



PROSPECTS OF OIL SANDS MINING IN NIGERIA

Omotehinse, A. O.

Department of Mining Engineering, Federal University of Technology Akure, Ondo State Nigeria

Corresponding Email: Omotehinseadeyinka@gmail.com

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Abstract

An overview of oil sands in the southwestern region of Nigeria was carried out to critically discuss why the oil sands should be developed. A review reserves statistics was carried out within different locations and it shows the presence of extensive oil sands deposits and indicates that the oil sands bearing beds are continuous throughout the study area. The laboratory analysis of samples collected during the fieldwork showed that the samples collected have a high bitumen content and the sulphur content was within the range of 1.91% and 0.89%. Outcrops of oil sands were visible on the banks of most of the rivers and farmlands are seen impregnated with bitumen. Some drilled holes were seen, which confirmed the previous exploration activities in the area. The presence of oil sands deposit at a very shallow depth was confirmed indicating that surface mining can be carried out in the area. Therefore, oil sands should be developed in Nigeria for the country's self-reliance on its own natural resource, and the exploitation of this resource will offer a great opportunity for technological development. In addition, the country will be able to save a huge amount of foreign exchange and reduce the dependence on crude oil resources.

Keywords: Surface mining, in-situ mining, upgrading, Nigerian oil sands, Athabasca oil sands, oil sands prospects

Introduction

The economic development and the growth in population in recent years have caused a continuous increase in demand for world energy. For many decades, the world has relied on conventional oil resources for energy and this has resulted into a decline of its availability (Giesy *et al.*, 2010; Santos *et al.*, 2014) and new discoveries of conventional oil are insufficient to meet the increase in energy demand (Santos *et al.*, 2014). Sequel to decline of conventional oil reserves, new oil discoveries were made and these oils have a clearly distinct nature from those inherent to light oils (conventional oils) and are therefore called "unconventional" (Santos *et al.*, 2014).

Unconventional resources have grown in importance and the development will require a paradigm shift in exploration and production as compared to conventional resources considering the physical and chemical properties and the recovery methods and rates (Arthur & Cole, 2014). The unconventional oils cannot be recovered in their natural state by applying normal production methods used for conventional oils because of its resistance to flow, but require heating and dilution during transport. This majorly differentiates unconventional oil from the conventional oil and it increases the recovery costs (Santos *et al.*, 2014).

Studies estimate that unconventional oil reserves exceed 6 trillion barrels, which is equivalent to about 70% of all energy resources derived from fossil fuels in the world. The large sum of proven and recoverable oil reserves in North America and South America can be related to the giant reserves of heavy oils and bitumen from Venezuela and Canada. Unconventional oils resources include heavy oil, extra heavy oil, oil sand, tar sands, oil shale and bitumen. However, these terms are often interchanged and confused because of their similar characteristics. The oil quality is defined based on the American Petroleum Institute gravity (or API gravity), which is the oil density-based standard used and is reported in degrees; this is the most widely used definition for heavy oil (Omotehinse, 2020). Characteristics of heavy oils include high specific gravity, high viscosity, low H/C ratio as well as high contents of asphaltene, resin, heavy metals, sulfur and nitrogen, often featuring a black color (Santos *et al.*, 2014).

Oil sand is an unconventional source of petroleum that occurs naturally; it consists of a mixture of clay, sand, water and bitumen, small amounts of heavy metals and other contaminants (Brandt, 2012). The oil in oil sands is called bitumen and it comprises about 10% of the oil sands (Mech, 2011). Oil sands can be found in countries including Alberta, Canada and Venezuela.

An estimate of about 5.6 trillion barrels of bitumen and heavy oil resources can be found in the world with more than 80% found in Venezuela, Canada and the U.S.A. (Hein, 2006; Omotehinse and De Tomi, 2021). The Alberta, Canada accounts for more than 70 % of World bitumen in place with the largest oil-sand deposits (Tenenbaum, 2009).

