Asian Journal of Applied Sciences (ISSN: 2321 – 0893)
Volume 05 – Issue 04, August 2017

Evaluation of Akaibiri Creek Sand at Akaibiri Town and Environments, Central Niger Delta, Nigeria, for Industrial Applications

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ABSTRACT----- ***The colours of fifteen shallow dept non-weathered field samples of Akaibiri creek sand at Akaibiri Town and environments collected for physical and chemical properties investigation in the laboratory using BS:2975: 1958/1988 standards specifications were bright yellow, brown, reddish-brown, white and dark grey. The physical sieve grade size distribution was 2mm(3.0%), 1mm(6.11%), 500µm(13.88%), 300µm(54.25%), 180µm(9.33%), l06µm(7.14%), 63µm(2.87%), and <63µm(1.37%). The grade size analysis result indicated that the sand was of medium grade. The physical properties combined with a moisture content of 7.3% presented the sand as a material suitable for use in the construction, transport, building, refractory and sanitary industries as aggregates, but not for any type of glassmaking except processed for use in making general glass. The X-ray Fluorescence (XRF) analysis Geochemical composition was SiO_2(92.50%), CaO(0.355%), MnO(0.018%), Fe_2O_3(1.00%), TiO_2(0.91%), Na_2O(0.09%), K_2O(2.26%) and L. O. I.(0.35%). This composition is representative of the sand. The most important industrial use determining elements in the sand were the Silica (Si), Iron (Fe), K_2O (K) and Titanium (Ti). The Silica (SiO_2) content of 92.50%, was low and the sand cannot be used as it is, for glass making. The iron (Fe_2O_3) content (1.00%), Ti (0.91%), K (2.26%), Na (0.09%) and even the L.O.I (0.35%) were too high for making any type of glass. The sand was generally not suitable for glass making particularly, o f colourless glass based on the geochemical properties and loss on ignition. The non-detection of Alumina (Al) in the sand suggests its suitability for use in the manufacture of common glass and the presence of high content of colouring agents Ti and Fe suggests the suitability for coloured glass making. The contents of Si and K, (92.50% and 2.26%) respectively and the non detection of Al, can make the sand also suitable for use in the refractory and sanitaryware industries.***

Keywords--- Akaibiri Town, Akaibiri creek, sand, physical properties, geochemical properties, aggregates, glass. Industrial Applications

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1. INTRODUCTION

Physically, sand ranges in size from 2.00mm to 0.0625mm. Sand can be natural or a synthesized material reduced to this size grade. Many researchers including, Udden(1914), (WenthWorth(1922), PettiJohn (1957), Durotoye (1976),Tucker (1981), Arumala & Akpokodje, (1987). Amajor, (1989), Egirani & Obande, (2003), Wessey (1984; 2016) have studied the origins, composition, grade size distributions, porosity, moisture content and the geochemistry of natural sands and their subsequent uses arising from research results. Gutt (1972), Gutt and Nurse (1974), Wessey (1988, 2016; 2017), have also reported on sand derived from synthetic materials like iron and steelmaking slags. Natural and synthetic sands have found many uses in many industries including the building, transport, construction, foundries and sanitaryware, glassmaking, ceramics and the abrasives industries based on physical and geochemical properties' standard specifications (Knill, 1978; Collins and Fox, 1985; Slack, 1987; Hamascch, 1991; Leibe, 1999; Egirani and Obande, 2003; Wessey, 1988, 2016, 2017; BS 2975: 1988). Porter (1963), also studied the mineralogy of sand using electron microscopy and the polarizing light microscope respectively.

Sand, with high levels of silica content known as silica sand or industrial sand is used for glassmaking. Akpokodje and Etu-Efeotor (1987) have reported on the engineering properties and economics of Niger Delta sand. This work investigated the sand of Akaibiri creek at Akaibiri town and environments to determine its potentials as an industrial raw material particularly, in the building, construction, refractory, sanitary and glassmaking industries.

