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Localization of Wax Deposition Zones in Oil Flowlines: A Case Study of the SEKE-03S Field, Niger Delta

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Abstract

Hydrocarbon production in cooling environments often faces significant flow assurance challenges due to wax deposition. This accumulation restricts flow, increases pressure drop, and necessitates costly interventions such as mechanical pigging or chemical solvent injection. To optimize mitigation strategies, precise localization of the deposition zone is required.

This study investigates the wax deposition profile of the SEKE-03S flowline in the Niger Delta to determine the critical point of blockage. Field data regarding the flowline temperature profile were combined with laboratory analysis of crude samples to determine the Wax Appearance Temperature (WAT) using the cold finger method. Analytical modeling indicated a WAT of 20°C. Results reveal that at a wellhead temperature of 25°C, the critical deposition zone is located between 960m and 980m from the wellhead. The study recommends the strategic installation of a Wax Inhibition Tool (WIT) at this specific interval to dissolve precipitates and prevent blockage without requiring production shutdowns.

Keywords: Flow Assurance, Wax Appearance Temperature (WAT), Paraffin Deposition, Niger Delta Basin, Pipeline Temperature Profile.

INTRODUCTION

Crude oil is a mixture of Paraffins (Waxes), Naphthene, Aromatics, Asphaltenes, and Resins. The wax present in crude oil primarily consists of paraffin hydrocarbon (C_{15}-C_{36}) known as paraffin wax, and iso-paraffin hydrocarbon (C_{30}-C_{60}) known as naphthenic wax. The crystals formed of paraffin are called macro-crystalline wax while those formed of naphthenic are called micro-crystalline wax [1]. At typical reservoir temperatures (70–150°C) and pressures (>2000 psi), wax molecules are dissolved in the crude oil. As the crude oil flows through a pipeline, the temperature of oil decreases because of the heat loss to the surroundings. When the temperature of waxy crude is lowered below the wax appearance temperature during transportation or storage the heavier fraction of its wax content starts to drop out. The paraffin that crystallizes in cold flow line wall creates deposit layers that increase pressure drop thereby increasing the cost of transportation and reduction in productivity [2]. It also leads to the plugging of flow lines which requires mechanical pigging to clean the flow line which leads to a further increase in operating expenses, it causes pump suction filter and clogging of strainer which require a high intervention rate. In the worst case, production must be stopped and the plugged

portion of the pipeline must be replaced. The cost of this replacement and downtime is estimated approximately $30,000,000 per incident [3]. These indicate that wax deposition can cause considerable economic losses.

Geology of Niger Delta Sedimentary Basin

The Niger Delta Basin is an extensional rift basin located in the Niger Delta and the Gulf of Guinea on the passive continental margin near the western coast of Nigeria [4]. It is a complex basin which carries high economic values as it contains a very productive petroleum system. The Niger delta basin is one of the largest subaerial basins in Africa. It has a subaerial area of about 75,000 km^2, a total area of 300,000 km^2, and a sediment fill of 500,000 km^3 [4]. The sediment fill has a depth between 9 –12 km [5]. It is composed of several different geologic formations that indicate how this basin could have formed, as well as the regional and large scale tectonics of the area. The Niger Delta Basin is an extensional basin surrounded by many other basins in the area that all formed from similar processes. The Niger Delta Basin lies in the south westernmost part of a larger tectonic structure, the Benue Trough. The other side of the basin is bounded by the Cameroon Volcanic Line and the transform passive continental margin [5].

Properties of Niger Delta Crude Oil

High wax crude oils are generated from organic matter derived from either land plants [6] or fresh water algae [7]. The environment of deposition of source rock has significant effect on the nature of crude oil derived from the organic matter [8]. The physical and chemical properties of the oil in the Niger Delta are highly variable, even down to the reservoir level. The oil within the delta has a gravity range of 16-50° API, with the lighter oils having a greenish-brown color [9]. Fifty-six percent of Niger Delta oils have API gravity between 30° and 40° [10]. Most oils fall within one of two groups. The first group are light paraffin based, waxy oils from deeper reservoirs (wax content up to 20%, but commonly around 5%; [11, 12] high n-paraffin/naphthene. The second group of oils are biodegraded and from shallow reservoirs. They have lower API gravity, average API of 26°; [11] and are naphthenic non-waxy oils. Biodegradation and washing is extreme in some Pleistocene sands of the Agbada Formation, forming extra heavy oils (API 8-20°). Oils with less than 25° API account for only 15% of the Niger Delta reserves [10]. Oils derived from terrestrial organic matter such as those in the Niger Delta have high pristane:phytane ratios. If the oils are derived from terrestrial organic matter younger than mid-Cretaceous, then the oleanane: C_{30}-hopane ratios are high as well.

