International Journal of Science and Healthcare Research
Vol.1; Issue: 3; July-Sept. 2016
Website: www.gkpublication.in/ijshr
Original Research Article *ISSN: 2455-7587*

Determination of Cloud and Pour Point of Crude Oil with Reference to Crude Transportation

Emmanuel, O. Eyankware[1], Wisdom, C. Ulakpa[2], Moses O. Eyankware[3]

[1]Department of Gas Engineering, Faculty of Engineering, University of Port-Harcourt, P. M. B 5323, Rivers State, Nigeria.
[2]Department of Chemical Engineering, Faculty of Engineering, Odumegwu Ojukwu University, Anambra State, Nigeria.
[3]Department of Geology, Ebonyi State University, Abakaliki,. P.M.B. 053. Ebonyi State.

Corresponding Author: Emmanuel, O. Eyankware

Received: 27/05/2016 | Revised: 03/08/2016 | Accepted: 04/08/2016

ABSTRACT

In this study, the cloud and pour point of the Nigerian Niger Delta Crude oil were determined so as to ascertain the temperature at which wax crystallizes and precipitates during crude transportation. Four (4) crude samples were collected and analysed in the laboratory and the results showed that each of the samples had varying cloud points; Sample A - 23^0C, Sample B - 14^0C, Sample C - 23^0C and Sample D - 20^0C with a mean value of 20^0C. Same trend was also exhibited by the pour points; Sample A - 11^0C, Sample B - 2^0C, Sample C - 14^0C and Sample D - 8^0C with a mean value of 8.75^0C. It was then concluded that wax deposition during crude transportation in the region can be prevented especially in onshore pipelines if efficient preventive measures are put in place being that the region in the tropics with a minimum ambient temperature of 18^0C. Factors that affect cloud and pour point of crude oil were also highlighted and recommendations that will help prevent crude oil from wax crystallization and precipitations were given.

Keywords: Cloud Point, Pour Point, Crude oil, Wax Deposition, Paraffin Wax.

INTRODUCTION

Crude oil is a naturally occurring mixture, consisting predominantly of hydrocarbons, sulphur, nitrogen and metals (Yasin, *et al.*, 2013). Crude oils are complex but mainly paraffinic, napthenic and aromatic (Wang *et al.*, 1994). Crude oils contain all normal alkenes from C_1 to C_{120} (Khanorkar *et al.*, 1996). However, this percentage rises to 35% in highly paraffinic and decreases to zero in highly biograded oils (Ali, *et al.*, 1989). Ajienka and Ikoku, (1997) stated that Nigeria has a substantial reserve of paraffinic crude oils known for their good quality (low sulphur, high API gravity), and containing moderate to high contents of paraffinic waxes. Waxy crude oils have undesirably high pour points and are difficult to handle where the flowing and ambient temperatures are about or less than the pour-point and according to Peng *et al.*, (2014) high pour point oil reservoirs are usually part of the developed oilfields in various regions worldwide. Elijah *et al.*, (2012) also stated that waxy crude oils exhibit Bingham non-Newtonian flow behaviour below the cloud point due to wax crystallization.

The Nigerian Niger Delta crude oil, which is the mainstay of Nigerian economy, exhibits waxiness, with deposits in the range of 30-45 % (Adewusi, 1997; Fasesan and Adewumi, 2003; Taiwo *et al.*, 2009 and Oladiipo *et al.*, 2009). During its transportation, because oil temperature at initial station is higher than the ambient temperature, the oil temperature continues to decrease, and when it decreases to the wax precipitation point of crude oil, wax crystal in crude oil starts to precipitate, grow, and deposit on the pipe wall finally; sediments on pipeline will reduce the effective flow area of the pipeline, increase friction, and thus reduce transmission capacity of the pipeline (Tian *et al.,* 2014). Also, production tubing had waxed up in several cases and this had resulted in the expensive maintenance procedure of wax cutting which involves using scrapers conveyed by wireline. Billions of dollars has been lost to its prevention and remediation (Oladiipo *et. al.,* 2009). Wax deposition in crude oils has been a problem in crude transportation for a long time and according to Al-Besharah *et al.,* (1987) the difficulties in pipeline transportation are due to this complex nature of crude oil, which cause a variety of difficulties during the production, separation, transportation and refining of oil.

