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EFFECTS AND REMEDIATION OF WAX IN OIL PIPELINE AND EQUIPMENT USING A SAMPLE OF NIGER DELTA CRUDE OIL

Peter Edimeh[1], Mukhtar Abdulkadir[2]

[1,2]Department of Chemical Engineering, Federal University of Technology Minna, Niger State, Nigeria.

Abstract: **In the petroleum industry, still a major problem is the deposition of paraffin wax especially during exploitation in Deepwater field. This study is aimed at characterizing crude oil sample, understanding the characteristic of paraffin wax and testing the solubility of the precipitated wax in xylene and kerosene at different blend ratios. The crude oil sample which was obtained from Eleme community in Niger Delta, Nigeria, was characterized and the cloud point and pour point were obtained as 20°C and 12°C respectively. Results obtained from the solubility test shows that 100% Xylene dissolves 99.4% of the precipitated wax in 150 min and 90.1 % in 90 min. While for same quantity 100% kerosene shows solubility of 35.4% in 150 min and 26.2% in 90 min which implies that xylene although expensive is a better solvent for paraffin wax cleanup when compared to kerosene. At different xylene – kerosene blend ratios, the blend of 70:30%, Xylene: Kerosene mixture also gave an excellent result, far from the one obtainable in the 50:50%, and in very close proximity with the 80:20% blend. This indicates that Kerosene which is cheap and readily available when blended with xylene, an excellent solvent can be used on an industrial scale for the cleanup or dissolution of wax deposit in a cost effective and efficient manner.**

Keywords: **Wax, Paraffin, Chemical, Remediation, Eleme, Xylene, Solvent, Pipeline, Deposition.**

I. INTRODUCTION

The petroleum industry is still bedeviled by complications arising from the deposition of paraffin wax on the inner walls of production and transportation pipelines. At reservoir condition, paraffin wax is a soluble constituent of crude oil at equilibrium, however, as condition changes along the production lines, these paraffin wax can crystallize and form thick layers on the wall of production equipment. Most crude oils contain some amounts of wax and paraffin, as a hydrocarbon, wax contains 20 to 40 carbon atoms in a chain that consists of different structural types such as straight-chain, branched-chain and cyclic chain, and aromatic hydrocarbons [1]. Wax molecules can change its structure from linear or branching to cyclic form as well as aromatic hydrocarbons in the presence of other cyclic hydrocarbons [2]. This dynamic behavior can have an effect on the melting point and the solubility of the wax [3]. This problem can be solved by the study of the effect of some parameters on the precipitation of wax [4]. Paraffin wax is a colorless and odorless solid at room temperature, thus making it easy to determine the formation of wax in crude oil samples [5]. The formation or precipitation of wax is caused by factors such as the reduction of temperature of the crude oil during the transportation of the oil along pipelines from the rig to the shore [6], the flow rate at which crude oil is transported; low flowrates leads to a higher chance of wax precipitation as there is a greater number of particles available for deposition under a laminar flow regime. Also, the severity of this wax deposition challenge depends on the type of the crude oil transported and the composition of the formed wax; straight-chain compounds easily crystallize while the cyclo-paraffins (naphthene) do not tend to crystallize and deposit on surfaces easily.

Controlling and remediating wax depositions is still one of the critical challenges in oil and gas industries as the industry explores in increasingly challenging environments, such as deepwater and subarctic conditions based on remarks of Simon Richard, SPE, who is the Principle Consultant for EP Consult. The deposition of paraffin wax causes major problems such as flow rate reduction, complete flowline blockage, increase in pumping power, reduction in production output, decrease in equipment performance [7, 8, 9], and ultimately increase in the cost of production [10].

Solving waxy crude oil challenge can be done using either a preventive or corrective approach. The preventive approach is adopted when steps are taken to inhibit the growth of paraffin crystals, this involves the insulation of production line to prevent heat loss, optimized pipeline design for effective flow, injection of chemical inhibitors, dispersants, or solvents that have a controlled effect on wax appearance temperature (WAT). The chemical method of preventing wax precipitation in pipelines has captured the interest of researchers due to its effectiveness, low cost, and ease of application. This has made the use of chemical additives such as wax crystal modifiers (inhibitors) and pour point depressant common [11]. Many wax crystal inhibitors have been studied by various researchers, these among others are; poly(octadecyl acrylate) [12], poly-octadecyl acrylate / nano-silica hybrid particles [13], *Sapindus mukorossi spp* [14], Poly meth(acrylates) [15], Cashew nut shell oil [16], Jatropha seed oil [17] and poly (acrylate) ester copolymer [18].

