent (%) are presented on Tables 2-10. Images of sand samples are shown in Figs.1, 3, 5 and 7(a and b).

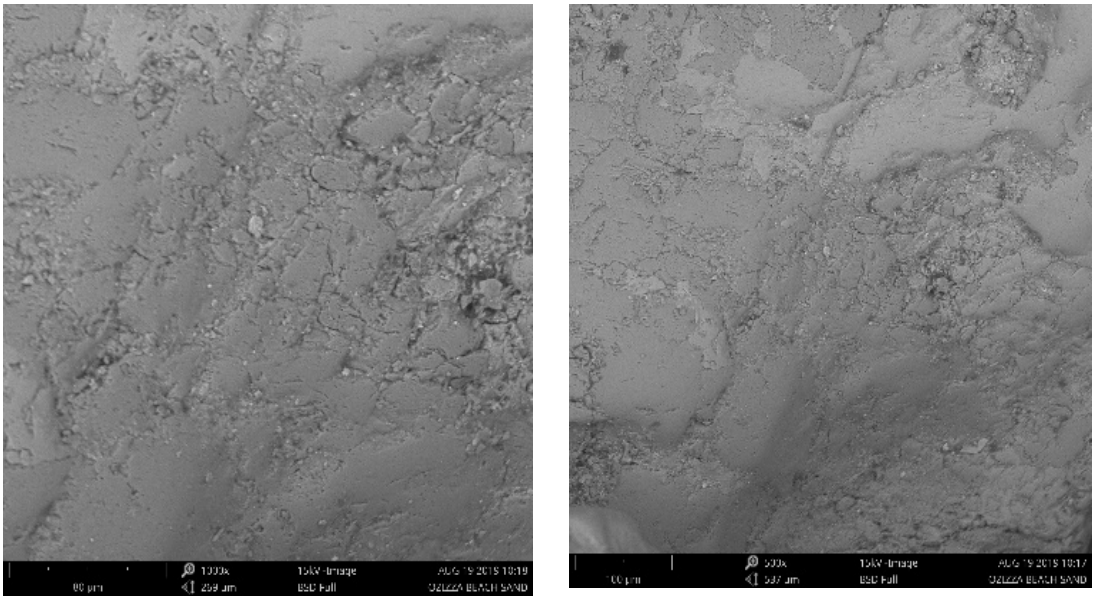
Table 1. Moisture content and the mean for the Cross River sand at Ozizza, Ndibe, Kpoghirikpo and Unwana in per centage (%)

Ozizza		Ndibe		Kpoghirikpo		Unwana	
Sample no.	**Moisture content (%)**	**Sample no.**	**Moisture content (%)**	**Sample no.**	**Moisture content (%)**	**Sample no.**	**Moisture content (%)**
A	3.5	A	2.5	A	2.6	A	2.8
B	3.6	B	4.0	B	1.1	B	1.2
C	3.1	C	4.2	C	1.2	C	1.3
D	4.1	D	3.3	D	3.1	D	3.2
E	2.5	E	2.6	E	2.5	E	2.8
F	3.9	F	4.2	F	4.1	F	4.2
G	1.9	G	1.4	G	1.2	G	1.2
H	2.1	H	0.5	H	0.4	H	0.5
I	3.1	I	3.2	I	5.8	I	4.3
J	3.7	J	4.5	J	4.4	J	4.5
K	4.1	K	3.9	K	4.1	K	6.2
Mean	**3.24**	**Mean**	**3.12**	**Mean**	**2.77**	**Mean**	**2.95**

Table 2. Element composition at Ozizza location

Element name	Element symbol	Element Number	Atomic Conc. (%)	Weight Conc. (%)
Silicon	Si	14	61.28	57.56
Aluminium	Al	13	20.79	18.76
Potassium	K	19	6.16	8.06
Iron	Fe	26	2.63	4.92
Sodium	Na	11	5.17	3.97
Zirconium	Zr	40	1.19	3.64
Magnesium	Mg	12	1.53	1.24
Titanium	Ti	22	0.66	1.05
Calcium	Ca	20	0.58	0.78

A. Ozizza



A **b**

Fig. 1. 269µm:1000X and 537µm:500X (a & b) SEM images of all eleven mixed samples of Ozizza sand

