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Vaporization Kinetics of Nigerian Crude Oil from Different Soil Samples of Niger Delta

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Abstract: The vaporization/volatilization kinetics of different Nigerian crude oil spilled on different soil samples has been investigated. The rates of disappearance of these crude oil samples were low from soil samples of high clay, organic matter content and low porosity and vise versa. Crude oil samples with high molecular hydrocarbons contents also experience low disappearance rate.

Key words: Vaporization kinetics, Nigerian crude oil, soil samples, hydrocarbons, viscosity

INTRODUCTION

Crude oil contains basic hydrocarbons which include; normal, branched or cyclic saturated hydrocarbons, aromatics hydrocarbons and other substances associated with the hydrocarbons. The mobility of these hydrocarbons through media is largely dependent on their chemical and physical properties.

Some of these hydrocarbons can experience losses within the environment. Studies indicate that the losses of organic compounds can be described by the first order rate reactions in which the rate of loss of substance is proportional to the chemical andthe model is given as:

$$\int_{c_0}^{c} \frac{dc}{c} - K \int dt \qquad (1)$$

$$\text{In}\frac{c}{c_0} = -Kt$$

$$C = Ce^{-Kt} \qquad (2)$$

Where,

C = Concentration of the substance
t = Time
K = First order rate reaction constant (time^{-1})
C_0 = Initial concentration.

Chemical loss rates can also be measured with respect to half-life ($t_{1/2}$) i.e., the time required to degrade or lose one-half of the chemical concentration. This can be mathematically expressed in terms of the first-order rate constant as:

$$t_{1/2} = 0.693/K \quad \text{(Randall } et\ al., 1992)$$

During spillages on the soil, the hydrocarbons undergo some chemical loss mechanisms. These mechanisms include; biodegradation, chemical degradation, hydrolysis, photolysis and volatilization (De jonge *et al*., 1997).

Volatilization and biodegradation are the major mechanisms that determine the fate of total petroleum hydrocarbons in the soil . Volatilization is a function of the vapor pressure of the hydrocarbons and the contact between the hydrocarbons in the soil and the gaseous phase or atmosphere (Erickson, 2000). Biodegradation systems are mixed or aerated to provide adequate oxygen input and aerobic conditions for the volatile compound to be released to the atmosphere (Randel *et al*., 1999).

Also, the volatilization or vaporization capacity of crude oil from the soil is highly influenced by such factors as the compositions of the soil and that of crude oil some researchers have found that vaporization rate from the soil media is well correlated with the molecular hydrocarbons of the crude samples and negatively correlated with the amount of organic matter and clay content of the soil (Fekarurhobo and Obomame, 2002).

The aim of this research is therefore to investigate the volatilization rates of different Nigerian crude from Nigerian soils.

MATERIALS AND METHODS

Characterization of soil: Soil samples were collected from 4 different locations within Niger-Delta. The 4 soil samples were designated as A, B, C and D, respectively. Textual

Table 1: Results of the soil analysis

	Sample A	Sample B	Sample C	Sample D
Particle size distribution	Clay 20.5%	Clay 30.1%	Clay12.50%	Clay 48.0%
	Silt 22.0%	Silt 47.0%	Silt 21.7%	Silt 25.00%
	Sand 42.50%	Sand 13.0%	50.01%	Sand11.00%
Bulk density	1.08	1.1	1.01	1.12
organic matter	1.01	1.27	0.5	31.00
Porosity (n)	0.41	0.65	3.60	0.50

Table 2: Hydrocarbon fraction of Qua Iboe crude oil

Names of HC	Amount (ppm)
C8	12.77588
C9	19.54248
C10	8.03412
C11	20.08928
C12	53.30671
C13	61.74350
C14	32.36028
C15	25.07088
C16	20.49947
C17	44.36232
C18	52.78931
C19	252.28369
C20	209.25590
C22	36.94771
C24	28.77263
C26	69.72344
C28	141.99363
C30	36.65499
C32	79.33855
C34	32.32091
C36	10.64703
C38	-
C40	-
Total	1248.51069

characteristics of the soil samples were determined by analyzing for the particle size distribution and the uniform coefficient which categorized the soil samples based on the percentage mixture of clay, silt and sand particles using SB sieve. Also analyzed were the porosity, bulk density and the percentage organic matter using standard methods. Their results are displayed in the Table 1.

