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Characterization of Corrosion Behaviour of Soil on Mild Steel C-1026 Pipeline

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ABSTRACT: *Pipeline is very paramount in the oil and gas industry. They are utilized for the extraction, exploration and transportation of oil and gas from the production site to the central processing site. However, the running of pipeline in the cycle of operation cannot be done without involving the soil. They are mostly laid in the soil. Soil is a major component that causes corrosion on pipeline because of the Chloride ions in it. Mild Steel C-1026 pipeline coupons were investigated in soil samples of three communities in three Local Government Areas in Bayelsa State of Nigeria. It was observed that the soil with the highest Chloride ions corroded the MS coupon which is Yenagoa while Ayamasa and Angiama had lower corrosivity. However, three green plants extracts; Scent Leaf, Cassava Leaf and Neem Leaf as corrosion inhibitors were studied in five corrosive environments with the MS coupons immersed in them. The main focus of this investigation is to enable oil and gas industries to apply the green plant extracts to inhibit corrosion on pipelines in whichever soil that it is more applicable. The green plant extracts were all effective inhibitors in the various corrosive media: Seawater, Sodium Chloride, Sodium Sulphate, Sodium Carbonate and Zinc Sulphate.*

KEY WORDS: *Corrosion, Corrosion inhibitor, Green plant leaves, Mild Steel,* Pipeline, *Soil.*

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I. INTRODUCTION

The extraction, exploration and transportation of crude oil from the production site to the central processing site cannot be completed without Mild Steel. The oil and gas prospecting companies run their pipelines underground [**1**]. The pipelines run across the breadth and width of Nigeria and the world at large are buried beneath the soil. Soil is a predominant source that causes corrosion on pipeline [1,2,3,4]. The corrosive effect of soil on pipeline is attributed to the Chloride ions in it [1,5]. This menace on pipeline is detrimental and has cost implication on oil and gas companies. Corrosion is a gradual depreciation of metal due to electrochemical reaction between the material and its environment [1,6,7]. In order to subvert this depreciation, inhibitor is applied on the system. Inhibitor is a substance when added in small concentration reduces the corrosion rate [1,7,8]. Pipelines have been protected from corrosion by means of inorganic compounds, such as chromates, dichromate, phosphates and arsenates. These compounds are hazardous to human being because of their toxicity. Furthermore, they are costly and scarce [9]. Observing the shortcomings of these inorganic substances, researchers have developed other means to substitute them. They decided to use green plant extracts to inhibit corrosion in the oil and gas industries on pipeline and other equipment. A good number of green plant extracts has been utilized and they have performed creditably well as efficient corrosion inhibitors. Green plant extracts investigated by different researchers which proved to be effective inhibitors are: Nymphae Pubscens, [6]; Nypa Fruticans Wumb, [10]; Delonix regia extract, Abiola, et al., 2007 [11]; Aloe Vera Barbadensis, Kalada and James, 2014 [12]; Sida Acuta, Clerodendrum Splendens, Voacanga Africans, Tridax Procumbens and Landolphia Dulcis, [13]; Grewa Venusta [14]; Senna-Italica Extract [15]; Bread Fruit Peel [**16**]; Neem Leaf Extract [7]; Vernonia amygdalina (Bitter Leaf), [5]; Sida Acuta, [17]; Azadirachta indica, [18]; Chanca Piedra (Phyllanthus niruri), [19]; Thyme Leaves, Ibraham, et al, 2012 [20]; Carica papaya extract, [21]; Carica papaya and Azadirachta indica extracts, Sharma et al. 2015[22]; Delonix regia, [23]; Carica papaya leaf extracts, Kavitha, et al., 2014 [24], etc.