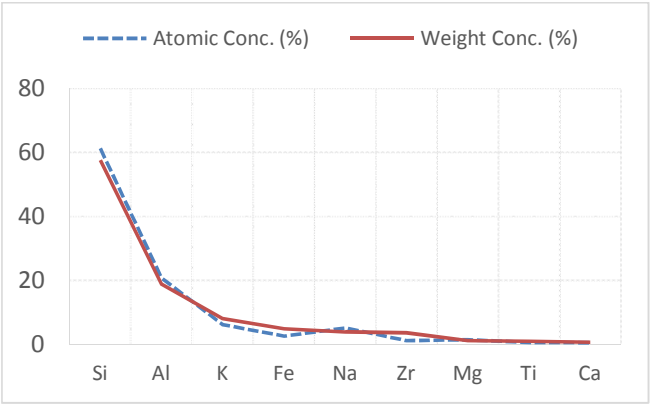
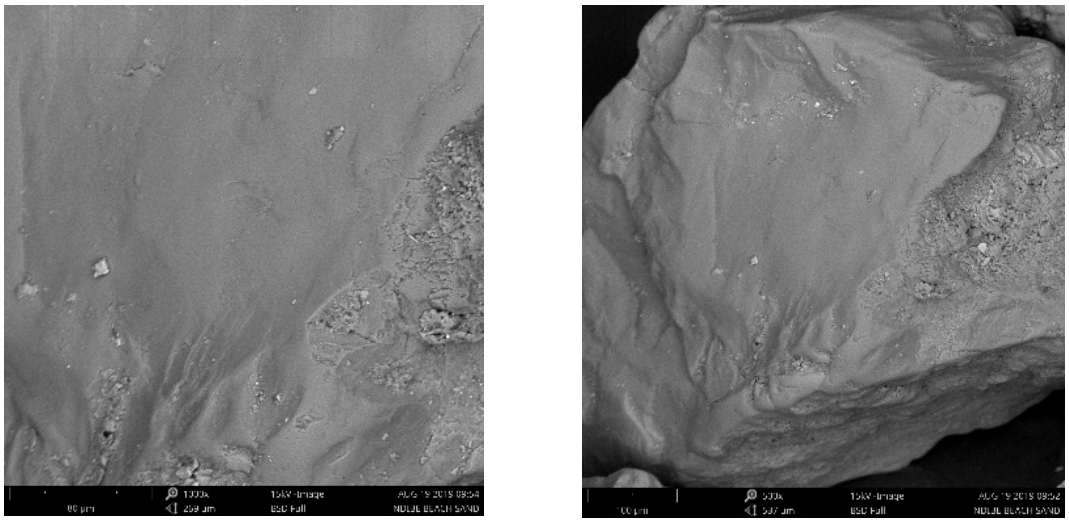


Fig. 2. Element composition of Ozizza sand

Table 3. Element composition at Ndibe location

Element Name	Element symbol	Element Number	Atomic Conc.(%)	Weight Conc.(%)
Silicon	Si	14	92.40	11.31
Aluminium	Al	13	4.83	4.59
Zirconium	Fe	26	0.48	1.55
Potassium	K	19	0.79	1.09
Calcium	Zr	40	0.38	0.54
Magnesium	Mg	12	0.60	0.52
Sodium	Na	11	0.50	0.41

B. Ndibe



a b

Fig. 3. 269µm:1000X and 537µm:500X (a & b) SEM images of all eleven mixed samples of Ndibe sand

