Global Journal of Engineering and Technology [GJET].
ISSN: **2583-3359** (Online)
Frequency: Monthly
Published By GSAR Publishers
Journal Homepage Link- https://gsarpublishers.com/journal-gjet-home/

Modelling the effect of temperature on wax deposition for offshore and onshore pipeline corrosion

By

Nnorom Obinichi[1*], Eseonu Obioma[2]

[1,2]Department of Mechanical Engineering, University of Port Harcourt, Nigeria

Article History

Received: 17/03/2026
Accepted: 27/03/2026
Published: 30/03/2026

Vol – 5 Issue – 3

PP: - 17-22

Abstract

The study aims to model the effect of temperature on wax deposition for offshore and onshore pipeline corrosion. When the temperature of the producing stream dips during normal flow, gas lifting, or pumping, paraffins precipitate and cling to the liner, tubing, sucker rods, and surface equipment. Wax deposition is a complex process that is one of the primary unsolved difficulties in flow assurance in pipelines and manufacturing equipment. Another issue that the oil and gas industry is grappling with is corrosion in steel pipes. The paraffin wax on the surface of the crude oil pipeline provides good corrosion protection, whilst others only give poor or no protection. However, due to the long chain paraffin layer being physically removed from the surface during periods of elevated temperature, the majority of the corrosion protection has been lost. Despite the lack of surface chemical activity, paraffin can form on the pipe surface at low temperatures, below the so-called wax appearance temperature. When the wax layer covers the steel surface, it can slow down corrosion by preventing corrosive species from diffusing to the surface. An experimental flow loop was designed for the pipeline to investigate the effect of temperature of wax deposition on pipeline. The linear polarization resistance method was used to measure the corrosion rate in mils per year (mpy) against time (minutes) using MS1000 Corrosion Meter. MATLAB software was used for simulation with the experimental results and the input parameter from the wax physical properties and operating conditions. Based on the analysis, it was observed that at temperature of 15^oC and flow rate at 10.21 L/min during the corrosion inhibition. At time 18 minutes, the experimental and model results predicted a significant reduction of corrosion rates and excellent corrosion protection while others gave only moderate or negligible protection to the pipeline. From the profile plot, the values of the corrosion rate (mpy) against time (min) of the experimental and model results are 3 (0.65 mpy, 0.57 mpy), 6 (0.41 mpy, 0.47 mpy), 9(0.35 mpy, 0.37 mpy), 12 (0.21 mpy, 0.26 mpy), 15 (0.16 mpy, 0.16 mpy), 18 (0.11 mpy, 0.06 mpy). But the variation of the experimental and model results in terms of deviation is (0%) indicating that both results are insignificant in variation, showing positive agreement between the experimental and model results.

Keywords *–Modelling, offshore, onshore, wax, temperature, deposition*

1. Introduction

Paraffin wax and CO2 corrosion have caused many problems in oil and gas industry (Gjermundsen, 2018). These problems mainly caused in the transportation and utilities where the pipelines are severely corroded. The paraffin wax on the surface provides excellent corrosion protection, while others provided only moderate or negligible protection in the crude oil pipeline, but most of the corrosion protection has been lost due to the long chain paraffin layer being physically removed from the surface during the periods of increased temperature or increased flow rates. The protection of paraffins can be assumed to be due to physisorption caused by relatively weak intermolecular forces such as van der Waals forces (Gjermundsen, 2018). Despite the lack of surface chemical activity, at low temperatures-below the so-called wax appearance temperature (WAT), paraffins can precipitate and deposit on the pipe surface. When the wax layer covers the steel surface, it can slow down corrosion processes by hindering the diffusion of corrosive species to the surface. However, if the temperature stays below the WAT for extended period of time, the wax layer becomes thicker with time, and can, in the long run, cause partial or total blockage of the pipe. It was found that crude oils can generate corrosion

*Corresponding Author: Nnorom Obinichi

inhibition, but the extent of inhibition varied from one crude oil to another.

Paraffin wax deposition is a complex process that is one of the primary unsolved difficulties in Flow Assurance in pipelines and manufacturing equipment. When the temperature of the producing stream dips during normal flow, gas lifting, or pumping, paraffins precipitate and cling to the liner, tubing, sucker rods, and surface equipment (Kermani and Morshed, 2017). Paraffin deposits can be found in wellbores, production tubing, and flowlines. Under some circumstances, paraffin deposition can occur in the producing formation. These deposits generate problems due to limited flow, which causes increased flowline pressure, lower production, and mechanical issues (Kermani and Morshed, 2017). Another issue that the oil and gas industry is grappling with is corrosion in steel pipes. Because of the heterogeneous nature of the bulk material and its surface, corrosion is an electrochemical reaction that occurs when anode and cathode sites arise on a material's surface. An electrolyte as well as an electrical connection are required for electrochemical corrosion.