The corrective approach on the other hand involves the routine removal of wax deposits which have accumulated on walls of equipment over time since wax precipitation cannot be prevented all the time. There are three major wax remediation techniques namely;

➢ The mechanical technique: This involves the use of techniques such as pigging where deposited wax is mechanically removed by launching a pipeline pig into the line to scrape wax from the pipe wall as it is forced through by pressure from the oil. This method however is prone to mechanical failure. [9]

➢ The thermal technique: Since wax formation is highly temperature-dependent, the thermal technique can be highly effective. This technique utilizes approaches such as – Hot oiling, where oil is heated to a temperature well above the melting point of the wax and then channeled into the well or pipeline using any suitable method. The hot oil circulated melts and dissolves the wax. This technique however can lead to emulsion problems. – Hot water treatment though less effective than the hot oil treatment is often used. Here, surfactants are often added to the water to aid wax dispersion in the water phase. The major merit of this approach is that water has a greater specific heat capacity than oil. – Inductive heating is also another technique used in the thermal remediation method. Here, an inductive heating device is attached to a plugged section of a pipe. This method proves especially effective for cases where the pipeline is completely blocked in a horizontal section and almost impossible to flow chemicals to the blockage [11]

➢ The chemical method: This method involves the introduction of chemicals to mostly dissolve the already formed wax. Various chemicals used often function using different mechanisms. Some of these include, - The wax crystal modifiers which act at the molecular level to reduce the tendency of wax to network and form lattice structures, hence lowering wax gel strength. – Dispersants, which is a type of surfactant that helps disperse the wax crystals into the produced oil or water. This dispersing of the wax crystals into the produce oil or water helps prevents the deposition of the wax and also has a positive effect on the viscosity and gel strength [1]. – Surfactants are a general class of chemicals that are most often used to clean vessels, tanks, pipes, or any place where wax may deposit. Surfactants can also be used in combination with hot oil and water treatments for a more desirable result. And finally – Solvents such as benzene, gasoline, and Methy-ethyl-ketone can be used to treat wax deposition challenges [19]. A combination of the two approaches could be used if deemed best as the optimal wax control strategy.

In this study, the effect of pure xylene, pure kerosene, and ratio of xylene to kerosene will be investigated on paraffin wax. Therefore, the objective of the research is to study and compare the influence of the various solvents on the variation of solubility of the wax precipitate with time.

II. MATERIALS AND METHODS

Experimental Setup: The experiment was conducted using standard laboratory equipment. The properties of the fluid (crude oil sample) were determined using standard procedures.

Cloud Point:

- A warm crude oil sample was poured to the level mark of the test jar, tightly closed with the cork carrying the thermometer, the tube was placed into a refrigerator.

- The temperature was checked at an interval of three (3) seconds without disturbing the sample until it forms a cloudy appearance at the bottom of the test jar. The temperature at this point was noted and recorded.

Pour Point:

- A warm crude oil sample was poured to the level mark of the test tube, tightly closed with the and placed into a refrigerator.

- The test tube was inspected at an interval of three (3) minutes by bending and holding in a horizontal position for a few seconds before returning it to cool.

- 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 temperature of the oil was taken (3˚C higher than the thermometer reading) by inserting the thermometer into the oil and allowing it to cool for 10 seconds.

Wax Precipitation:

The wax precipitation experiment was carried out using [25] method which is the modification of the [26] method; 40g of crude oil was dissolved in 40 mL of petroleum ether and stirred for 30 min using the magnetic stirrer. A prepared anti-solvent mixture (3:1 acetone/n-pentane ratio) which is equivalent to 30mL: 10mL was added to the mixture and then cooled to 253K (-20^{o}C) for 24 hours in a refrigerator. Thereafter, the solid phase present in the oil was separated by filtration in a Buchner funnel using a Whatman 934-AH glass microfiber filter. The precipitate was re-dissolved in n-hexane to separate the Asphaltenes, and finally, the wax was weighed after solvent evaporation.

Wax Solubility:

To determine the solubility of wax in different solvents, 5 g of the precipitated wax was added to 40 mL 100% xylene solvent in a conical flask and left to stay for 30 minutes without swaying or stirring it. An empty filter paper was weighed using a weighing balance. After 30 mins, the solution was filtered through a filter paper and dried at a constant temperature of 29^{o}C after which the weight of the filter paper was subtracted from the total wight to determine the weight of the wax residue. The amount of wax soluble in the solvent was determined by subtracting the amount of the insoluble Wax from the 5g initially added to the solvent. The insoluble Wax was dried and added to the solvent again, the same procedure was repeated for 50, 70, 90, 120, and 150 minutes. The above procedure was repeated for 40 mL 100% kerosene, and xylene: kerosene solvent blends of 80:20, 70:30, 60:40, 50:50, and 40:60.

