Petroleum and Coal

Article **Open Access**

APPRAISAL OF THE BULK PROPERTIES OF BITUMEN SAMPLES FROM FOUR DEPOSITS IN SOUTH WEST, NIGERIA

M. C. Onojake and C. O. Ndubuka

Petroleum Chemistry Research Group, Department of Pure and Industrial Chemistry, University of Port Harcourt, P.M.B 5323, Choba, Port Harcourt, Nigeria

Received May 25, 2016; Accepted June 30, 2016

Abstract

Bulk properties such as American Petroleum Institute gravity, specific gravity, cloud point, Kinematic viscosities, moisture content and gum content of bitumen samples collected from four different deposits in south - west Nigeria were evaluated using standard American Society for Testing and Material methods. Results show ^{0}API gravity ranging from 8.88 – 10.780 specific gravity ranges from 0.99 –1.01, kinematic viscosity ranges from 4.3x103–5.4x103 cSt, moisture content ranges from 1.62–32.48%, gum content ranges from 1347– 6525mg/100 ml, cloud point -12 to -25 ^{0}C. The results show that the samples have similar characteristics with each other, but the Ode-Irele bitumen has better characteristics than all analyzed samples. Results of ^{0}API gravity shows the bitumen samples were found to belong to the class of extra heavy oil.

Keywords: Bitumen; American Petroleum Institute; Heavy oil, ASTM, Principal component analysis.

1. Introduction

The rising energy demand has lead the Oil and Gas Companies to look actively towards heavier crude oil sources to help meet the requirements and take advantage of large heavy oil reserves. Heavy oil includes very viscous oil resources like those found in some fields in Canada, California and Venezuela, oil shale, and tar sands. Bitumen otherwise known as 'oil tar sand' occurs in the southwestern part of Nigeria covering Ondo, Ogun, Edo and parts of Lagos, with a combined proven reserve of about 14.86 billion barrels. The discovery of bitumen as a viscous black tar oozing out of river valleys and farmlands of Agbabu and environs dates back to several decades and Its scientific discovery in Nigeria dates back to early twentieth century [1-2].

Nigeria has the largest oil sands/bitumen resources in Africa and is one of the leading countries in the world regarding its significant deposit potential [3].

Geological studies and physicochemical properties confirmed that Nigerian bitumen is a primary source of energy and an alternative source of hydrocarbon and raw material for the petrochemical industry [4-5]. Bitumen represents an alternative energy source because it has immense potential as an additional hydrocarbon based energy resource in Nigeria. Bitumen produces synthetic crude oil which can be combined with Nigeria conventional crude oil will prolong the life span of the latter.

There is renewed interest in alternative oils which includes shale oils, tar sand, and bitumen which is aimed at diversifying the economy that has been solely dependent on crude oil and its refined products.

The aim of this paper is to use the Bulk properties of the bitumen samples to characterize it with a view of evaluating its economic potential. This will enable users to determine its desired suitability levels for particular applications.

2. Materials and methods

2.1. Description of study area

Bitumen samples were collected from four different locations, Ilubirin, Agbabu, Loda, and Ode-Irele sites, where bitumen outcrops occur. The study area falls between longitudes 4°48´and 4°54´ E and between latitudes 6°35´ and 6°39´ N. It is an area of lowlands with few ridges, about the plains; the hills are very high which are characteristic of the tropical rainforest of southwestern Nigeria. The temperature is relatively high during the dry season with a temperature reaching about 30°C. The Harmattan brought in the northeasterly winds from December to February, which has ameliorating effects on the dry season high temperatures. The area is well drained by NE-SW trending rivers such as Omilala, Ogun, Shasha, Oba and Opeki. The area falls within the 1:50 000 standard topographic sheets 282 (Okitipupa south-east). Each sample location was plotted using a global positioning system.

2.2. Sample collection and analyses

The bitumen samples selected for the study were collected from the richest bitumen spots from south-west, Nigeria. One sample was collected from a standard extraction hole drilled by early explorers of bitumen in Agbabu village (AB), two samples were collected from a drilled well in Ode- Irele village (OI), two sample were collected from clear outcrop deposits in a waterlogged area on the outskirt of Ilubirin village (IL) and finally one sample was collected from clear outcrop deposits in a waterlogged area on the outskirt of Loda village (LD) Figure 1.

