



## Assessment of Bituminous Sand from Agbabu, Southwestern Nigeria Using Geochemical and Sedimentological Approach

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### Abstract

#### Keywords:

Bitumen, Geo Accumulation, Sedimentation, Agbabu, Hydrocarbon

Bituminous sands consists of sand and other associated clastic rocks which are impregnated with heavy hydrocarbon (bitumen), chemically similar to conventional oils but which have high densities or low API gravities (<120 API) and high viscosities. A total of ten (10) samples were collected from the study areas and used for geochemical and sedimentological analysis. The order of the mean concentrations of tested heavy metals in the sampled bitumen within the area are; Mn>Ba>Pb>Cr>Cd>Cu>Co>Ni>. Based on the Geo Accumulation Index ( $I_{geo}$ ), the study areas are generally classified as unpolluted with regards to the measured heavy metals. From the interpretation of the analysis, the values of the mean, standard deviation, skewness and kurtosis were found to range between 1.1-2, 0.89- 1.753, -0.454 - (-0.1866), 0.84- 1.548. The mean and standard deviation signifies that the sediment was generally medium grain size and moderately sorted which implies that the sands have undergone a fairly long transportation history. The values of skewness and kurtosis signify that the sample are generally coarse skewed and leptokurtic. Results of bitumen saturation analysis revealed that the average percentage weight of the bitumen in the surface samples ranged between 23.68% and 96.54% with an average bitumen saturation of over 40%. The presence of heavy mineral suites of Zircon, Tourmaline and Rutile in all the samples indicates that the sediments were derived from igneous and metamorphic rock of nearby basement rocks but their accumulation was strongly controlled by mechanical process of sedimentation.

Accepted: 28<sup>th</sup> Nov 2018

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### INTRODUCTION

The chemical composition of bitumen is complex and varies depending upon the geology of the source, age and maturity (Yen, 1984). Bitumen consists of a mixture of hydrocarbons, its chemical compound containing hydrogen and carbon with other trace compound. Bitumen is viscous to extract from the ground by conventional production techniques. Oil sands and other associated clastic rock are impregnated with heavy hydrocarbon (bitumen), and are chemically similar to conventional oils but have high density (approximately 1000kg/m<sup>3</sup>) or low API gravities

(>180 API) and high viscosities. Each grain of sand is covered by a film of water, which is then surrounded by a slick of heavy oil (bitumen). The sands are bonded firmly together by grain-to-grain contact. The sand is composed of 92% quartz with traces of mica, rutile, zircon, tourmaline, titanium, nickel, iron, vanadium and pyrite. The sand is triangular in shape, making it very abrasive. On the Moh's hardness scale, with diamond being 10, oil sand is 7.4. Bitumen is about 20% of the actual oil sands found in Nigeria while 76% is for mineral matter that include clay and sand and 4% water. Oil sands must be mined or recovered Insitu. The recovery process includes extraction and separation

systems to remove the bitumen from the sand and water. This natural resource occur in parts of Ondo and Ogun states in Nigeria and are found outcropping an area of 120km by 6km belt in south western Nigeria from the Okitipupa ridge of the tertiary Nigeria Delta as far as west of Ijebu-Ode in Ogun State. Total reserves of heavy oil are estimated to exceed 30 million barrels (Adegoke, 1980).

Research activities on the vast deposit of Agbabu natural bitumen in Nigeria have largely been concentrated on the physico-chemical characterization (Ekweozor and Nwachukwu, 1989; Oluwole et al., 1985), geological mapping and examination (Adegoke, 1980), and effect of future exploitation of this important material on the soil and water samples of the area (Olajire et al., 2007; 2008). Very little investigation has been carried out on the geochemical and sedimentological analysis of the solid bitumen in Agbabu to determine if the bitumen can be refined to obtain maximum utilization value.

The approach to the work is to describe it section by section, and ten different sections were used. However, this study is focused on the Geochemical (major oxides, trace elements and heavy metals) and Sedimentological (grain size, shape, skewness, roundness, and kurtosis) analysis of solid Bitumen in Agbabu area of Ondo state. Previous works have been done on the Geology and the economic potential of this fairly extensive non-conventional crude oil deposit. Parkinson, (1962); Crockett and Wescott (1954); Coursey (1963); Durham and Picket, (1966); Jones and Hockey, (1964).

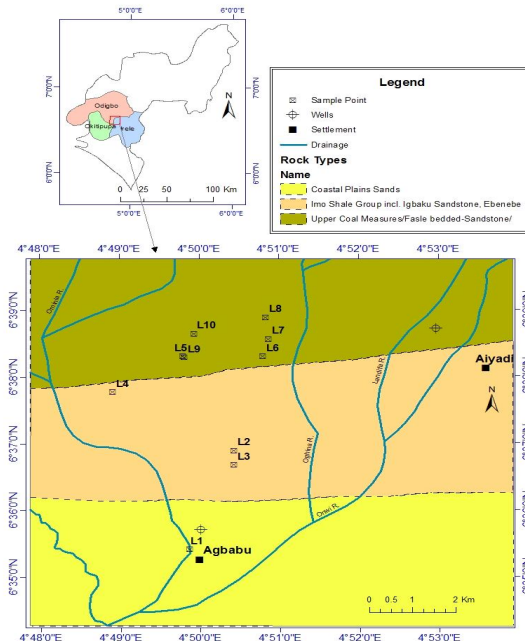
A lot of people have worked on Agbabu bitumen belt, the origin of tar sands was studied by Ekweozor and Nwachukwu (1989). The geology of the deposit, its oil saturation and reserve estimate as well as the textural characteristics of the associated sands has been described (Adegoke et al., 1980, 1981; Adegoke and Ibe, 1982; Enu, 1987). Bitumen chemical properties and their relation to production and processing also have been studied (Ekweozor, 1985; Oluwole et al., 1985).

Between 1975 and 1980, the department of Geology, Obafemi Awolowo University (OAU), Ile-Ife carried out series of studies on the outcrops and shallow coreholes and boreholes section of the bituminous horizon within the 110km belt, stretching from Agbabu (Odigbo LGA) to Siloko and Akotogbo areas in the Okitipupa division (Ondo state). The Origin of Tar Sand South Western Nigeria (Ekweozor and Nwachukwu, 1989). Bitumen saturation and reserve estimates of the Okitipupa oil sands (Coker, 1988). The fauna and microfacies of the sedimentary deposit in the Basin (Adegoke et al, 1971, 1980; Dessaugie, 1970; Berggren, 1960; Evamy, 1957; Fayose and

Azeez, 1970, 1972; Petters, 1979; Reymont, 1960, 1963, 1964, 1965a, 1965b, 1965c, and Russ, 1924).