III. RESULTS AND DISCUSSION

A. Characteristics of Crude oil sample

TABLE I: CHARACTERISTICS OF CRUDE OIL SAMPLE

Properties	Values
API gravity	154.576
Cloud point(◦C)	20
Pour point (◦C)	12
Asphaltene content (wt %)	4.25
Sulphur content (wt %)	0.1
Wax content (wt %)	13.25

B. Viscosity variation with temperature

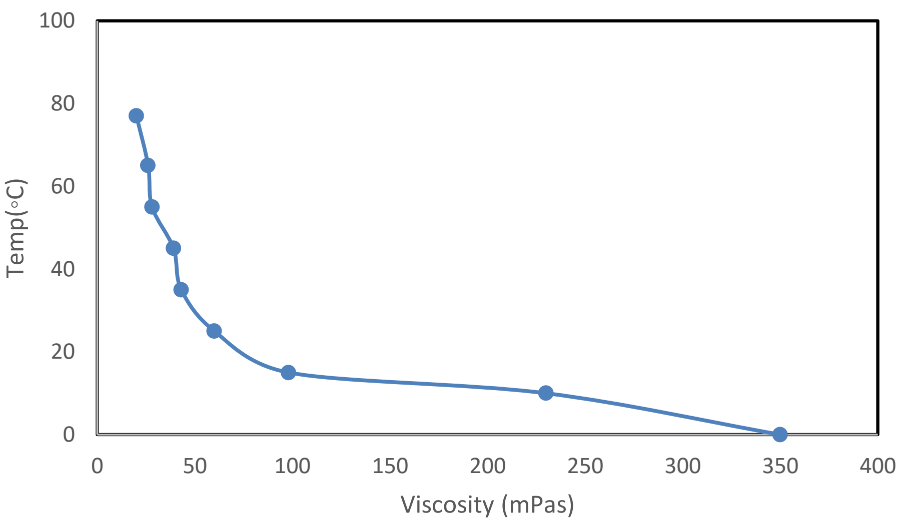

Figure 1: Variation of Viscosity with Temperature

Figure 1 shows the viscosity of the crude oil sample at different temperatures. From the figure, it is seen that the viscosity of crude oil greatly depends on temperature. As the temperature drops the viscosity of the crude oil sample tends to increase in a non-uniform manner. For instance, at temperature 0°C, the crude oil assumed the highest viscosity of 350 mPas indicating insignificant shear deformation of the crude oil and hence the start of the deposition of wax. This thereby results in a reduction in the flow rate of the crude oil, this problem can be resolved by application of a high amount of pressure to the flow and as a result, contribute to energy consumption. This finding is in agreement with the reports of the researchers [17, 21]. As the temperature is further increased to 10°C, 15°C, 25°C, 25°C and 35°C , the viscosity was further observed to reduce drastically respectively at 98 mPas, 60 mPas, and 43 mPas. The sharp reduction in the value of viscosity may be attributed to the rise of the crude oil temperature above the pour point [16]. This goes a long way to show how the crude oil will behave at a low enough temperature as temperatures in subsea pipelines can go as low as -5°C

C. Wax and asphaltene quantification

TABLE II: WAX AND ASPHALTENE QUANTIFICATION

	Values
Weight of Crude Oil	40.00g
Weight of Filter Paper	0.50g
Weight of Wax Precipitate (Before Adding Hexane)	5.30g
Weight of Wax Precipitate (After Adding Hexane)	3.60g
Asphaltene Content	4.25%
Wax content	13.25%

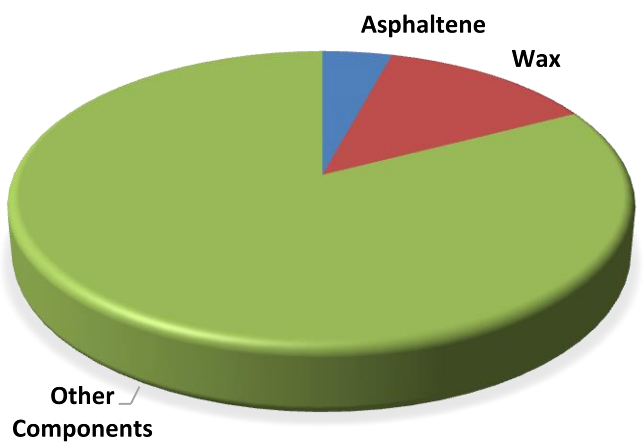

Figure 2: Crude oil sample composition

From the quantification result obtained, it can be seen that 13.25% (3.60g) of 40g of crude oil was wax and 4.25% (1.70g) was asphaltene. Wax content of crude oil can however go as high as 27 wt% or more which conforms with the result obtained by [22].