Methods of Extracting Bitumen from Oil Sands

The extraction methods are selected based on the depth of the deposit (Bhattacharjee, 2011) or on the overburden ratio, which is the ratio between the thickness of the overburden and the thickness of the bitumen deposit. When the deposit is near the surface, there will be low overburden ratio, generally below 1 and the surface mining technique can be used. However, the in-situ mining method is used if the deposit is deeper below the surface (Zhang, 2014)'—. Oil sands that are mineable by surface mining methods in Alberta is about 8-20 %, while deeper deposits can be mined using secondary recovery methods (Tenenbaum, 2009). Oil sands can be converted to petroleum products, such as diesel, gasoline and jet fuel and it is an important source of energy (Adamu *et al.*, 2014). In oil sands operation, maximum recovery always encompass the three basic operations: mining, extraction and upgrading.

Mining

The surface mining operation of oil sands include techniques such as open pit, open cast and strip mining methods (Mech, 2011) and can be done when the depth is less than 75m below the surface (Banerjee, 2012; Omotehinse and De Tomi, 2020). In surface mining, there is removal of the vegetation and the overburden, which can be the underlying clay, silt and gravel, thereby exposing the oil sands deposits (Zhang, 2014). The deposit is thereafter excavated and transported to a processing facility (Brandt, 2012). The oil sands thickness is usually between 40 to 60m. The overburden removal and the mining operation use “benches” that are up to 15 to 17m high. The oil sand can either be mined with diesel or electric hydraulic shovels or using trucks and shovel technology (Bhattacharjee, 2011).

Extraction

The ore that was mined by the truck and shovel operation is crushed for size reduction and hot water is added to make an ore slurry. This slurry is transported in a pipeline so as to separate the bitumen from the water and sand (tailings) (Bhattacharjee, 2011). The slurry is fed into the primary separation vessel (PSV) where it separates into three primary streams, which are the impure bitumen that is recovered as froth, the coarse tailings majorly sands and the middling consisting of clay, sand, water and some bitumen (Zhang, 2014). The bitumen froth is treated using naphtha or paraffinic solvents and a bitumen ready for upgrading to synthetic crude oil is produced (Brandt, 2012).

Upgrading Processes

Upgrading involves the conversion of the bitumen to lighter fractions with fewer contaminants by reducing the size of the hydrocarbon molecules and increasing the hydrogen-to-carbon ratio of the oil (McWhinney, 2014). The upgrading comprises two stages, which are primary and secondary upgrading. Primary upgrading is carried out either thermally, by the coking process, or catalytically, by the resid-hydrocracking process or both. In the secondary-upgrading stage, the resulting liquid oil from the primary step is further processed to produce a syncrude that meets the refiner feedstock specifications (Banerjee, 2012; Omotehinse, 2020). The product obtained is called the synthetic crude oil, which can be refined to products like jet fuels, gasoline and other petroleum products. There are four various methods or processes to the upgrading process: Thermal Conversion (coking), Catalytic Conversion, Distillation, and Hydrotreating (Bhattacharjee, 2011).

In-situ Extraction Process

The in situ technique is used when the depth of the deposit is greater than 75m usually about 350 to 600 metres below the surface (Mech, 2011) and a variety of in situ techniques is used to recover bitumen from deposits that are too deep from surface (Brandt, 2012). All in-situ techniques involve drilling of two wells and injecting energy (steam) into the ore body from one of the wells thereby reducing the viscosity and increasing the ease of flow and thus forcing bitumen to exit through the other drilled wells. The first well is called the injection well and the second well is called the production well. Extraction of bitumen by in situ methods of extraction is done directly from the ground and the bitumen is separated from the sand without removing it from the ground (McWhinney, 2014; Zhang, 2014).

Oil Sands Occurrence in Nigeria

Oil sands have been known to occur in southwestern Nigeria especially in parts of Ondo, Ogun, Edo and Lagos states (Omotehinse *et al.*, 2020) since early 1900s. There have been various industrial attempt to conduct exploration of these deposits. The first attempt was by the defunct Nigeria Bitumen Corporation in 1908-1914. Shell Darcy carried out surface geological surveys and four wells were drilled in Agbabu, Araromi, Gbekebo and Benin west localities in 1922-1935. Tennessee Nigeria Inc. drilled three wells Ise I, Ise 2 and Orimedu localities in 1963 (Figure 1). The oil sand deposits in Nigeria are estimated to be between 32-47 billion barrels in place. The deposits cover about 5-8 km wide belt stretching over a region of 120 km in length (Adegoke *et al.*, 1980; Ako *et al.*, 1983; Enu, 1985).

