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Characterization of Selected Niger Delta Crude Oil Blends

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Abstract: *The process of determining a crude oil type's chemical and physical characteristics is known as crude oil characterization. The properties obtained from characterization lay the foundation for crude commercial valuation, engineering design, upstream processes, downstream processes, and a better understanding of individual crude blends, hence the need for this study. The primary objective of the study was to experimentally determine five different Niger Delta crude blends from different terminals to understand, carefully characterize, and compute other parameters based on experimental data using ASTM procedures. These properties included API gravity and kinematic viscosity at elevated temperatures. The results show that the crudes are softly naphthenic to fairly paraffinic, with UoPK ranging from 11.4 to 12.1, with supportive VGC values that increase as molecular weight increases. Specific gravity increased with an increase in molecular weight and the mean average boiling point. The API gravity ranges from 18.65 to 47.45, and kinematic viscosity decreases at an increasing temperature of 50 ^oC. Agbami Light had the highest ^{o}API and the lowest estimated molecular weight of 168.050; Ebok crude had the lowest ^{o}API of 18.65 and the highest molecular weight of 301.684. The result shows a high content of sulphur at a lower API and a high specific gravity. This study has characterized the various crude oil blends, and the results show a clear relationship between the crude chemical properties.*

Keywords: Petroleum constituents, characterization, molecular weight, sulphur content, API gravity.

1. INTRODUCTION

A complicated blend of organic materials makes up crude oil. The primary components of petroleum are hydrocarbons, which are typically combined with smaller components such as sulphur, nitrogen, and oxygen. This pertains to gases, liquids, semisolids, and solids in general [1]. Samples of crude oil taken from various oil fields have varied chemical and physical characteristics. This is because the crude oil mix has varying amounts of distinct chemical elements, hydrocarbon diameters, and molecular weights [2]. The main constituents of natural gas and crude oil are hydrocarbon mixtures. Of this, methane, ethane, propane, and butane are examples of lower molecular weight hydrocarbons that exist as gases under normal ambient pressure and temperature circumstances. Whereas, pentane are higher molecular weight hydrocarbons, on the other hand, exists as liquids or solids. However, the amount of gas or liquid in subterranean oil reservoirs fluctuates based on subsurface temperature and pressure conditions [3].

Crude oil, which is normally of undefined composition, requires a characterization procedure to obtain relevant information [4]. The properties of the various crude oils differ greatly from one reservoir to another due to the significant variation in the distribution of the different types of hydrocarbons in petroleum [5, 6]. Odebunmi and Adeniyi [7] assert that a deeper understanding of the makeup, structure, and characteristics of petroleum products' fractions is necessary due to the growing chemical use of crude oils and petroleum products. Density, API gravity, pour point, kinetic viscosity, water content (%), salt content (%), sulphur content (%), asphaltene (%), ASTM distillation cracking point, and metal and mineral concentrations are among the parameters that are frequently evaluated in crude oil. These important parameters are used in the specification and classification of crude oil blends [8].

In Nigeria, crude oil is produced mainly in the Niger Delta region. The oil fields are characterized by multiple sand reservoirs of tertiary sedimentary deposits [9]. Consequently, on the outfields, the wells exist as pockets, with each crude possessing a unique character. Therefore, for convenience of commerce, economics, and processing, crude oils are often blended into a mix that has a unique character. Presently, there are more than fourteen commercially available crude oil blends in Nigeria [10]. These include Bonny light, Bonny medium, Qua Ibom light, Escravos light, Brass Blend, Pennington light, Forcados blends, Amenam blend, Oso condensate, Yoho light, Erha blend, Bonga blends, and Agbami light [11]. The demand for petroleum, a non-renewable energy source, is high worldwide. Yet, the rate at which petroleum-based fuels are being depleted is at its highest in the transportation, heating, and industrial sectors, among other areas [12]. Characterizing crude oil has long been an issue for the refining industry; however, knowing the chemical makeup of crude has become crucial for both upstream and downstream operations. This is because understanding the makeup of crude oil helps petroleum engineers make much better decisions about reserve estimation, crude recoverability, and refinery processes.

Hence, this study aims to characterize various crude oil blends from the Niger Delta Region of Nigeria by experimentally determining kinematic viscosity at 40 ºC, 50 ºC, and specific gravity to establish a characterization factor and, in turn, ascertain the various oil molecular weights and other properties.