D. Percentage Solubility

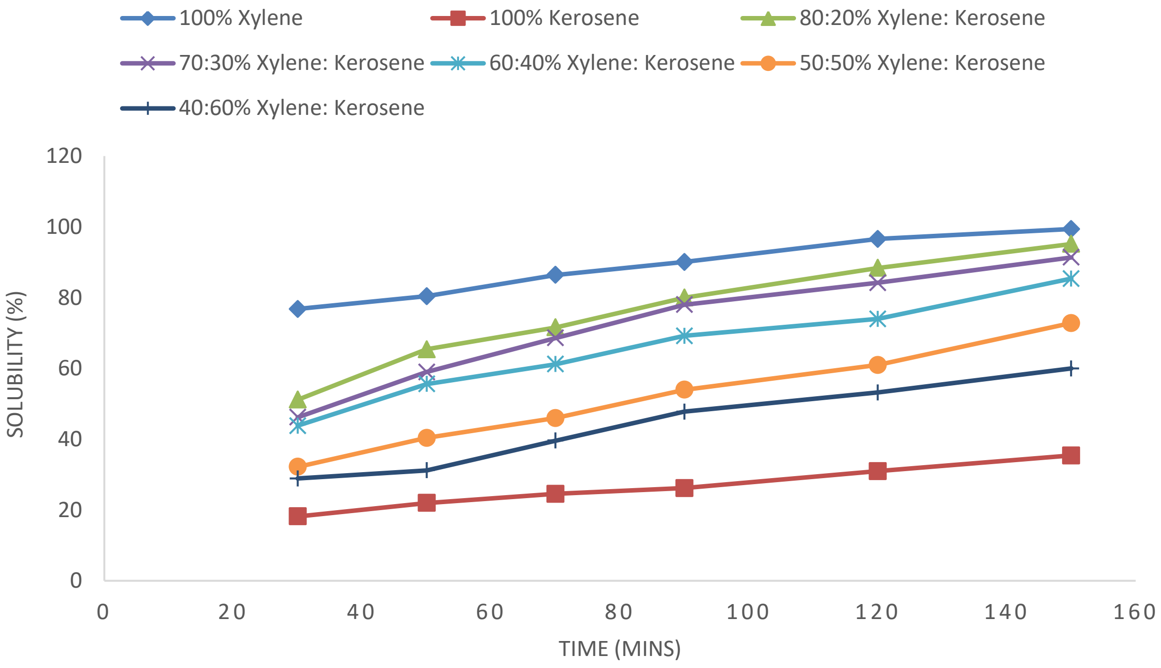

Figure 3: Plot of Solubility (%) against Time (Minutes) for the solvent blends

As obtained in figure 4, the plot of solubility versus time, the 100% Xylene peaks at the highest and has the highest value at each time, which indicates excellent performance. This indicates that 100% Xylene, compared to kerosene, is an excellent solvent for the dissolution of paraffin wax [23]. This solvent may however be expensive to use in situations involving large-scale wax cleanup, hence it is not advisable to use unless in case of 100% blockage, where there is an urgent need to clean up wax. Also observing the different blend ratios, it is seen that the mix with higher xylene to kerosene blend shows better performance at each time peak with little variation observed between 70:30 and 80:30 xylene – kerosene blend. Results obtained confirmed that 100% Xylene is an excellent solvent in dissolving wax, however, this method cannot be seen to be cost effective. However 70: 30% Xylene: Kerosene mixture also gave an excellent result, far from the one obtainable in the 50:50%, and in very close proximity with the 80:20% blend. As the xylene concentration becomes thinner the efficiency of the blend becomes weaker and with 100% kerosene solvent, the peaks are the lowest for each time implying a weak performance [24].

IV. CONCLUSION

This research has described a novel chemical blend for remediation of paraffin wax. Results obtained confirmed that 100% Xylene is an excellent solvent in dissolving wax, however, this method cannot be seen to be cost effective. However 70: 30% Xylene: Kerosene mixture also gave an excellent result, far from the one obtainable in the 50:50%, and in very close proximity with the 80:20% blend. It can be predicted to clean up a large proportion if enough time is allowed since 150 minutes is not considered a “great deal” in solving wax problem in the actual sense, considering the amount of money that will be saved in the process since kerosene is a very cheap and readily available solvent. The other results obtained in this research work can also be applied depending on the severity of the wax deposition problem.

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