2. THE STUDIED AREA

The study area comprises of the villages of Akaibiri, Bomondi, Tombia and Agudama/Ekpetiama (Akaibiri and environments), in the central Niger Delta Region of Nigeria. The geology is similar to that of the Region. It is located at longitude $6°00^1$ to $6°5^1$ East of the Greenwich meridian and latitude $4° 48^1$ to $5°00^1$ North of the Equator and accessible by rivers such as the meandering Akaibiri Creek, Igbumotoru Creek and Opuama Creek, all distributaries of a meandering River Nun, a distributary of a meandering River Niger draining to the Atlantic Ocean. The rivers and creeks sometimes meander very acutely and have diurnal tides of 6 hours each. The area is also accessible by roads off the East-West road. Topographically, the entire area is built up by the sedimentation pattern of the Niger Delta which includes fresh water swamps. There is no marine incursion throughout the year. It is a middle delta stage. Akaibiri and environments experience a humid hot equatorial climate weather conditions brought about by the moist tropical maritime air mass blowing from the Atlantic Ocean prevalent during the rainy season, and the dry dust laden tropical continental air mass originating from the high pressure belt of the Sahara Desert. The dry air blows over the area in the dry season. The Rainfall spread over 8 to 9 months, between March and November with a mean annual range of 2,000 to 4,000mm. This period coincided with the wet season. There is a slight break during the rainy season between July and September in agreement with the general Niger Delta Regional conditions. This short dry period is called the August break. The duration of the dry season, a period of three months usually began from December and on till February, a considerably short period when compared to the period of the rainy season (Oyegun, 1999). However, with climate change the difference between marked rainy and dry seasons in the area is becoming less distinct. The area had a fairly constant mean temperature of 30^0C sometimes rising to a maximum of 40^0C. It also experienced a short spell of cold, hazy and foggy period called the Harmattan lasting December to January (sometimes from November) during the dry season. The vegetation of the area was characterized by fresh water swamp and tropical rainforest rich in multitudes of evergreen trees such as mahogany, abura, raffia palm, ebony, iroko, palm tree, cane sugar and climbing plants. There were also floating species such as Vossia Capsidala and Nymphae Lotus. During the months of July to October the area was flooded bringing detrital or classic sediments to the area from River Niger, through River Nun. The river and creeks formed a good network traversing the entire study area making movement by boat easy. The sand in the area of Quaternary deposits was Eocene to Recent in age overlying the Benin Formation (Allen, 1965); Burke and Durotoye, (1970b); Durotoye, (1976); Tse and Akpokodje, (2010).

There is well documented knowledge on the geology, the size, thickness of deposits, soils and stratigraphy of the Niger Delta by Allen (1965), Reyment (1965), Short and Stauble (1967), Murat (1970), Weber (1971), Schoeld (1978), Avbovbo (1979), Doust and Omatsola (1989), Okonny (1999), Tse and Akpokodje and exploration reports of oil companies. The Niger Delta is presented as a sequence of marine clays overlain by paralic sediments which are capped by continental gravels and sands. These are regarded as regressive clastic sequence of 10,000m to 12,000m thickness in an area of 923,766Km^2. Short and Stauble (1967), based on environment of deposition reported the stratigraphic sequence of a complex, Tertiary Niger Delta as having the three major Formations of Akata, Agbada and Benin in a bottom up order. The Akata Formation, a deep marine pro-delta unit composed of mainly shales and of Paleocene age (63Ma), is the oldest. The shales of the Formation are the source of the hydrocarbon rocks of the Niger Delta. The Agbada Formation of Eocene to Recent age in the middle overlying the Akata Formation consists of paralic sequences of sandstones and shales. The sandstone units constitute the hydrocarbon reservoir while the shales form the seal. The Benin Formation, also of Eocene to Recent age, is the topmost and youngest layer and deposited in continental fluviatile conditions. The Formation consists of mainly over 90% massive porous sand with localized clay/shale interbeds or intercalations and constitutes the regional aquifer unit. The Benin Formation has the unit of superficial quaternary deposits overlying it. These deposits are either a relatively uniform lithology or an alternating sequence of Recent deltaic sand, silt, clay-peat or sand-silt-clay mixtures, the presence of clay and peat becoming increasingly predominant seaward.