Problem Statement

SEKE-3S, SEKE-6T, SEKE-8T and SEKE-11T are the SEKE wells that flow to the Central Processing Facility (CPF). These wells were initially flowing to SEKE flow station until the year 2010 when they were channeled via a manifold to CPF, a longer distance away. Since these wells started flowing to the CPF, there had been constant clogging of export pump suction strainers and filters by wax which results in incessant pump trip. Pigging operation was carried out and a preliminary investigation was carried out by selective closure of SEKE wells. It was observed that the constant tripping of the pumps stopped when SEKE-3S was closed in suggesting that it may be responsible for the wax blockage, hence there is need to first determine the possible point of deposition of wax along the SEKE-3S flow line for proper removal and to design an effective method of preventing further wax deposition.

Research Objectives

The objectives set out to be accomplished at the end of this research include; (1) To evaluate the mechanisms that control wax deposition in oil wells.

(2) To determine the possible point of wax deposition along SEKE-03S oil flow line in Niger Delta.

(3) To recommend a cost effective method to prevent wax deposition in oil well.

Location of SEKE Field

The SEKE field is situated in OML 28 onshore land, about 110km west of Port Harcourt. It is located on the dip fault closure of a mega-structure about 2.1km North of Gbaran-2 in Bayelsa State within the Central Swamp depobelt, Niger Delta. The field was discovered in 1964 by an exploration well. The Coordinate of the area are 5.025086, 6.359502. The location of the study area within the Niger Delta depobelt is shown in Fig. 1 and the map of the area is shown in Fig. 2 below.

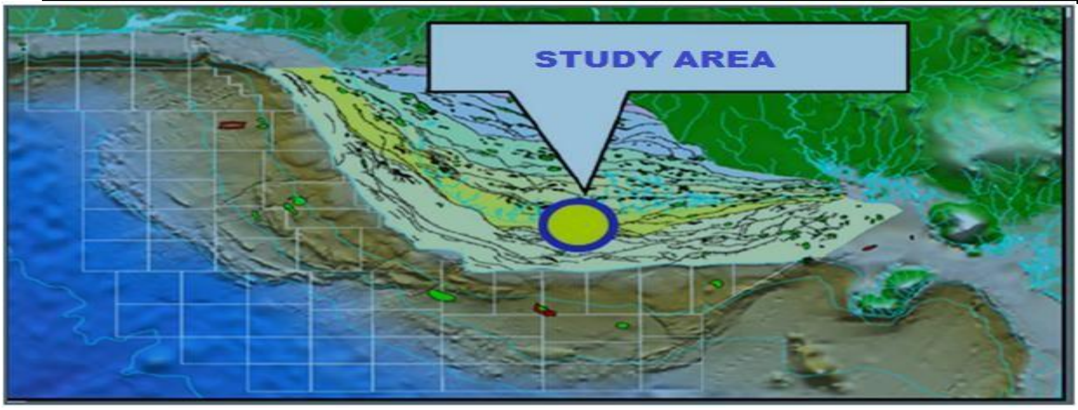

Fig. 1 Niger Delta Depobelt showing study area (http://www.ijstre.com)

Fig. 2 Map of study area (Sources: http://www.oilmapng.com/viewOilBlock)

