Global Journal of Engineering and Technology Advances

eISSN: 2582-5003

Cross Ref DOI: 10.30574/gjeta

Journal homepage: https://gjeta.com/

(Research Article)

Check for updates

Investigation of FTIR and SEM Elemental Characteristics of Mild Steel in *Ocimum Gratissimum* and *Azadirachta Indica* Extracts as Corrosion Inhibitors in Seawater

Nairobi Cletus Madawa [1,*], Emomotimi Amula [1], Tari Kilakime [1] and Seigha Gumus [2]

[1] *Department of Mechanical Engineering, Niger Delta University, Amassoma. Bayelsa State. Nigeria.*

[2] *Department of Science, Policy and Innovation Studies, South-South Office National Center for Technology Management, Federal Secretariat, Yenagoa, Bayelsa State, Nigeria.*

Global Journal of Engineering and Technology Advances, 2025, 25(01), 083-094

Publication history: Received on 09 August 2025; revised on 04 October 2025; accepted on 07 October 2025

Article DOI: https://doi.org/10.30574/gjeta.2025.25.1.0276

Abstract

This investigation is to discover the various elements contained in Mild Steel, MS coupons via the green plants inhibitors and corrosive medium concentrations from the Fourier Infrared Spectroscopy and Scanning Electron Microscopy analysis that contributed to the corrosion inhibition on Mild Steel. Corrosion inhibitory effect and behaviour of *Ocimum Gratissimum* (Scent Leaf, SL) and *Azadirachta Indica* (Neem Leaf, NL) green plants extracts on Mild Steel C-1026 pipeline in Seawater were evaluated using weight loss methods. The inhibitory property was enhanced with addition of some pineapple juice in the concentration. Corrosion Rate, Inhibition Efficiency, phytochemical analysis, Surface Roughness, Scanning Electron Microscopy, and Fourier Transform Infrared Spectroscopy were also carried out in the study. From the investigation, it was revealed that there was good inhibition efficiency on the Mild Steel pipeline owed to the adsorption the secondary metabolic constituent of the green plant extracts on the MS surface. Neem Leaf has maximum inhibition efficiency of 96.86%, while Scent Leaf had 96.51%. Further still, it was discovered that Corrosion rate was reduced when the green plant inhibitors were added. In addition, the organic compounds exerted much positive impact on the surface roughness on the Mild Steel surfaces. Consequently, it shows that the chemical bioactive constituents as well as the functional groups in the green plant extracts possess some inhibitive properties which were adsorbed on the oil and gas pipeline surfaces.

Keywords: Chemical bioactive constituents; Corrosion; Corrosion inhibitor; Mild Steel; Green plant *extracts*

1. Introduction

In the industrial applications, Mild Steel, MS plays very momentous and prevalent role but they experience corrosion easily [1, 2]. There is an immense destruction of corrosion on Mild Steel in acidic environment and the most practical method to protect MS against corrosion is by the use of corrosion inhibitors [1, 2, 3]. Corrosion is regarded as a growth on metal because of thermodynamic instability [4, 5]. According to Bulicek et al [6], thermodynamic instability is a state whereby a system is not in equilibrium and predisposed to change spontaneously towards a more stable state. Inhibitor as protective material is considered as a component when mixed in little concentration diminishes the gravity of corrosion [4, 7, 8]. In the engineering and industries applications to restrain corrosion, inorganic compounds like phosphates, chromates, dichromate and arsenates have been predominantly used as corrosion inhibitors. These substances consist heteroatoms such as Oxygen, Sulphur, Nitrogen and multiple bonds in their molecules which are effectively adsorbed on the metal surface but they are expensive and highly toxic to human beings [3, 4, 9, 10, 11]. Researchers after observing the defects of these compounds to human health and other related factors have resorted to the use of green plant extracts which are organic compound as an alternative corrosion inhibitors that are environmentally benign, ecologically acceptable, readily available, less costly [4,11,12]. Some of these green plant

* Corresponding author: Madawa, Nairobi Cletus

extracts are: Water hyacinth extract [13], Citrus Sinensis Leaf extract [14], Theobroma cacao peel extract [15], Sida Acuta [16], Neem Leaf Extract [11], Bitter Leaf [17], Moringa Oleifera [18], Hibiscus Syracuse [19], Acalypha indica [20], Pennyroyal mint (Mentha pulegium, PM) extracts [21], Phoenix dactylifera, Lawsonia inermis and Zea mays extracts [22], Henna (Lawsonia) Leaf extract [23], etc

In addition, the functional groups such as C=C bending of alkene, monosubstituted stretching O–H phenol bending stretching of hydrogen bonded carboxylic acids and alcohol stretching, C–H bending of alkane, methylene group, N–O stretching of nitro compound, C=C=C stretching of alkene, N=C=S stretching isothiocyanate, etc all contributed to the effectiveness of the inhibitors on the MS surfaces. According to Umoren and Eduok, [24] these functional groups in the green leaf extracts have strong adsorption and film foundation on the metal surfaces. The multi-dentate binding results to better coverage and corrosion inhibition in the corrosive medium. Moreover, according to Meryem et al; Emregul and Hayvali, and Moretti et al, [25, 26, 27], active functional groups like nitro (NO_2), hydroxyl (OH) and conjugated groups form coordinated bond by directing their electron pairs towards the 3d of the iron atom to create effective corrosion inhibition.