## STUDY AREA

The study area is located in the southern part of Ondo state in South -Western Nigeria and falls within Odigbo and Okitipupa Local Government areas of Ondo state. It lies between latitudes  $6^{\circ}33'N$  and  $6^{\circ}46'N$ ; and longitudes  $4^{\circ}44'E$  and  $4^{\circ}54'E$  (Table 1). This location falls within the Western part of Dahomey embayment of the southern part of Nigeria with a number of villages located within the study area to include Oja Baale, Aba Odomode, Olowo, Boridele, Mulekangbo and Ilubinrin (Figure 1). The villages are linked together with both major and minor road networks and some clear footpaths. The study area is generally low lying, varying in altitude from less than 5m to about 50m above the sea level. The bitumen outcrop, which is about 5-8km wide and 120km long, runs through Edo, Ondo, Ogun and Lagos States. The area of study is characterized by dense drainage although; it is well drained with perennial flooding of rivers during the raining season. The major rivers in the area are Oluwa River, River Ufara and Osse River (Figures 2 and 3). They show a considerable degree of meandering simply because they are closer to the shore. The study area lies within the tropical rainforest region of Nigeria as shown in the climate map of Nigeria (Figure 4). There exist two distinct seasons in the area; the dry and wet seasons. Being a tropical zone, there are high rainfall, high humidity and variation in the temperature with average daily maximum of about  $30^{\circ}C$  in February/March to an average daily minimum of about  $21^{\circ}C$  in July/August.



**Figure 1: Geological map of the study area showing sample locations (Source: From field work embarked upon by authors).**

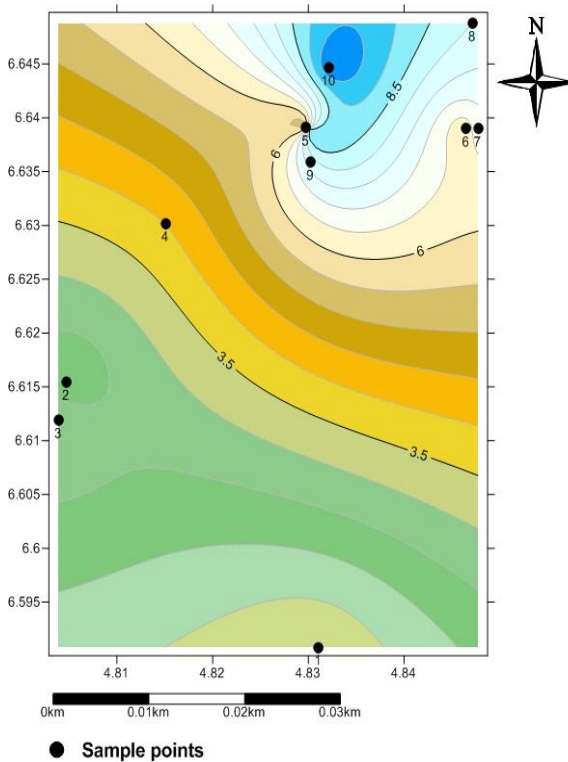
**Table 1: Showing the Sampling Locations**

S/N	LOCATION	LATITUDE	LONGITUDE	ELEVATION
S1	A	N 06°35'26.9"	E004°49'51.8"	35FT
S2	B	N 06°36'55.6"	E004°49'49.7"	65FT
S3	B	N 06°36'42.8"	E004°50'25.4"	70FT
S4	B	N 06°37'48.7"	E004°48'54.3"	84FT
S5	C	N 06°38'20.7"	E004°49'47.0"	136FT
S6	C	N 06°38'20.3"	E004°50'47.3"	134FT
S7	C	N 06°38'35.9"	E004°50'51.8"	122FT
S8	C	N 06°38'55.6"	E004°50'49.7"	126FT
S9	C	N 06°38'19.6"	E004°49'48.1"	118FT

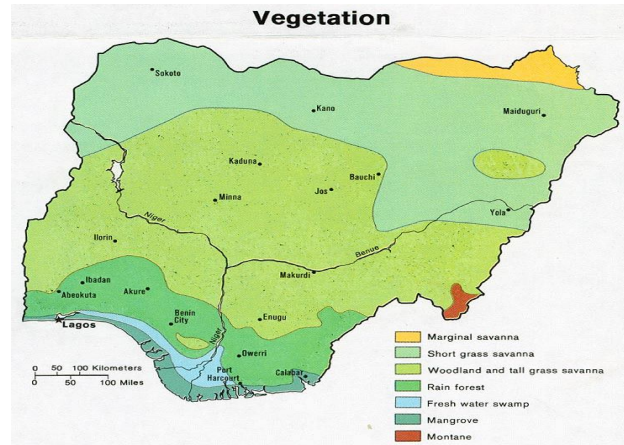
**LOCATION A:** *Agbabu village*

**LOCATION B:** *Mile 2 along agbabu road*

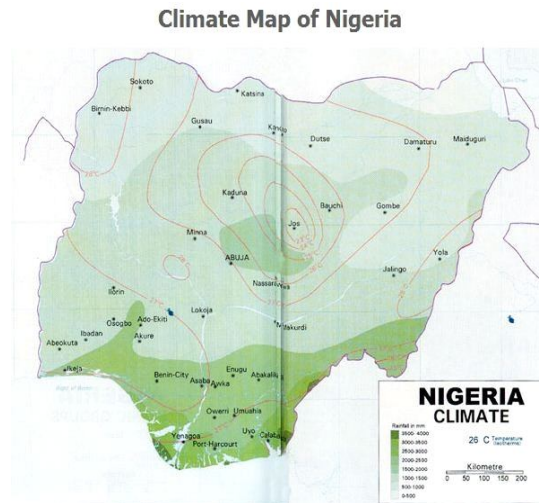
**LOCATION C:** *Ilubirin along agbabu road*



**Figure 2: Topographic map of the study area showing sample locations.**(Source: Department of Earth Sciences, AAUA).



**Figure 3: Vegetation map of Nigeria showing the study area** (Source: Nigerian Geological Survey Agency).



**Figure 4: Climate map of Nigeria showing the study area** (Source: Nigerian Meteorological Agency)

**Geological Setting of Study Area**

The study area is located in the southern part of Ondo State and underlain by Cretaceous sedimentary rocks of the Dahomey basin(Figure 5) consisting of sands, sandstone, shale, clays and limestone. The Dahomey Basin known to be formed from a marginal pull-apart (type 5) basin (Klemme, 1975) or margin sag basin (Kingston et al., 1983) was initiated during the early Cretaceous separation of African and south American plates. Sediment arrangement shows a stratigraphy composed of basal portion dominated by fine - medium grained bituminous sands, overlain by shales and siltstones with interbedded sandy shales and clays with bio detrital limestone(Figure 6). Thin lignite bands are also common. The shale and light grey to black, mostly marine and with high organic contents. The age is thought to range from Upper Maastrichtian to Lower Paleocene. It is equivalent to the unit informally.