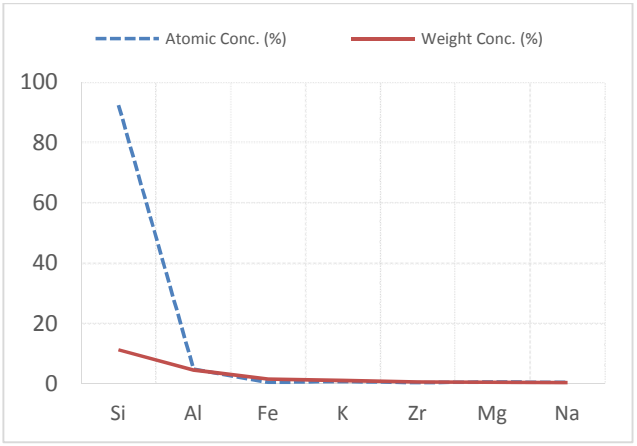
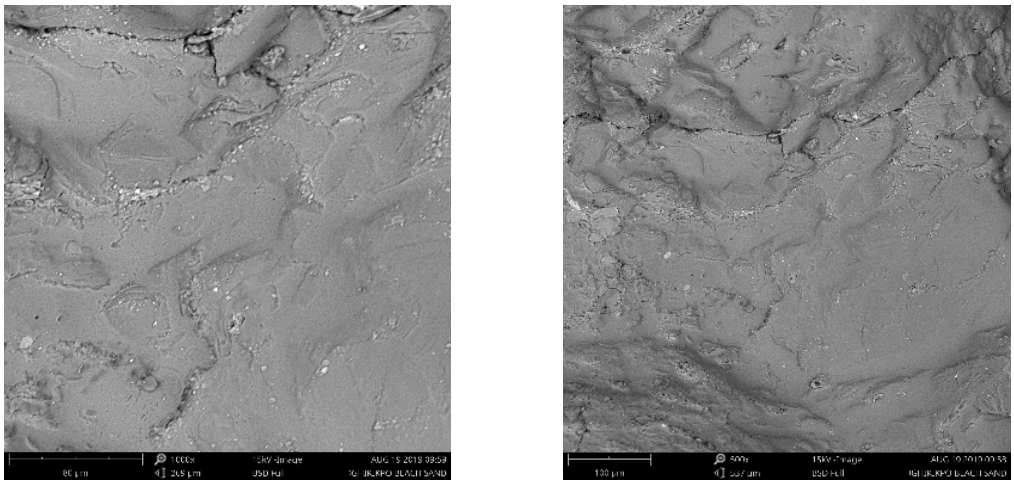


Fig. 4. Element composition of Ndibe sand

Table 4. Element composition at Kpoghirikpo location

Element name	Element symbol	Element number	Atomic Conc. (%)	Weight Conc. (%)
Silicon	Si	14	89.74	86.54
Aluminium	Al	13	5.21	4.82
Potassium	K	19	0.39	0.52
Iron	Fe	26	2.27	4.36
Sodium	Na	11	5.17	3.97
Zirconium	Zr	40	0.66	2.06
Magnesium	Mg	12	0.84	0.70
Titanium	Ti	22	0.33	0.54

C. Kpoghirikpo



a b

Fig. 5. 269µm:1000X and 537µm:500X (a & b) SEM images of all eleven mixed samples of K poghirikpo sand

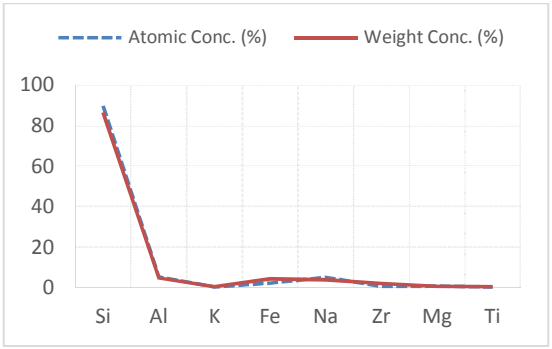
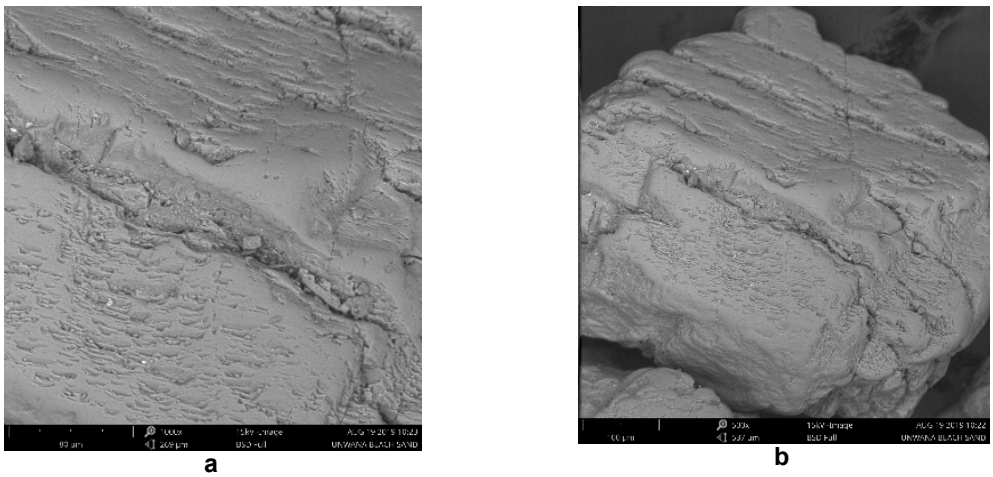