History and Performance Review of SEKE-03s Well

SEKE-3S was completed with two set of perforations (10089-10092, 10096-10099ftah) on the reservoir D8.300N. It started production in August 1973 with an oil production rate of 632bopd and Gas-Oil-ratio (GOR) of 951scf/bbl. The GOR increased to 2570scf/bbl in May 1974 and remained fairly stable until late 1981 when it increased to over 3000scf/bbl. The interval was closed-in in June 1984 after the producing GOR had risen to over 4000scf/bbl, more than three times above the initial solution Gas-Oil-Ratio (Rsi). The observed gas production was believed to be due to gas cusping. The interval was re-opened in July 1988 after it was closed in. The well produced until June 2011 when it was closed in due to wax problem. Fig. 3 shows the production profile of SEKE-wells from 1973 to 2011

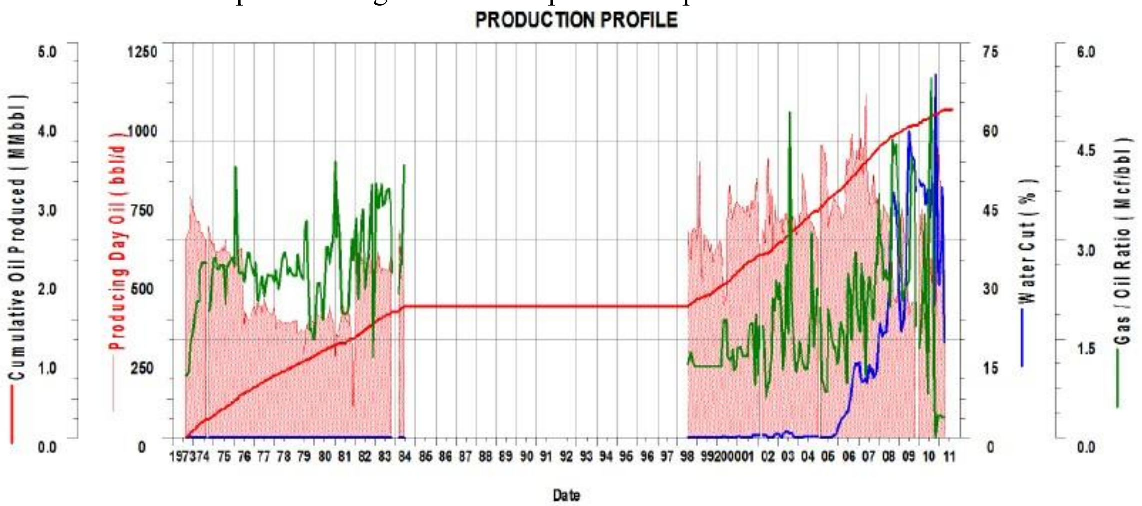

Fig. 3 Production profile of SEKE Wells

METHODOLOGY

This chapter contains the detailed procedure used to obtain data which served as input in the determination of the point of wax deposition along the flow line.

Data Inventory

The data set available for this study is shown in Table 1 below:

Table -1 Data set inventory

WELLS	DATA SET						
	PRODUCTION HISTORY			BHP DATA	BHT DATA	WHT DATA	FLT DATA
	OIL	GAS	WATER				
SEKE-3S	YES	YES	YES	YES	YES	YES	YES
SEKE-6T	TES	YES	YES	NO	NO	NO	NO
SEKE-8T	YES	YES	YES	NO	NO	NO	NO
SEKE-11T	YES	YES	YES	YES	YES	YES	YES
Well completion history Well status diagram							

DATA GAP	MITIGATION MEASURE
Inconsistency in production history for SEKE-03S	SEKE- 11T producing from the same reservoir was used for comparison.
Incomplete bottom hole temperature data	Bottom hole temperature was assumed to be fairly constant.
Variation in well head and flow line temperatures under various weather conditions.	The temperatures were taken at different conditions and the average temperature was used.

Software and Applications Used for the Study

EXCEL: This is a spreadsheet application developed by Microsoft for both Windows and Mac OS. It features include calculations, graphing tools and add-ins enabled. It was used in plotting the graph of temperature drop against the flow line distance. This plot was used to determine the point of wax deposition along the flow line.