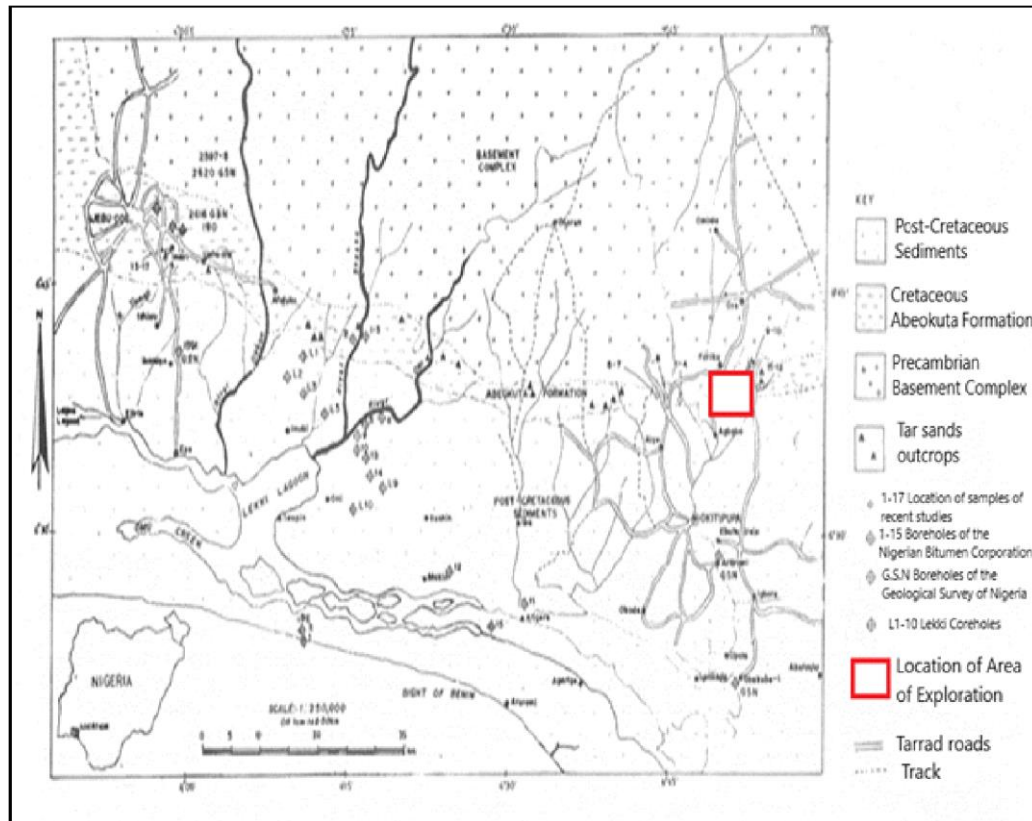


Figure 1: Geological Map of Southwestern Nigeria Showing Oil Sand Locations (Modified after Ako *et al.*, 1983)

The oil sands occur within the Cretaceous sequence of the Dahomey (Benin) Basin. The basin covers five West African countries coastline (Ghana, Ivory Coast, Togo, Benin republic and Nigeria) (Orire, 2009). The stratigraphy of the sequence was carried out by Omatsola and Adegoke, (1980) where three Formations (Ise, Afowo and Araromi) in the Abeokuta Group were recognized based on similarity of origin and lithologic homogeneity. The Abeokuta group is overlaid by the Imo (Ewekoro and Akinbo Formations), Oshosun, Ilaro Formations, Coastal plain sands and the Recent Alluvium (Adegoke *et al.*, 1980; Enu, 1985) group.

Methodology

The investigation for this research involved both the fieldwork and laboratory analysis. The fieldwork was carried out in Ondo state and some parts of Ogun state in Nigeria. This involved extensive bush trekking in order to collect oil sand samples and the exercise was carried out with the aid of global positioning system (GPS), sledge hammer, chisel, pen, and sample bags. A survey of the oil sand outcrops was carried out to observe the deposit. Some oil sands samples were collected from some locations in Ondo state for laboratory analysis. Eighteen samples of oil sands were collected at various depth for analysis as shown

in Table 1. The samples were taken to the laboratory to analyse the bituminous content, saturate, asphaltene, aromatic and sulphur content using the Soxhlet extraction technique using dichloromethane as a solvent. Each sample was weighed directly into the cellulose cartridge and the organic extract was concentrated on a rotary evaporator, which was weighed to determine the organic extract in the sample (% organic extract). Column chromatography was used to analyse the saturated and aromatic fractions. The aromatics were extracted using a hexane / dichloromethane mixture.