Fig. 6. Element composition of Kpoghirikpo sand

D. Unwana



a b

Fig. 7. 269µm:1000X and 537µm:500X (a & b) SEM images of all eleven mixed samples of Unwana sand

Table 5. Element composition at Unwana location

Element name	Element symbol	Element number	Atomic Conc. (%)	Weight Conc. (%)
Silicon	Si	14	56.54	52.26
Aluminium	Al	13	19.20	17.05
Zirconium	Fe	26	0.12	0.37
Potassium	K	19	16.33	21.01
Magnesium	Mg	12	1.03	0.83
Sodium	Na	11	1.81	1.37
Titanium	Ti	22	1.14	1.79
Iron	Fe	26	1.65	3.03
Sulphur	S	16	1.02	1.08
Phosphorus	P	15	1.01	1.03
Calcium	Ca	20	0.15	0.20

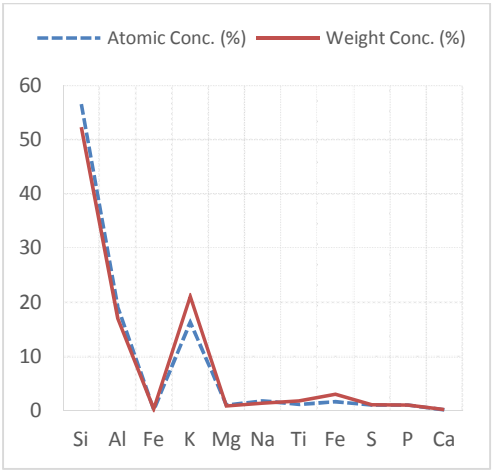


Fig. 8. Element composition of Unwana sand

Table 6. Elemental oxide, gaseous and solid compositions at Ozizza

Elemental Oxide	Mean Conc. (%)
SiO_2	90.1
K_2O	2.82
TiO_2	0.11
V_2O_5	0.018
Cr_2O_3	0.01
Fe_2O_3	1.959
CO_3O_4	0.0067
CuO	0.032
GeO_2	0.011
As_2O_3	0.002
Rb_2O	0.018
SrO	0.052
ZrO_2	0.032
Al_2O_3	3.14
BaO	0.24
Eu_2O_3	0.16
OsO_4	0.035
IrO_2	0.032
PbO	0.01
Cl	0.865
Au	0.025