In this study, we investigated on oil and gas pipeline buried in some soil environment in Bayelsa State of Nigeria and how the soil chemical components reacted on the pipeline coupons. They were buried for 100 days (2400 hours). There was disproportionate chemical reaction on each of the metals in the various environments. Three Communities in three Local Government Areas (LGAs) were investigated for the corrosivity on the pipeline Steel Metal C-1026. The Communities and Local Government Areas are: Ayamasa in Ekeremor LGA, Angiama in Sagbama LGA and Yenagoa in Yenagoa LGA. The investigation revealed that the soil with the highest Chloride ions had the maximum corrosive effect which is Yenagoa. Moreover, some green plant extracts were studied as corrosion inhibitors. These are: Ocimum gratissimum (Scent Leaf, SL), Manihot Esculenta (Cassava Leaf, CL) and Azadirachta indica (Neem Leaf, NL) extracts distinctly. They were added to various corrosive media to determine their inhibitive properties that will enable the oil and gas industries to apply in whichever environment that is necessary. The corrosive media for the research were Seawater (SW), Sodium Chloride (NaCl), Sodium Sulphate (Na_2SO_4), Sodium Carbonate (Na_2CO_3) and Zinc Sulphate ($ZnSO_4$). The green plant extracts were all effective inhibitors in the different corrosive environment probably because of the bioactive constituents embedded in them.

II. MATERIALS AND METHODS

ASTM G13 standard was used for the investigation. It is a recommended standard practice for Preparation of Mild Steel C-1026 Coupons

A cutting machine was used to cut 1cm cylindrical oil and gas pipeline Mild Steel C-1026 (%) containing Mn = 0.08%, Ti = 0.17%, As = 0.07%, Cu = 0.07% and Fe = 98.88% into coupon dimensions of 4 x 2 cm. They were polished with emery papers, washed with acetone and subjected to the various soil environments for a period of 100 days (2400 hours), Fig. 1. The Mild Steel coupons were retrieved at every 10 days interval, washed, dried, weighed and buried again until the 100 days were completed. Other materials were: Plastic container, distilled water, acetone, bowl, brush, soil samples, and electronic weighing balance.

Figure 1: Mild Steel coupons buried in Soils.

2.1 Weight Loss Method

The investigations were carried out based on ASTM G13: a standard practice recommended for laboratory immersion corrosion testing of materials [1,5].

Formulae were applied to calculate the weight loss and corrosion rate of the Mild Steel C-1026 coupons corroded in the soil samples and the inhibition efficiency occasioned by the addition of the green plant extracts of Scent Leaf, Cassava Leaf and Neem Leaf.

$$Weight\ Loss,\ WL = Wf - Wi \quad (1)$$

Where, Wf is Final Weight Loss and Wi is Initial Loss

$$Corrosion\ Rate, CR = \frac{K \times Loss\ in\ Weight\ (g)}{Surface\ Area \times Period\ of\ immersion\ (Hours) of\ Specimen \times Density\ of\ the\ Mild\ Steel} \quad (2)$$

$$CR = \text{K} \left(\frac{Wlost}{AT\rho}\right), = \text{K} \left(\frac{W2-W1}{AT\rho}\right)$$

Where, K is Constant, 87.6, Density (ρ) of Mild Steel is 7.9 g/m, $W1$ is Initial Weight and $W2$ is Final Weight of coupons [1,5,7,9].

Corrosion Inhibition Efficiency, IE (%) using the equation,

$$IE\ (\%) = 100 \left[\frac{1-W2}{W1}\right] \% \quad (3)$$

Where, $W1$ is Weight Loss without inhibitor and $W2$ is Weight Loss with inhibitor [1,25].

2.2 Collection of Soil Samples

The Soil Samples were collected from three different locations in Bayelsa State. The samples were dug at about 0.8m depth in Ayamasa in Ekeremor LGA, Angiama in Sagbama LGA and Yenagoa in Yenagoa LGA respectively. They were taken to Mechanical Engineering Laboratory in Niger Delta University of Bayelsa State to perform the experiment for the stipulated days and hours.

2.3 Experimentation

Soil Sample

The various soil samples of the three Communities were put into three plastic containers and the Mild Steel C-1026 coupons were buried in them. The MS coupons were retrieved, washed, dried and weighed with the Tari M200 electronic weighing balance at every 10 days interval for 100 days. In each of the readings, weight loss and corrosion rate were calculated to obtain the experimental values.

