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SPATIAL ANALYSIS AND VULNERABILITY MAPPING OF BITUMEN DEPOSIT IN OKITIPUPA LOCAL GOVERNMENT AREA OF ONDO STATE

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ABSTRACT

Oil spillage has been drastically affecting our ecosystem, there calls the need for the evaluation of its vulnerability in Okitipupa Local Government deposit sites.

Context and background:

It is quiet unfortunate that Settlers in crude oil deposited places always live an unhealthy lifestyle especially during the raining season. There is no other reason for this than the poor spatial data to support and guide safe exploration. This research work looks at spatial provision of solution to this problem using GIS and remote sensing techniques, with the objective to determine the geographical extent of bitumen locations as well as to assess its hazard vulnerability in the study area.

Methodology:

Differential Global Position System was used to acquire the coordinates of bitumen location and subsequently, the coordinates was used to download SRTM Digital Elevation Model from USGS which was used for the assessment of the hazardous effects of bitumen in the study area through hydrological analytical method.

Results:

It was discovered that the total area occupied by land use was 875.50 km^2 and out of which 88.08km^2 (10.15%) was affected by bitumen. The result of physical property test conducted were adjudged good when compared to the established standard while the chemical property test revealed high concentrations of Silicon Oxide which is injurious to health despite its suitability for construction industries. The study recommends that this research should serve as a guide in finding lasting solution to communities already affected and also settlements that are prone to bitumen hazard before it escalates further so as to protect lives, properties, and natural habitats in the study area.

Keywords:

Bitumen, tarry substance, Hazards, Porosity, bulk density, resistivity.

1. INTRODUCTION

Natural earth resources can mostly be categorized into three major kinds namely; land, mineral and renewable resources (Onuiri *et al.,* 2015). Natural mineral resources are valuable resources which can be finite or incapable of renewal, but they however constitute very important unprocessed materials in which many industries depend on for productivity and also serve as a major resource for development.

Bitumen, petroleum liquid or semi-liquid that is sticky, black, and highly viscous is available in continents around the world, particularly Africa. The presence of bitumen has helped in the construction of infrastructural development which in turn has facilitated the social economic growth of its countries (Barth, 1962).The aim of this study is to spatially analyze and map bitumen locations in Ondo State, a case study of Okitipupa Local Government (LGA) area with a view to examining and predict its environmental impact on the study area. Both the federal and state governments in Nigeria have pursued a neoliberal mining approach in order to explore bitumen without success. The major problem attributed to this includes but not limited to: (i)numerous licensed private investors that showed interest in the exploration of bitumen in Ondo State, but were confronted with the inadequate information about the locations, (ii) lack of information about spatial distribution of the bitumen deposit(iii)non availability of environmental impact assessment on the communities and (iv) Federal and State Governments bureaucratic bottleneck are some ofthe challenges that prevented the smooth take off bitumen exploration in the study area.

To be able to achieve the aim of the study and to also provide solution to the identified problems, the following questions were taking into consideration. (i) What are the geographic locations of bitumen deposit in the study area? (ii) Does bitumen deposit have either positive or negative impacts on the study area? And (iii) is there any economic significance to bitumen in the study area? By acquiring geographical data of bitumen locations in the study area and evaluate its hazardous effects, the research outcome proffer solutions to the inherent problems and it also provides relevant spatial analytic maps for assessing and visualizing bitumen environmental impacts in the study area.

Previous researchers such as Aluwonge *et al*., (2017), Rajendran and Sobhi (2018) worked on the usefulness of remote sensing applications in mineral extraction but impact of bitumen hazard vulnerability was not analyzed. Elsewhere, Aliyu (2013) studied mineral prospecting in Toro and Surroundings (Bauchi State) while Adejato*et al*., (2018)researchedon the assessment of how bitumen is been spatially distributed in Dahomey Sub- Basin, a region in Southwestern part of Nigeria (Ilubirin, Agbabu and Ode-Irele) but both researchers failed to map bitumen vulnerable zones and neither was the economic importance of bitumen in the study area analyzed. Finally, Alagbe (2020) delineated bitumen saturated zones in Agbabu, Southern Nigeria with the aim of incorporating ground magnetic and electrical resistivity measures using integrated geophysical method. The research was not only limited to mapping of bitumen vulnerable zones but also the assessment of bitumen physical and chemical properties for detecting bitumen economic relevance was left out.