2. Materials and Methodology

Five Niger Delta crude (Bonga blend, Agbami light, Akpo blend, Usan and Ebok) were sampled from their terminals. The NNPC provided two of the samples, while quality laboratories in Lagos provided the remaining samples. Prior to being divided into different collections, these samples were properly sealed, stored, and kept in a dry environment to protect their quality. ASTM D4057 was followed when doing the sampling. Other equipment's used includes a hydrometer (density, API, and specific gravity determination), SpectroVISC Q300 (Kinematic Viscosity) using the ASTM D 1298 and 445 methods.

2.1 Specific Gravity Measurement Using Hydrometer

With the aid of an ASTM D1298-compliant hydrometer setup, the density of the crude oil was ascertained. Every glass item was cleaned using distilled water and allowed to air dry with care. A two-way reading hydrometer calibrated to read off liquid density and API gravity is the type of hydrometer utilized. One well-sized volumetric cylinder is filled with distilled water, while another is filled with samples of crude that need to be quantified. The hydrometer is inserted into the water with great care to begin measuring liquids.

The purpose of this is to calibrate and verify the accuracy of the hydrometer that will be utilized. Before measuring the sample temperature, the crude sample density and API gravity were measured after a successful calibration. To prevent damage, the hydrometer was inserted into the oil-filled cylinder and then progressively immersed in the crude, with no contact between the cylinder and the hydrometer. The hydrometer is allowed to go under and back up until it stays in one place consistently. Meniscus error was avoided by reading the hydrometer from a level eye view. Density and API gravity were then read off and recorded, and the recorded value was then corrected to a reference temperature of 60 ºF (15 ºC). The hydrometer correction is indicated in Equation (1).

$$e^r = \frac{e^t}{1} - [23 * 10^{-6}(t-r) - 2 * 10^{-8}(t-r)^2] \quad (1)$$

where:
e^r = hydrometer reading at the reference temperature (°C)
e^t = hydrometer reading at hydrometer actual temperature (°C).
t = actual temperature (ºC)
r = reference temperature (usually at 15.56 ºC)

2.2 Kinematic Viscosity Measurement

In accordance with ASTM D445, a SpectroVISC Q300 S-Auto viscometer was used to measure kinetic viscosity. Its bath has a control column that is thermostatic. Four crudes could be measured simultaneously since it had four independently operating viscometer tubes and optical sensors at the beginning and end of each tube that provided incredibly accurate meniscus identification. After heating the crude sample bath to 50 ºC and 40 ºC, 0.4 ml of the sample was injected into the patented tubes. Before reaching the horizontal arm of the tubes, the sample was heated to bath temperature by the system's high conductivity as it moved down the tube. When the optical sensor detected the warmed-up sample, the measurement began, and it ended when the sample made contact with the second optical sensor. Following the second sensing, the kinematic viscosity result was recorded and shown on the system LCD. Before the following round of measurements, a cleaning procedure is started after each measurement.

2.3 Saybolt Universal Viscosity Determination

The viscosity of the fluid measured in Saybolt Universal Unit was computed using the analytical relation as previously reported by Daubert and Danner [13] and Sharafi et el. [14].

2.4 Watson Characterization Factor Determination (K_w)

The characterization factor is computed using previously reported co-relation by Watson et al. [15]. An API gravity-kinematic viscosity chart from U_OP 375 (U_OP Method 375-07) was employed to determine this factor.

2.5 Viscosity Gravity Constant (VGC) Measurement

ASTM D2501 VGC relation was used to obtain this constant directly from experimental kinematic viscosity values at 40 ºC.

2.6 Estimated Molecular Weight Determination

Since full boiling range data from ASTM D86 and ASTM D1160 were not available, the work of Whitson [16], which demonstrated the link between specific gravity and molecular weight when the Watson factor was available, was used to estimate the molecular weight of entire crude.

2.7 Mean Average Boiling Point Determination (Tb)

This is estimated off the relationship reported by Watson *et al.* [15]. Using the values of the crude's U_OPK factors from the chart and experimental API gravity

3. Results and Discussion

Table 1 displays all the experimental and computed parameters. Figure 1 illustrates the decreasing correlation between the sulphur concentration and the associated increase in API gravity of selected Niger Delta crudes. This is consistent with Ekwere's [17] assertion that the connection between sulphur concentration and API gravity is inverse.