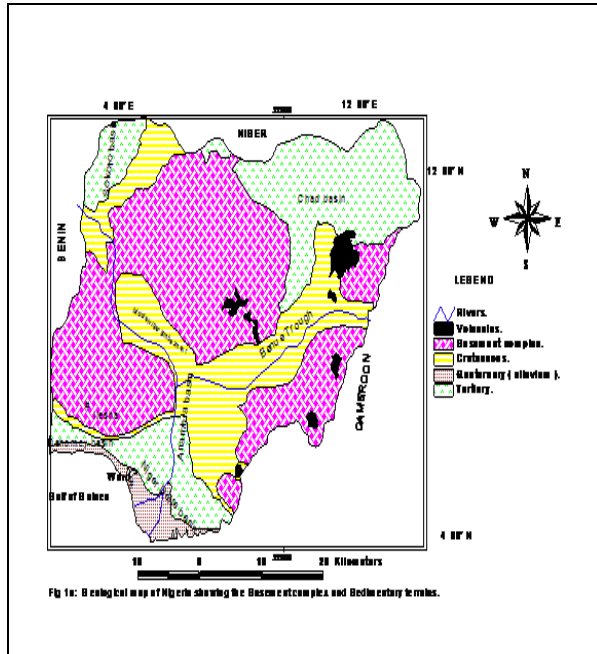


Figure 5: Geological Map of Nigeria Showing Dahomey Basin (Source: Nigerian Geological Survey Agency).

Generalized Lithology	Formation	Age	Thickness (feet)	Comments
Tertiary	Benin Fm., Coastal Plains Sands	Pleistocene - Oligocene	0 - 1600	coastal-plain clastics
	Oshosun - Ilaro - Ameki Fms.	Eocene	200 - 1000	fluvial and marine sands and clays
	Ewekoro Fm.	Paleocene	400 - 1000	marine shale, limestone
Cretaceous	Araromi Fm.	Maastrichtian	500 - 1000	coastal sand, shale, marine shale
	Abeokuta Fm.			
	Afowo Fm.	Campanian - Aptian	0 - 800	marine sandstone, shale, limestone
	Turonian Sst. Albian Sst.			
Ise Fm.	Barremian - Neocomian	0 - 6000+	continental and lacustrine rift-basin fill	
crystalline basement (undifferentiated)		Cambrian - Precambrian		metamorphic and igneous complex

Figure 6: Showing the Stratigraphy Summary of Dahomey Basin. (Source: Omatsola and Adegoke, 1981.)

## MATERIALS AND METHODS

Bituminous sands (Bitumen impregnated sands) were the major geologic earth material collected randomly from the various locations within the study area. Field and Laboratory equipment were also put to use which include Topographical map, Hand shovel, Sample bags, Global Positioning System, Sieve shakers, Weighing balance and some Laboratory consumables. Study methods adopted in this work include both field and laboratory approach. During field work a total of ten samples were collected for geochemical and sedimentological analysis. These samples were collected from different locations in Agbabu and its environ and labelled S1 to S10 appropriately for easy identification in the laboratory (See Figure 1 and Table 1). A systematic observation of the structures on the outcrop found, identifying the different lithology on the outcrop found, taking measurement of the thickness of the beds using a meter tape and outcrop description were all conducted in-situ on the field. Heavy and trace metals/elements were investigated on bitumen samples collected through the process of digestion. During digestion we make use of two methods: Dry method and wet method. Dry method involves the use of heat furnace (100-1000°C) in order to char (Burn away) the sample while the Wet method involves the use of mineral acids. Since Bitumen is a high organic compound, using dry method takes a lot of time, so we make use of the Wet method. 2g of the Bitumen sample was accurately weighed into a clean/dry evaporating dish or beaker, Add 50ml of freshly prepared Aqua regia (HCL+HNO<sub>3</sub>). Boil on hot plate to near dryness, then remove and add 20ml of 10% of HNO<sub>3</sub> (nitric acid) i.e. measure 10ml of the acid and add water to make it 100 and stir. Filter and make up the filtrate to 100ml with distilled or deionized water, then the mixture is being taken to the AAS in order to test for heavy and trace metals.

Sedimentological analysis involves bitumen separation, textural/Grain size Analysis, bitumen extraction and petrographic study. The process of oil sand separation is required or necessary due to the intimate co-existence of sand and bitumen. There exist a thin film of connate water around the sand grain, thereby disallowing direct contact between the sand grain and the bitumen.

The process involves the use of organic solvent e.g. Toluene/petrol or the mixture of biethyl ether petroleum spirit (in equal proportion). The samples were soaked in Toluene- petrol to dissolve bitumen. The process was done repeatedly to completely remove the sand grain and air dried thereafter. For the grain size analysis the pulverized sample was weighed (200 gram), wash with kerosene, detergent and water and over dried for 24 hours. The sample were carefully poured in to the topmost mesh in a stock of sieves with a pan at the base, fastened very lightly on to a sieve shaker machine. The sample was automatically subjected to constant shaking for 10

minutes. Samples retained on each sieve are weighed and recorded for each sample work on. The results of the analysis were plotted, to generate a histogram, particle size analysis curve, probability scale of cumulative frequency curve and bivariate plot. The purpose of grain size analysis is to determine the particle size distribution in sands which relate to availability of different sizes of particles in parent and disposal process operating where sediments were deposited along the course of flow