The gap that this research filled was the spatial analysis of bitumen locations and mapping of the vulnerability zones as well as provision of information on economic significance of the bitumen deposit in Okitipupa LGA of Ondo State to serves as one stop shop for future investors.

1.1 Study Area

Okitipupa the study area (fig. 1) is in Ondo State Southwest Nigeria. In 1991, the Ikale Local Government Area (LGA) was separated into Irele and Okitipupa Local Government Areas. The Local Government is located between latitudes 50° 45' and 80° 15' Northto longitudes 4° 03' and 6° 00' East. According to the Ondo State Bureau of Statistics year 2021, it has a population of about 356,349 people and a land area of about 803 km^2. Irele and Ese-Odo LGAs border it on the East, Odigbo LGA and certain portions of Ogun State border it on the West while Ilaje LGA shared boundary with the study area in the South. The People who live in the Local Government area are mainly Yoruba of the Ikale ethnic group and are the majority in the Local Government Area. As a result, Yoruba language is commonly spoken, despite the fact that English is the official language (Esu, 2013). The people are mostly farmer that grows both cash and food crops (Fish, Palm oil, Cassava, Rice and Kolanut).

They equally produce Local Gin (Ogogoro) from raffia palm which as abundant in the area. The Local Government has a high literacy rate plus a reservoir of highly skilled workforce that covers all sectors of human activities. The local government is a hilly landscape when compared to other LGAs in the riverine area of the State and is characterized by a unique red soil type. The study area has two well defined geological structures: The LGA's northern region has Precambrian basement complex granitic rocks, while the centre and southern parts have recent tertiary sandy sands. The area of study has an average temperature of 28^{0}C with a relatively high humidity of 54% and a yearly rainfall of about 2000mm and it also experiences a moderate dry season between November and March. (Esu *et al.,* 2014)

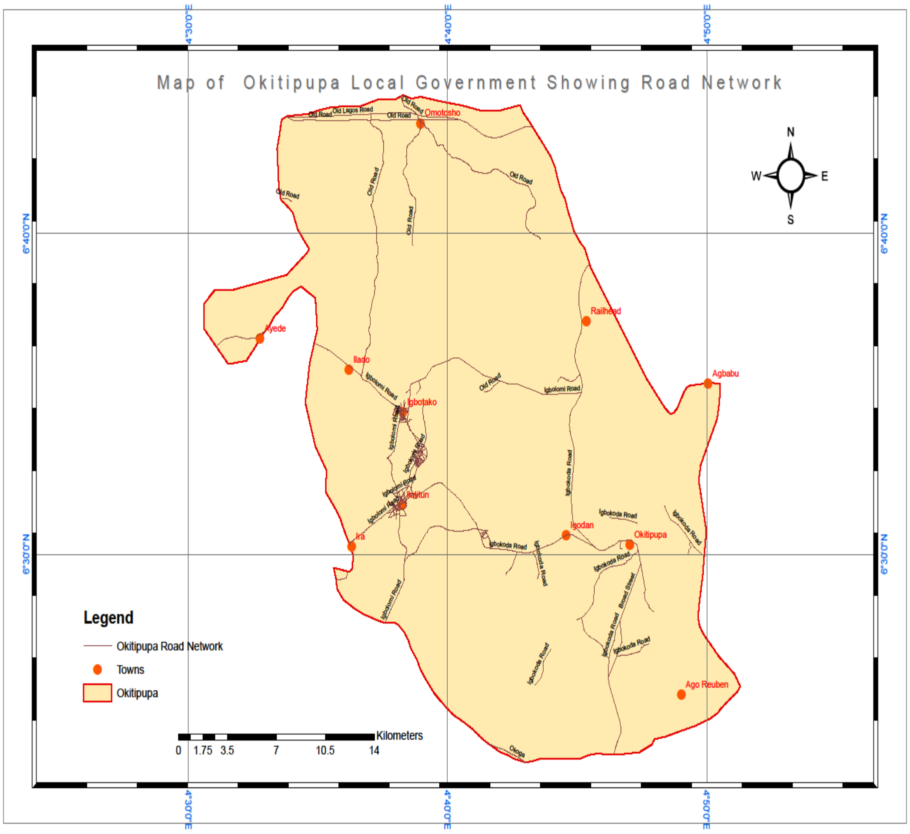

FIG 1.0: Study area Map

2. METHODOLOGY

There were two categories of data obtained in this study: primary and secondary data. The x, y, and z coordinates of bitumen places in the study area were collected using the Global Positioning System (GPS). Also collected at this stage was the bitumen samples scooped at corresponding coordinates points in order to determine their physical and chemical properties. Similarly, secondary data involved the downloading of satellite imagery of 2019from United States Geological Survey (USGS) websites while Shuttle Rader Topographic Mission (SRTM)was obtained from USGS Earth Explorer. Also, the study area's administrative map was obtained from the DIVA-GIS.com official website.