Crude oil characterization: The crude oil samples used for this experiment were got from 3 different oil wells in Niger Delta. These include; Brass river crude, Qua Iboe crude and Bonny Light crude.These crude samples were designated as samples A, B and C, respectively. The crude oil samples were subjected to the Viscosity, API gravity and density analysis. Hydro-Carbon fractions of these oil samples were also analyzed using the Gas chromatography.

The crude oil samples also were analyzed for the density, viscosity and ^{0}API using ASTM methods. Their results are shown on Table 2.

Vaporization/volatilization: Seventy gram of soil sample was weighed out and put into a conical flask using a standard weighing balance. Thirty gram of fresh crude oil sample A was also weighed out and added into the conical flask containing the weighed soil sample, making the flask content to 100 g. A 3 thick pyrex glass plate was made to suspend above the conical flask containing the mixing of oil and soil to facilitate normal air flow into and above the flask. The flask was allowed to stand in an open place for one day before the first weight taking, to know the change in weight. Subsequent weight takings were carried out at one day regular intervals until there was no significant weight change. This exercise was repeated with the rest of the soil and crude oil samples. The data collected from the experiment were done as follows:

- Weight of soil sample A (W1) = 70 g.
- Weight of crude oil sample A (W2) = 30 g.
- Sum of weight of soil and crude oil (W3) = 100 g.
- Weight after a time interval = Wt.
- Change in weight (W4) = Pervious weight-Present weight.

RESULTS AND DISCUSSION

Soil characterization: Table 1 shows the classification of various soil types used for this research. The soil types were classified according to their particle size distribution, bulk density, percentages of organic matter an d porosity.

Soil sample C has the highest percentage of sand while sample D has the least percentage of sand. In terms of percentage of clay, sample D has the highest value with sample C having the lowest. Soil sample B has the highest percentage of silt while sample C has the lowest silt percentage. Bulk density and percentages of organic matter of various soil samples show direct relationship with the percentage of clay of their corresponding soil samples. Porosity shows the inverse trend. These pattern of relationships seem to be in agreement with the work of (David *et al*., 2000).

Crude oil classification: The results of the characterization of various crude oil types (Brass river crude, Qua Iboe crude and bonny light) are shown on Table 2-4, respectively. The crude oil characterization was carried out based on the hydrocarbon fractions of the n-alkanes of various crude oil type, viscosity, API, gravity and density. The values for the total hydrocarbon fractions of the 3 crude oil types are 1248.5109, 1109.0751 and 1007.9991 ppm, respectively. The variations observed on the total hydrocarbon of the 3 crude oil samples could be attributed to the concentration levels of their hydrocarbon constituents. For instance, the concentrations of the high molecular weight hydrocarbon of brass crude oil were observed to be higher than that of Qua Iboe crude oil and bonny light. This pattern of

Table 3: Hydrocarbon fraction for Qua - Iboe crude oil

Names of HC	Amount(ppm)
C8	115.8890
C9	120.5401
C10	60.03412
C11	98.0090
C12	90.6306
C13	85.74150
C14	32.36117
C15	20.1105
C16	35.7918
C17	37.8180
C18	50.78931
C19	95.8201
C20	98.9606
C22	21.6198
C24	38.8106
C26	48.8021
C28	19.94035
C30	14.78090
C32	5.4011
C34	0.9701
C36	-
C38	-
C40	-
Total	1109.0751

Table 4: Hydrocarbon fraction for bonny light

Names of HC	Amount(ppm)
C8	105.9911
C9	95.4590
C10	100.0870
C11	87.8623
C12	101.7621
C13	89.3855
C14	35.3209
C15	29.9601
C16	70.8110
C17	20.1009
C18	39.4991
C19	51.3479
C20	71.64703
C22	05.90322
C24	25.80509
C26	29.38501
C28	18.11950
C30	21.94035
C32	01.74150
C34	1.0987
C36	-
C38	-
C40	-
Total	1007.9991

variation is evident on their viscosity anddensity values. The viscosity and density values of Brass river crude are higher than that of Qua Iboe crude with Bonny light having the lowest values (Table 5).