When a waxy crude oil is cooled, the heavier paraffinic constituents begin to separate as solid crystals once the solubility limit is exceeded (Karan, *et al.,* 2000). Elijah *et al.,* (2012) stated that thermodynamically, the solid-liquid phase boundary temperature, that is the maximum temperature at which the solid and liquid phases co-exist in equilibrium at a fixed pressure, is the wax appearance temperature (WAT). It is also known as the Cloud Point which according to (Holder and Winkler, 1965; Hussain *et al.,* 1999) depends on wax concentration, the crystallization habit of wax, and the shear stability of different wax structures. Crude oil starts to lose its flow characteristics when wax crystallization begins to occur. The lowest temperature at which the oil is mobile is termed Pour Point and these two temperature points are of immerse importance in crude transportation.

Aim and Objectives:

The aim of this research is to determine the cloud and point of Nigerian Niger Delta crude oil as to how it affects crude transportation. The specific objectives are listed below;

To determine the temperature at which the sampled crude oil becomes semi solid and loses their flow characteristics.

i.) To compare the cloud and pour point of the different crude samples.

ii.) To investigate the various factors that can affect the cloud and pour point of crude oils.

iii.) To make recommendations as to how wax deposition can be prevented during crude transportation.

LITERATURE REVIEW

Due to flow assurance problems encountered during crude transportation using pipelines in the oil and gas industry, it has become of paramount importance to study the different factors that enhance wax deposition in pipelines. Several researchers have done work on the subject matter and have been able to predict using scientific methods conditions that promote wax deposition while also professing ways to combat its undesirable occurrence. These researchers include; Hunt, (1962); Matlach *et al*., (1983); Agrawal *et al*., (1990); Bern *et al*., (1980); Burger and Perkins, (1981); Brown, Niesen and Erickson, (1993); Svendsen, (1993); Nazar *et al*, (2001); Mehrotra and Bhat, (2007); Zhang and Liu, (2010); Ramirez Jaramillo *et al*., (2004); Ribeiro *et al.*, (1997); Lee, (2008). Amongst the numerous researches done, some are discussed here.

Elijah *et al.,* (2012) stated that the main components of the heavy fraction of hydrocarbon which participate in the solid phase formation include asphaltenes, diamondoids, petroleum resins and wax. Petroleum wax consist mainly saturated paraffin hydrocarbons with number of carbon atoms in the range of 18-36. Wax may also contain small amounts of naphthenic hydrocarbons with their number of carbon atoms in the range of 30-60. Wax usually exists in intermediate crudes, heavy oils, tar sands and oil shales. There are three main factors that affect wax deposition in flow systems which according to Bott and Gudmundsson (1977) are flow rate, temperature deferential, and cooling rate, as well as surface properties.

Zhen *et al.* (2014) proposed that early studies suggested that, the mechanism of wax deposition could be summarized as the following four types: molecular diffusion, shear dispersion, Brownian diffusion and gravity settling, in which molecular diffusion was generally considered as the most important mechanism causing wax deposition. Singh *et al.*, (2000) confirmed that shear dispersion, Brownian diffusion and gravity settling had little influence on wax deposition, namely molecular diffusion was dominant mechanism of wax deposition. Hamouda and Davidsen (1995) also considered that shear dispersion had an influence on wax deposition, but the main cause was still molecular diffusion, and he ignored the influence of shear dispersion when establishing the prediction model of wax deposition.

Singh *et al.*, (2000) proposed that the process of wax deposition could be described by the following steps: (1). Gelation of the waxy oil on the cold surface, (2). Diffusion of waxes towards the gel layer from the bulk, (3). Internal diffusion of these molecules through the trapped oil, (4). Precipitation of these molecules in the deposit, (5). Counter diffusion of de-waxed oil out of the gel layer. This proposition was confirmed by measuring the carbon number distribution in the sample of wax deposition layer under different experimental time.

MATERIALS AND METHODS

Four (4) crude samples were obtained from the Niger Delta region in Nigeria and analyzed to determine parameters such as cloud and pour points, pH, density and specific gravity.

pH Determination:

The apparatus used to determine the pH of the samples are Hanna pH meter and beaker. The samples are poured into four beakers and the Hanna pH meter was used to measure their respective pH levels.
Hanna pH meter is as shown in Fig.1.