Ground surveying (coordinate method) and remote sensing (satellite imagery) method of data acquisition were adopted. Fresh bitumen samples representing a representative percentage of the whole outcrops were also obtained using a digger and hand trowel. The samples' precise location was documented with high accuracy GPS equipment in static operational mode to ensure the reliability and precision of the data collected before further manipulation and analysis. To prevent contamination, the bitumen specimens were maintained in well-labeled bag. The sample bags were annotated to avoid mix up of collected samples.

Physical and chemical test of the bitumen samples was carried out in the laboratory at Afe Babalola University Ado Ekiti, Ekiti State. The physical test consists mainly of three types: Porosity test, bulk density and Electrical Resistivity while the Chemical Test was conducted using x-ray fluorescence.

While carrying out the porosity test, a 500ml measuring cylinder was half-filled with water and the volume was recorded. Also, a volume of the bitumen sample collected from the study area was similarly poured into another 500ml measuring cylinder and thereafter recorded. As a precaution bitumen was poured into the water to avoid trapping air and the volume was recorded. The porosity of the bitumen was determined based on equation 1 according to Akinyemi *et al.,* (2013)

$^{\varphi} = A - (C - B) \div A$…………………….. eqn. i

Where: A = Volume of bitumen sample (bulk volume)

B = Volume of Water

C = the mixture of A and B

Significantly too, the cylinder that was half-filled with bitumen whose volume was earlier noted together with the weight of the measuring cylinder was also recorded after measurement has been taken. Bulk density of the collected specimen was calculated according toAkinyemi*et al.,* (2013)(Equation 2).

Bulk density = $D(g) \div A(cm^3)$……………….. eqn. ii

Where:

D= The bitumen sample weight as obtained in eqn. i

The resistance of a bitumen sample taken from the research region was ground and packed into a cylinder-shaped PVC pipe, which was then molded into regular shapes in order to create excellent contact with the metal cap (mercury) put into the sample. The voltage was supplied across the two ends of the cylindrical pipe using a direct current source at 8.0, 12.0, 16.0, 20.0, 24.0, 28.0, and

32.0mm voltage respectively and the corresponding current was recorded and computed using equation 3 in line with Lowrie (2007)

Resistivity = $p = RA \div L$…………………………eqn. 3

Where: P = Resistivity

R = Resistance

A = Cross Sectional Area

L = Length

Essentially, for chemical test, x-ray fluorescence was used to analyze the elemental composition of the sample based on energy-dispersive analysis (ED-XRF) method using machine model Varian EDX-8000VFchemical composition of the sample in a similar manner to Akinmosin *et al.,* (2013). Specifically, the experiment was performed by turning the EDX-8000VF power switch on and the instrument was allowed to initialize until a final click was heard to denote the completion of initialization while the filter wheel as well as the sample wheel were both rotated. As a precaution, the top left cover was opened to confirm that the Quest DPP light match the parameters listed in the EDX-8000VF Technical Manual. Thereafter, the X-Ray and Power switches were turned on and energy-dispersive analysis (ED-XRF) was selected from tray list shortcut with the file extension on the desktop. The tray list was completed by entering the sample information, method to be used and tray position number. The nitrogen gas was turned on and pressure was set at approximately 20 psi. The green LED on sample changer was checked to ensure that the first cassette is sensed by fifth changer and The loss of ignition (LOI) test was performed by heating a crucible containing 1.0g of dried material to 900°C for 30 minutes to produce a constant mass. Finally, using the method, the loss of ignition was determined as a mass percentage as seen in (equ. iv) by Akinmosin *et al.,* (2013).