Moreover, the elements contained in the metal when combine with the various green plants extracts contributed to corrosion inhibition. Some of these notable effective elements according to Williams et al, Abdelaziz, Raja et al, and Umoren et al, [28, 29, 30, 31**]** in their studies attested that elements like Potassium, Phosphorus, Silicon, Sulfur, Carbon, Calcium and Magnesium were efficient corrosion inhibitors. Potassium iodide has synergistic effect when combined with plant extract. By Synergistic effect, it is said to be the interaction of two or more agents that produce an effect that is greater than the summation of individual properties.

2. Materials and methods

ASTM G13 is an international standard practice proposed for immersion testing of materials in the laboratory [4, 8, 11, 17]. The research was performed according to this standard, ASTM G13.

There are some elemental compositions of the Mild Steel grade C-1026 coupons of oil and gas pipeline. They are: Mn 0.08%, Ti 0.17%, As 0.07%, Cu 0.07% and Fe 98.88%. The MS coupons were used for the investigation as both control and inhibited samples. The selected corrosive medium was Seawater, while *Ocimum Gratissimum* or Scent Leaf and *Azadirachta Indica* or Neem Leaf was the corrosion inhibitors. The coupons were suspended with ropes in plastic containers with the bath concentrations for the experiment. Tare M-200 electronic weighing balance was employed to take the weight of the Mild Steel coupons before and after immersion in each experiment [4, 8].

2.1. Sample Surface Preparation and Mild Steel Coupons

In order to attain a better adhesive surface, the Mild Steel coupon surfaces were polished with **coarse and** smooth grit emery papers, rinsed in water, degreased in acetone, dried in air and weighed with Tare M-200 electronic weighing balance. After that, they were subjected into test solutions for a period of 2400 Hours [4]. The Mild Steel C-1026 samples from cylindrical oil and gas of pipeline were cut into 4 x 2cm and they were properly prepared for the investigation [4].

2.2. Preparation of Leaf Paste Inhibitors and Corrosive Media

Ocimum Gratissimum and *Azadirachta Indica* fresh green plant leaf inhibitors as well as Pineapple fruit were gathered from Akenfa market and Agudama-epie forest in Bayelsa State of Nigeria, while the Seawater was obtained from Furupa Community River in Bayelsa State. 31g each of the green plant leaves were weighed and meticulously crushed with mortar and pestle. Distilled water was added to the pound green plant extracts and filtered with filtration cloth. Thereafter, 250ml of Seawater was mixed with the green plant solution for the study [4, 8]. While for the corrosive medium, 250ml of Seawater was measured with calibrated cylindrical flask and poured into a plastic container to conduct the investigation.

2.3. Weight - Loss Analysis

The Mild Steel C-1026 coupons were first properly prepared and treated. The weighing balance was used to take the initial weights of the coupons before they were subjected into the corrosive medium with inhibitors concentrations. Another bath was prepared as control for comparison of the Mild Steel coupons.

For the computation of the corrosion rate and inhibition efficiency of the green plant leaves on the Mild Steel, the following formulae were adopted.

$$\text{Corrosion Rate, CR} = \frac{\text{K x Loss in weight (g)}}{\text{Surface Area x Period of immersion (Hours)of the specimen x Density of the Mild Steel.}}$$

$$\text{CR} = \frac{\text{K (Wlost)}}{\text{AT}\rho}, = \frac{\text{K (W2}-\text{W1)}}{\text{AT}\rho} \quad \ldots\ldots \quad 1$$

Where, K is Constant, 87.6 and Density (ρ) of Mild Steel is 7.9 g/m, W_1 is Initial Weight and W_2 is Final Weight of coupons [4, 5, 8, 11, 17, 32].

Corrosion Inhibition Efficiency, IE using the equation,

$$\text{IE (\%)} = 100 \left[\frac{1 - \text{W2}}{\text{W1}}\right]\% \quad 2$$

Where, W_1 is Weight Loss in the Absence of inhibitor and W_2 is Weight Loss in the Presence of inhibitor [4, 5, 8, 33, 34].