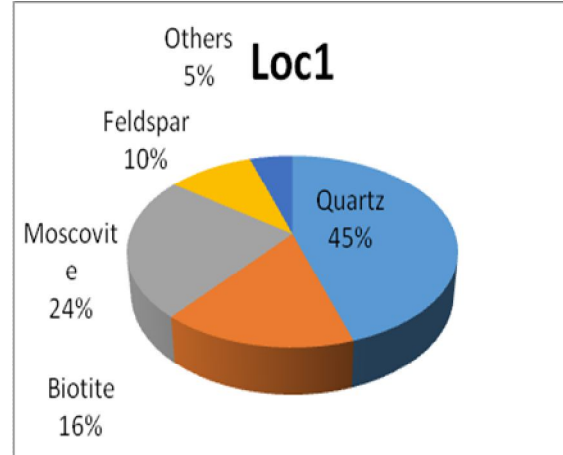
## RESULTS AND DISCUSSIONS

The table below shows the percentage of Sand and Bitumen in the collected sample within the sample locations. The percentage of sand varies between 3.46% - 62.08% and that of bitumen is between 23.68% - 96.54%.

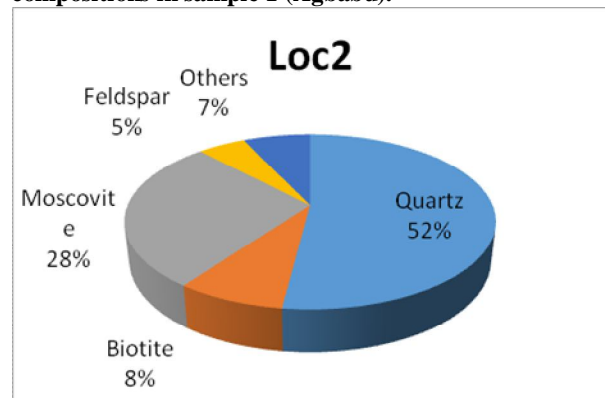
**Table 2: Showing the Percentage of Sand and Bitumen (Bitumen Saturation).**

SP/N	LOCALITY	% SAND	% BITUMEN
1	Agbabu	3.46	96.54
2	Mile 2	3.09	96.91
3	Mile 2	82.06	17.94
4	Mile 2	76.32	23.68
5	Ilubinrin	64.28	35.72
6	Ilubinrin	68.53	31.47
7	Ilubinrin	62.11	37.89
8	Ilubinrin	55.86	34.14
9	Ilubinrin	53.14	46.86
10	Ilubinrin	62.08	37.92

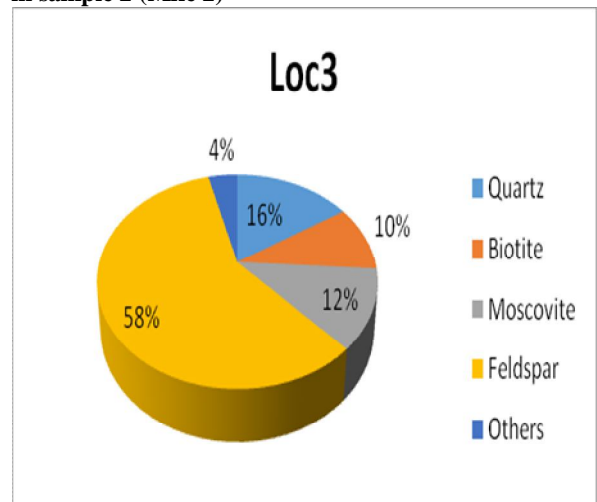
The analysis was carried out on surface samples and it revealed that the percentage weight of the bitumen occupied by the tar sands in the surface samples ranged between 23.68% and 96.54% with an average bitumen saturation of over 40wt%. This can be compared to the Athabasca oil – sands deposits in Canada which is 41% and the Eastern Venezuela deposit which is relatively 48% (Tissot and Weite, 1984). According to Coker, (1988), tar sands with bitumen saturation above mass fraction 10 % (or above volume fraction 19.2 %) is classified as bitumen-rich sands. Based on the analyses carried out on the surface deposits, The Agbabu tar sands can be categorized as rich in bitumen. The component minerals of the tar sands collected are quartz, biotite, muscovite, feldspar and others minerals. The mean percentage of these minerals within the study area range from 3.5% - 57% with Quartz having a percentage of 57%, Biotite 16% , Muscovite 12.7% , Feldspar 17.3% and accessory minerals 3.5%. Figures 7-16 show pie chart of each location with the percentage of minerals of Tar sand within the location.



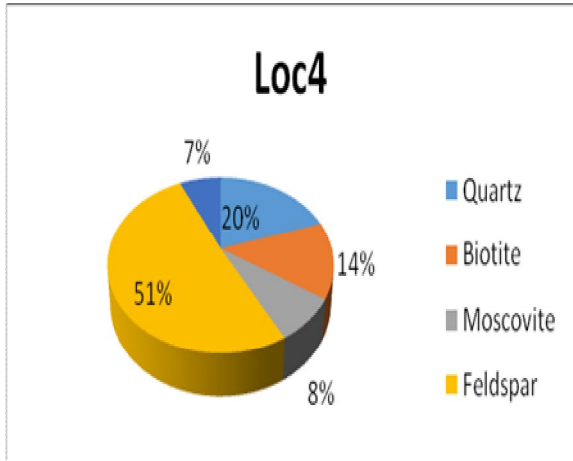
**Figure 7: Showing the percentage of mineral compositions in sample 1 (Agbabu).**



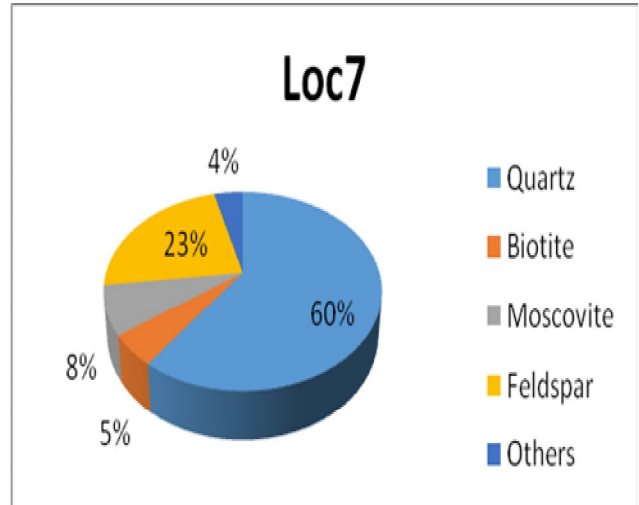
**Figure 8: Showing the percentage of mineral compositions in sample 2 (Mile 2)**