2. Materials and Methods

2.1 Materials

The material used are, flow-loop build with steel pipe, 0.5hp pump, flow meter, MS1000 Corrosion Meter, waxy crude oil was used in this study.

2.2 Methods

The effect of temperature on wax deposit on corrosion of crude oil pipeline, the crude oil sample is pumped into the flow-loop set up under different operating conditions. The range of the inlet temperature of the waxy crude oil was (10-40^{o}C). The experiment was conducted 5 times, at time interval of 3-18 minutes, temperature were varied between 15-35^{o}C and flow rate were also varied between 10.21-50.70 L/min. The experiment were carried out at varying flow rate with time while temperature is kept constant. At flow rate of 10.21, 20.37, 30.45, 40.28 and 50.70 L/min and time at 3, 6, 9, 12, 15 and 18 min while keeping temperature constant for each of the experimental run at 15, 20, 25, 30 and 35 ^{o}C to determine the corrosion rate against time. After testing the corrosion rate of the waxy crude oil to ascertain the effect of temperature at varying flow rate and time of the paraffin wax deposited on the crude oil pipeline. The results were recorded, the graph of corrosion rate (mpy) against time (min) was plotted and the result were analyzed.

2.2.1 Model Simulation

To solve the governing equations a computer program was developed, which is used to simulate the models using the parameters from wax operating conditions and the experimental data from the effect of temperature on corrosion against time in minutes. MATLAB software was used for simulation.

$$\boldsymbol{T} = \boldsymbol{T_1} + \frac{q_g}{4k}(r_1^2 - r_2^2) + \left[(T_1 - T_2)\left(\frac{-q_g}{4k}\right)(r_2^2 - r_1^2)\right]\frac{\log_e\left(\frac{r}{r_1}\right)}{\log_e\left(\frac{r_1}{r_2}\right)} \quad \textbf{(1)}$$

is the Temperature distribution model used for simulation to determine the effect of temperature on wax deposit on corrosion rate (mpy) against time (min) in crude oil pipeline. The results of the model were recorded, graph plotted and analyzed to compare the experimental and model data on wax deposition

3. Results and Discussion

Effect of Temperature on Wax Deposition on Corrosion of Crude Oil Pipeline

Time (min)	Corrosion Rate (mpy) @10.21 L/min	Corrosion Rate (mpy) @ 20.37 L/min	Corrosion Rate (mpy) @ 30.45 L/min	Corrosion Rate (mpy) @ 40.28 L/min	Corrosion Rate (mpy) @ 50.70 L/min
3	0.65	0.53	0.39	0.56	0.48
6	0.41	0.48	0.55	0.79	0.52
9	0.35	0.49	0.31	0.51	0.69
12	0.21	0.29	0.44	0.61	0.49
15	0.16	0.22	0.32	0.47	0.66
18	0.11	0.14	0.45	0.54	0.43

Table 1A: Effect of Temperature at 15^{o}C on Corrosion Rate (mpy) against Time (min) on Wax Deposition

Table 1B: MAT LAB Simulation of the Effect of Temperature on Wax Deposit on Corrosion Rate (mpy) versus Time (min) at constant 15 ^{o}C Temperature while adjusting the Flow Rate (10.21 L/min, 20.37 L/min, 30.45 L/min, 40.28 L/min and 50.70 L/min)

Time (min)	Corrosion Rate @ 10.21 L/min	Corrosion Rate @ 20.37 L/min	Corrosion Rate @ 30.45 L/min	Corrosion Rate @ 40.28 L/min	Corrosion Rate @ 50.70 L/min
0	0.674	0.6513	0.436	0.676	0.548
1	0.6398	0.6234	0.4335	0.6669	0.5477
2	0.6056	0.5955	0.431	0.6578	0.5474
3	0.5714	0.5676	0.4285	0.6487	0.5471
4	0.5372	0.5397	0.426	0.6396	0.5468
5	0.503	0.5118	0.4235	0.6305	0.5465
6	0.4688	0.4839	0.421	0.6214	0.5462
7	0.4346	0.456	0.4185	0.6123	0.5459
8	0.4004	0.4281	0.416	0.6032	0.5456
9	0.3662	0.4002	0.4135	0.5941	0.5453