3. MATERIALS AND METHODS

The complimentary field and laboratory methods used for this investigation of the physical and geochemical properties of the test sand, were in accordance with the British Standard Institute (BS:2975: 1958/1988) specifications.

3.1. Field method

Field work involved the collection of about one kilogram (1Kg) each of fifteen (15) disturbed samples from the banks and beds of the Creeks flowing by Akaibiri, Bomondi, Agudama/Ekpetiama and Tombia villages using steel buckets and trowels. The creeks were distributaries of the River Nun. Four composite samples were collected from each village site. The samples after macroscopic observations, were collected into polythene sample bags with the trowels, taped with masking tapes and labeled accordingly. These were taken for laboratory analysis. At the river banks the sand deposit was stratified with varying thickness of 17.50cm, 22.50cm, 48.00cm and 15.90cm respectively. The sand provided the base for economic activities in the area.

3.2. Laboratory analysis

The laboratory analysis was in accordance with BS 2975:1958/1988 and the Glass Making Raw Materials, Sand, Reference 48/340, 1974 specifications. The analysis included physical determination of moisture content and grade size analysis (sieve analysis- using sieves in agreement with BS 410), and Geochemical analysis using the X-Ray Fluorescence (XRF) analysis method. In the laboratory, collected field samples were left to drain for twenty four hours (24hrs), each was thoroughly mixed, coned and quartered to obtain suitable representative samples. 150 grams of each sample was oven (wagtech) dried at 110^0C for 24 hrs, left in a dessicator to cool for 24 hrs and weighed again for moisture content determination.

100 grams of each sample so treated was sieved through 2.00mm, 1.00mm, 500µm, 300µm, 180µm, 106µm, 63µm and <63µm sieves for grain size distribution analysis. After sieving, the percentage retention on each sieve was calculated for each sample.

4. RESULTS AND DISCUSSION

The results obtained from the physical analysis of the sand are shown in Table 1 (porosity and moisture content); Table 2 (Grain size distribution) and Table 3 (Geochemical- XRF analysis).

4.1. Colour, texture and shape

The sand of the study area was by eye observation, characterized by bright colours of white, yellow, brown and dark grey; texturally, very coarse to very fine grade sizes and in shape, sub angular, rounded to well rounded. At the river banks the sand was stratified into varying thicknesses, colour and texture. The stratified layers showed a fining upward sequence. There were sedimentary cross-bed structures.

4.2. Moisture content

The results of the moisture content of some selected samples are shown in Table 1.

Table 1. Moisture content of some selected sand samples of Akaiblri Creek sand at Akaibiri Town and environs in per centage (%).

Sample No	Weight loss (C) (g)	Moisture Content (m) (%)
AK1	7.05	4.7
AK2	6.0	4.0
AK3	13.95	9.3
BO4	10.05	6.7
BO5	6.0	4.0
BO6	16.43	10.9
AE7	10.95	7.3
AE8	4.05	2.7
AE9	16.05	10.7
TO10	18.45	12.3
Total	76.13	72.6
Mean	7.63	7.3

*Note Samples. AK= Akaibiri, BO = Bomondi, AE= Agudama/Ekpetiama and TO =Tombia denote samples from those locations.

4.3. Grade size distribution

The grade size distribution of the test samples is shown in Table 2.

Table 2 Grade size distribution analysis results of sieve analysis of Akaibiri Creek sand at Akaibiri and environments. Percent retained per sieve size.