Finally, based on some data from available literatures, the potential for the development of the Nigerian oil sands were analysed in comparison with Athabasca oil sands.

Table 1: Samples Location and Depth at which they were Collected

Pit no	Sample no	Depth	Location
P1	1	800cm	
	2	850cm	
P2	3	350cm	06° 38'32.3''N 04° 49'46.8''E
	4	400cm	
P3A	5	150cm	06° 38'32.9''N 04° 49'46.6''E
	6	200cm	
P3W	7	110cm	06° 38'32.9''N 04° 49'46.6''E
	8	160cm	
	9	200cm	
P4A	10	570cm	06° 38'12.9''N 04° 49'52.8''E
P4B	11	570cm	
Ilubirin tar sand	12	50cm	06° 38'16.1''N 04° 49'50.7''E
Mulekangbo tar sand	13	50cm	06° 39.406'N 04° 50.497'E
Point 5 outcrop 1	14	20cm	
Point 5 outcrop 2	15	20cm	
Agbabu bitumen	16	Borehole	06° 35'24.6''N 04° 49'56.3''E
Mile 2 bitumen	17	Water surface	06° 36'47''N 04° 49'55.1''E
Mulekangbo bitumen	18	Borehole	

Results

Field work

Extensive bitumen seepages occur across the streams in Mile 2 and Ilubirin communities as shown in Figure 2. A sealed and an unsealed drilled hole of oil sands deposit was located during the recognisance survey as shown in Figure 3, which showed that exploration activities were carried out in the area. Figure 4 shows

a thick clay sequence that is overlain by oil sands indicating the presence of oil sands at shallow depths. The presence of oil sands deposit at a very shallow depth was confirmed from the holes that was dug hole as shown in Figure 5, indicating that surface mining can be carried out on some of the oil sands deposits in Ondo state. An extensive outcrop which covers some kilometres was intercepted by our team at different locations in Ogun state as shown in Figure 6.



Figure 2: Bitumen seepages on river in Mile 2 and Ilubirin communities



Figure 3a: Sealed drilled holes



Figure 3b: Unsealed drilled holes



Figure 4a: Observing thick clay sequence overlaid by oil sands



Figure 4b: Thick clay sequence overlaid by oil sands



Figure 5: A shallow well dug to locate bitumen deposit during the field trip



Figure 6a: Tar sand outcrops in Onipanu, Ogun state



Figure 6b: Tar sand outcrops in Imeri, Ogun state

Locations of oil sands outcrops in Ondo and Ogun States, Nigeria

Surface and subsurface evidences as observed during the field work strongly indicate that the oil sands bearing beds are continuous throughout the study area. Outcrops of oil sands are visible on the banks of most of the rivers in Agbabu and Irele of Ondo state and in Ijebu-Ife area of Ogun state. In the vicinity of Camp Loda and Ilubirin, of Ondo state, the farmlands are mostly on bitumen impregnated soil. The oil sands consist predominantly of coarse to fine grain quartz. The coarsest sediments outcrop in central portion are found around Abusoro and Gbegude villages in Ondo state. In the west of this region, which is Imeri near Ijebu-Ode, Ogun state, the sands tends to be finer. Some of the well-known outcrop locations and wells as seen during the field work are as presented in Sections 4.2.1 and 4.2.2

Ondo State

Loda I 6°39'N and 4°52.5'E: The bituminous outcrop is overlain by overburden of clayey material. Loda I is about 8km on the east of the road from Olowo junction to Ode-Irele.

Loda II 6°39'N and 4°53'E: An extensive oil sands outcrop is present in this region. This location is approximately 1.2km northwest of Loda I on the road to Igbobini.

Petu Village 6°39.5'N and 4°55'E: A highly indurated bituminous sand forms the water table. Exposures of the sand occur on both banks of the stream.

Gbogi 6°39.5'N and 4°56'E: The tar sand is coarsely grained, highly indurated and forms a cliff, which is approximately 0.3m high. It is associated with a waterfall.