2.4 Green Plant Extracts with Corrosive Media

35g of the green plants extracts were crushed with mortar and pestle added with distilled water then filtered with filtration cloth. The MS C-1026 coupons were immersed in the various Bathes for 100 days. Every 10 days interval, the coupons were retrieved from the concentrations, washed with acetone and dried. The process was performed repeatedly until 100 days were completed. The experimental data were computed to obtain the results.

III. RESULTS

3.1 Elemental Composition of Various Soil Samples

Investigation on the elemental composition of the various Soil samples of the Communities with Chloride ions revealed that Yenagoa had 40.501mg/kg, Angiama had 39.900mg/kg and Ayamasa had 20.379mg/kg. Yenagoa having the highest Chloride ions indicated that it is more corrosive. The study on Corrosion Rate of the various MS C-1026 coupons in the Soil samples indicated that Yenagoa had 0.00038676 or 3.8×10^{-5} mpy, Angiama had 0.00023143 or 2.3×10^{-5} mpy and Ayamasa had 0.00023681 or 2.3×10^{-5} mpy. The rate of maximum corrosivity of MS C-1026 in Yenagoa might be owed to the presence of Chloride ions in the soil because it is a major element that causes corrosion mostly. Table 1 shows the Elemental Composition of Soil Samples and their concentrations. Moreover, Table 2 shows the Weight Loss of Mild Steel C-1026 investigated in the different Soil Samples. Furthermore, Table.3 and 4 shows the Corrosion Rate of Mild Steel C-1026 at various exposure times at different locations in Bayelsa Sate, while Table 5 shows the pH value of the different Soil Samples in the various locations under research. Figure 2 conspicuously shows the pH value of Mild Steel C-1026 in Soil Samples of Ayamasa, Angiama and Yenagoa, while Figure 5 shows the pH value of the different Soil Samples whereby Ayamasa had 10.89, Angiama had 9.11 and Yenagoa had 7.30.

Table 1: Elemental Composition of Soil Samples.

Element	Concentration (mg/kg) of Soil		
	AYA	ANG	YEN
Mg	21770.767	2947.920	1784.571
Al	5725.079	7192.359	5146.507
Si	6152.794	6350.295	4958.466
S	168.856	181.051	152.841
Cl	20.379	39.900	40.501
Ca	233.870	342.781	288.045
Ti	1428.817	1559.628	1291.746
Mn	73.123	80.090	43.040
Fe	3654.273	5232.249	3304.503
Co	34.307	45.939	19.969
Mo	9.368	-	-
Sn	3014.131	3184.014	3514.693
Ba	56.446	63.973	-
Cr	-	13.601	-
Zn	-	20.231	-
V	-	-	27.595

KEY: AYA – Ayamasa, ANG – Angiama, YEN – Yenagoa

Table 2: Weight Loss of Mild Steel C-1026 investigated in the different Soil Samples.

Exposure Time (Hr)	**Weight Loss (g)**		
	Location		
	AYA	ANG	YEN
0	60.4	57.3	61.7
240	60.3	57.25	61.65
480	60.2	57.2	61.6
720	60.15	57.2	61.55
960	60.25	57.05	61.5
1200	60.2	57	61.5
1440	60.15	56.95	61.45
1680	60.2	56.95	61.45
1920	60.15	56.95	61.5
2160	60.15	56.85	61.45
2400	60.15	56.85	61.43
Average	**66.23**	**62.75**	**61.53**

Table.3: Corrosion Rate of Mild Steel C-1026 at various exposure times at different locations in Bayelsa Sate.