Table 1: Results for experimental and computed properties/parameters

Parameters	Agbami Light	Akpo Blend	Bonga Blend	Ebok	Usan
API Gravity(°API)	47.45	45.3	28.9	18.65	28.45
Specific Gravity@15 °C	0.7907	0.7978	0.8823	0.9424	0.8847
Sulphur Content (Provided)	0.042	0.064	0.241	0.436	0.268
Kinematic Viscosity @40 °C (cSt)	1.46	1.996	6.3	57.1	13.27
Kinematic Viscosity@50 °C (cSt)	1.2	1.55	4.65	35.45	5.758
Kinematic-Viscosity@100 °C (Computed)	0.674	0.723	1.88	6.577	2.27
UoPK Factor (Correlated: UOP Method 375-07)	12.1	12	11.5	11.4	11.6
VGC (Computed)	Not applicable	Not Applicable	0.87	0.9	0.849
Molecular Weight (Computed)	168.05	170.193	221.177	301.684	237.855
Mean Average Tb (°F) (Computed)	875.851	885.86	1044.118	1239.961	1080.664
Saybolt Universal Viscosity (Computed)	29.863	31.093	41.33	166.289	44.839

The five samples show that, as stated by the USEIA [18], regions with significant concentrations of sulfuric rock deposits are likewise linked to locations with heavy crude oil samples. Compared to the other five samples, Ebok has a greater crude sulphur level. Whereas, Agbami Light has the least amount of sulphur accumulated in it.

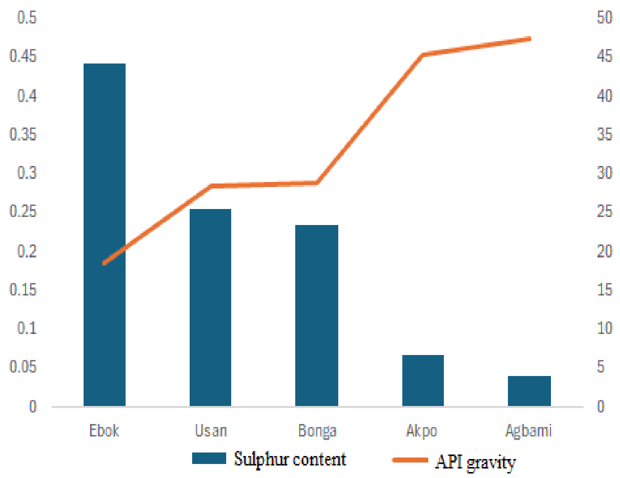

Figure 1: Relationship between sulphur content and API gravity

It has also been shown that the sulphur level of crude oil blends and API gravity are inversely correlated [17]. Additionally, it is well known that when crude oil's specific gravity rises, so does its sulphur concentration [19]. The geologic makeup of the regions where these crude oils are found can help to explain this [20]. Research has revealed that regions with significant concentrations of sulphur-rich rock deposits are likewise linked to reports of heavy crude oil samples [21, 22]. While the majority of light crude oil samples are discovered in regions with minimal sulphur rock concentrations. Sulphur is also a somewhat heavy element. Consequently, the specific gravity of oil samples will rise due to its presence. This also explains the low specific gravity of crude oil samples with low sulphur concentration and vice versa.

Research [7, 23, 9] has already demonstrated that the relationship between API gravity and specific gravity as well as the percentage of sulphur content is inverse. Additional research [24, 25] also revealed a correlation between the specific gravity of crude oil samples and their sulphur level. According to the API standard, all of the study's samples can be categorized as sweet crude because their sulphur level is less than 0.5%. Since sweet crude samples are less likely to corrode and pollute, which raises production costs, they are typically chosen over sour crude samples for the creation of the most value refined products [26]. The grade or quality of crude oils is determined by the API gravity. According to API gravity, samples of crude oil are often categorized as light crude oil if their API gravity is larger than 31, as medium crude if it is between 22 and 31, and as heavy crude oil if it is 20 or below [27]. The majority of the crude oil blends acquired from Nigeria are light crude oils, as can be shown by comparing the API gravity values obtained for the crude oil blends in this study with those found in API Standard (Figure 1) [27]. The findings for the sulphur content and API gravity of the crude oil samples from Nigeria are consistent with previously published findings [8]. The study's findings thus support the notion that the majority of Nigerian crude oil blends fall primarily into the light crude oil category and often have low sulphur contents. Their inclinations in the oil market and refinery operations are enhanced by the implied superior quality.