Figure 1: Hanna pH meter determining the pH of a crude sample

Specific Gravity Determination:

Apparatus used in specific gravity determination were hydrometer and 200ml volumetric cylinder. The cylinder was filled to the mark with the respective crude samples and the hydrometer was inserted into the medium to determine their specific gravity as shown in Fig. 2. Reading was taken from the lower meniscus.

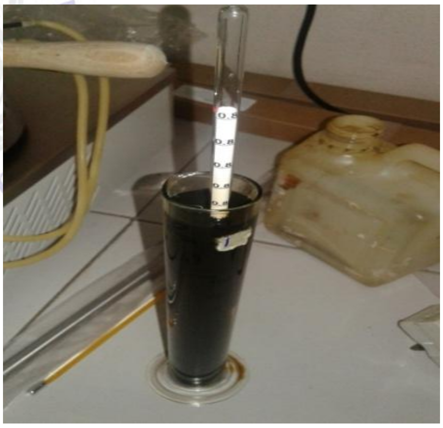

Figure 2: Specific gravity of a crude sample being determined with a hydrometer

Figure 3: Water bath and heater

Density Determination:

This was determined using the equation;

$\rho_{\text{crude oil}}$ = Specific Gravity * ρ_{water}

where $\rho_{\text{crude oil}}$ = Density of crude oil sample

ρ_{water} = Density of water = 1000 kg/m^3

Cloud Point Determination:

Apparatus used in cloud point determination were test jar, cork carrying thermometer, water bath with heater, cloud point chamber and crushed ice. Experimental procedures are as enumerated below;

a) Test jar was filled to the level mark, closed tightly by the cork carrying the thermometer and placed into a bath of crushed ice as shown in Fig. 3.
b) Test jar was removed from the jacket quickly without disturbing the specimen. Inspection for cloud point was done and jacket replaced. Operation was done without exceeding time duration of three (3) seconds.
c) Since cloud point is the temperature of a liquid specimen when the smallest observable cluster of hydrocarbon crystals first occurs upon cooling under prescribed conditions, observation was done and cloud point was reported to the nearest 1˚C. At this point, cloud is observed at the bottom of the test jar, which is confirmed by continued cooling.

Pour Point Determination:

Same apparatus that were used in cloud point determination were used in pour point determination. Experimental procedures are enumerated below;

A sample of worm crude was filled to the level mark. The test jar was tightly closed by the cork carrying the test thermometer and placed in a bath of crushed ice.

a) The test jar was inspected at an interval of at three (3) minutes by holding in a horizontal position for a few seconds before returning it to cool.
b) The pour point was reached when the oil surface stayed in the vertical position for a period of 5 seconds without sagging. At this point the thermometer was inserted to cool for 10 seconds and the temperature of the oil was taken.
c) The pour point was 3˚C higher than the thermometer reading. Crude sample at pour point is shown in Fig. 4. Also, Fig. 5 shows cloud and pour point chambers.

Figure 4: Crude sample at pour point

Figure 5: Cloud and pour point chamber with test jar inserted

RESULTS AND DISCUSSIONS

Table 1 shows the results of the experiments carried out to determine pH, density, specific gravity, cloud and pour point of the four (4) crude oil samples.

Table 1: Results showing pH, Density, Specific Gravity, Cloud and Pour Point of Crude Samples.

Parameter	Unit	Sample A	Sample B	Sample C	Sample D	Mean
pH	-	5.2	5.7	5.2	5.8	5.5
Density	kg/m^3	850	790	830	900	842.50
Specific Gravity	-	0.85	0.79	0.83	0.90	0.84
Pour Point	(^{0}C)	11	2	14	8	8.75
Cloud Point	(^{0}C)	23	14	23	20	20

From Table 1, it can be noticed that the cloud points of crude samples A, C and D have temperature limit that is higher than the least expected annual mean temperature (>18^{0}C) being that Nigeria has a tropical climate with the exception of sample B which implies that wax deposition can be easily prevented in the region. Also from the table, it is evident that the pour points of the samples are below ambient temperature especially for onshore pipeline facilities in the Niger Delta region. A critical look at Table 1 shows that sample C has the highest pour point while sample B has the lowest pour point signifying that sample C has the highest paraffin content while sample B has the lowest paraffin content.