Exposure Time (Hr)	**Corrosion Rate, CR (mpy)**		
	Location		
	AYA	ANG	YEN
0	0	0	0
240	0.0004679	0.0002339	0.0002339
480	0.0004679	0.0001871	0.0002339
720	0.0003899	0.00016	0.0002339
960	0.0001754	0.0003001	0.0002339
1200	0.0001403	0.0002807	0.0001678
1440	0.0002001	0.0002729	0.0001748
1680	0.0001336	0.0002339	0.0001165
1920	0.0001462	0.0002047	0.0001048
2160	0.0001299	0.0002339	0.0001165
2400	0.0001169	0.0002071	0.0001132
Average	**0.00023681**	**0.0002314**	**0.0003868**

Table.4: Average Corrosion Rate of Mild Steel C-1026 in Soil at various exposure times at different locations in Bayelsa Sate.

Location	**Average Corrosion Rate (mpy)**
AYA	0.00023681 or 2.3×10^{-5}
ANG	0.00023143 or 2.3×10^{-5}
YEN	0.00038676 or 3.8×10^{-5}

Table 5: pH value of the different Soil Samples.

Location	**pH Value of Soil**
Ayamasa	10.89
Angiama	9.11
Yenagoa	7.30

A. Soil sample analysis

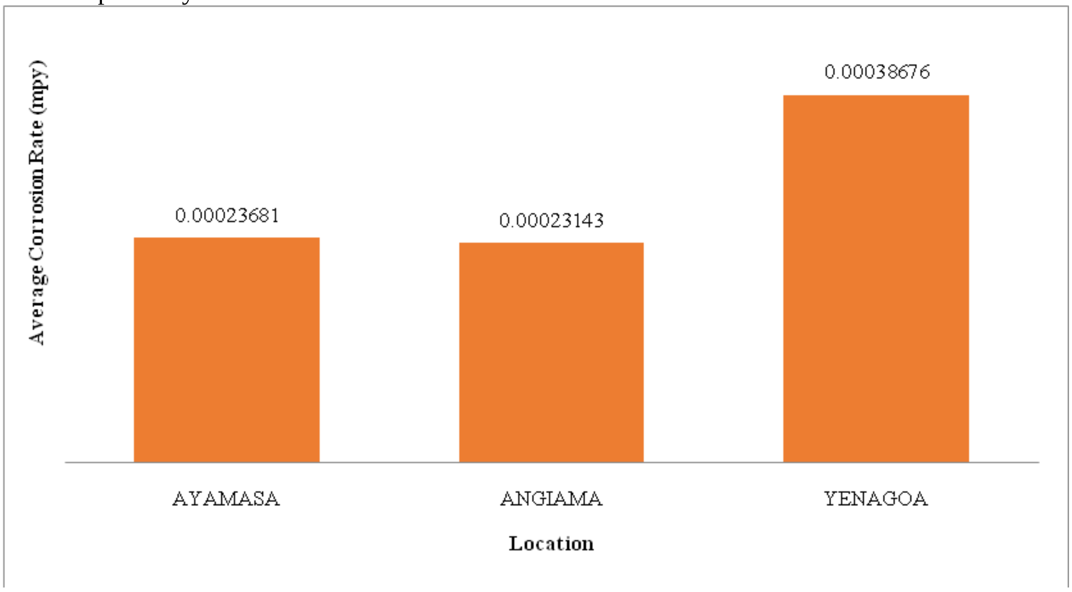

Figure 2: Average Corrosion Rate of Mild Steel C-1026 in Soil Samples of AYA, ANG and YEN.