Sample No	2mm	1mm	500µm	300µm	180µm	106 µm	63 µm	<63 µm	Total	Sample loss
AK1	2.2	8.2	24.1	42.1	3.2	12.5	4.4	1.0	97.7	2.3
AK2	3.7	9.7	26.1	40.3	3.5	6.4	3.6	3.6	96.9	3.1
AK3	9.1	8.5	19.2	29.3	4.0	24.3	3.7	1.1	97.2	2.8
BO4	2.9	10.0	16.9	40.0	10.6	8.6	5.9	1.8	96.7	3.3
BO5	5.0	5.0	15.0	60.0	1.0	10.0	2.0	1.0	99.0	1.0
BO6	2.4	6.0	4.6	52.1	20.0	4.8	3.6	2.9	96.3	3.7
AE7	1.0	6.7	18.6	62.4	4.4	2.0	2.5	1.2	98.8	1.2
AE8	1.1	4.0	9.4	70.0	10.3	1.8	1.0	6.0	97.6	2.4
TO9	1.2	2.0	3.0	72.0	18.3	1.0	1.0	1.3	99.8	0.2
TO10	1.4	1.0	2.0	74.3	18.0	1.0	1.0	1.0	98.7	1.3
Mean	3.0	6.11	13.88	54.25	9.33	7.14	2.87	1.37	97.87	2.13

*Note. AK= Akaibiri, BO = Bomondi, AE = Agudama/Ekpetiam and TO = Tombia denote samples from those locations.

5. GEOCHEMISTRY

The X-Ray Fluorescence Geochemical analysis results of Akaibiri Creek sand at Akaibiri town and environments in elemental oxide percentage (%) composition is presented in Table 3.

Table 3 XRF Geochemical analysis results of selected Akaibiri Creek sand samples at Akaibiri Town and environment and the mean (oxide weight percent (%).

OXIDE	AK1	AK2	AK3	AE7	AE8	BO4	BO6	TO8	TO9	T10	Mean
SiO_2	92.51	92.50	92.50	92.51	92.49	92.49	92.51	92.50	92.50	92.51	92.51
CaO	0.355	0.355	0.334	0.335	0.355	0.356	0.356	0.355	0.355	0.355	0.355
M_nO	0.018	0.018	0.017	0.018	0.017	0.017	0.018	0.018	0.018	0.018	0.018
Fe_2O_3	1.00	1.00	1.01	1.00	1.00	1.01	1.01	1.00	1.00	1.00	1.00
$A1_2O_3$	-	-	-	-	-	-	-	-	-	-	-
TiO_2	0.91	0.90	0.90	0.91	0.91	0.90	0.91	0.91	0.91	0.91	0.91
Na_2O	0.09	0.08	0.09	0.09	0.08	0.09	0.09	0.08	0.09	0.09	0.09
K_20	2.26	2.26	2.26	2.25	2.25	2.26	2.26	2.26	2.26	2.26	2.26
L.O.I	0.34	0.35	0.34	0.35	0.35	0.36	0.34	0.35	0.35	0.34	0.34
TOTAL	97.48	97.46	97.45	97.48	97.45	97.48	97.50	97.45	97.48	97.48	97.48

*Note. AK= Akaibiri, BO = Bomondi, AE = Agudama/Ekpetiam and TO = Tombia denote samples from those locations.

6. DISCUSSION

The overall results obtained from the investigation of test sand are discussed below in relation to possible industrial applications of the sand.

6.1. *Colour and texture*

The occurrence of sedimentary structures like cross-beds identified on the depositional strata on the bank of the river were good indicators of paleocurrent direction and also of high tide and low tide level in times past. From the colour and texture the sand can be mainly useful for the building and construction industries as aggregate (Wessey, 2016).