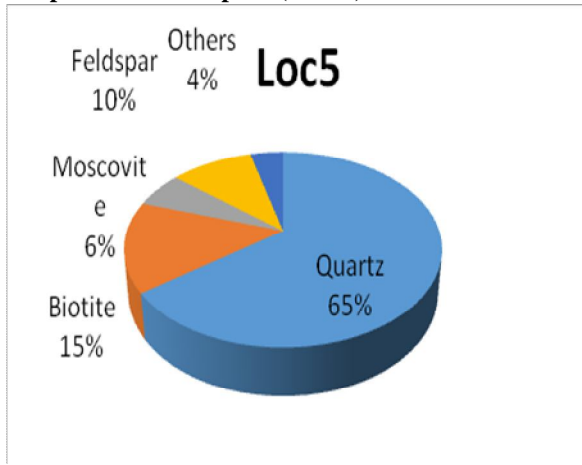
**Figure 9: Showing the percentage of mineral compositions in sample 3 (Mile 2).**



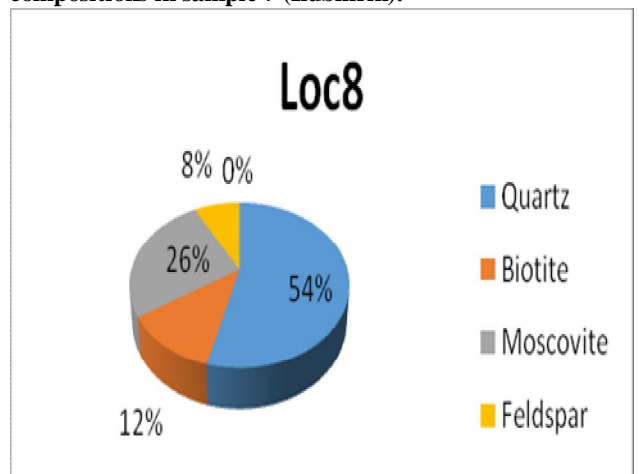
**Figure 10: Showing the percentage of mineral compositions in sample 4 (Mile 2).**



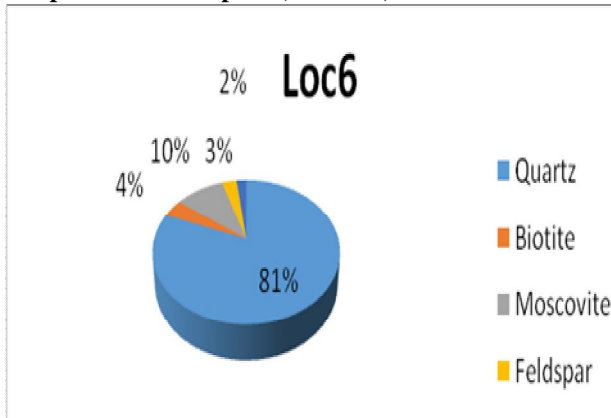
**Figure 13: Showing the percentage of mineral compositions in sample 7 (Iubinrin).**



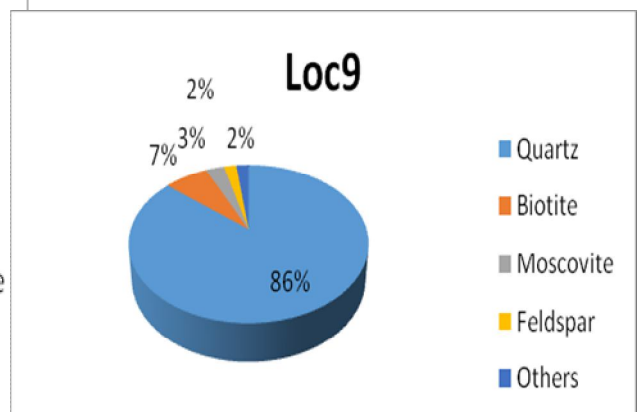
**Figure 11: Showing the percentage of mineral compositions in sample 5 (Iubinrin).**



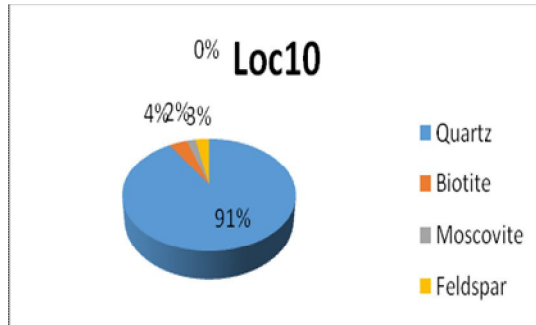
**Figure 14: Showing the percentage of mineral compositions in sample 8 (Iubinrin).**



**Figure 12: Showing the percentage of mineral compositions in sample 6 (Iubinrin).**



**Figure 15: Showing the percentage of mineral compositions in sample 9 (Iubinrin).**



**Figure 16: Showing the percentage of mineral compositions in sample 10 (Ilubinrin).**

The table below shows the result of heavy minerals result of the sample locations. The minerals are Rutile, Tourmaline, Zircon, Topaz, Apatite, Staurolite, Sillimanite and other associated opaque minerals within the samples locations. The result shows that Rutile, Tourmaline, Zircon and Staurolite are present in all the sample locations. Some of these heavy minerals could turn out to be economically viable as large tonnages of sands (Enu and Adegoke, 1984; Coker, 1990).

**Table 3: Showing the heavy minerals result of the sample locations.**

SP/N	LOCALITY	R	T	Z	G	AP	EP	ST	SILL	TP	MG	OP
1	Agbabu	2	4	2	-	1	-	4	1	-	-	106
2	Mile 2	1	2	2	-	-	-	4	-	-	-	128
3	Mile 2	4	6	4	1	1	1	8	2	1	-	152
4	Mile 2	3	6	4	1	2	-	10	1	-	1	216
5	Ilubinrin	6	2	6	2	1	2	14	4	-	-	182
6	Ilubinrin	7	9	7	1	-	4	12	1	2	-	242
7	Ilubinrin	3	4	4	1	1	1	10	2	-	-	186
8	Ilubinrin	14	6	7	1	-	1	8	2	-	1	112
9	Ilubinrin	8	2	4	-	-	2	12	1	-	-	158
10	Ilubinrin	12	4	6	1	1	1	10	4	1	-	204

**NB:** R = Rutile, T = Tourmaline, Z = Zircon, G = Garnet, EP = Epidote, MG = Magnetite TP = Topaz, AP = Apatite, ST = Staurolite, SILL = Sillimanite, OP = Opaque minerals (-)= Implies absence of heavy minerals.