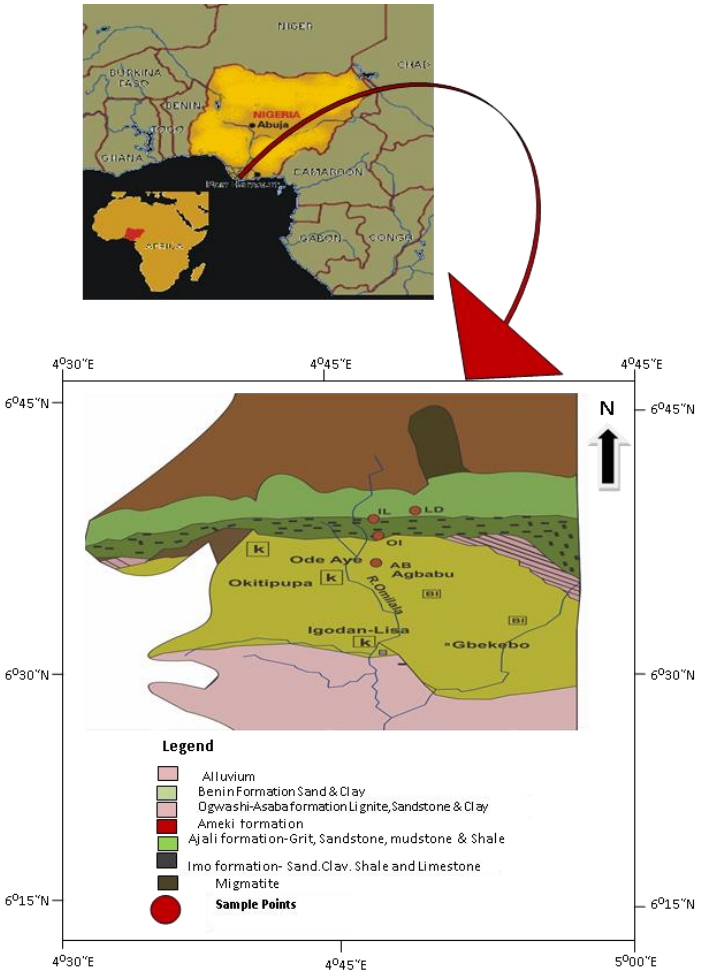

Figure 1. Map of Study area showing sample collection site

The samples were assigned identification names as AB1, OI1, OI2, IL1, IL2 and LD respectively.

Fifty grams (50g) of the sample was weighed into a conical flask and 50ml of dichloromethane was then added to dissolve the sample and left undisturbed for about 30 minutes. The completely digested sample was washed with dichloromethane into a 100ml volumetric flask and was then made up to mark by adding petroleum ether. The resultant solution above was then filtered through a glass funnel containing Whatman No.1 filter paper into a 120mL sample bottle for storage and further analysis.

3. Results and discussion

3.1. Bulk oil parameters

The bulk properties of bitumen samples are presented in Table 1. The results indicate that the analyzed bitumen samples are of good qualities and are comparable with those from different locations of the world [6]. Bulk properties such as specific gravity and API gravity are useful for initial screening and tentative identification of genetically related oils. The specific gravity of the bitumen gives a rough measure of the amount of lighter hydrocarbons present. Lower specific gravity and higher API gravity leads to a greater yield of the lighter fractions when carrying out fractional distillation [7]. The specific gravity of the bitumen samples ranges from 0.99 - 1.01. The specific gravity of each bitumen sample is within the range for asphalt standard of 0.91 - 1.013 obtained by Adebayo [8] from another bitumen location but within the same geographical area is an indication that the bitumen samples are of high quality. Low API gravity is associated with either biodegraded oils or with immature sulphur-rich oils [9], while samples, which exhibit medium to high API gravities suggests that they have been generated from clay-rich source rocks [10- 11].

Table 1. Result of the bulk properties of the bitumen samples

Parameter	Unit	AB	OI1	OI2	IL1	IL2	LD
Density @ 15^0C	g/cm^3	1.009	0.993	0.999	1.001	1.007	1.007
Specific gravity @ 60F		1.011	0.995	1.001	1.002	1.008	1.008
^{0}API Gravity	degrees	8.46	10.78	9.93	9.72	8.88	8.88
Kinematic Viscosity	cSt	5.4x10^3	4.4x10^3	4.6x10^3	4.8x10^3	4.3x10^3	4.5x10^3
Cloud point	^{0}C	-15.00	-15.00	-16.00	-25.00	-20.00	-12.00
Moisture content	%	32.48	1.62	1.62	2.3	15.39	26.53
Gum content	mg/100mL	1347.00	2646.00	3092.00	2573.00	1449.00	6525.00

Key: AB = Agbabu, OI = Ode - irele, IL = Ilubirin and LD = Loda.