Fig. 6 shows that a linear relationship exists between specific gravity and cloud point of the crude samples. It is also shown in Fig. 7 that a linear relationship exists between specific gravity and pour point of the crude samples. This linear trend for crude oils is reported by Modesty (Kelechukwu, 2011).

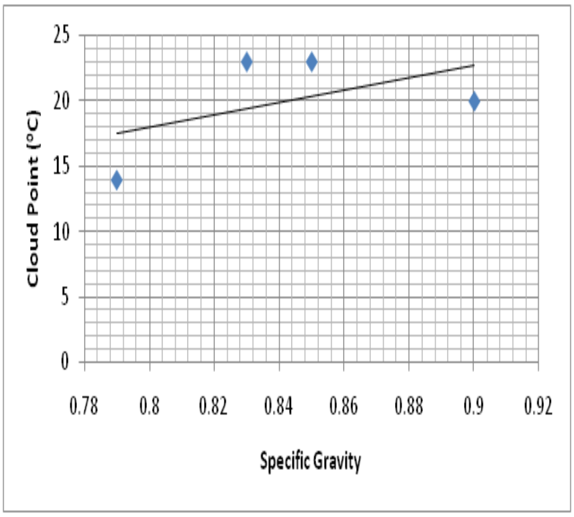

Figure.6: Graph showing relationship between specific gravity and cloud point

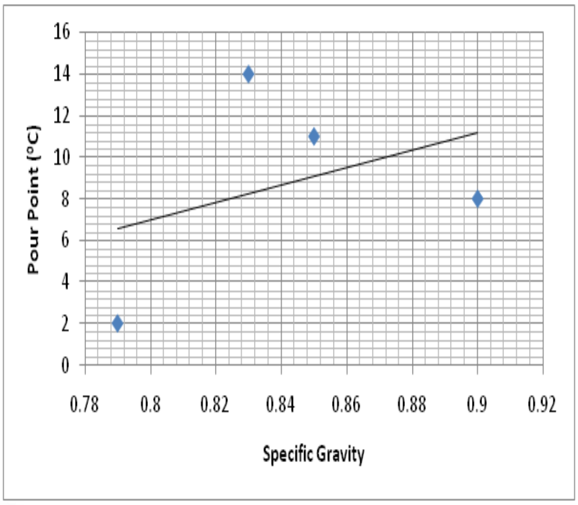

Figure 7: Graph showing relationship between specific gravity and pour Point.

Based on the findings, it is imperative to say that the Nigerian Niger Delta crude oil is the type of crude oil that has a low tendency towards forming wax crystals especially in onshore pipeline facilities as far as the minimum flow temperature is kept above the cloud point which is at a mean value of 20^{0}C for the crude samples. In order words, costly extreme wax deposition management measures can be avoided if crude temperature can be maintained at a temperature higher than the average cloud point.

Factors Affecting Cloud and Pour Points of Crude Oil

There are certain factors that directly affect the cloud and our point of crude oil. Proper management of these parameters will help control the rate with which crude oil reaches its cloud and pour point. These parameters are discussed as follows;

a) **Temperature Differential:** Wax deposit decreases with an increase in temperature difference (Kelechukwu *et al.*, 2010). This proposition is in total agreement with previous studies carried out by Cole and

Jossen (1960); Haq (1978) and Tang *et al.,* (2002), but however, disagreed experimentally that wax deposition would increase by increasing temperature difference between cold pipe wall temperature and feed temperature as reported by Nazar *et al.,* (2001), and Jennings and Weispfennig (2005). This drop in wax deposition rate with increase in temperature difference could be attributed to the extra heat gained or added in the solution, which would further move the solution away from its cloud point. Hence the process of crystal formation and their deposition is a function of temperature difference (Norman, 1989). Since wax deposition is directly affected by cloud and pour point, there exists a direct relationship between these temperature points and temperature differential between the waxy crude and pipeline wall.