Both opaque and non-opaque minerals were observed. From the table above, the percentage of the opaque mineral is more than that of the non-opaque minerals. The non-opaque minerals identified are Zircon, Tourmaline, Rutile, Garnet, Epidote, Sillimanite, Aplite and Staurolite. The opaque minerals are dark under the petrographic microscope, which are probably Haematite, Limonite and or Magnetite. Zircon, Rutile and Tourmaline, which are ultrastable heavy minerals that can withstand prolonged abrasion and survive many reworkings (Feo-codecido, 1956) were found the heavy metal concentrations (mg kg-1 dry weight) of sediments of the sampled location can be summarized as follows: 0.0112±0.01 for Ba, 0.002667±0.0019 for Co, 0.1585±0.36 for Mn, 0.002±0.0014 for Ni, 0.009±0.0089 for Pb, 0.0071±0.007 for Cd, 0.0082±0.0073 for Cr and 0.0041 ±0.0035 for Cu. Indication is that Ba, Fe, and Mn respectively constitute the highest abundance in terms of concentrations in the sampled sediments.

in all the samples, this implies that the minerals were reworked from older sediments. And also the histogram plots shows unimodal samples which implies that they are from one source. The presence of Zircon, Rutile and Tourmaline, Apatite, indicates an Acid Igneous Rock source. Straurolite, Garnet, Epidote, indicate a dynamo thermal metamorphic source. The concentration of heavy metals and relevant statistical summaries for sediments of the study area is given in Table 4.

A cursory appraisal of Table 4 show the respective abundance trend recorded for sediments of study location as: Ba>Pb>Cr>Cd>Cu>Co>Ni>Mn and

**Table 4: Elemental Composition of sampled Tar Sand.**

SP/N	Ba	Co	Mn	Ni	Pb	Cd	Cr	Fe	Cu
1	0.013	0.001	0.001	ND	0.003	0.001	0.004	3.081	ND
2	0.024	0.005	0.01	ND	0.004	0.000	0.013	3.453	0.003
3	0.014	0.001	0.16	0.004	0.001	ND	0.001	5.692	0.001
4	0.002	0.001	0.025	0.001	0.013	0.0001	0.005	6.029	0.006
5	0.005	0.001	0.021	ND	ND	0.002	0.001	1.437	ND
6	0.004	0.003	1.172	0.003	0.005	0.001	0.016	0.712	ND
7	0.032	0.005	0.08	0.001	ND	0.000	0.011	3.813	0.003
8	0.003	0.001	0.03	ND	0.028	ND	0.023	2.235	0.011
9	0.006	0.005	0.001	0.001	0.005	ND	0.002	7.102	0.001
10	0.009	0.002	0.085	ND	0.014	0.001	0.006	1.982	0.004
Min	0.002	0.001	0.001	0.001	0.001	0.000	0.001	0.712	0.001
Max	0.032	0.005	1.172	0.028	0.28	0.002	0.023	7.102	0.011
Mean	0.011	0.003	0.159	0.002	0.009	0.007	0.008	3.554	0.004
S.D	0.01	0.002	0.36	0.001	0.001	0.001	0.007	2.117	0.003

**NB:** Ba= Barium, Co= Cobalt, Mn=Manganese, Ni=Nickel, Pb= Lead, Cd= Cadmium, Cr= Chromium, Fe= Iron, Cu= Copper, ND= Not Detectable.

The Index of Geoaccumulation (Igeo), which involves comparing observed concentration of the metal (n) in the sediment with pre-industrial levels or background levels, was used to assess the level of heavy metal pollution in the sediments. The Igeo was calculated, using the method of Muller (1979), Abraham & Parker (2008), as follows:

$$I_{geo} = \log_2 ([C_n] / 1.5 * [B_n])$$

Where, C<sub>n</sub> is the measured concentration of element 'n' in the sediment and B<sub>n</sub> is the geochemical background for element 'n'. The Table 5 below shows the contaminating status of the sediments in study area using Contamination Factor and the Degree of contamination of the samples taken in the sampled locations. According

to Hakanson 1980, Contamination Factor in Table 6 which is less than one is considered as Low contamination which implies that the effect of the toxic substance is low. Also from the Degree of contamination calculated as shown in Table 5, it is clearly observed all the sampled location within the study area have a Degree of Contamination which is less than one which implies that the degree of contamination is low Hakanson 1980 (Table 5) . On the basis of the mean values of Contamination Factor, sediments of the study area are enriched for metals in the order: Cd>Mn>Co>Pb>Cr>Cu>Ba>Ni.

**Table .5: Contamination Factor (CF) and Degree of Contamination (Cd) for the samples.**

SP/N	Ba	Co	Mn	Ni	Pb	Cd	Cr	Cu	Degree of Contamination
1	0.00011	0.00010	0.000002173	ND	0.00008333	0.00101	0.00093023	ND	0.001399
2	0.0002	0.00051	0.000021739	ND	0.00011111	0.00010	0.00030232	0.000093	0.001239
3	0.00012	0.00010	0.000347826	0.000174	0.00002778	ND	0.000023256	0.000031	0.000823
4	0.00002	0.00010	0.000054348	0.000044	0.00036111	0.00010	0.000116279	0.000188	0.000982
5	0.00004	0.00010	0.000045652	ND	ND	0.00202	0.000023256	ND	0.002233
6	0.00003	0.00031	0.002547826	0.00013	0.00013889	0.00101	0.000372093	ND	0.004539
7	0.00027	0.00051	0.000173913	0.000044	ND	0.0001	0.000255814	0.000094	0.001344
8	0.00003	0.00010	0.000065217	ND	0.00077778	ND	0.000534884	0.000344	0.001849
9	0.00005	0.00051	0.000002174	0.0000435	0.000138889	ND	0.0000465116	0.0000313	0.000823
10	0.000075	0.000204	0.000184783	ND	0.00038889	0.00101	0.000139535	0.000125	0.002127
Mean	0.00009333	0.000255	0.000344565	0.000087	0.000253472	0.000736	0.000190698	0.000129	0.001736