LOI = Mo − M_1 x 100/ Mo ……………………eqn.iv

where: Mo is the mass of the initial sample while M_1 is the mass of the sample at the end of ignition and LOI is loss of ignition

In addition, the GPS observed data as well as the SRTM data obtained were processed in the ArcMAP software environment. The data processing using SRTM data was limited to the determination of boundary, Creation of Contour, Flow Accumulation, Watershed, Flow Direction, Slope, Hill-Shade, TIN and DTM in other to map and assess the Environmental impact assessment (EIA) in the area of study. The Getis-ordGi statistic model was used in the ArcGIS environment as an analytical approach. (Equation v) in line with Manepalli *et al.,*(2011)

$$\boldsymbol{G_i} = \frac{\sum_{a=b}^{n} w_{b,a}x_a - X\sum_{a=1}^{n} w_{b,a}}{S\sqrt{\frac{\left[n\sum_{a=1}^{n} w_{b,a}^2 - \left(\sum_{a=1}^{n} w_{b,a}\right)^2\right]}{n-1}}} \text{………………eqn. v}$$

Where x_a is the feature's attribute value, while $w_{b,a}$ is the spatial weight between features b and a, and n is the number of features. Furthermore, X and S are as shown in equations 6 and 7, respectively, and G_b is a z-score statistic.

$$X = \frac{\sum_{a=1}^{n} x_a}{n} \text{…………………………… eqn.6}$$

$$S = \sqrt{\frac{\sum_{a=1}^{n} x_a^2}{n} - (X)^2} \text{……………………………..eqn.7}$$

Since the G_b is a z-score, no additional computations are needed.

Result of the Z-score from the equation is -33.694570

3. RESULTS AND DISCUSSION

The results and analysis considered includes: Bitumen hazard zones, land use land cover, physical and chemical properties. The Environmental Impact of bitumen in Okitipupa LGA indicates that the areas in red colour on the map(figure 2) are the communities that falls within the hazard zone, this includes: Igodan-Lisa, Ago Bonema, Epinnipinni, Igbo Ayeka, Okitipupa, Erinje-Ekeji, Jemidudu, Igbotako, Erinje, Ago Woli, Odole and Oluabgo, and it is of great importance to understand that people living in that locality are open to the hazard effect of bitumen hence, it is advisable to relocate them from such places because the harmful substances from bitumen can cause different health challenges when consumed through water intake or food. Also, the Latitude and longitude of affected communities are listed in table 1 for charting and easy access to the area.

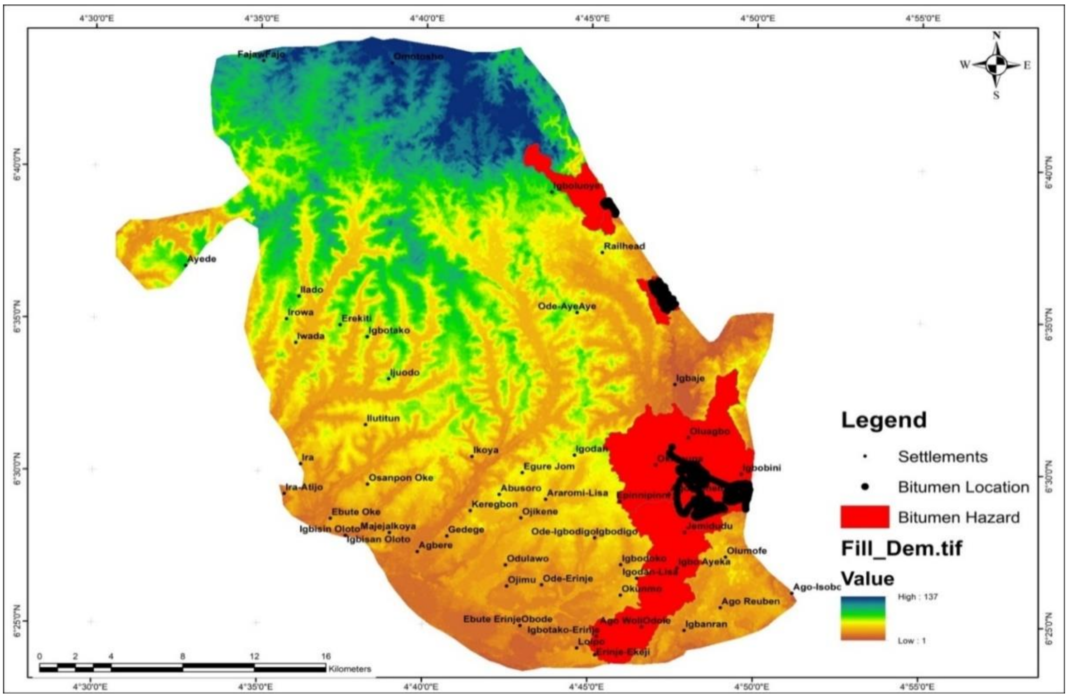

Figure 2: Settlement Bitumen Hazard of Okitipupa LGA

S/N	NAME	CLASSIFICATION	LATITUDE	LONGITUDE
1	Igodan-Lisa	Village	6.442691	4.774791
2	Ago Bonema	Village	6.4886577	4.790737
3	Epinnipinni	Village	6.484654	4.7659625
4	Igbo Ayeka	Village	6.448415	4.795068