b) **Paraffin Wax Content:** The amount of paraffin wax in a crude oil sample affects its cloud and pour point temperatures. Wax deposition has a higher tendency to occur in crude oils with high paraffin wax content than those with lesser paraffin wax because wax can easily agglomerate when it is high in content than when it is not. As such, the amounts of paraffin wax present in a crude sample directly affect the rate at which it will reach its cloud and pour point.

c) **Flow rate:** Mohammed (2007) hypothesized that a higher flow shear, which is a function of flow rate, leads to lesser but likely harder wax deposit build up. Thus wax deposition gradually decreases with increase in flow rate and turbulence. The effect of increasing flow rate, decreasing the amount of wax deposited or entrapped oil in the deposited, was also reported in two subsequent coaxial shear cell studies by Lee-Tuffnell (1996) and Dawson (1996). This can be explained; that as the velocity of the moving stream increases, the molecules gain more energy with a corresponding increase in temperature which would reduce the tendency with which the waxy crude would reach its cloud and pour point.

d) **Surface Properties:** Properties such as density, specific gravity and viscosity are determinants of the cloud and pour point of crude oil sample. There exists a relationship between density and specific gravity as shown in Table 1. Also, viscosity is affected by specific gravity because the denser a fluid, the more viscous it becomes. Since viscosity directly affects cloud and pour point, it is essential to state that the higher the density, specific gravity and viscosity of crude oil sample, the more its tendency towards reaching its cloud and pour point as shown in Fig. 6 and Fig. 7 respectively.

CONCLUSION AND RECOMMENDATIONS

In oil and gas industry, wax deposition has been an age long problem and its determination and control has been a very important topic for researchers. A pertinent factor of wax deposition is the cloud and pour point at which crude oil forms wax crystals and loses its flow characteristics which has been the focus of this research. As highlighted by the researcher, there are certain factors that influence cloud and pour point temperature which if properly managed will help curb the occurrence of wax crystallization and deposition. So, these factors should be effectively and efficiently managed by midstream companies involved in the transportation of crude oil in a bid to prevent deposition of wax.

The Nigerian Niger Delta crude oil as shown in this research is one that can be easily managed especially onshore at conditions that will help prevent wax deposition. Following this, preventive measures such as installation of heaters along flow lines to help keep crude temperature above the cloud point of the fluid should be carried out. Also, the use of chemical solvents like wax inhibitors and Pour Point Depressants (PPD's) should be encouraged. (Bagdat and Masoud, 2015) also proposed that Ethylene Tetra-Fluoro Ethylene (ETFE) internal plastic pipe coating is the most appropriate solution for paraffin deposition in the pipelines. As such its usage can be encouraged over rigid PVC pipes and steel pipes which are commonly used in the oil and gas industry for crude transportation.