3.2 Estimated Parameters and Factors

Figure 2 is a plot with K_w and VGC data. At lower VGC values, there is higher K_w values. This is because a decrease in the VGC value of a crude indicates an increasing paraffin-based type crude and vice versa. VGC values are not computable for crude with kinematic viscosity lower than 5.1 cSt (ASTMD 2501).

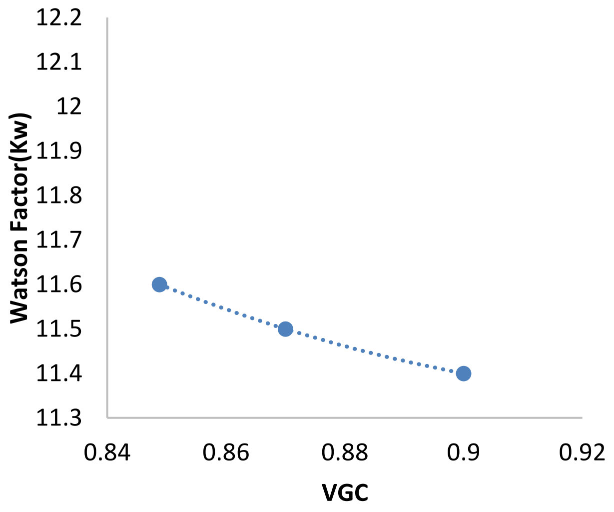

Figure 2: Plot showing the relation between Watson factor and VGC

The correlation between the estimated molecular weight and Tb of five crude samples is displayed in Figure 3. The values of each individual molecular weight were plotted against individual T_b, and a fair relational mapping was achieved, showing a corresponding increase and decrease of T_b and M_w properties from one to another. This is reasonable and natural because higher molecular-weight hydrocarbons have a much higher boiling point compared to lower varieties, in compliance with a relation observed by Riazi [1]. Ebok crude has an estimated molecular weight of 301 with a corresponding mean average boiling point of 1240 °R and Agbami light has the lowest molecular weight of approximately 168 with a corresponding mean average boiling point 876 °R.

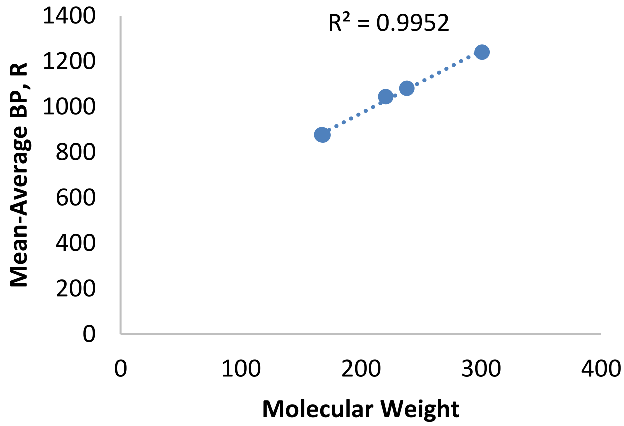

Figure 3: Plot showing relation between molecular weight and mean average boiling points

As per the API gravity value of the select crudes, Akpo Blend and Agbami Light are more commercially viable and have higher prices compared to the other three. This isn't just because of the API gravity alone, but because Akpo Blend and Agbami Light have far lower sulphur contents. Commercially speaking, the sweet spot for crude is usually those that fall between 40° and 45°; Refineries find less value in molecular chains that are shorter than this range [28].

Akpo and Agbami light are denoted as light crudes; Usan and Bonga blends are medium crudes. Only Ebok crude is heavy among the selected crudes. Though the definition of heavy and light crude is location and market criteria-dependent, the samples here in Nigeria fall into the classification stated above [27].

The relationship between the specific gravity and molecular weight of certain crude and mean average boiling points, respectively, is shown in Figures 4 and 5. It is evident that the mean average boiling point and molecular weight exhibit a similar trend. Higher specific gravity (denser crude) commands a higher value of both molecular weight and boiling point.