Osumo 6°32.2'N and 4°54'E: The bituminous outcrop is also present along a streambed. It has an overburden thickness of 1m and it is underlain by white clay.

Abusoro 6°38'N and 4°44'E.

Abusoro I: here the bituminous sand is approximately 0.69m thick and it is underlain by 0.07m of hard clayey material. Tar sands occurs on the cliff surface. The outcrop forms the water table.

Abusoro II: the outcrop lies to the southeast of Abusoro I. The bituminous sands outcrop is over 1m thick. A thick vegetation cover is present and it is associated with a waterfall. The material is highly indurated. At both Abusoro I and II, the tar sand is coarse grained.

Ilubirin 6°38'N and 4°50'E: This outcrop is located at kilometre 5 on the Foriku-Agbabu road, approximately 184m east of Ilubirin camp. A clay sequence, which is approximately 0.6m thick is overlain by tar sand.

Mile 2 6°37.08'N and 4°50.5'E: There are no visible outcrop in this location, however extensive bitumen seepage occurs across the streams in the area.

Agbabu 6°35.8'N and 4°49.5'E: No bituminous outcrop was found at Agbabu. However, an extraction probably abandoned by the former Nigeria Bituminous Corporation was located at community leader's backyard (now fenced).

Gbegude 6°40.5'N and 4°25'E: The bituminous sand is arched and forms a cliff, which is 3m high above the river channel. A miniature is also present. Tar seepage forms a thin natural blanket over a cliff surface. The sand is very coarse-grained and easily separates from the bitumen.

Idobilayo 6°39'N and 4°35'E: The Idobilayo outcrop is situated along the bank of Ofara river. A cliff that is 6m above the river channel constitute the bituminous sand outcrop in this locality. A waterfall is present. Natural seepage occurs and this forms a thin blanket on the top of the outcrop.

Lagba 6°38.8'N and 4°45.5'E: Few natural seepages occur within cultivated areas. These natural bitumen seepages are highly indurated and covers the top soil for over a stretch, which is 250m by the bank of the River Oluwa near the old village of Lagba.

Ogun State

Mafowoku 6°41.6'N and 4°12.1'E: No outcrop of appreciable thickness occur, however, a sealed borehole is present.

Onipanu 6°41.6'N - 6°43'N and 4°12'E - 4°43'E: Extensive bitumen seepage occurs across the Oke-Odo streams. The tar sands flows into the stream on hot days and especially during the dry seasons. Over eight other spots of natural tar seepage within the locality was seen.

Imeri 6°47'N and 3°59'E: The Imeri outcrop probably extends eastwards, which is some 2.2km away. The bituminous outcrop is fairly extensive along the Yemaji river near Imeri village.

Oso/Iwopin 6°42'N and 4°15'E: Other outcrops in Ogun state include those at Obada and Irele/Ijebu-Ode.

Laboratory analysis results of collected samples

The laboratory analysis result (Table 2) shows that sample 14 has the highest bitumen content, which is 67.7% while sample 8 has the lowest with 0.08%. Sample 5 has the highest saturate content with 76.9% and sample 13 has the lowest with 12.7%. Sample 2 has the highest aromatic content with 60.9% while sample 5 has the lowest with 10.1%. Sample 6 has the highest asphaltene content with 72.2% and sample 5 has the lowest with 13%. The sulphur content analysis shows sample 5 has the highest sulphur content with 1.91% sulphur and sample 12 has the lowest with 0.89%.

Table 2: Saturates, Aromatics, Asphaltenes and Sulphur content analysis in oil sands samples