*Corresponding Author: Nnorom Obinichi

10	0.332	0.3723	0.411	0.585	0.545
11	0.2978	0.3444	0.4085	0.5759	0.5447
12	0.2636	0.3165	0.406	0.5668	0.5444
13	0.2294	0.2886	0.4035	0.5577	0.5441
14	0.1952	0.2607	0.401	0.5486	0.5438
15	0.161	0.2328	0.3985	0.5395	0.5435
16	0.1268	0.2049	0.396	0.5304	0.5432
17	0.0926	0.177	0.3935	0.5213	0.5429
18	0.0584	0.1491	0.391	0.5122	0.5426

Table 1 – 5 and Figure 1 – 5: Comparison of Experimental and Model Results of the Effect of Temperature on Wax Deposit on Corrosion against Time at Constant Temperature of 15 ºC, 20 ºC, 25 ºC, 30 ºC and 35ºC while keeping the Flow Rate at (10.21 L/min, 20.37 L/min, 30.45 L/min, 40.28 L/min and 50.70 L/min)

Table 1: Comparison of Experimental and Model Results of the Effect of Temperature on Wax Deposit on Corrosion Rate (mpy) against Time (min) at Temperature of 15ºC and Flow rate at 10.21 L/min

Time (min)	CR EXP (mpy)	CR MODEL (mpy)	ERROR
3	0.65	0.57	0.08
6	0.41	0.47	-0.06
9	0.35	0.37	-0.02
12	0.21	0.26	-0.05
15	0.16	0.16	0
18	0.11	0.06	0.05

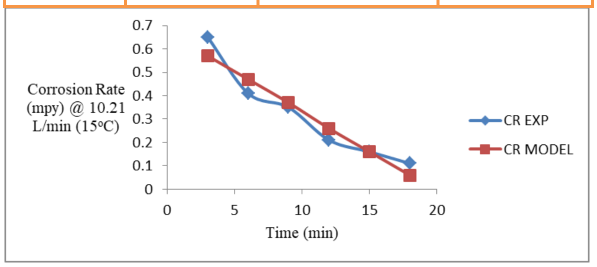

Figure 1: Comparison of Experimental and Model Results of the Effect of Temperature on Wax Deposit on Corrosion Rate (mpy) against Time (min) at Temperature of 15ºC and Flow Rate at 10.21 L/min

Figure 1: illustrate the variation profile plot of experimental and model results of the effect of temperature on wax deposit on corrosion rate (mpy) against time (min) at temperature of 15ºC and flow rate at 10.21 L/min during the corrosion inhibition.

At time 18 minutes, the experimental and model results predicted a significant reduction of corrosion rates and excellent corrosion protection while others gave only moderate or negligible protection to the pipeline

From the profile plot, the values of the corrosion rate (mpy) against time (min) of the experimental and model results are 3 (0.65 mpy, 0.57 mpy), 6 (0.41 mpy, 0.47 mpy), 9(0.35 mpy, 0.37 mpy), 12 (0.21 mpy, 0.26 mpy), 15 (0.16 mpy, 0.16 mpy), 18 (0.11 mpy, 0.06 mpy). But the variation of the experimental and model results in terms of deviation is (0%) indicating that both results are insignificant in variation, showing positive agreement between the experimental and model results.

Table 2: Comparison of Experimental and Model Results of the Effect of Temperature on Wax Deposit on Corrosion Rate (mpy) against Time (min) at Temperature of 15ºC and Flow Rate at 20.37 L/min

Time (min)	CR EXP(mpy)	CR MODEL(mpy)	ERROR
3	0.53	0.57	-0.04
6	0.48	0.48	0
9	0.49	0.40	0.09
12	0.29	0.32	-0.03
15	0.22	0.23	-0.01
18	0.14	0.15	-0.01