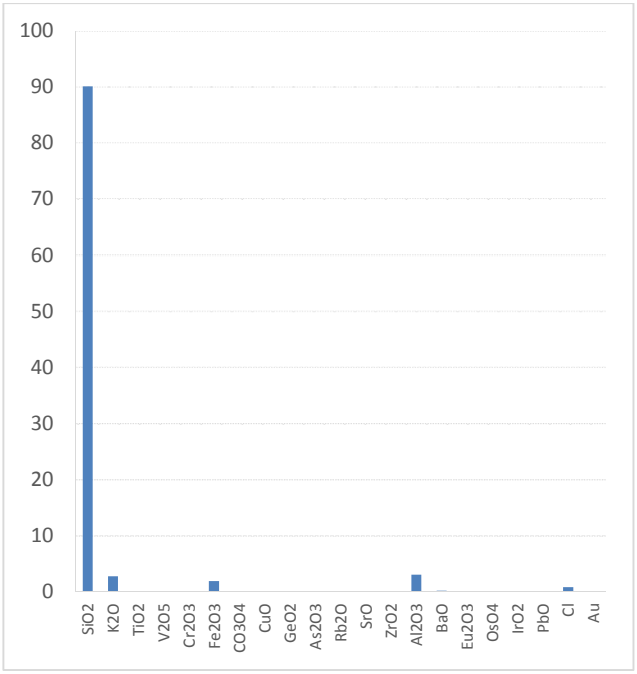


Fig. 9. Oxide, gaseous and solid compositions of Ozizza sand

Table 7. Elemental oxide, gaseous and solid compositions at Ndibe

Elemental oxide symbol	Mean concentration (%)
SiO_2	90.1
K_2O	2.
TiO_2	0.304
V_2O_5	0.016
Cr_2O_3	0.01
Fe_2O_3	1.32
CO_3O_4	0.0067
CuO	0.022
GeO_2	0.011
As_2O_3	0.001
Rb_2O	0.016
SrO	0.043
ZrO_2	0.025
Al_2O_3	6.59
Eu_2O_3	0.096
OsO_4	0.035
IrO_2	0.044
PbO	0.01
MnO	0.059
CeO_2	0.11
Ti_2O_3	0.031
Cl	1.13
Au	0.045

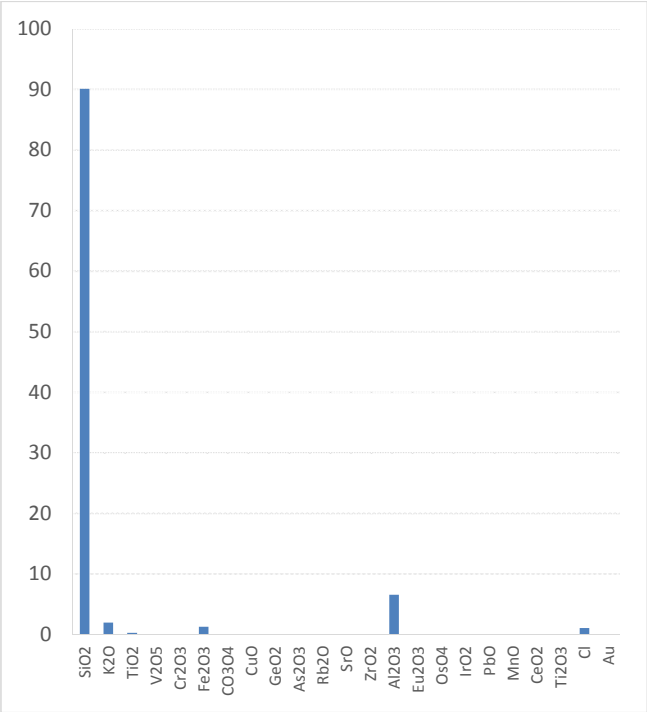


Fig. 10. Elemental oxide, gaseous and solid mineral compositions of Ndibe sand

Table 8. Elemental oxide, gaseous and solid compositions at Kpoghirikpo location

Elemental oxide	Mean Conc (%)
SiO_2	91.7
TiO_2	0.27
V_2O_5	0.035
Cr_2O_3	0.027
Fe_2O_3	1.29
CO_3O_4	0.0067
CuO	0.02
Ga_2O_2	0.02
As_2O_3	0.005
Rb_2O	0.016
SrO	0.043
ZrO_2	0.041
RuO_2	0.34
Al_2O_3	4.52
BaO	0.02
CeO_2	0.077
Eu_2O_3	0.14
PbO	0.031
Bi_2O_3	0.029
Cl	1.32
Au	0.039