B. Soil pH Analysis

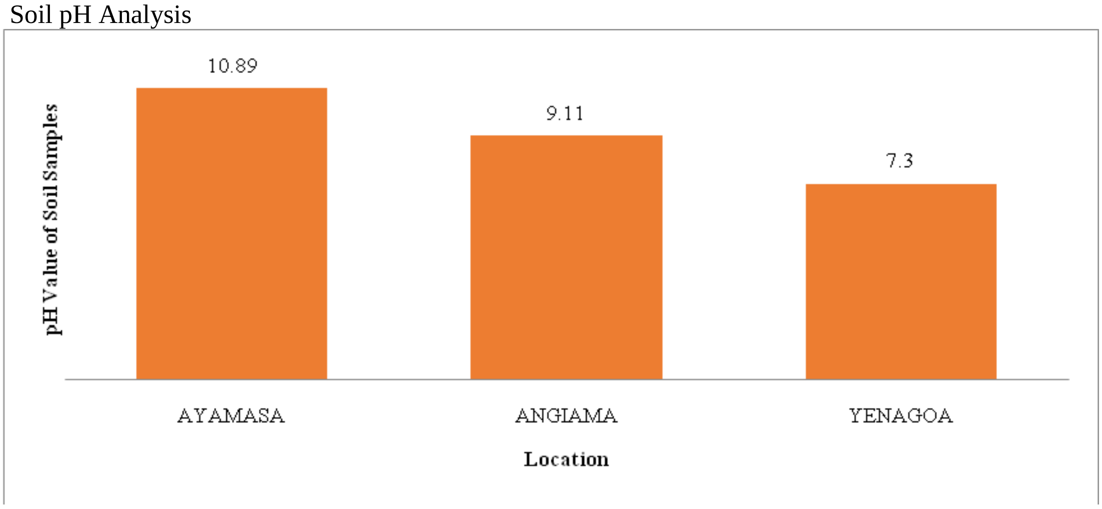

Figure 3: pH value of the different Soil Samples.

Inhibition Efficiency (IE %) of different Corrosion Inhibitors on MS C-1026 in the various Corrosive Media

Table 6-10 and Figure 4-8 shows that when the MS C-1026 coupons were subjected into Seawater, Sodium Chloride, Sodium Sulphate, Sodium Carbonate and Zinc Sulphate containing Scent Leaf, Cassava Leaf and Neem Leaf inhibitors for 2400 hours (100 days), the coupons in Zinc Sulphate with Scent Leaf solution had the highest Average Inhibition Efficiency, IE of 97.68%, while coupon in Seawater with Cassava Leaf extract had the least value of 96.51%. Others were Seawater with Scent Leaf 96.54%, Seawater with Neem Leaf extracts 96.82%. Sodium Chloride with Scent Leaf 97.26, Sodium Chloride with Cassava Leaf 97.58%, Sodium Chloride with Neem Leaf 97.42%, Sodium Sulphate with Scent Leaf 97.58%, Sodium Sulphate with Cassava Leaf 97.42%, Sodium Sulphate with Neem Leaf 97.53%, Sodium Carbonate with Scent Leaf 97.34%, Sodium Carbonate with Cassava Leaf 97.67%, Sodium Carbonate with Neem Leaf 97.61%, Zinc Sulphate with Scent Leaf 97.68%, Zinc Sulphate with Cassava Leaf 97.66%, Zinc Sulphate with Neem Leaf 97.67%. The results show that Seawater environment with Scent Leaf extract exhibited least corrosion inhibition efficiency on MS C-1026 coupon. The variation of the various corrosion inhibition efficiencies might be attributed to the secondary metabolic constituents contained in the green plant extracts.

Seawater

Table 6: Inhibition Efficiency of different Corrosion Inhibitors on MS C-1026 in Seawater

Exposure Time (Hr)	Inhibition Efficiency (%)		
	SW + SL 250ml+31g/150ml	SW + CL 250ml+31g/150ml	SW + NL 250ml+31g/150ml
240	96.76	96.58	96.81
480	96.79	96.51	96.78
720	96.82	96.58	96.84
960	96.76	96.64	96.94
1200	96.70	96.68	96.90
1440	96.51	96.61	96.90
1680	96.35	96.51	96.87
1920	96.32	96.51	96.87
2160	96.26	96.32	96.72
2400	96.17	96.16	96.63
Average	**96.54**	**96.51**	**96.82**