Sample	E.O (mg)	%	Saturates (mg)	%	Aromatic (mg)	%	Asphaltenes (mg)	%	% Sulphur (S)
Sample 1	1727.1	10.4	3.9	20.2	6.4	33.2	9.0	46.6	0.96
Sample 2	2533.8	16.5	6.1	24.6	15.1	60.9	3.6	14.5	0.90
Sample 3	782.6	5.1	5.3	22.4	5.5	23.2	12.9	54.4	0.95
Sample 4	105.3	1.97	4.2	22.6	3.9	21.0	10.5	56.5	0.90
Sample 5	23.8	0.55	18.3	76.9	2.4	10.1	3.1	13.0	1.91
Sample 6	268.3	1.66	3.8	17.6	2.2	10.2	15.6	72.2	0.96
Sample 8	10.2	0.08	3.2	31.4	1.8	17.6	5.2	51.0	0.92
Sample 9	273.6	1.73	6.8	34.7	5.9	30.1	6.9	35.2	1.21
Sample 11	630.0	6.0	6.5	29.0	6.1	27.2	9.8	43.8	0.92
Sample 12	3930.3	20.9	6.6	27.4	7.1	29.5	10.4	43.2	0.89
Sample 13	4925.7	34.5	3.2	12.7	6.0	23.9	15.9	63.3	0.96
Sample 14	8394.6	67.7	3.5	14.5	5.7	23.6	15.0	62.0	0.96
Sample 16	0.0	####	6.0	24.1	5.7	22.9	13.2	53.0	0.96
Sample 17	0.0	####	6.1	25.1	14.4	59.3	3.8	15.6	0.95
Sample 18	0.0	####	4.7	19.7	6.7	28.2	12.4	52.1	0.94

Note: There was no bitumen extraction from samples 16, 17 and 18. They were directly fractionated.

Potential of Nigerian oil sands in comparison with Athabasca oil sands

The data used for this comparison was sourced from available literature, which were cited accordingly. Table 3 shows some peculiar similarities in the textural characteristics of the Nigeria and Athabasca oil sands formation. Both deposits are divided into three formations occurring in marine environment in the upper cretaceous to Palaeocene between Neocomian and Albian times (Orire, 2009). The two deposits sit on an angular unconformity and both have wet sand grains, similar textural parameter and have high mean oil saturation content.

The average clay content for the Nigerian oil sands was lower than the Athabasca oil sands and often, oil contents in oil sands is controlled by the clay content and the particle size (Enu, 1985). The low clay content of the Nigerian oil sands can help to hasten the settling of clay in the tailing ponds thereby enhancing recycling of wastewater.

In summary, the Nigerian government can invest in technology transfer, which will be between the two countries with little modification to accommodate the visible differences (viscosity, resin, asphaltenes, sulphur and heavy metal contents).

Table 3: Major Textural Characteristic of the Nigerian and Athabasca Oil Sands Formation (Carrigy, 1973; Enu 1985)

Characteristics	Nigeria	Athabasca (Canada)
Rock unit	Afowo Formation	McMurray Formation
Age of sands	Upper Cretaceous	Early Cretaceous
Net thickness of oil impregnated sands	27m	60m
Grain size	Fine to medium sands	Fine to medium sands
Sorting	Moderately well sorted	Moderately well sorted
Skewness	Positively skewed to near-symmetrical	Positively fine skewed
Kurtosis	Mesokurtic	Leptokurtic
Grain shape	Sub-angular to sub-rounded	Angular to sub-angular
Clay content	2-7%	10-25%
Porosity	24-35%	Average 35%
Oil content (wt%)	8-16%	Average 16%
Packing	Water wet	Water wet
Mineral content	Rare	Rare
Nodules	Pyrite	Pyrite and siderite
Organic matter	Lignite	Lignite, commented carbon
Mineral composition		
(a) Major constituents	Quartz, feldspar, mica, staurolite, zircon and rutile	Quartz and K-feldspar, muscovite
(b) Significant non-opaque heavy mineral	Tourmaline	Tourmaline, zircon and chloritoid
(c) Dominant clay	Kaolinite and illite	Kaolinite and illite
Environment of deposition	Fluviatile	Fluviatile
Fossil content	Foraminifera, pollen, spores, molluscs	Agglutinated foraminifera, pollen, spores, fish teeth

Table 4 shows the result of some elemental analysis of the bitumen samples. It was seen that the value for C, H, O are slightly higher than the Athabasca bitumen, while the other elements have lower values. The higher sulphur content of the Athabasca bitumen is said to be as a result of microbial degradation as sulphur compounds are resistant to bacteria degradation. The calorific values are higher for the Nigerian bitumen

and this may be reflection of the gross elemental composition. Most of the values for the trace metals are lower; this may be of significance in the upgrading and refining processes. The chromatographic result shows that the Nigerian bitumen have slightly more Asphaltene, which may cause more hydro-cracking volume while the Athabasca bitumen have more saturates, aromatics and resins.