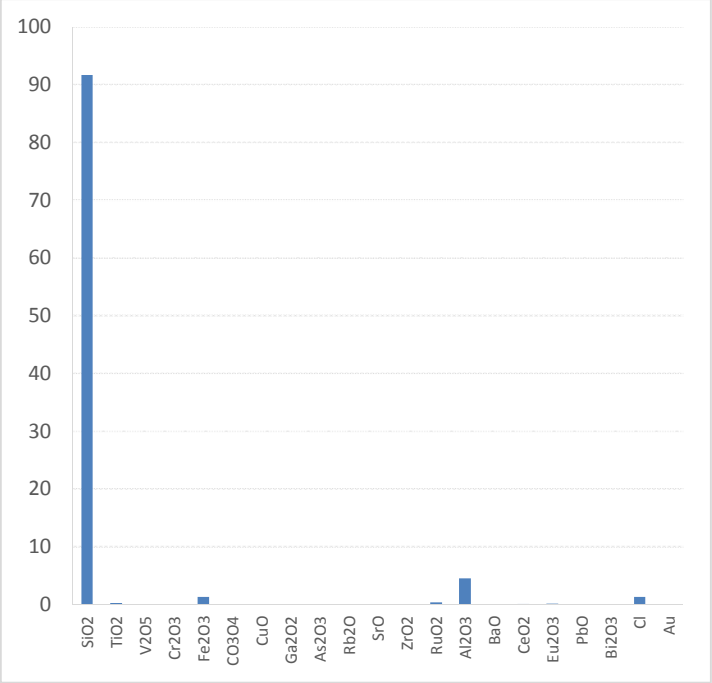


Fig. 11. Elemental oxide, gaseous and solid mineral compositions of Kpoghirikpo sand

Table 9. Elemental oxide, gaseous and solid compositions at Unwana

Elemental oxide	Mean Conc. (%)
SiO_2	95.0
K_2O	0.65
CaO	0.18
TiO_2	0.15
V_2O_5	0.026
Cr_2O_3	0.012
Fe_2O_3	0.850
CuO	0.025
SeO_2	0.007
Rb_2O	0.014
SrO	0.037
ZrO_2	0.032
Al_2O_3	2.7
BaO	0.04
CeO_2	0.03
Eu_2O_3	0.11
Er_2O_3	0.022
IrO_2	0.033
HgO	0.022
Ti_2O_3	0.02
PbO	0.019
Au	0.027

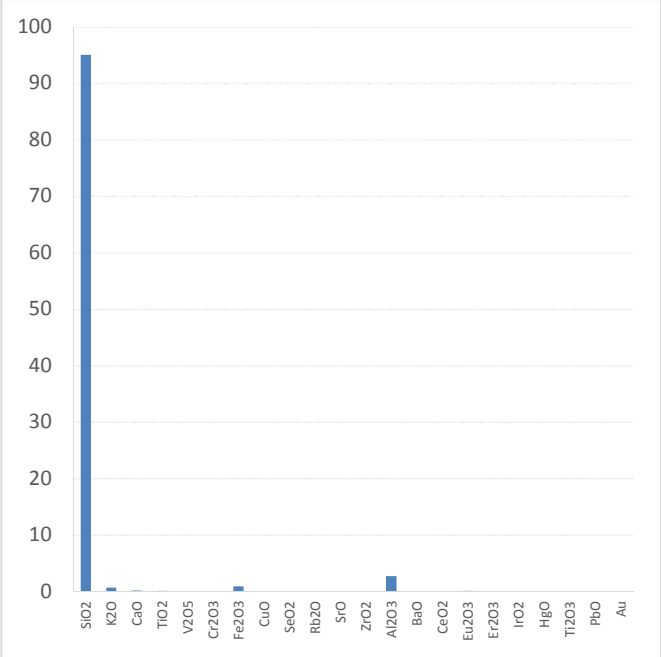


Fig. 12. Elemental oxide, gaseous and solid mineral compositions of Unwana sand

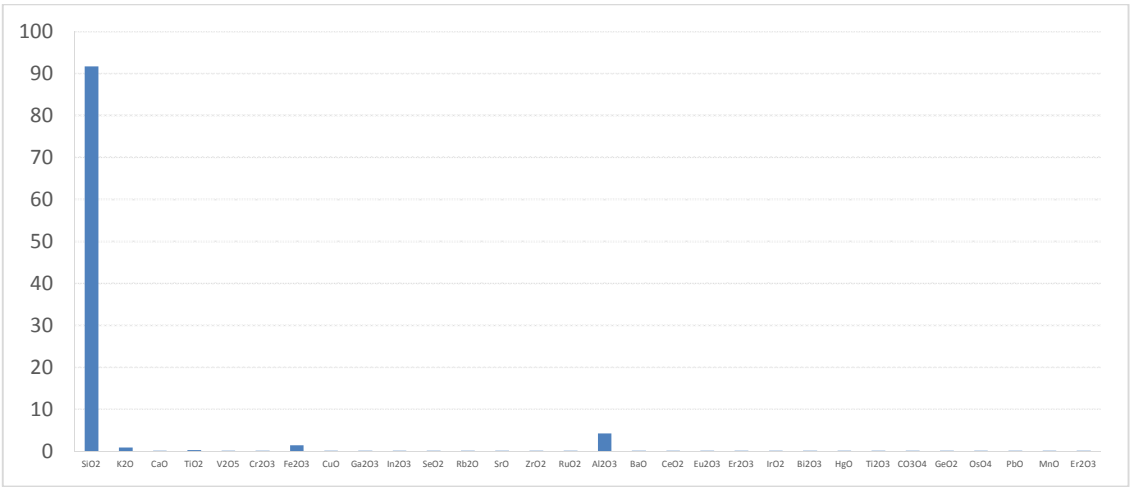


Fig. 13. Elemental oxide mineral compositions of the four (4) locations along the Cross River within Afikpo-North L.G, A., South-East Nigeria