**Table 6: Contamination Factor and Level of Contamination (Hakanson 1980).**

Contamination Factor (Cf)	Level of Contamination
Cf<1	Low contamination
1≤Cf<3	Moderate contamination
3≤Cf<6	Considerable contamination
Cf>6	Very high contamination

**Table 7: Percentage Mineral Components of Tar sand**

Minerals	Loc1 (%)	Loc2 (%)	Loc3 (%)	Loc4 (%)	Loc5 (%)	Loc6 (%)	Loc7 (%)	Loc8 (%)	Loc9 (%)	Loc10 (%)	Mean (%)
Quartz	45	52	16	20	65	81	60	54	86	91	57
Biotite	16	8	10	14	15	4	5	12	7	4	9.5
Muscovite	24	28	12	8	6	10	8	26	3	2	12.7
Feldspar	10	5	58	51	10	3	23	8	2	3	17.3
Others	5	7	4	7	4	2	4	0	2	0	3.5

The Igeo values and their corresponding contamination intensity for heavy metals in sediments from the study area are presented in Table 8 and the variations are shown graphically. It is evident from the figure that the Igeo values for all the metals fall in class '0' (Table 8) in all the ten

sampling locations indicating that there is no pollution from these metals in the investigated sediments. On the basis of the mean values of Igeo, sediments of the study area are enriched for metals in the order: Cd>Co>Pb>Cr>Cu>Ni>Ba>Mn

**Table 8: Geo-accumulation Index for the study area**

SP/N	Ba	Co	Mn	Ni	Pb	Cd	Cr	Cu
1	-13.7571977	-13.8435285	-19.3962368	ND	-14.1357093	-10.5362	-13.9770115	ND
2	-12.8726749	-11.5216004	-16.0743087	ND	-13.7206718	ND	-12.2765718	-13.9658
3	-13.6502825	-13.8435285	-12.0743087	-13.0743	-15.7206718	ND	-15.9770115	-15.5507
4	-16.4576374	-13.8435285	-14.7523806	-15.0743	-12.0202321	-13.8582	-13.6550834	-12.9658
5	-15.1357093	-13.8435285	-15.0039194	ND	ND	-9.53625	-15.9770115	ND
6	-15.4576374	-12.258566	-9.20147998	-13.4893	-13.3987437	-10.5362	-11.9770115	ND
7	-12.4576374	-11.5216004	-13.0743087	-15.0743	ND	ND	-12.5175799	-13.9658
8	-15.8726749	-13.8435285	-14.4893462	ND	-10.9133169	ND	-11.4534496	-12.0913
9	-14.8726749	-11.5216004	-19.3962368	-15.0743	-13.3987437	ND	-14.9770115	-15.5507
10	-14.2877124	-12.8435285	-12.9868459	ND	-11.9133169	-10.5362	-13.392049	-13.5507
Mean	-14.4821839	-12.8884539	-14.6449372	-14.3573	-13.1526758	-11.0006	-13.6179792	-13.9487
Igeo class	0	0	0	0	0	0	0	0
Remark	unpolluted	unpolluted	unpolluted	unpolluted	unpolluted	unpolluted	unpolluted	unpolluted

The textural/ Grain size analysis for both sample 1 and 2 could not be carried out due to the low percentage of sand as shown in Table 4. The weight of the various grain size recorded for the rest of the

samples were calculated in percentage for passing and retained. Eight samples (S3-S10) were selected based on textural observation as shown in the table below

**Table 9: Result of grain size analysis for sample S3**

<i>(mm)</i>	<i>(phi)</i>	<i>mass retained (g)</i>	<i>Percent Retained (%)</i>	<i>Cummulative Mass Retained (%)</i>	<i>Percentage Passing (%)</i>
2.36	-1.23879	0	0	0	0
1.18	-0.23879	3.3	4.3	4.3	95.7
0.85	0.234465	3.6	4.7	9	91
0.6	0.736966	5.1	6.66	15.66	84.34
0.3	1.736966	15.3	19.97	35.63	64.37
0.15	2.736966	37	48.3	83.93	16.07

**Table 10: Result of grain size analysis for sample S4**

<i>(mm)</i>	<i>(phi)</i>	<i>mass retained (g)</i>	<i>Percent Retained (%)</i>	<i>Cummulative Mass Retained (%)</i>	<i>Percentage Passing (%)</i>
2.36	-1.23879	0.8	0.72	0.72	99.28
1.18	-0.23879	3.8	3.44	4.16	95.84
0.85	0.234465	2.1	1.9	6.06	93.94
0.6	0.736966	2.5	2.62	8.68	91.68
0.3	1.736966	23.7	21.45	30.13	70.23
0.15	2.736966	59	53.39	83.52	16.84
0.075	3.736966	16.3	14.75	98.27	2.09
0.063	3.988504	1.3	1.17	99.44	0.91

**Table 11: Result of grain size analysis for sample S5**

<i>(mm)</i>	<i>(phi)</i>	<i>mass retained (g)</i>	<i>Percent Retained (%)</i>	<i>Cummulative Mass Retained (%)</i>	<i>Percentage Passing (%)</i>
2.36	-1.23879	5	6.11	6.11	93.9
1.18	-0.23879	5.5	6.72	12.83	87.18
0.85	0.234465	1.9	2.32	15.15	84.86
0.6	0.736966	2.2	2.69	17.84	82.17
0.3	1.736966	9.3	11.36	29.2	70.81
0.15	2.736966	32.7	39.93	69.13	3.88
0.075	3.736966	23.9	29.18	98.31	1.7
0.063	3.988504	1	1.22	99.53	0.48

**Table 12: Result of grain size analysis for ample S6**

<i>(mm)</i>	<i>(phi)</i>	<i>mass retained (g)</i>	<i>Percent Retained (%)</i>	<i>Cummulative Mass Retained (%)</i>	<i>Percentage Passing (%)</i>
2.36	-1.23879	2.3	2.9	2.9	97.1
1.18	-0.23879	3.3	4.16	7.06	92.94
0.85	0.234465	1.6	2.02	9.08	90.92
0.6	0.736966	2.2	2.77	11.85	58.15
0.3	1.736966	9.8	13.36	25.21	74.79
0.15	2.736966	28.3	35.69	60.9	39.11
0.075	3.736966	9.5	11.98	72.88	27.13
0.063	3.988504	0.3	0.38	73.26	27.75