Generally, API gravity determines the grade of bitumen and its value increases with a decrease in specific gravity. The bitumen samples show a close range of API gravity values in the range of (8.88 – 10.78) which falls within the specifications of Nigerian Association of State Highways and Transportation Officials Standards for Road Materials [12]. The range of API gravity when compared with those obtained from Alberta Canada and Cold Lake bitumen samples, with specific gravity and API gravity as 0.9916 - 1.0075; and 9.8 – 13.2 respectively [13]. Canada produces lube oil from their bituminous oil, which also suggests that the Nigerian bitumen could also provide a high quality of lube oil for both domestic consumptions and export.

Viscosity is a measure of internal friction of a liquid or the reluctance of a fluid to free flow. It, therefore, indicates the flowing ability of oils from one point to another. Viscosity affects the performance of injection systems. Low viscosity can result in excessive wear in some injection pumps and power loss due to pump and injector leakage. High viscosity fluids cause excessive pump resistance or filter damage and higher line pressures. If the viscosity is low, then the oil sample will have more light fractions. The result of this study shows that the bitumen samples are of high viscosity with a range from 4.3 x10^3 – 5.4x10^{3}cSt. The high viscosities of bitumen are also attributed to its asphaltene content. This is expected since bitu-

men is classified as heavy oil, these values are higher than ones obtained by Kogbe [13], which ranged from 3.05x103 – 4.00x106cSt. Ekweozor and Nwachukwu [14] had reported that the Nigerian bituminous sands are higher in viscosity than its Athabasca counterpart. This property implies that the bitumen samples will not flow into the environment to cause pollution in the event of spillage like the conventional oil will do.

The cloud point is the temperature at which haze or a cloud first appears in a sample of oil when cooled in a prescribed manner. The cloudiness forms as a finite and detectable amount of wax or waxy crystals. This is an indication of the performance of the fuel both in tropical and cold climatic conditions. Mummah and Muktar [15] had reported the value for cloud point for good grade bitumen samples to be in the range of -10 to -30°C.

The gum content is the measure of the degree of unsaturated hydrocarbons in petroleum, which can easily combine with atmospheric oxygen to form a nonvolatile sticky substance called gum. The gum content of samples ranges from 1347.00 to 6525.00 mg/100mL. This is one of the physical properties of bitumen, which infers the presence of unsaturated hydrocarbons in bitumen samples.

The moisture content is an important quality determining parameter because; small quantities of moisture can cause catastrophic damage to a diesel system, wear of machine parts of the injection system promotes corrosion and may cause filter plugging. The moisture content of the studied samples ranges from 16.20 to 26.53%. There was a slight difference from the result obtained from this study and that of Adebiyi and Omode [16] who reported the water content of bitumen from Agbabu bituminous sand to be 15.14%. Moisture extraction from bitumen before modification is necessary as the presence of moisture tends to reduce the adhesiveness of bitumen to aggregate during compaction in pavement construction [17].

3.2. Statistical methods

Principal component analysis (PCA) is useful in reducing the number of variables in a dataset to a few components. These components or factors may represent most of the variation in the original data that simplifies the interpretation of multiple variables [18]. The essence of performing the PCA plot is to obtain a better-quality resolution of discriminant analysis with a better understanding of the relationship from the correlation of sets of variables representing the same geological origin and/or geochemical source between the oil fields and the oils from the fields [19-20]. The basis of PCA is on the eigenanalysis of the correlation matrix, and the Varimax rotation which is usually adopted to maximize the variation in the different components. An eigenvalue gives a measure of the significance of the factor: eigenvalues of 1.0 or greater are considered significant [21–22]. In this study, the Multivariate statistical approach which comprises of the principal component analysis (PCA) and hierarchical clustering analysis (HCA) were utilized in the classification of oils into genetic types.

Loading analysis was performed on the bulk characteristics of the bitumen samples from various locations. The variables that were used in PCA, the obtained loadings and eigenvalues are shown in Tables 2 and 3, figure 2.