5	Okitipupa	Town	6.504748	4.7839524
6	Erinje-Ekeji	Village	6.4005675	4.7539845
7	Jemidudu	Village	6.467988	4.798767
8	Igbotako-Erinje	Village	6.410767	4.754756
9	Ago Woli	Village	6.4160505	4.7774325
10	Igbobini	Village	6.500088	4.82708
11	Odole	Village	6.4160505	4.7774325
12	Oluagbo	Village	6.519879	4.8002745

Table 1: Bitumen Hazard affected communities.

Similarly, the proportion of various land use in the study area by percentage was depicted in table 2. The result shows that bare surface was about 0.6%, while built up area, vegetation and water bodies occupied 10.74%, 88.33% and 0.32% respectively. Also, based on the percentage of affected land use in the study area, it could be seen that 1.313% of bare surface, 27.355% of built up area, 69.774% of vegetation as well as 1.558% water bodies was affected.

	General _ Landuse			**Affected _ Landuse**		**Affected Area in %**
Landuse	Area (ha)	Area (km^2)	%	Area(ha)	Area (km^2)	%
Bare Surface	526.91	5.2691	0.6	116.65	1.1665	1.31317
Built up Area	9405.68	94.057	10.74	2429.92	24.2992	27.35448
Vegetation	77333.78	773.3378	88.33	6198.09	61.9809	69.77411
Waterbody	283.62	2.826	0.32	138.42	1.3842	1.558243
Total	87549.98	875.49	100	8883.08	88.8308	100

Table 2: Land Use Land Cover *(Source: Authors field work)*

The physical attributes' outcome components of the bitumen sample as obtained (table 3) were acceptable because it falls within the specified standard. Specifically, the results obtained for Porosity (0.27kgm/s^2), Bulk density (1.651 which is less than 10.0 g/cm^3) and electrical resistivity (35Ω·m) were within the specified limits

Physical Properties	**Bitumen Sample**	**Standard**
Porosity Test (kgm/s^2)	0.27	0.16 -0.35 kgm/s^2

Bulk density (g/cm^3)	1.651	< 10.0 g/cm^3
Electrical Resistivity (Ωm)	35	10 – 104 Ωm

Table 3: Result of Physical Properties *(Source: Authors field work)*

Notably too, the results of chemical analysis conducted on bitumen sample (Table 4) revealed that the loss of ignition (LOI) was 6.52%. The composition of silica (SiO_2) was 62.27%, while for other elements was as listed. The sample is rich in Silica Oxide as the content of Alumina and Ferric Oxide is less than 10%.

S/N	Parameters	Formulae	% Composition
1	Silicon Oxide	SiO_2	62.72
2	Aluminum Oxide	Al_2O_3	8.83
3	Ferric Oxide	Fe_2O_3	3.68
4	Titanium Oxide	TiO_2	0.94
5	Calcium Oxide	Cao	0.16
6	Lead Oxide	Pb_2O_5	0.05
7	Magnesium Oxide	MgO	0.04
8	Sulphide	SO_3	0.06
9	Sodium Oxide	Na_2O	0.02
10	Potassium Oxide	K_2O	0.01
11	Manganese Oxide	MnO	0.01
12	Loss on Ignition	LOI	6.52

Table 4: Results of Chemical Properties *(Source: Authors field work)*

3.1 Discussions

The results of a z-score is the GIS value obtained for each attribute which ranges from <2.58 to >2.58. Essentially, a positive z-scores shows that the higher the value of the z-score, the more strong the level of clustering of extreme values (hot spot) while negative statistically significant z-scores(smaller z-score), indicates that the bitumen location are not evenly distributed over space, but they are situated closely. The result shows that the nearest neighbor ratio is 0.263571 (mean distance observed divided by mean distance expected), with critical value -33.69 and a test of significant P value of 0.000. The result of the breakdown shows that the spatial pattern of bitumen Location in Okitipupa is clustered and the likelihood that this clustered pattern could be the result of random chance is not up to 1%.