**Table 13: Result of grain size analysis for sample S7**

<i>(mm)</i>	<i>(phi)</i>	<i>mass retained (g)</i>	<i>Percent Retained (%)</i>	<i>Cummulative Mass Retained (%)</i>	<i>Percentage Passing (%)</i>
2.36	-1.23879	2.1	5.39	5.39	94.6
1.18	-0.23879	2	5.14	10.53	89.46
0.85	0.234465	1.1	2.83	13.36	86.63
0.6	0.736966	1.5	3.86	17.22	82.77
0.3	1.736966	6.3	16.2	33.42	66.57
0.15	2.736966	16.4	42.16	75.58	24.41
0.075	3.736966	8.8	22.62	98.2	1.79
0.063	3.988504	0	0	98.2	0

**Table 14: Result of grain size analysis for sample S8**

<i>(mm)</i>	<i>(phi)</i>	<i>mass retained (g)</i>	<i>Percent Retained (%)</i>	<i>Cummulative Mass Retained (%)</i>	<i>Percentage Passing (%)</i>
2.36	-1.23879	1.7	2.14	2.14	97.86
1.18	-0.23879	3	3.78	5.92	94.08
0.85	0.234465	2.5	3.15	9.07	90.93
0.6	0.736966	2.8	3.52	12.59	87.41
0.3	1.736966	14.6	18.39	30.98	69.02
0.15	2.736966	36.7	46.22	77.2	22.8
0.075	3.736966	16.8	21.16	98.36	1.64
0.063	3.988504	0.8	1.01	99.37	0.63

**Table 15: Result of grain size analysis for sample S9**

<i>(mm)</i>	<i>(phi)</i>	<i>mass retained (g)</i>	<i>Percent Retained (%)</i>	<i>Cummulative Mass Retained (%)</i>	<i>Percentage Passing (%)</i>
2.36	-1.23879	10.3	13.55263158	13.55263158	86.54
1.18	-0.23879	7.8	10.26315789	23.81578947	76.35
0.85	0.234465	3.4	4.473684211	28.28947369	71.91
0.6	0.736966	3.8	5	33.28947369	66.94
0.3	1.736966	12.3	16.18421053	49.47368421	50.87
0.15	2.736966	27.8	36.57894737	86.05263158	14.53
0.075	3.736966	10.3	13.55263158	99.60526316	1.07
0.063	3.988504	0.3	0.394736842	100	0.68

**Table 16: Result of grain size analysis for sample S10**

<i>(mm)</i>	<i>(phi)</i>	<i>mass retained (g)</i>	<i>Percent Retained (%)</i>	<i>Cummulative Mass Retained (%)</i>	<i>Percentage Passing (%)</i>
2.36	-1.23879	2.4	5.96	5.96	94.04
1.18	-0.23879	4.5	11.17	17.13	82.87
0.85	0.234465	2.2	5.46	22.59	77.41
0.6	0.736966	2.4	5.96	28.55	71.45
0.3	1.736966	7.6	18.86	47.41	52.59
0.15	2.736966	16.1	39.95	87.36	12.64
0.075	3.736966	4.8	11.91	99.27	0.73
0.063	3.988504	0.2	0.49	99.76	0.24

**Table 17: Summary of the result from various parameters used to make deductions.**

Sample code	Description of Mean	Description of standard deviation	Description of skewness	Description of kurtosis
S3	Medium grain	Moderately sorted	Coarse skewed	Leptokurtic
S4	Fine grained	Moderately sorted	Coarse skewed	Leptokurtic
S5	Medium grained	Poorly sorted	Coarse skewed	Leptokurtic
S6	Medium grained			
S7	Medium grained	Moderately sorted	Coarse skewed	Leptokurtic
S8	Fine grained	Moderately sorted	Finely skewed	Leptokurtic
S9	Medium grained	Poorly sorted	Coarse skewed	Platykurtic
S10	Medium grained	Poorly sorted	Coarse skewed	Mesokurtic
Average	Medium grained	Moderately sorted	Coarse skewed	Leptokurtic

## CONCLUSION

Geochemical and sedimentological techniques were useful in determining the quality and environmental impact of the bitumen in the study area. Data available in this study can be used as the exploitation base line for the Agbabu bitumen deposit. The mean concentration of some heavy metals were high in the samples but not beyond the values recommended in Consensus-Based sediment quality guidelines of Wisconsin. The order of the mean concentrations of tested heavy metals in the sampled bitumen within the area where the samples were collected are: Mn>Ba>Pb>Cr>Cd>Cu>Co>Ni>, where both Ba and Mn constitute the highest concentration with mean elemental composition of 0.0112±0.01 and 0.159±0.36 respectively.

Contamination factor (Cf) and Degree of Contamination, Geo-accumulation index (Igeo) have been successfully applied for the assessment of contamination status of the study area. Indication from both the contamination factor and degree of contamination from all the measured heavy metals exhibits low contamination status in the study area. The samples were also described on the graphic method of Folk and Ward (1957). This method was used to deduce statistical parameters of grain size distribution (i.e. the mean, mode, median, standard deviation, skewness and kurtosis). From the interpretation of the bitumen saturation and textural analysis, the mean signifies that the samples ranges from fine grain size to medium grain size, while the standard deviation indicates that the samples ranges from poorly sorted to moderately sorted grains. The values of skewness and kurtosis signifies that the samples are generally fine skewed to coarse skewed and mesokurtic to leptokurtic. These deductions are all characteristics of fluvial particles.

Similarly, the histogram distribution plot indicates that all the samples from the outcrop are unimodal which means that their sediment is sourced from one parent material. Medium grain-size of surface samples, their moderate sorting, and low content of fine grains suggest that Agbabu oil sands reservoir

will be of good quality. The percentage weight of the bitumen in the surface samples ranged between 23.68% and 96.54% with an average bitumen saturation of over 40% which can be compared to the Athabasca oil – sands deposits in Canada which is 41% and the Eastern Venezuela deposit which is relatively 48% (Tissot and Weite, 1984). According to Coker, (1988), tar sands with bitumen saturation above mass fraction 10 % (or above volume fraction 19.2 %) is classified as bitumen-rich sands. Based on the analyses carried out on the surface deposits, The Agbabu tar sands can be categorized as rich in bitumen.

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