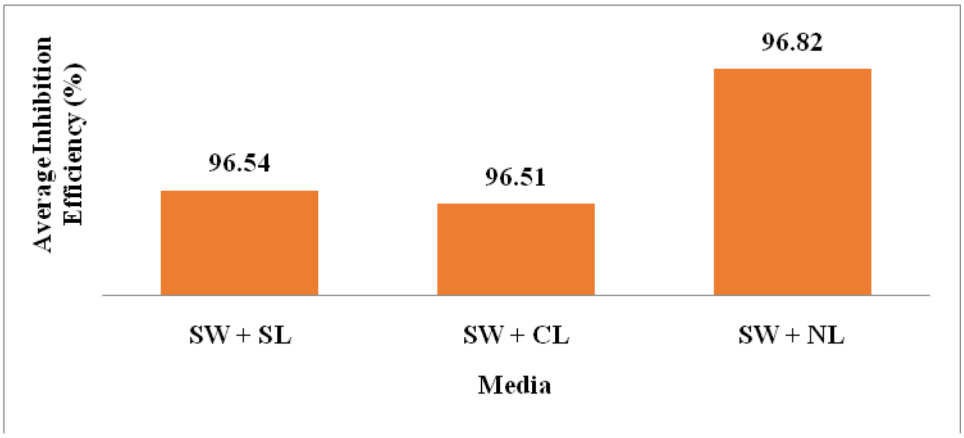

Figure 4: Average Inhibition Efficiency (IE %) of Corrosion Media

Sodium Chloride

Table 7: Inhibition Efficiency of Corrosion Inhibitors on MS C-1026 in Sodium Chloride Bath.

Exposure Time (Hr)	Inhibition Efficiency (%)		
	NaCl + SL 3.5wt%+31g/150ml	NaCl + CL 3.5wt%+31g/150ml	NaCl + NL 3.5wt%+31g/150ml
240	97.73	97.70	97.58
480	97.47	97.63	97.48
720	97.40	97.59	97.48
960	97.40	97.59	97.41
1200	97.33	97.59	97.43
1440	97.26	97.57	97.39
1680	97.21	97.54	97.41
1920	97.07	97.57	97.36
2160	97.02	97.54	97.43
2400	97.02	97.50	97.29
Average	**97.29**	**97.58**	**97.42**

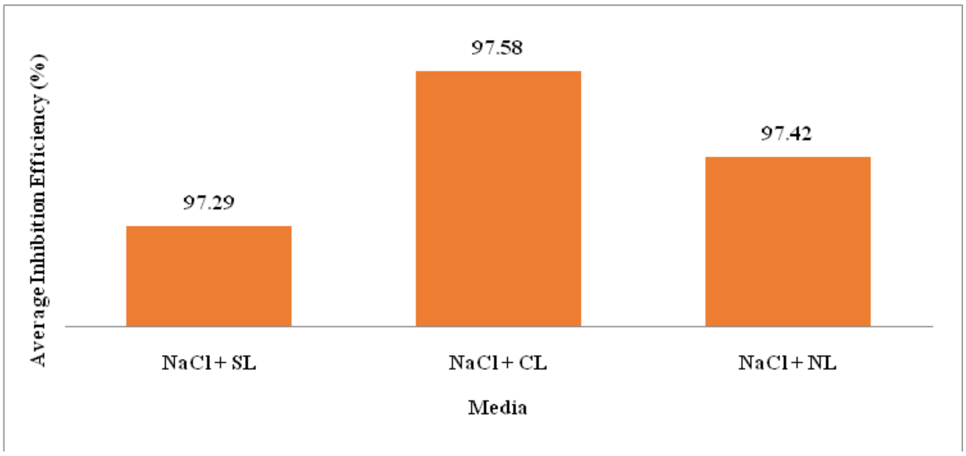

Figure 5: Average Inhibition Efficiency (IE %) of Corrosion Inhibitors on MS C-1026 in Sodium Chloride.