6.2. *Moisture content*

The moisture content results of selected samples (Table 1) ranged between 2.7 to 12.3 with a mean value of 7.3%. Based on the overall moisture content, the sand quality falls outside strict standard industrial use specifications particularly of glassmaking (BS 2975: 1988, Glass Making Raw Materials: Sand Reference:48/340, 1974). However, the sand can be used as local building and construction purpose aggregates particularly in block making, concrete and fill material. The very fine component of the sand was 4.26%. This can contain the expansive clays. When the sand is used in bulk as an aggregate, the expansive clay in the very fine grade sand could cause swell and fracture problems resulting in structural failure. The very fine grade size sand (4.26%) is negligible in comparison with remaining sand grades (95.74%). It could be ignored.

6.3. *Grade size distribution*

Table 2 is the percentage retention per sieve size showing the grade size distribution of the test sand. The results show that the texture of the sand was very coarse sand (2mm)-3.0%, coarse sand (1mm)- 6.11%, medium sand (500µm-300µm)- 68.21% and find sand (180µm - l06µm)- 16.47%, and very fine sand (63µm - <63µm) which had 4.24% . The sand was thus a medium grade sand making up 68.13% of the total sand, from the grade size distribution, was poorly sorted and the grains were sub-angular to well rounded. The medium grade size, poor sorting and sub-angular to well rounded shape was generally like other sands of the Niger Delta River channels, streams and estuarine recent sands of the Benin Formation (Reyment, (1965). The poor sorting characteristic of the sand made it unsuitable for colourless glass manufacture but suitable as a landfill, other building and construction aggregate. The sub-angular property gave it a good binding property when used in cement and asphalt mix in road and building construction. The fines can fill void spaces in the mix when the sand is used in concrete mixes and mortar. The sub-angular to rounded shape and the medium grade size property can result in low energy consumption on heating which can make the sand suitable for glass manufacture.

6.4. *Geochemistry*

The X-ray Fluorescence geochemical analysis results of the selected test samples (Table 3) showed a mean elemental oxide percentage composition of SiO_2 (92.50), CaO (0.355), MnO (0.018), Fe_2O_3 (1.00), TiO_2 (0.91), Na_2O (0.09), K_2O (2.26) and L.O.I. (0.35) making a total oxide composition of 97.48%. This composition was representative of the sand. The most industrial use determining elements in the sand were Silica (Si), Iron (Fe), K_2O (K) and Titanium (Ti). The Silica (SiO_2) content of 92.50%, was low and cannot be used as it was for glass making (BS: 2795:1988). The iron (Fe_2O_3) content (1.00%), Ti (0.91%), K (2.26%), Na (0.09%) and even the L.O.I (0.35%) were too high for making any type of glass. The sand was generally not a glass making sand particularly of colourless glass based on the geochemical propeties and loss on ignition (Glass Making Raw Materials, Reference 48/340, 1974); except on processing (Wessey, 1984, 2016). The non detection of Alumina (Al) in the sand made it suitable for use in the manufacture of common glass, particularly coloured glass due to the presence of high content colouring agents, Ti and Fe. The contents of Si and K, 92.50% and 2.26% respectively and the non detection of Al, created the suitability of the sand for use in the refractory and sanitaryware industries. The high contents of Si and Fe were high enough for use as fertilizer material for plant nutrition in agriculture (Wessey, 2017).

7. CONCLUSION

The poorly sorted medium grade size (500µm-300µm - 68.21%), sub-angular, rounded to well rounded characteristics of the sand can find main local applications as bulk land fill and reclamation, building and road construction aggregates. The considerably high alkali content of potash (2.26%) and Soda (0.09%) gave the sand a heat resistant quality for possible use as a refractory furnace lining material. The 92.50 per cent considerably low content SiO_2 and the very high 1.00 per cent content Fe_2O_3, critical contents for glass making, present the sand as unsuitable for making any type of glass. Beneficiation of the sand for glassmaking is likely to be too costly. It is recommended that the sand be used as aggregate in the building and construction, sanitary ware and refractory industries and as fertilizer in agriculture.

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