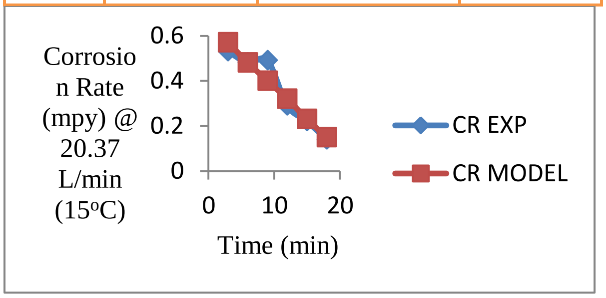

Figure 2: Comparison of Experimental and Model Results of the Effect of Temperature on Wax Deposit on Corrosion Rate (mpy) against Time (min) at Temperature of 15ºC and Flow Rate at 20.37 L/min

Figure 2: illustrate the variation profile plot of experimental and model results of the effect of temperature on wax deposit on corrosion rate (mpy) against time (min) at temperature of 15ºC and flow rate at 20.37 L/min during the corrosion inhibition.

At time 18 minutes, the experimental and model results predicted a significant reduction of corrosion rates and excellent corrosion protection while others gave only moderate or negligible protection to the pipeline.

From the profile plot, the values of the corrosion rate (mpy) against time (min) of the experimental and model results are 3 (0.53 mpy, 0.57 mpy), 6 (0.48 mpy, 0.48 mpy), 9(0.49 mpy,

*Corresponding Author: Nnorom Obinichi

0.40 mpy), 12 (0.29 mpy, 0.32 mpy), 15 (0.22 mpy, 0.23 mpy), 18 (0.14 mpy, 0.15 mpy). But the variation of the experimental and model results in terms of deviation is (0%) indicating that both results are insignificant in variation, showing positive agreement between the experimental and model results.

Table 3: Comparison of Experimental and Model Results of the Effect of Temperature on Wax Deposit on Corrosion Rate (mpy) against Time (min) at Temperature of 15°C and Flow Rate at 30.45 L/min

Time (min)	CR EXP(mpy)	CR MODEL(mpy)	ERROR
3	0.39	0.43	-0.04
6	0.55	0.42	0.13
9	0.31	0.41	-0.1
12	0.44	0.41	0.03
15	0.32	0.40	-0.08
18	0.45	0.39	0.06

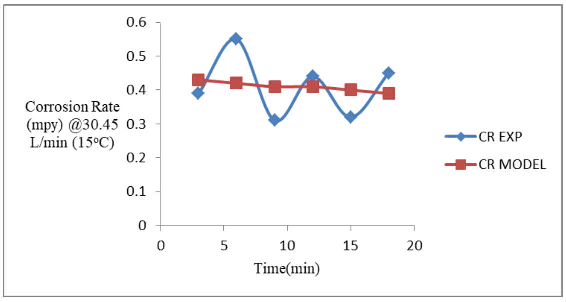

Figure 3: Comparison of Experimental and Model Results of the Effect of Temperature on Wax Deposit on Corrosion Rate (mpy) against Time (min) at Temperature of 15°C and Flow Rate at 30.45 L/min

Figure 3: shows the variation profile plot of experimental and model results of the effect of temperature on wax deposit on corrosion rate (mpy) against time (min) at temperature of 15°C and flow rate at 30.45 L/min during the corrosion inhibition.

At time 9 and 18 minutes the experimental and the model results predicted a significant reduction of corrosion rates while others gave only moderate or negligible protection to the crude oil pipeline.

From the profile plot, the values of the corrosion rate (mpy) against time (min) of the experimental and model results are 3 (0.39 mpy, 0.43 mpy), 6 (0.55 mpy, 0.42 mpy), 9(0.31 mpy, 0.41 mpy), 12 (0.44 mpy, 0.41 mpy), 15 (0.32 mpy, 0.40 mpy), 18 (0.45 mpy, 0.39 mpy). But the variation of the experimental and model results in terms of deviation is (0%) indicating that both results are insignificant in variation, showing positive agreement between the experimental and model result

Table 4: Comparison of Experimental and Model Results of the Effect of Temperature on Wax Deposit on Corrosion Rate (mpy) against Time (min) at Temperature of 15°C and Flow Rate at 40.28 L/min

Time (min)	CR EXP(mpy)	CR MODEL(mpy)	ERROR
3	0.56	0.65	-0.09
6	0.79	0.62	0.17
9	0.51	0.59	-0.08
12	0.61	0.57	0.04
15	0.47	0.54	-0.07
18	0.54	0.51	0.03