Project Workflow

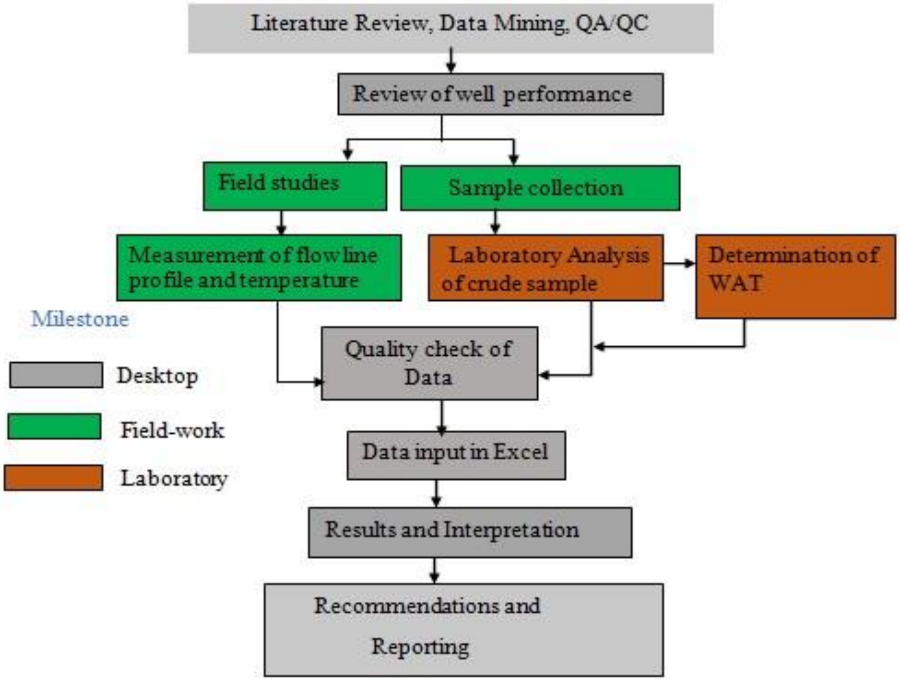

Fig. 4 Project workflow

Data Gathering and QC

The data sets used in the research work were gathered through two main sources namely:

- ✓ Field studies and sample collection
- ✓ Laboratory analysis

The data was then quality checked and assured okay for the study, thereafter it was analyzed using excel software.

Field Studies and Sample Collection

In an attempt to determine the point of deposition of wax along SEKE-3S flowline, the wax Appearance temperature (WAT) of the crude, well head temperature, and the temperature drop with corresponding distance along the flowline were required. A field visit was conducted to study the flow line profile of the SEKE-3S. Wellhead temperature of SEKE-3S was measured and crude oil sample was taken for laboratory analysis. The equipment used for the field study is shown in Table 2 below

Table -2 Equipments used for the study

Equipment	Function
Infrared gun	Used to measure the temperature along the flowline
Tap rule	Used to measure the flowline distance
Drawings (P&ID)	Served as the process flow scheme and location map

Laboratory Analysis

A crude sample from SEKE-3S was taken downstream of the choke at the wellhead. A total of 4 wells producing from the same field were sampled. The wax appearance temperature (WAT) and the amount of wax formed at a given temperature were measured at stock-tank crude oils condition. This analysis was conducted in the production chemistry laboratory of Shell Petroleum Development Company (SPDC) Port Harcourt. The cold finger method was used to determine the Wax Appearance Temperature (WAT).