	(P Value)		**(Z-Score)**
	0.01		< 2.58
	0.05		<2.58 to(-1.96)
	0.10		-1.96 to (-1.65)
Significant Value	0	**Critical Value**	-1.65 to 1.65
	0.10		1.65 to 1.96
	0.05		1.96 to 2.58
	0.01		>2.58

Table 5: Significant Value and Critical Value Result

(Source: Authors field work)

In order to determine the communities affected by bitumen, and the use of land in the study area, land use analysis of the area was carried out and the result from the analysis revealed that the total area covered by land use was 875.50 km^2 and out of which88.08km^2(10.15%) was affected by bitumen. The study area is a forested area as visualized during the field work and it was quite difficult to separate farm lands from vegetation since most farmers in the study area plants within the vegetation land use category. From the analysis, apparently, the vegetation land use category was the most affected area by bitumen deposit and may negatively impact the economy of the occupants of the study area because most of them are farmers and some bitumen contents is capable of damaging food crops. This will in turn result to scarcity of food, reduced rate of income generation for the farmers among other negative impacts on the farmland.

Similarly, the 27.5 % of built up area affected may put some of the residents at risk of bitumen spillage, exposure and implication on health, hence the need to relocate the residential buildings, commercial centers etc. in the study area to a very safe environment. This may rendered some persons homeless, going through some hard and tough time in trying to settle down at the new place, some businesses are likely to close down or may take time for some businesses to get back on track as they need to re- build fresh customer relationships in the new place.

The analyses of the physical properties of the sample collected were acceptable when compared to the standard and the result obtained implies that the bitumen is of economic relevance. In addition, the results of chemical analysis conducted on bitumen sample revealed that the sample was rich in Silica Oxide. The content of Alumina and Ferric Oxide was less than 10% while the average percentage of other constituents is 0.18%.Although silicon dioxide is a good food additive but constantly inhaling silica dust is dangerous to human health. Silicon crystalline irritates the skin, eyes and when breathed, it irritates the lungs and produces mucus membrane while Skin inflammation is characterized by reddening, scaling, and itching in line with Poinen *et al.,* (2016).

4. CONCLUSION AND RECOMMENDATION

The study revealed that there is presence of bitumen in the study area. The hydrological analysis including land use and land cover showed that larger percentage of the affected area is vegetation and forested areas followed by built up and smaller percentage of water body. The economy of the study area will experience growth if proper exploitation of this resources is given worthy consideration. The chemical analysis of the bitumen from the study area is averagely consistent as compared to other localities and areas. The results confirmed that the bitumen sample analyzed is rich in silica (SiO_2) and alumina Al_2O_3) which makes the material a great asset for various industrial applications and utilization. The bitumen deposit from the study area will be a good binder in construction industry if appropriately modified and could also be used as road pavement materials because the sample is low in sulphur.

The study recommends that;

i. The impacts on communities should be mitigated by negotiating with the communities and by moving them before exploitation commences because the air pollution from bitumen and the resultant health issues can only be forestalled by not extracting the bitumen.

ii. Government at every level should consider deliberate investment into research and investigations of mineral resources in Nigeria, this will lead to deeper discoveries of presence of more mineral resources at various locations within the country, and this will in turn become major sources of income generation for states and the nation at large.

iii. Proper planning and exploitation of bitumen will lead to more job opportunities in the study area and rate of unemployment/poverty will be greatly minimized and the willingness to study will be fully awakened in young researchers and scientists.

iv. Today's government should appreciate the importance of creating an enabling political environment in view of attracting both local and international investors that are interested in the exploitation of bitumen. Basic facilities such as electric power generation and water supply which are nonexistence as observed during the field work should be made available.

v. Immediate response should be taken by the government and other organization on exploitation of the bitumen and affected citizens should be well compensated.

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Ayeni Samuel Olalekan contributed to this work as the researcher and writer.

Ijaware Victor Ayodele contributed to this work as a Reviewer.

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8. KEY TERMS and DEFINITIONS

Bitumen: A natural oily hydrocarbon sometimes called asphalt

Bulk Density: Weight with respect to the total mass

Hazards: Harmful resultant effect of an action

Porosity: The state or degree of having loopholes

Resistivity: Ability to be impenetrable

Tarry Substance: A black, oily, sticky and viscous substance