REFERENCES

- Adewusi, V. A., (1997). Prediction of wax deposition potential of hydrocarbon systems for viscosity-pressure correlations. Fuel 76:1079-1083.
- Agrawal, K.M., Khan, H.U., Surianarayanan, M., Joshi, G.C., (1990).Wax Deposition of Bombay High Crude Oil under Flowing Conditions, Fuel, 69, 794-796.
- Ajienka, J.A., Ikoku, C.V., (1997). Waxy crude oil handling in Nigeria: practices, problems and prospects, Energy sources. 12(4): 463-478.
- Al-Besharah, J.M., Salman, O.A., and Akashah, S.A., (1987). Viscosity of crude oil blends. Industrial and Engineering Chemistry Research, 26, 2445–2449.
- Ali, M.F., Bukhari, A., Hassan, M., (1989). Structural characterization of Arabian Heavy crude oil residues. J. Fuel Sci. Technol. Int. 7:1179-1208.
- Bagdat, M., Masoud R., (2015). Control of Paraffin Deposition in Production Operation by Using Ethylene-Tetra Fluoro Ethylene (ETFE), Proceedings of the International Conference on Integrated Petroleum Engineering and Geosciences.
- Bern, P.A., Withers, V.R., Cairns, J.R., (1980). Wax Deposition in Crude Oil Pipelines. 206-1980-MS, European Offshore Petroleum Conference and Exhibition, London.
- Brown, T.S., Niesen, V.G., Erickson, D.D., (1993). Measurement and Prediction of Kinetics of Paraffin Deposition," 26548-MS, SPE Annual Technical Conference and Exhibition, Houston, Texas.
- Burger, E.D., Perkins, T.K., Striegler, J.H., (1981). Studies of Wax Deposition in the Trans-Alaska Pipeline. Journal of Petroleum Technology, 33, 1075-1086.
- Cole, R.J., Jessen, F.W., (1960). Paraffin Deposition. Oil Gas J., 58: 38-87.
- Dawson R.V., (1996). 3 SCR 783 - Supreme Court of Canada - Docket Number: 24883.
- Elijah Taiwo, John Otolorin and Tinuade Afolabi (2012). Crude Oil Transportation: Nigerian Niger DeltaWaxy Crude, Crude Oil Exploration in the World, Prof. Mohamed Younes (Ed.), ISBN: 978-953-51-0379-0, In Tech, Available from:http://www.intechopen.com/books /crude-oil-exploration-in-the-world/crude-oil-transportationnigerian-niger-delta-waxy-crude-oi
- Fasesan, S.O., Adewunmi, O.O., (2003). Wax variation in some Nigerian oil wells in Delta Field. Petroleum Science and Technology, 21:91-111.
- Gudmundsson J.S., Bott T.R., (1977). Deposition of paraffin wax from kerosene in cooled heat exchanger tubes. Can. J. Chem. Eng., 55(4): 381-385.
- Haq, M.A., (1978). Deposition of paraffin wax from its solution with hydrocarbons.
- Hamouda, A.A., Davidsen, S., (1995). An Approach for Simulation of Paraffin Deposition in Pipelines as a Function of Flow Characteristics with a Reference to Teesside Oil Pipeline, 28966-MS, SPE International Symposium on Oilfield Chemistry, San Antonio, Texas. http://dx.doi.org/10.2118/28966-MS

- Holder, G.A., Winkler, J., (1965). Wax crystallization from distillate fuels. Part 1 and 2 Journal of Institute of Petroleum 51(499), 238-252.
- Hunt, E.B.Jr., (1962). Laboratory Study of Paraffin Deposition, Journal of Petroleum Technology, 14,
- Hussain, M., Mansoori, G. A., Ghotbi, S., (1999). Phase behavior prediction of petroleum fluids with minimum characterization data. Journal of Petroleum Science and Engineering, 22(1-3), 1999, 67-93.
- Jennings D.W., Weispffennig K., (2005). Effects of Shear and Temperature on Wax Deposition: Cold finger Investigation with a Gulf of Mexico Crude Oil. Energy Fuels, 19: 1376-1386.
- Karan, K., Ratulowski, J., and German P., (2000). Measurement of waxy crude properties using novel laboratory techniques. SPE Annual conference and Exhibition, Dallas, Texas, 1-4, October 2000. SPE 62945
- Kelechukwu, E.M., (2011). Prediction of wax deposition risk of Malaysian crude from viscocity-temperature correlation for dead crude. Int. J. Sci. Adv. Technol., 1: 89-100.
- Kelechukwu, E.M., Al Salim, H.S.S., Yassin, A.A.M., (2010). Influencing factors governing paraffin wax deposition during crude production. International Journal of the Physical Sciences. 5(15): 2351-2362
- Khanorkar S, Bhakuni H, Wate, S.R, Sarin R., (1996). “Identification of nC4~nC14 Fraction in Crude Oil and its Preliminary Geological Application”. J. Chem. 12(2):155-162.
- Lee, H.S., (2008). Computational and Rheological Study of Wax Deposition and Gelation in Subsea Pipelines, Ph.D. Thesis, The University of Michigan, Michigan, United States.
- Lee-Tuffnell C (1996). A laboratory study of the effects on wax deposition of shear, temperature and live end addition to dead crude oils, p. 29.
- Matlach, W.J., Newberry, M.E., (1983). Paraffin Deposition and Rheological Evaluation of High Wax Content Altamont Crude Oils, 11851-MS, SPE Rocky Mountain Regional Meeting, Salt Lake City, Utah.
- Mehrotra, A.K.., Bhat, N.V., (2007). Modelling the Effect of Shear Stress on Deposition from “Waxy” Mixtures under Laminar Flow with Heat Transfer. Energy and Fuels, 21, 1277-1286.
- Mohammed, Z., (2007). Industrial & Engineering Chemistry Research, ACI., 46: 14.
- Nazar, A.R.S, Dabir, B., Islam, M.R., (2001). Measurement and Modeling of Wax Deposition in Crude Oil Pipelines, 69425-MS, SPE Latin American and Caribbean Petroleum Engineering Conference, Buenos Aires, Argentina.
- Nazar I., Tulkun Y., Yulduz D., (2001). Use of and optical sensor (greenseeker): an innovative tool for screening germplasm, predicting biomass and grain yield and management of fertilizer nitrogen, p. 28.
- Norman FC (1989). Paraffin Deposition in Petroleum Production.
- Oladiipo A., Bankole A., and Taiwo E., (2009). Artificial Neural Network Modeling of Viscosity and Wax Deposition Potential of Nigerian Crude Oil and Gas Condensates. 33rd Annual SPE International Technical Conference and Exhibition in Abuja, Nigeria, August 3-5, 2009. SPE 128600
- Peng, Y., Zhonghua, T., Muhammad, A.M., Ehsan, M., (2014). Study on the Temperature Distribution of High Pour Point Oil by Integrated Method Based on Well Log, Geological Data and Experiment. Research Journal of Applied Sciences, Engineering and Technology 7(23): 4945-4965.
- Ramirez-Jaramillo, E., Lira-Galeana, C., Manero, O., (2004). Modeling Wax Deposition in Pipelines. Petroleum Science and Technology, 22, 821-861.
- Ribeiro, F.S., Mendes, P.R.S., Braga, S.L., (1997). Obstruction of Pipelines due to Paraffin Deposition during the Flow of Crude Oils. International Journal of Heat Mass Transfer, 18, 4319-4328.