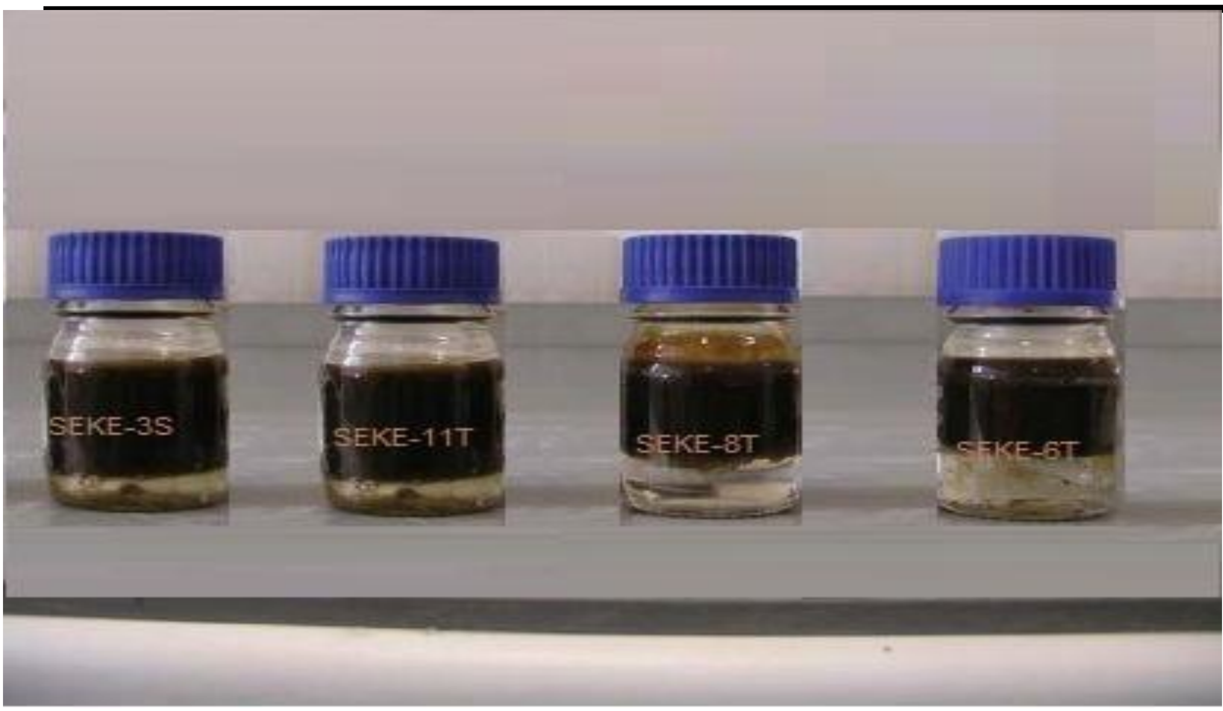

Fig. 5 Samples of crude oil from SEKE wells taken for laboratory analysis

RESULTS AND DISCUSSION Flow Line Profile of SEKE-3S

The results of the flowline profile of SEKE-03S and SEKE-11T are shown in Figures 6 and 7 below and the following interpretations were made;

- SEKE-3S well head is at a distance of 1000m from the manifold while SEKE-11T well head is at a distance of 3500m from the manifold.
- The flowline distance from the well head to the point of burial for SEKE-3S and SEKE-11T are equal.
- The flowline distance from the point of burial to the point where it rises in the manifold for SEKE-3S is 960m and for SEKE-11T is 3460m
- The flowline distance from the point where it rises in the manifold to where it enters the bulk header for SEKE3S and SEKE-11T are equal

From the interpretations above, the temperature gradient for buried flowline and surface flowline conditions along SEKE-3S and SEKE-11T flowlines could be assumed to be the same.

SEKE-3S and SEKE-11T have the same flowline configuration but their distances from the manifold differ. The well head to manifold flow line distance of SEKE-3S and SEKE-11T are illustrated in Figure 4.0 and Figure 4.1 below.