Sodium Sulphate

Table 8: Inhibition Efficiency (IE %) of different Corrosion Inhibitors on MS C-1026 in Sodium Sulphate

Exposure Time (Hr)	Inhibition Efficiency (%)		
	Na_2SO_4 + SL 3.5wt%+31g/150ml	Na_2SO_4 + CL 3.5wt%+31g/150ml	Na_2SO_4 + NL 3.5wt%+31g/150ml
240	97.71	97.53	97.62
480	97.69	97.46	97.62
720	97.73	97.49	97.60
960	97.62	97.44	97.58
1200	97.62	97.41	97.55
1440	97.60	97.39	97.55
1680	97.56	97.37	97.48
1920	97.51	97.34	97.46
2160	97.49	97.32	97.44
2400	97.36	97.46	97.41
Average	**97.58**	**97.42**	**97.53**

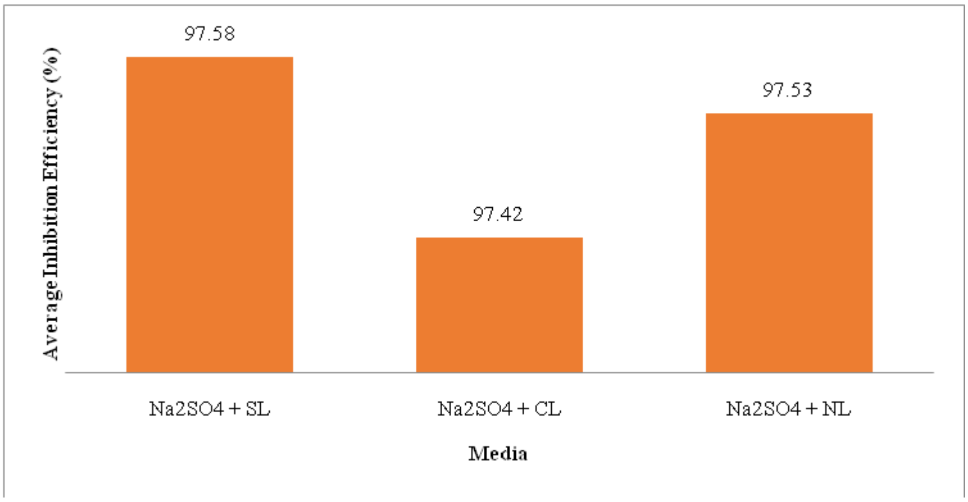

Figure 6: Average Inhibition Efficiency (IE %) of various Corrosion Inhibitors on MS C-1026 in Sodium Sulphate.

Sodium Carbonate

Table 9: Inhibition Efficiency of Corrosion Inhibitors on MS C-1026 in Sodium Carbonate Bath.

Exposure Time (Hr)	Inhibition Efficiency, IE (%)		
	Na_2CO_3 + SL 3.5wt%+31g/150ml	Na_2CO_3 + CL 3.5wt%+31g/150ml	Na_2CO_3 + NL 3.5wt%+31g/150ml
240	97.37	97.68	97.56
480	97.35	97.70	97.68
720	97.33	97.68	97.61

960	97.35	97.68	97.68
1200	97.35	97.70	97.63
1440	97.35	97.70	97.61
1680	97.35	97.68	97.61
1920	97.30	97.68	97.61
2160	97.37	97.66	97.59
2400	97.35	97.63	97.59
Average	**97.34**	**97.67**	**97.61**