From Table 10 or Fig. 13, the greater percentage of SiO_2 indicates the greater presence of other silicates, and heavy mineral assemblage [15]. However, the sand can be processed to reduce the content of other colouring elemental oxides particularly, Fe_2O_3, to about 0.03% maximum from 1.36%, by the use of decolouring agents such as metallic gold, selenium, cobalt, niobium and manganese. This can increase the SiO_2 content to between 98.8-99.7% [18]. This is because the further greater the silicate content, the greater the hardness and therefore the ability to abrade metals. However, the silica content (91.73%) of the sand is well above the industrial specification of 80% for sanitaryware making and suitable for the silica brick industry, for road dressing mixed with asphalt and for use as an abrasive (sand paper, sand blasting).

Table 10. Elemental oxide compositions (%) at the four (4) different locations of the Cross River sand

Elemental oxide	OZZIZA	NDIBE	KPOGHIRIKPO	UNWANA	Mean
SiO_2	90.1	90.1	91.7	95.0	91.73
K_2O	2.80	0	0	0.65	0.86
CaO	0	0	0	0.18	0.045
TiO_2	0.11	0.304	0.27	0.15	0.21
V_2O_5	0.018	0.016	0.035	0.026	0.024
Cr_2O_3	0.017	0	0.027	0.012	0.014
Fe_2O_3	1.959	1.32	1.29	0.850	1.36
CuO	0.032	0.022	0.02	0.025	0.025
Ga_2O_3	0	0	0.02	0	0.005
In_2O_3	0.002	0.001	0.005	0	0.002
SeO_2	0	0	0	0.007	0.0018
Rb_2O	0.018	0.016	0.016	0.014	0.016
SrO	0.052	0.043	0.043	0.037	0.043
ZrO_2	0.032	0.025	0.041	0.032	0.033
RuO_2	0	0	0.34	0	0.085
Al_2O_3	3.14	6.59	4.52	2.7	4.24
BaO	0.24	0	0.02	0.04	0.075
CeO_2	0	0.11	0.077	0.03	0.054
Eu_2O_3	0.16	0.096	0.14	0.022	0.11
Er_2O_3	0	0	0	0.022	0.0055
IrO_2	0.032	0.044	0	0.033	0.027
Bi_2O_3	0	0	0.029	0	0.0073
HgO	0	0	0	0.022	0.0055
Ti_2O_3	0	0.031	0	0.02	0.013
CO_3O_4	0.0067	0	0	0	0.0017
GeO_2	0.011	0	0	0	0.0028
OsO_4	0.035	0	0	0	0.0088
PbO	0.01	0.01	0.031	0.019	0.018
MnO	0	0.059	0	0	0.015
Er_2O_3	0	0	0	0.022	0.00554
Total	98.78	98.79	98.62	99.89	**99.02**

4. CONCLUSION

The standard field and laboratory physical, and chemical analysis results have shown that the Cross River sand at Ozizza, Ndibe, Kpoghirikpo and Unwana can primarily be used in the abrasive and glassmaking, building and construction industries. It can also be used in making sanitaryware such as washing sinks and baths; low quality glass types such as common window glass and pyrex. The sand can be processed by washing, floatation, mechanical separation and chemical treatment to improve the quality of sand for use in colourless glassmaking as well as abrasives that can cut harder metals.

DISCLAIMER

The products used for this research are commonly and predominantly found in our area of research and country. There is absolutely no conflict of interest between the authors and owners of the sand because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge in line with the R & D mandate of our institution. Also, the research is an Institution Based Research (IBR) funded by the Tet Fund governmental agency of Nigeria.

COMPETING INTERESTS

Authors have declared that no competing interest s exist.

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