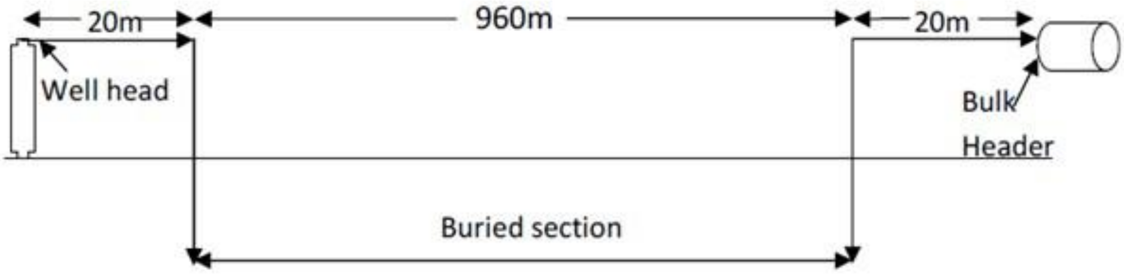

Fig. 6 SEKE-3S well head to manifold flowline distance

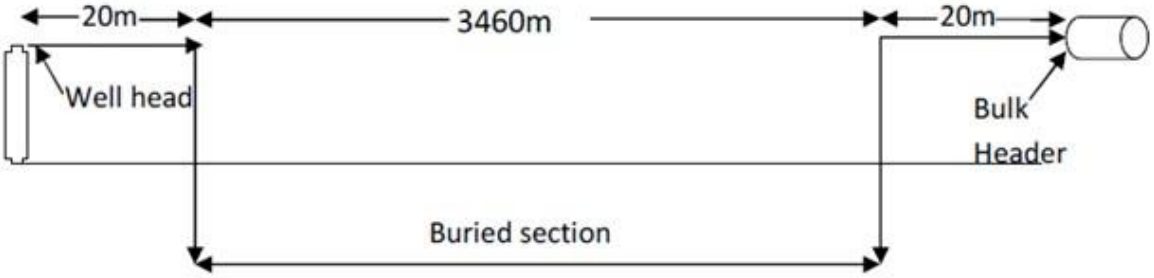

Fig. 7 SEKE-11T Well head to manifold flowline distance

Pressure Profile of SEKE-3S

From the flow line configuration of SEKE-3S and SEKE-11T in Figure 6 and 7 above, at the well head there are several valves and these include the flow line safety valve, the Cameron Control Unit (CCU), the bean, gate valve, transmitters and flanges while at the bulk manifold there are 6 valves, one fixed manual choke, pressure transmitter and flanges. There are pressure losses at the well head and the bulk manifold because of the number of valves and chokes.

Temperature Profile of SEKE-3S

The temperature drop across SEKE-11T flowline is illustrated in Figure 8 below. From the figure, a total temperature drop of 15ºC from the well head to the point where the flowline enters the bulk header in the manifold was obtained.

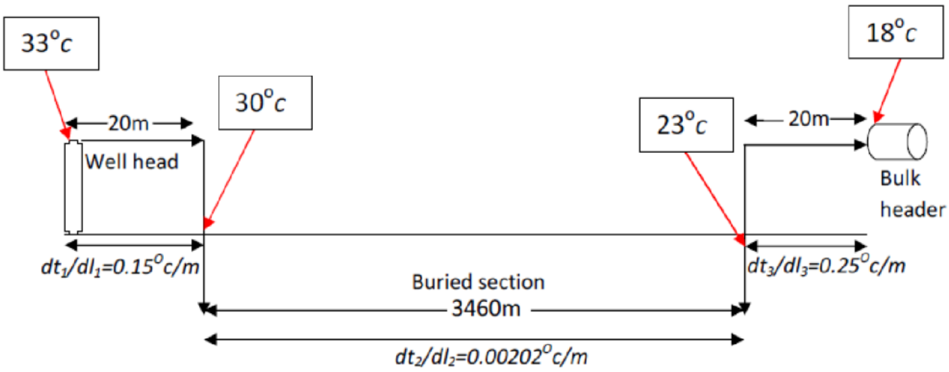

Fig. 8 Temperature gradient along Flowline of SEKE-11T

Figure 9 below illustrates a possible temperature drop across SEKE-3S flowline. From the Figure, the total temperature drop from the well head to the point where the flowline enters the bulk header in the manifold is 10ºC.

Fig. 9 Temperature profile of SEKE-3S flowline at WHT of 35ºC

Table -3 Temperature drop across SEKE-03 Flowline for various WHT

Distance (m)	WHT (35ºC)	WHT(30ºC)	WHT(25ºC)
0	35	30	25

20	32	27	22
980	30	25	20
1000	25	20	15

Temperature Drop Vs Flowline profile for SEKE-3S

Figure 10 below shows possible points of wax deposition along SEKE-3S flowline for various well head temperatures. From the graph, the well head is at a distance zero and the point just before the flowline enters the bulk header is at a distance of 1000m from the well head. For a well head temperature of 25°C the deposition of wax is at distance of between 960m - 980m from the well head which is just around the rising point of the flowline in the manifold. However, for a wellhead temperature of 30°C the wax deposition point is at a distance of about 1000m from the well head which is around the point just before the flowline enters the bulk header in the manifold. This is the maximum temperature at which wax is expected to be precipitated between the well head and the point where the flowline enters the bulk header. At temperatures higher than 30°C wax precipitation may occur between the bulk header and oil inlet manifold in the central processing facility.