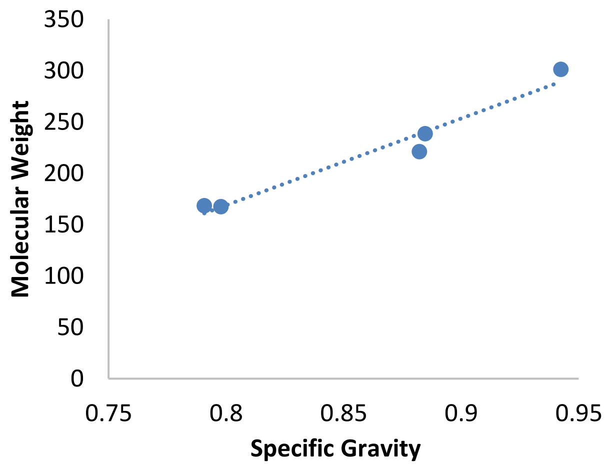

Figure 4: Plot showing relationship of specific gravity to molecular weight

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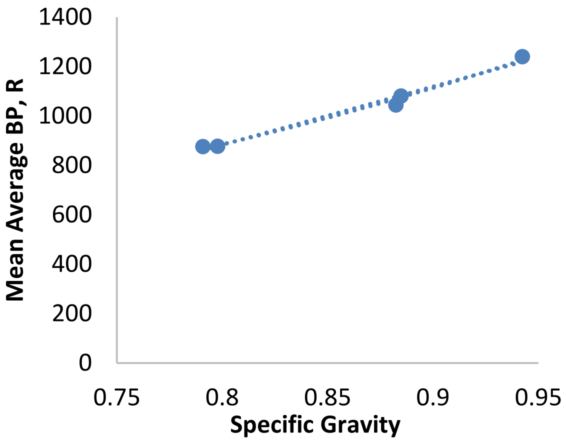

Figure 5: Plot showing relationship between specific gravity to Tb

With relatively low kinematic viscosity values, lighter crudes like Agbami light and Akpo blends are easier to flow through production tubes and porous media until they reach storage. As a result, they require less intervention for efficient production and transportation. The thickest blends in the group, Bonga blend, Usan blend, and Ebok blend, have a lower fluid flow than the light crude. More work is needed for transport from the reservoir up to storage and the pipeline to designated points; therefore, heating and raising the temperature of the crude to meet the needed flow rate all boil down to extra costs relative to the lighter crude. This trend generally implies that Akpo and Agbami Light remain relatively less expensive to transport and produce, and that more barrels can be produced and transported at a much quicker rate. And this also means that in the event of spillage, the Akpo and Agbami Light crude would cause more environmental issues since they can flow quickly compared to the others.

4. CONCLUSION

The results from this research have clearly shown the nature of the selected crude samples and have established the crudes to be mostly naphthenic to softly paraffinic in nature. This means that Akpo blend and Agbami light, which have UoPK factors of 12 and 12.1, are generally more valuable, sweeter, and lighter than the other samples because the other samples will produce more distillates.

In summary, as clearly seen, the Niger Delta crude values in relation to one another show the following key trends. Sulphur content is higher with a lower API gravity and a higher specific gravity. Kinematic viscosity decreases as temperature increases. A higher estimated molecular weight has a higher mean average boiling point. The Watson factor increases as the molecular weight of the sample decreases. VGC values increase (become more aromatic) as molecular weights increase. As VGC values increase, U_OPK values decrease, and vice versa. Increasing specific gravity shows an increase in molecular weight. Also, increasing specific gravity records an increase in the mean average boiling point.