Vaporization/volatilization: The amount of crude oil that volatilized was measured in grams for different soil and crude oil samples and was observed for 16 days. The amount of crude that vaporized decreased with time. The classical pattern of decrease in the amount of hydrocarbon shows first order exponential kinetics. The amount also vary with soil samples and crude oil samples.

Table 5: Results of other physical analysis of the crude oil samples

Types of crude	Viscosity	Density	^{0}API
Brass river crude (sample A)	7.14	0.866	15.78
Qua ibom crude(sample B)	5.47	0.758	26.93
Bonny light (sample C)	2.67	0.528	38.11

Table 6: Showing the concentration of vaporized crude

Oil type	Soil sample	Amount of crude vaporized (W4) (ppm)
A	A	5.9209
	B	4.2570
	C	13.9058
	D	1.1697
B	A	11.438
	B	3.821
	C	9.886
	D	2.4788
C	A	10.224
	B	7.8213
	C	14.1180
	D	3.7504

Table 6 shows the variations of the amount of total hydrocarbon that vaporized. The result shows that the highest amount of hydrocarbon of various oil samples vaporized from soil sample C while the lowest amount of hydrocarbon vaporized from soil sample D. This variations could be explained by the amount of organic matter present in the various soil samples. Soil sample D has a high degree of organic matter content and therefore has the tendency to bind to the crude oil thereby impairing vaporization process. The reciprocal was true for soil sample C and other soil samples of similar textual characteristics due to their poor absorbing capacity. Wang *et al.* (1998) observed that volatilization is numerically greater in soil with lower clay and organic matter content due to small cat ion exchange capacity. This observation validated the present observation. Also, the amount of disappearance in grams of crude oil sample C (Bonny light) from various soil types was more and faster in rate than that of other crude oil types because the low molecular weight hydrocarbons which have the readiness to volatilize constitute the large component of the crude. In comparison, the volatilization in grams of crude oil sample A and B i.e., Brass and Qua Iboe crude, respectively were slow due to the fact that oil sample A and B consist largely of high molecular weight hydrocarbons. Therefore oil samples A and B are less volatile and more persistence in the soil than soil sample C (Fig. 1-3).

Figure 1-4 show that oil sample C is most volatile among the 3 crude oil samples due to its high low molecular hydrocarbon content. The results generally show that the persistence of various crude in soil samples increase in the following order Brass oil > Qua Iboe > Bonny light (Table 1 and Fig. 5-7).