Table 2. Eigenanalysis of the Correlation Matrix

Eigenvalue	4.037	1.635	0.804	0.421	0.102
Proportion	0.577	0.234	0.115	0.060	0.015
Cumulative	0.577	0.810	0.925	0.985	1.000

Among the three (3) sets of PCs, PC1 has a variance of 4.03 (eigenvalue) which represents 57.7% of the total variation and has a positive loading on all the variables except API gravity. The PC2 has a variance of 1.64 which accounts for 23.4% of the total variance, has a negative loading on density, specific gravity, and kinematic viscosity (Table 3 figure 2). The PC3, with variance 0.80 accounts for 11.5% of the total data variation, has a positive loading with all studied parameters except density, specific gravity, and gum content (Table 3). The first three principal components with the eigenvalues greater than 1 represent 0.93 (93.0%) of the total variability, suggesting that three principal components adequately explain the variation in the

data set. The high correlation between each variable and each Principal component is very significant which probably signify a single genetic origin of bitumen samples.

Table 3. Loading table of experimental variables on principal components for bitumen data sets

Variable	Unit	PC1	PC2	PC3
Density @ 15^{0}C	g/cm^3	0.454	-0.087	-0.375
Specific gravity @ 60F		0.491	-0.013	-0.094
^{0}API Gravity	degrees	-0.473	-0.067	0.195
Kinematic Viscosity	cSt	0.271	-0.330	0.708
Cloud point	^{0}C	0.140	0623	0.507
Moisture content	%	0.485	0.143	0.101
Gum content	mg/100mL	0.015	0.686	-0.210

Hierarchical Cluster Analysis (HCA) uses some different methods to organize objects (observations) into groups called clusters. Objects within the groups are similar, whereas objects in different clusters are dissimilar [20]. Results of cluster analysis are shown in figure 3. This was used to find out the similarity of the study site were bitumen samples were collected. The sample locations were fused into clusters because of their relative similarity. Sites AB and IL2 grouped together with a similarity level of 97% while the second group comprises sites OI1, OI2, IL1 and LD with about 98% similarity. These study sites belonging to the same cluster/group are likely to have a common organic matter source and some genetic relationship

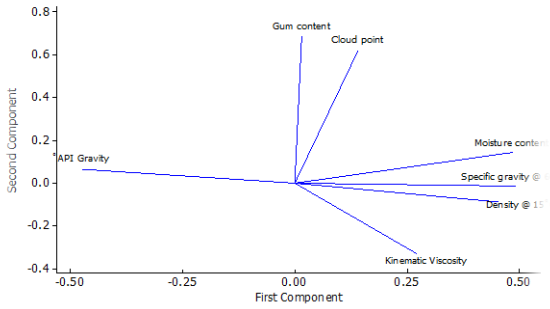

Figure 2. Loading plot of the PCA of bitumen sample

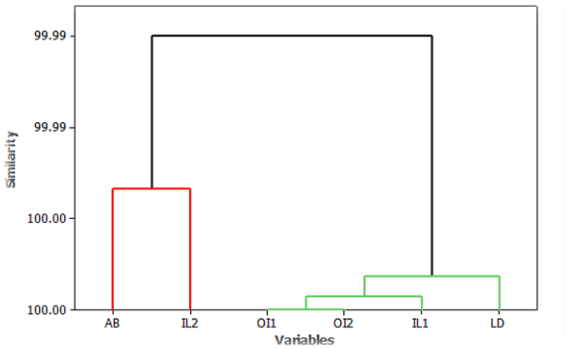

Figure 3. Hierarchical Cluster analysis of the various sample sites

4. Conclusion

The bulk properties have been used to evaluate bitumen samples from four deposits within the study area. The information presented is essential and a contribution towards utilizing the abundant bitumen resources at the four locations for technological applications. This research has shown that the qualities of the bitumen from samples from Agbabu, Ode Irele, Loda and Ilubirin have similar chemical characteristics and are of good qualities which are comparable with those from different locations of the world. The application of Principal components analysis and Hierarchical cluster analysis in the interpretation of the data also shows high similarity of 93.0% and 98.0 % among data set and study locations respectively. This infers the likelihood of a conventional organic matter source and some genetic relationship.

Acknowledgements

The researchers gratefully acknowledge the Department of Petroleum Resource (DPR) for granting us access to the bitumen samples used for this research work and the Management and staff of INDORAMA-Eleme Petrochemical Company Ltd for the use of their Laboratory in

the analyses of bitumen samples. We sincerely thank Dr. Abrakasa Selegha for his useful and constructive comments which helped to improve the quality of this manuscript.