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REFERENCES

[1] M. Riazi, "Characterization and properties of petroleum fractions.," West Conshohocken, 2005.
[2] R. A. Oderinde, "Studies on Nigeria's Petroleum Part 1. Varietal Differences in Vanadium and Titanium Contents," *Nigerian Journal of Sciences,* vol. 18, pp. 143-148, 1984.
[3] E. Peretomode, "Determining the Relationship between Specific Gravity (60 °C) and Kinematic Viscosity of the Crude Oil Samples in Selected Nigerian Oilfields," *JOST,* pp. 11(2): 10-14, 2021.
[4] A. Abdulkareem and A. Kovo, "Simulation of the Viscosity of Different Nigerian Crude Oil," *Leonardo Journal of Sciences,* vol. 8, pp. 7-12, 2006.
[5] J. Speight, "The Chemistry and Technology of Petroleum," Marcel Dekker, pp. 215-216, 1999.
[6] N. Hyne, "Nontechnical Guide to Petroleum Geology, Exploration, Drilling, and Production," PennWell, pp. 1-4, ISBN 0-87814-823-X, 2001.
[7] O. Odebunmi and S. Adeniyi, "Infrared And Ultra Violet Spectrophotometric Analysis of Chroma Tographic Fractions of Crude Oils and Petroleum Products. Bull," Chern. Soc. Ethiop., pp. 21(1),135-140, 2007.
[8] L. Oyenkunle and O. Famakin, "Studies of Nigerian Crudes I. Characterization of Crude Oil Mixtures," Petroleum Science and Technology, pp. 22(5&6): 665-675., 2004.
[9] E. Peretomode, "Determining the Relationship between Specific Gravity (60 °C) and Kinematic Viscosity of the Crude Oil Samples in Selected Nigerian Oilfields," JoST, pp. 10-14, 2021.
[10] U. Dickson and E. Udoessien, "Physicochemical Studies of Nigeria's Crude Oil Blends," Petroleum & Coal, pp. 54 (3) 243-251, 2012.
[11] NNPC, "Research and services. Crude assay and petrochemistry," Nigerian National Petroleum Corporation, 2002.
[12] M. Ali, M. Khan, R. Tuhin, M. Kabir, A. Azad and O. Farrok, "Chapter 9 - Hydrogen energy storage and transportation challenges: A review of recent advances," in Global energy demand, 2024, pp. 255-287.
[13] T. E. Daubert and R. E. Danner, API Technical Data Book- Petroleum Refining, 6th ed., Washington, DC: American Petroleum Institute (API), 1997.
[14] M. Sharafi, M. Ghanem and N. Baryin, "Fluid and Rock Properpies Laboratory. Experiment: Determination of Saybolt Viscosity of Crude Oil," Petroleum and Natural Gas Engineering Department, Izmir Katip Celebi University, Turkey, 2020.
[15] K. M. Watson and E. E. Nelson, "Improved Methods for Approximating Critical and Thermal Properties of

Petroleum Fractions," Industrial and Engineering Chemistry, vol. 25, pp. 880-887, 1933.

[16] C. Whitson, "Characterizing Hydrocarbon Plus Fractions," SPE J, vol. 23, no. 4, pp. 683-694, 1983.

[17] D. Ekwere, "Oil and Gas Operations: its Theory and Experimentation," Houston, 1991.

[18] USEIA, "Short Term Energy Outlook Market Prices and Uncertainty Report Independent Statistics & Analysis,"www.eia.doe.gov/emeu/steo/pub/contents.html, 2011.

[19] S. Awad and H. Al-Mimar, "Statistical Analysis of the Relations between API, Specific Gravity and Sulphur Content in the Universal Crude Oil," International Journal of Science and Research, vol. 4, no. 5, pp. 2319-7064, 2015.

[20] J. Udene and I. Etim, "Physicochemical Studies of Nigeria's Crude Oil Blends," Petroleum & Coal, pp. 54(3): 243-251, 2012.

[21] E. Reigel and J. Kent, "Kent and Reigels handbook of industrial chemistry and biotechnology," in handbook of industrial chemistry and biotechnology, New York, Springer, 2007, p. 117.

[22] I. A. USEIA-United States Energy, "Short term Outlook Market Prices and Uncertainty Report Independent Statistics & Analysis.," 25 March 2011. [Online]. Available: www.eia.doe.gov/emeu/steo/pub/contents.html.

[23] A. Madu, P. Njoku and G. Iwuoha, "Extent of Heavy Metals in Oil Samples in Escravous, Abiteye and Malu Platforms in Delta State Nigeria.," Learning Publics Journal of Agriculture and Environmental Studies, pp. 2 (2).41- 44, 2011.

[24] O. Joel and C. Amajuoyi, "Physicochemical Characteristics and Microbial Quality of an Oil Polluted Site in Gokana, Rivers State," J. Appl. Sci, p. Environ. Manage.13(3) 99 – 103, 2009.

[25] C. Ukpaka, "The Effect of Mesophilic and Thermophilic Temperature on Bonny Light Crude Oil Degradation in Niger Delta Area of Nigeria using Pseudomonas sp.," Journal of Engineering and Technology Research, pp. Vol. 3(13): 360-370., 2011.

[26] H. Volk, S. George, H. Middleton and S. Schofield, "Geochemical Comparison of Fluid Inclusion and Present-Day Oil Accumulations in the Papuan Foreland – Evidence for Previously Unrecognized Petroleum Source Rocks," Organic Geochemistry, pp. 36(1):29-51, 2006.

[27] API, "API Specification for Materials and Testing for Petroleum Products," Dallas, 2011.

[28] R. Gomez, "Louisiana Energy facts annual," Department of natural resources, Louisiana, 1989.