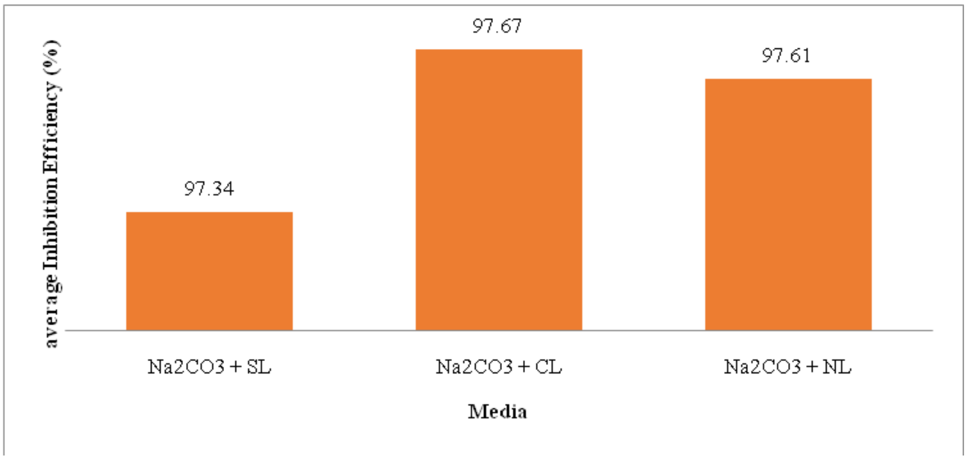

Figure 7: Average Inhibition Efficiency (IE %) of Corrosion Inhibitors on MS C-1026 in a Sodium Carbonate.

Zinc Sulphate

Table 10: Inhibition Efficiency of Corrosion Inhibitors on MS C-1026 in Zinc Sulphate Bath.

Exposure Time (Hr)	**Corrosion Inhibition Efficiency (%)**		
	$ZnSO_4$ + SL 3.5wt%+31g/150ml	**$ZnSO_4$ + CL 3.5wt%+31g/150ml**	**$ZnSO_4$ + NL 3.5wt%+31g/150ml**
240	97.73	97.70	97.73
480	97.69	97.70	97.71
720	97.71	97.69	97.70
960	97.70	97.68	97.70
1200	97.68	97.67	97.69
1440	97.67	97.65	97.67
1680	97.67	97.65	97.67
1920	97.66	97.65	97.65
2160	97.65	97.64	97.64
2400	97.64	97.63	97.63
Average	**97.68**	**97.66**	**97.67**

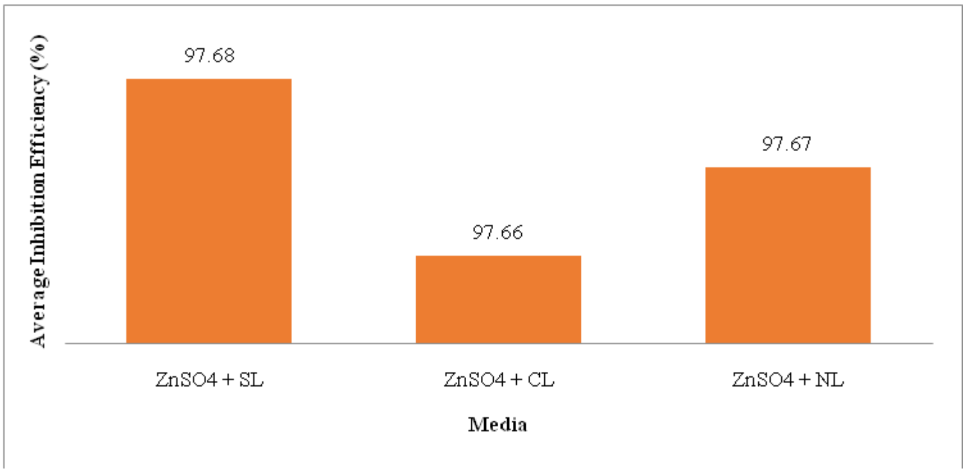

Figure 8: Average Inhibition Efficiency (IE %) of Corrosion Inhibitors on MS C-1026 in Zinc Sulphate bath.

IV. CONCLUSION

This investigation will enable oil and gas prospecting multi-national companies to lay their pipelines by having cognizance of the corrosivity of soil in various locations. Wherever corrosion is more ramparts, more frequent maintenance is required in those locations. It was revealed from the study that Yenagoa, Ayamasa and Angiama soils have varying corrosion behaviours because of the Chloride ions constituents in them. The soil with much Chloride ions will deserve much corrosion inhibitor and immediate maintenance routine. Therefore, Yenagoa should have higher inhibitor concentration than Ayamasa and Angiama communities. The corrosion inhibition efficiency study on the green plants disclosed that they performed efficiently and effectively in their various degrees in the areas of application.

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