Table 4: Comparative Analysis of the Elemental and Chromatographic Analysis of the Nigeria and Athabasca Oil Sands (Oluwole *et al.*, 1987)

Characteristics	Nigerian oil sands	Athabasca oil sands
C	85.56	82.59
H	11.55	10.26
N	0.13	0.50
Cl	0.12	-
S	1.13	4.64
O	1.52	1.21
N	0.103	-
Calorific value:		
kJ/Kg	53,500	41,700
Btu/lb	18,740	17,900
C/H atomic ratio	0.68	0.67
Molecular weight	634	544
Trace metals (ppm by weight):		
Calcium	133	21.1
Iron	57.7	54.2
Potassium	5.38	15.5
Magnesium	3.9	4.9
Sodium	7.58	17
Nickel	35.8	74.9
Vanadium	28.9	198
Chromatographic analysis:		
Saturates	22.3	22.5
Aromatics	12.9	19.3
Resin	33.2	36.7
Asphaltenes	21.3	18.2

Why the development of the Nigerian Oil sands is necessary

There are several reasons why the development of the Nigerian oil sands deposits should begin. These include:

- i) The Nigerian government is totally dependent on imported materials, in which bitumen is not excluded; the national instinct for survival and self-reliance makes it imperative for the country to develop her own resources at any cost.
- ii) It has been demonstrated from the Canadian and Venezuelan experience that availability of conventional crude oil does not stop the production of

synthetic crude oil from oil sands and it is economically viable in today's oil prices.

- iii) The development of oil sands mining and extraction plant will offer Nigeria a great opportunity for technological development. The mine will offer engineers, scientists and operators unlimited scope to adapt mining equipment and technology and in-situ mining will similarly offer unlimited scope for human resource development and technology acquisition.
- iv) The total development of oil sands takes about 10-15 years of hard and sustained serious work to achieve. If Nigeria were to begin today, positive results will not

come until Year 2040. The abandoned refinery at Kaduna, Kaduna state can be recouped to meet this need. This will result in saving of a huge amount of foreign exchange thereby developing our local oil sands resources. With the commercialisation of a less capital intensive in-situ plants, Nigeria's prospect for developing her oil sands resources will be much brighter. The oil from the oil sands can be sent to refineries to make gasoline, diesel, aviation fuel and other consumer products.

v) As exemplified by Canada, despite its light crude oil resources, the country still meets about 40% of her domestic hydrocarbon from oil sands sources. This can be done in Nigeria without totally reliance of our crude oil resources.

vi) Over 68 billion CAD \$ was added to the economy in 2019 by the oil sands extraction companies in Alberta, which was over 18% of Alberta's provincial GDP. The mining of oil sands will be economically viable if the country can plan it right and follow due processes not neglecting the environmental and social impacts of oil sands development.

vii) The by-products such as bitumen, sulphur, ammonia, pitch and phenol are important feedstock for other industries, which will be economically useful in Nigeria.

Conclusion and Recommendation

It can be concluded from the outcome of this research, that there is an abundance of oil sand deposits in Ondo state, Nigeria. It was seen that the deposits have been left untapped and the little exploration activities that were carried out in the late 1970's were not improved on nor continued. The close similarity in the characteristics of the Nigeria and Athabasca oil sands indicated that the experience from Canada can be used as a model for the development of Nigerian oil sands.

Therefore, it is recommended that the development of oil sand deposits should be treated as a national project as the same priority as crude oil in the country. Exploration studies in the other parts of Ondo states and other states within the bituminous belt region should commence. Exploration should also be carried out to prove that the oil sands can be exploited by the in-situ mining method. The search for technology for the commercialization of the oil sand deposits must continue at a steady pace with incentives for private sector participation. Research and development should not be abandoned because of a short-term perception of low economic return on investment or because of crude oil presence in the country.

Studies aimed at scientific and technological development as well as innovation of existing

technologies and in particular, technical manpower development should be funded and encouraged in various universities and research centres in order to accelerate the pace of this development. A research institute on oil sands should be set up to coordinate the development activities and act as a centre for the technological knowledge acquired or developed locally.

It is recommended that the government should consider the mixed ownership mode of investment for the oil sands mining, so as to attract private capitals. The small-scale mining for production of tar should also be encouraged in the country, as this will minimize the importation of tar for road construction.

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