References

[1] Cassey DG, Hubbard FH and Hitch IS. 1963. Preliminary observation on Tar sand deposits Western Nigeria. Federal Ministry of Commerce and Industry, Lagos. 18.
[2] Crockett LO and Wescott BE. 1954. Asphalt samples from West Africa being extracted from the Geology and Prospects of Nigeria. Report No17617.
[3] Meyer RF, Freeman PA and Attanasi ED. 2007. Heavy Oil and Natural Bitumen Strategic Petroleum Resources USGS Fact Sheet 70-03.
[4] Adedimila AS. 1987. Okitipupa bituminous sands: New construction materials for flexible pavements. Nig. Eng. 22: 1- 14.
[5] Ukwuoma O. 1999. Study of composition of Nigerian Tar sand bitumen. Petroleum science and Technology 17: 57- 65.
[6] Odebunmi EO, Ogunsakin EA and Ilkhor PEP. 2002. Characterization of Crude oils and Petroleum Products: (I) Elution Liquid Chromatographic Separation and Gas Chromatographic analysis of Crude Oils and Petroleum Products. J. Bull. Chem. Soc. Ethiop. 16(2):115-132.
[7] Ghulam Y, Muhammad IB,Tariq MA, Syed M, Sibtain RN, Muhammad A, Khizar A and Farah NT. 2013. Quality and chemistry of crude oils. Journal of Petroleum Technology and Alternative Fuels 4(3):53-63.
[8] Adebayo EA. 2004. Extraction and Characterization of Bitumen from Ondo State Tarsand, Proceedings of the 8th National Engineering conference of Kaduna Polytechnic, Nigeria 82-88.
[9] Baskin DK. and Peters KE. [1992] Early generation characteristics of a sulfur-rich Monterey kerogen. American Association of Petroleum Geologists Bulletin. 76:1-13.
[10] Hedberg HD. 1968 Significance of high-wax oil with respect to genesis of petroleum American Association of Petroleum Geologists Bulletin 52: 387-391.
[11] Gransch JA and Posthuma J. 1973. On the origin of sulfur in crudes. In: Advances of Organic Geochemistry. (Tissot, B. and Bienner, F., eds.) Editions Technip, Paris 727-739.
[12] Nigerian General Specification (NGS, 2005). Roads and Bridges volume II, Federal Republic of Nigeria Federal Ministry of Works. Nigeria Meteorological Agency.
[13] Kogbe CB. 1996. Bituminous Chemistry related to oil production and upgrading. Unpublished Report Hydrocarbon research center chemistry department University of Alberta Edmonton, Canada.
[14] Ekweozor CM and Nwachukwu JI. 1989. The Origin of Tar sands of South Western Nigeria. Nig. Assoc. Petrol. Explor. Bull 4: 82-94.
[15] Mumah SN and Muktar S. 2001. Improving Road Pavements with Natural Rubber. Journal of Engineering Technology and Industrial Applications 1(3): 208 -220.
[16] Adebiyi FM and Omode AA. 2007. Organic, Chemical and Elemental Characterization of Components of Nigerian Bituminous Sands Bitumen. Energy Sources, Part A: Recovery, Utilization, and Environmental Effects. 29(8): 669-676.
[17] Hassan O, Bakare AO, Esan OM. Olabemiwo. 2015. Characterisation of Agbabu Natural Bitumen and Its Fractions Using Fourier Transform Infrared Spectrometry. Chemistry and Materials Research 7 (8): 1-11.
[18] Hair JF, Anderson RE, Tatham RL and Black W. 1998. Multivariate Data Analysis, 5th edition. Prentice-Hall, New Jersey; 87–138.
[19] Sappa G, Ergul S and Ferrant F. 2014. Geochemical modeling and multivariate statistical evaluation of trace elements in arsenic contaminated groundwater systems of Viterbo Area, (Central Italy). Springer Plus; 3:237.
[20] Onojake MC, Abrakasa S and Osuji Leo C. 2015. Chemometric Representation of Molecular Marker Data of Some Niger Delta Crude Oils. Egyptian Journal of Petroleum 24: 139–143.

[21] Everitt BS, Landau S, Leese M, Stahl D. Cluster Analysis, 5th edition. John Wiley & Sons Ltd., Hoboken, NJ, USA 2011; 330.
[22] Onojake MC, Ukerun SO and Iwuoha G. 2011. A Statistical Approach for Evaluation of the Effects of Industrial and Municipal Wastes on Warri Rivers, Niger Delta, Nigeria Water Qual Expo Health 3:91– 99.

*Corresponding author. Phone: +234- 8035404696; e-mail ononed@yahoo.com, mudiaga.onojake@uniport.edu.ng