A total temperature drop of 10°C will occur between SEKE-3S well head and the point where the flowline enters the bulk header which is 1000m away from the well head. This drop could be attributed to the high thermal conductivity of the flowline and the restrictions on the flowline. The drop in temperature between well head and the point where the flowline enters the bulk header will be fairly constant as long as all valves remain fully open while the well head temperature will change from time to time. The well head temperature will determine the point at which the fluid temperature will drop to it's the wax deposition temperature. If the well head temperature is higher than 30 °C wax is expected to be deposited between the bulk header in the manifold and the oil inlet manifold in the central processing facility otherwise it will deposited along its flowline.

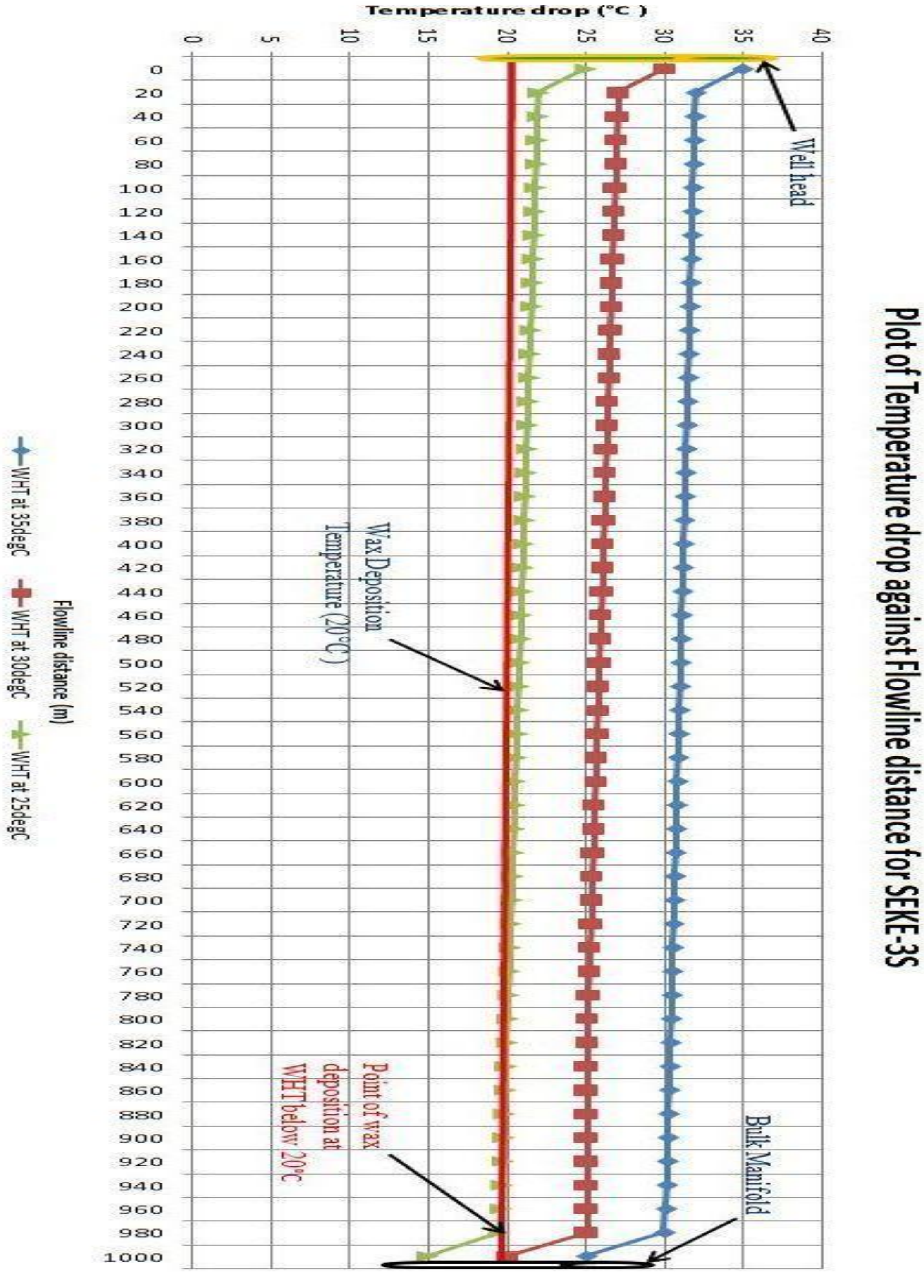

Fig. 10 Plot of Temperature drop against flowline distance for SEKE-3S

CONCLUSION

This research successfully characterized the thermal behavior and wax deposition risks associated with the SEKE-03S flowline. Laboratory analysis confirmed that all wells in the SEKE field produce waxy crude, with a determined Wax Appearance Temperature (WAT) of 20°C. The study established that temperature maintenance is the critical factor in flow assurance; specifically, wax precipitation is negated when fluid temperature is maintained above the WAT.

The thermal profiling identified a critical total temperature drop of 10°C over the initial 1000m. Consequently, for a wellhead temperature of 25°C, the wax deposition window was pinpointed to the 960m–980m interval. It is concluded that localized thermal management or the placement of a Wax Inhibition Tool within this specific zone provides a cost-effective and time-saving alternative to conventional remediation methods.

Conflicts of Interest: All authors declare that they have no conflict of interest associated with this research work. **Funding:** No special funding was received for this research work.