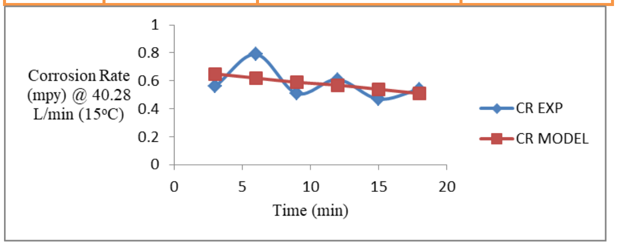

Figure 4: Comparison of Experimental and Model Results of the Effect of Temperature on Wax Deposit on Corrosion Rate (mpy) against Time (min) at Temperature of 15°C and Flow Rate at 40.28 L/min

Figure 4: shows the variation profile plot of experimental and model results of the effect of temperature on wax deposit on corrosion rate (mpy) against time (min) at temperature of 15°C and flow rate at 40.28 L/min during the corrosion inhibition.

At time 15 and 18 minutes, the experimental and the model results predicted a significant reduction of corrosion rates while others gave only moderate or negligible protection to the pipeline.

From the profile plot, the values of the corrosion rate (mpy) against time (min) of the experimental and model results are 3 (0.56 mpy, 0.65 mpy), 6 (0.79 mpy, 0.62 mpy), 9(0.51 mpy, 0.59 mpy), 12 (0.61 mpy, 0.57 mpy), 15 (0.47 mpy, 0.54 mpy), 18 (0.54 mpy, 0.51 mpy). But the variation of the experimental and model results in terms of deviation is (0%) indicating that both results are insignificant in variation, showing positive agreement between the experimental and model results.

Table 5: Comparison of Experimental and Model Results of the Effect of Temperature on Wax Deposit on Corrosion Rate (mpy) against Time (min) at Temperature of 15°C and Flow Rate at 50.70 L/min

Time (min)	CR EXP(mpy)	CR MODEL(mpy)	ERROR
3	0.48	0.5471	-0.0671

*Corresponding Author: Nnorom Obinichi

6	0.52	0.5462	-0.0262
9	0.69	0.5453	0.1447
12	0.49	0.5444	-0.0544
15	0.66	0.5435	0.1165
18	0.43	0.5426	-0.1126

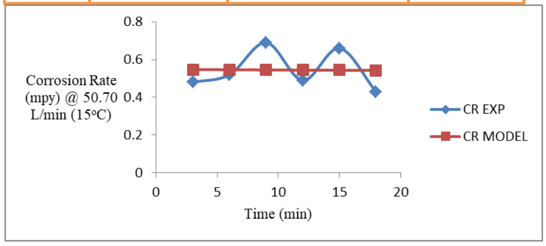

Figure 5: Comparison of Experimental and Model Results of the Effect of Temperature on Wax Deposit on Corrosion Rate (mpy) against Time (min) at Temperature of 15°C and Flow Rate at 50.70 L/min

Figure 5: illustrate the variation profile plot of experimental and model results of the effect of temperature on wax deposit on corrosion rate (mpy) against time (min) at temperature of 15°C and flow rate at 50.70 L/min during the corrosion inhibition.

At 18 minutes, the experimental and model results predicted a significant reduction of corrosion rates while others gave only moderate or negligible protection to the pipeline.

From the profile plot, the values of the corrosion rate (mpy) against time (min) of the experimental and model results are 3 (0.48 mpy, 0.5471 mpy), 6 (0.52 mpy, 0.462 mpy), 9(0.69 mpy, 0.5453 mpy), 12 (0.49 mpy, 0.5444 mpy), 15 (0.66 mpy, 0.5435 mpy), 18 (0.43 mpy, 0.5426 mpy). But the variation of the experimental and model results in terms of deviation is (0.03%) indicating that both results are insignificant in variation, showing positive agreement between the experimental and model results.

4. Conclusion

When the temperature of the producing stream dips during normal flow, gas lifting, or pumping, paraffins precipitate and cling to the liner, tubing, sucker rods, and surface equipment. Paraffin wax deposition is a complex process that is one of the primary unsolved difficulties in Flow Assurance in pipelines and manufacturing equipment. Paraffin deposits can be found in wellbores, production tubing, and flowlines. Under some circumstances, paraffin deposition can occur in the producing formation. These deposits generate problems due to limited flow, which causes increased flowline pressure, lower production, and mechanical issues. Another issue that the oil and gas industry is grappling with is corrosion in steel pipes. The paraffin wax on the surface of the crude oil pipeline provides good corrosion protection, whilst others only give poor or no protection. However, due to the long chain paraffin layer being physically removed from the surface during periods of elevated temperature, the majority of the corrosion protection has been lost. The protection provided by paraffin is assumed to be due to physisorption, which is caused by weak intermolecular interactions such as van der Waals forces. Despite the lack of surface chemical activity, paraffin can form on the pipe surface at low temperatures, below the so-called wax appearance temperature. When the wax layer covers the steel surface, it can slow down corrosion by preventing corrosive species from diffusing to the surface.