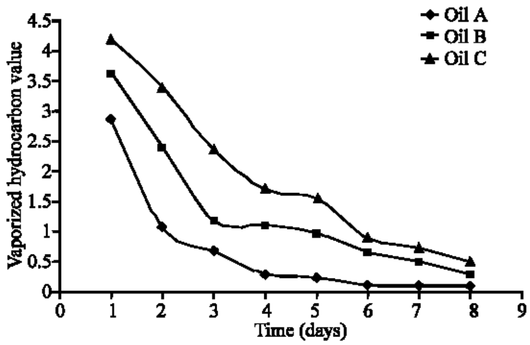

Fig. 1: Variations of vaporized hydrocarbon valuse with time for soil sample A

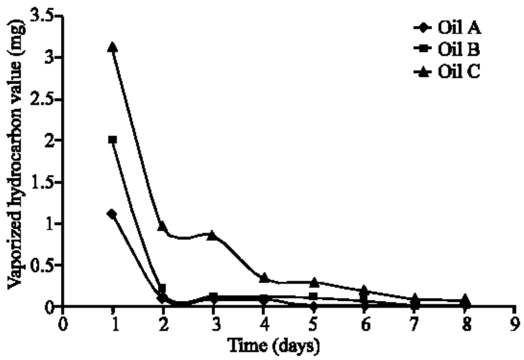

Fig. 2: Variations of vaporized hydrocarbon valuse with time for soil sample B

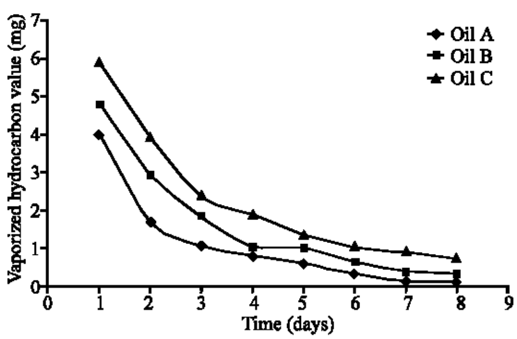

Fig. 3: Variations of vaporized hydrocarbon valuse with time for soil sample C

It was also observed that volatility losses of various crude from various soil samples was rapid and high within the first day of the experiment and the loss reduced exponentially with time. The reason behind this trend of HC l oss can be due to accumulation of vapor pressure built up by the low molecular HC which escaped in mass on attaining the latent heat of vaporization as the crude was exposed to

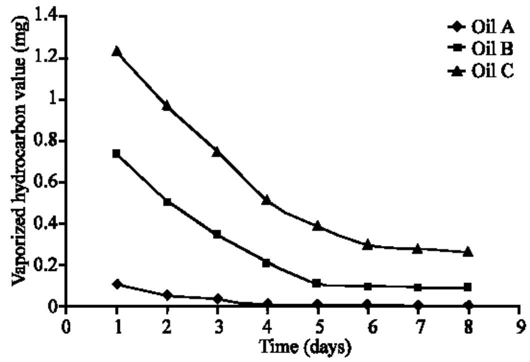

Fig. 4: Variations of vaporized hydrocarbon with time for soil sample D

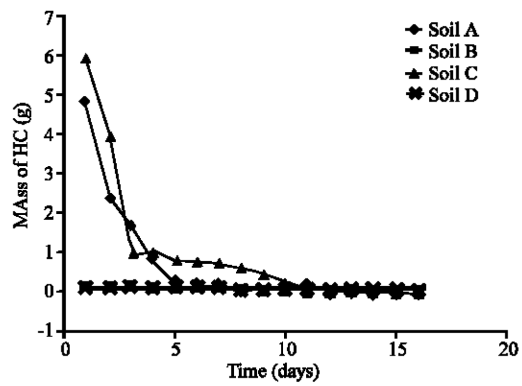

Fig. 5: Mass of oil sample A that vaporized versus time

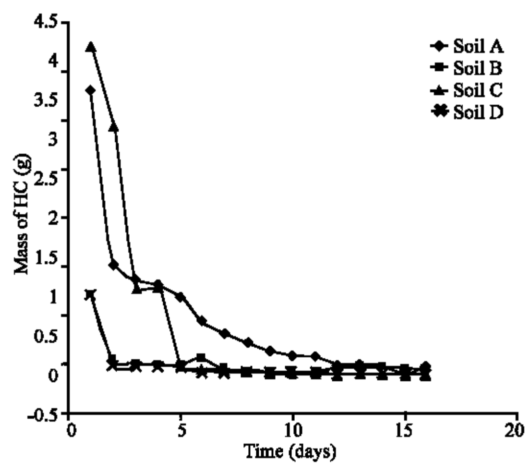

Fig. 6: Graph of mass HC that varized from oil sample B versus time

the open surrounding. The loss was also more with crude that consist mainly of lower molecular weight hydrocarbon components and with soil samples of lower clay and organic matter contents.

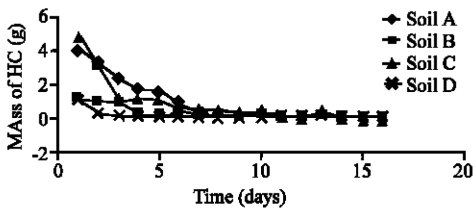

Fig. 7: Mass of oil sample A that vaprized versus time

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