REFERENCES

[1]. Mansoori G. A, Lindsey B. H, Glen M (2003) Petroleum Waxes, ASTM Int'l, West Conshohocken, Pp. 525-558
[2]. Farina A, Fasano A (1996) Flow characteristics of waxy crude oils in laboratory Experimental loops, Elsevier science Ltd, Great Britain, vol. 25, No 5, Pp. 75-76.
[3]. Lee H.S, Singh P, Thomason W.H, Fogler H.S (2007) Waxy Oil Gel Breaking Mechanisms: Adhesive versus Cohesive Failure, Energy and Fuel.
[4]. Tuttle M, Charpentier R, Brownfield M (2015) The Niger Delta Petroleum System: Niger Delta Province, Nigeria, Cameroon, and Equatorial Guinea, Africa. United States Geologic Survey.
[5]. Fatoke O. A (2010) Sequence Stratigraphy of the Pliocene-Pleistocene Strata and Shelf-Margin Deltas of the Eastern Niger Delta, Nigeria (Ph.D.). University of Houston.
[6]. Hedberg, H.D (1968) Significance of high wax oils with respect to genesis of Petroleum. American Assoc. Pet. Bull. 52, Pp. 736-750.
[7]. Volkman, J.K., (1988) Biological marker compounds as indicators of the depositional environments of petroleum source rocks, In. Lacustrine Petroleum source rock Eds A.J., fleet, K kelts and M.R.Talbot, Spec. publ. Geol Asoc. London, No. 40, Pp. 103-122.
[8]. Samanta, U., Chandra, S., Kailash, N., (1993) Indian high wax crude oils and the Depositional environment of their source rock: Geochemistry Division, Institute of Petroleum Exploration, Uttar Pradesh, India, p. 2-3
[9]. Whiteman, A.J., (1982) Nigeria: It's Petroleum Geology: Resources and Potential.1&2.Graham and Trottan: London, UK. Pp. 394.
[10]. Thomas, (1995) Niger delta oil production, reserves, field sizes assessed: Oil & Gas Journal, November 13, Pp. 101-103.
[11]. Kulke, H., (1995) Nigeria, Regional Petroleum Geology of the World. Part II: Africa, America, Australia and Antarctica: Berlin, Gebrüder Borntraeger, Pp. 143-172.
[12]. Doust, H., Omatsola, E.M., (1990) Niger Delta in Divergent/Passive Margin Basins, AAPG Memoir 45: Oklahoma, Pp. 200-335