References

1. Al-Yaari, M. (2011). Paraffin Wax Deposition: Mitigation and Removal Techniques, Presented at the Society of Petroluem Engineers professionals Technical Symposium held in Dhahran, Saudi-Arabia.
2. Antropov, L. I., Makushin E. M., and Panasenko. V. F. (2001). Inhibitors of Metal Corrosion, Metallurgia, Moscow.
3. Asan, A., Soylu, S., Kıyak T, Yıldırım, F., Oztas, S. G., Ancın N, Kabasakaloglu M. (2006). Investigation on some Schiff bases as corrosion inhibitors for mild steel, Corrosion science, 48, 3933.
4. Ash, M. and Ash I. (2001). Handbook of Corrosion Inhibitors, National Association of Corrosion Engineers, Texas: Houston.
5. Azevedo, L. F., and Teixeira., A. M. (2003). A Critical Review of the Modeling of Wax Deposition Mechanism, Petroleum Science and Technology, 21(3 & 4), 393-408
6. Bailey, J. C., Porter, F. C., Pearson A. W., and Jarman R. A. (2004). Aluminum and Corrosion Prevention Control, Journal of Electrochemical Control, 16, 245.
7. Burger, E. D., Perkins, T. K., Striegler, J. H. (2003). Studies of Wax Deposition in the Trans-Alaska Pipeline, *Journal of American Chemical Society*, 33 (6), 1075-1086.
8. Badea G. E. (2010). Polarisation Measurements Used for Corrosion', *Journal of Sustainable Energy*, 1-2.
9. Callister, W. D. (2007). Materials Science and Engineering- An Introduction, 7th ed., John Wiley and Sons, Inc.
10. Carnahan, N. F. (2004). Paraffin Deposition in Petroleum Production, Society of Petroleum Engineer *Journal of Petroleum Technology*, (10), 1024-1025, 1106.
11. Chow, R. (2000). Precipitation of Wax from Crude under the Influence of a Magnetic Field, *Journal of Canadian Petroleum Technology*, 39(6)
12. Cisse, M. B., Zerga, B., El Kalai, F., Touhami, M. E., Sfaira, M., Taleb, M. (2011). *Corrosion Journal*, 33, 297.
13. Clayton, C. R., Olefjord R. P., Marcus, J., Oudar, M. D. (2005). Corrosion Mechanisms in Theory and Practice, New York.

*Corresponding Author: Nnorom Obinichi

14. Creek, J. L., Lund, H. J., Brill, J. P., and Volk, M. (2000). Wax Deposition in Single Phase Flow, Fluid Phase Equilibria, 158, 801-811.
15. Dobbs, J. B. (2002). A Unique Method of Paraffin Control in Production Operation, in Society of Petroluem Engineers Rocky Mountain Regional Meeting, Society of Petroleum engineer Inc., Gillette, Wyoming,
16. Edmonds, B. Moorwood, T., Szczepanski, R., and Zhang, X. (2008). Simulating Wax Deposition in Pipelines for Flow Assurance, Energy and Fuels, 22, 729-741.
17. Fasano, A., Fusi, L., Correra, S. (2004). Mathematical Models for Waxy Crude Oils, Meccanica, 39, 441-482
18. Garcia, M. L. (2001). Correlation between Oil Composition and Paraffin Inhibitors Activity', Society of Petroluem Engineers Annual Technical Conference and Exhibition.
19. Gjermundsen, I. (2018). A Model for Wax Deposition in Offshore Pipelines.Internal Hydro report, Porsgrunn.
20. Gjermundsen, I., and Duenas, M. (2015). Wax Deposition: A Comparison between Measurements and Predictions from a Commercial Model, Proceeding of the 7th International Conference on Petroleum Phase Behaviour and Fouling, 25-29.
21. Kermani, M. B, Morshed A. (2017). Carbon Dioxide Corrosion in Oil and Gas Production. A Compendium, Corrosion, 59, 659.

*Corresponding Author: Nnorom Obinichi