- Singh, P., Venkatesan, R., Fogler, H.S., Nagarajan N., (2000). Formation and Aging of Incipient Thin Film Wax-Oil Gels," AIChE Journal, 46, 1059-1074. http://dx.doi.org/10.1002/aic.690460517
- Svendsen, J.A., (1993). Mathematical Modelling of Wax Deposition in Oil Pipeline Systems. AIChE Journal, 39, 1377-1388.
- Taiwo, E. A., Fasesan, S. O. and Akinyemi, O. P. (2009). Rheology of Doped Nigerian Niger Delta Waxy Crude Oil. Petroleum Science and Technology, 27(13), 1381 - 1393
- Taiwo E., Otolorin J., Afolabi T., (2012). Crude Oil Transportation: Nigerian Niger Delta Waxy Crude, Crude Oil Exploration in the World, Prof. Mohamed Younes (Ed.), ISBN: 978-953-51-0379-0, InTech, Available from: http://www.intechopen.com/books/crude-oil-exploration-in-the-world/crude-oil-transportationnigerian-niger-delta-waxy-crude-oil
- Tang N.L., Hwu W.L., Chan R.T., Law L.K., Fung L.M., Zhang W.M. (2002). A Founder Mutation (R254X) of SLC22A5 (OCTN2). Hum. Mutat., 20(3): 232.
- Tian Z., Jin W., Wang L., Jin Z., (2014). The Study of Temperature Profile inside Wax Deposition Layer of Waxy Crude Oil in Pipeline. Frontiers in Heat and Mass Transfer (FHMT), 5, 5 (2014)
- Wang Z., Fingas M., Li K., (1994). Fractionation of a Light Crude Oil and Identification and Quantification of Aliphatic, Aromatic, and Biomarker Compounds by GC-FID and GC-MS, part I. J. Chromatogr. Sci. 32(9):361-366.
- Yasin, G., Bhanger, M.I., Ansari T.M., Naqvi S.M., Ashraf M., Khizar A., Talpur F.N., (2013). Quality and chemistry of crude oils. Journal of Petroleum Technology and Alternative Fuels Vol. 4(3), pp. 53-63,
- Zhang, G.Z., Liu, G., (2010). Study on the Wax Deposition of Waxy Crude in Pipelines and Its Application. Journal of Petroleum Science and Engineering, 70, 1-9.

How to cite this article: Eyankware EO, Ulakpa WC, Eyankware MO. Determination of cloud and pour point of crude oil with reference to crude transportation. International Journal of Science & Healthcare Research. 2016; 1(3): 20-28.

******