2.4. Surface Roughness Analysis

The MS C-1026 coupons surfaces were analysed with SRT 6100 Surface Roughness Tester instrument. Three readings on each of the coupons were performed. After placing the notches of the instrument on every coupon surface, the reading continues until it clicked to stop. The glass screen of the instrument displays the readings which were recorded as the surface roughness [4, 8].

2.5. Fourier Transform Infrared Spectroscopy

Fourier Transform Infrared Spectroscopy explains the functional group or type of compound present in a particular coupon. The FTIR analysis of the green plant leaves and those of the corrosion products (inhibited and uninhibited) were carried out with Carry-630 Agilent Fourier Transform Infra-red spectrophotometer [4, 8].

2.6. Scanning Electron Microscope Analysis

Determination of the various coupons morphology was done by Scanning Electron Microscopy, SEM. It was precisely employed to establish the disproportionate surface morphology and microstructure of the inhibited and uninhibited coupons [4, 8].

3. Result and discussions

3.1. Effect of Exposure Time on Weight Loss of MS C-1026 in Seawater with different Corrosion Inhibitors

From Fig. 1, the results revealed that when the coupons were subjected to Seawater with inhibitors of Scent Leaf and Neem Leaf extracts for an interval of 2400 hours, the coupon in Scent Leaf solution had the maximum Average Weight Loss of 0.093g, while coupon in Neem Leaf had the minimum weight loss of 0.022g. However, when inhibitors were added, weight loss was reduced as compared with the coupon in the Seawater solution which had an average weight loss value of 0.271g. MS coupon in Seawater experienced significant weight loss without corrosion inhibitor [35]. While for MS coupons with corrosion inhibitors, it was evident that the inhibitors initiated some passivation on the coupons surfaces. Weight loss gradually increased with time of exposure [36]. Figure 1 shows the trend of the average weight loss of the coupons in the absence and presence of the corrosion inhibitors.

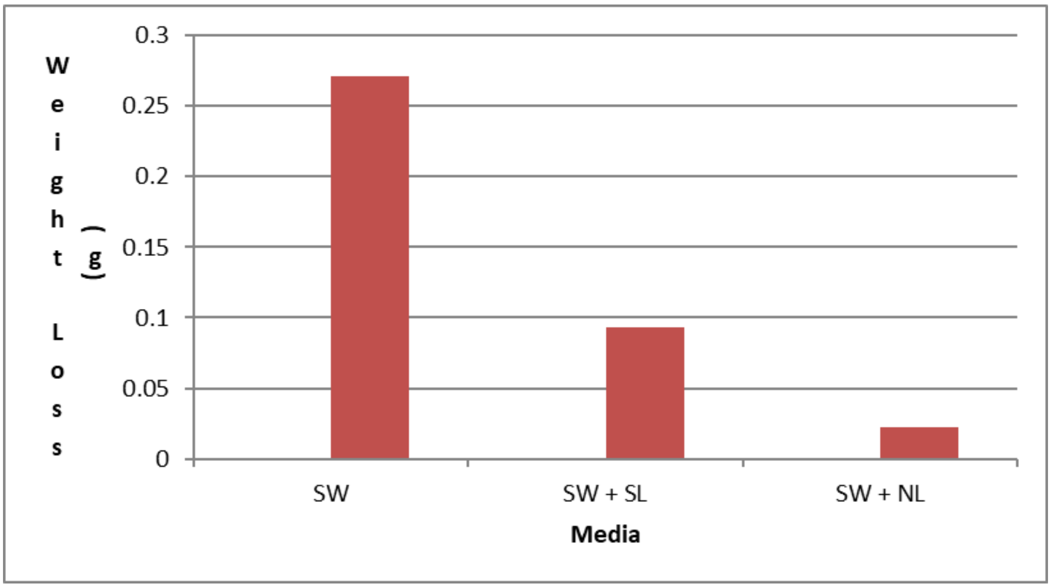

Figure 1 Effect of Exposure Time on Weight Loss of MS C-1026 in Seawater with different Corrosion Inhibitors

3.2. Corrosion Rate of MS C-1026 in Seawater with different Corrosion Inhibitors.

Fig. 2 shows that when the coupons were subjected into Seawater with different inhibitors for 100 days, Scent Leaf had 3.177mpy and Neem Leaf 3.111mpy. The Neem Leaf coupon had lower value of Corrosion Rate. It was observed that Neem Leaf coupon with low CR might be due to adsorption of much protective film on the coupon surface by the chemical constituent of the plant extract. Nevertheless, the way of inhibition is perhaps through adsorption of the inhibitor molecules onto the MS surface. Ndukwe [16] reported that the principle of inhibition appears to be via adsorption of phytochemical molecules in the plant extract on the surface of the metal by displacing water molecules at the corroding surface. Fig. 2 shows the Average Corrosion Rate of MS C-1026 in Seawater with different Corrosion Inhibitors [8].

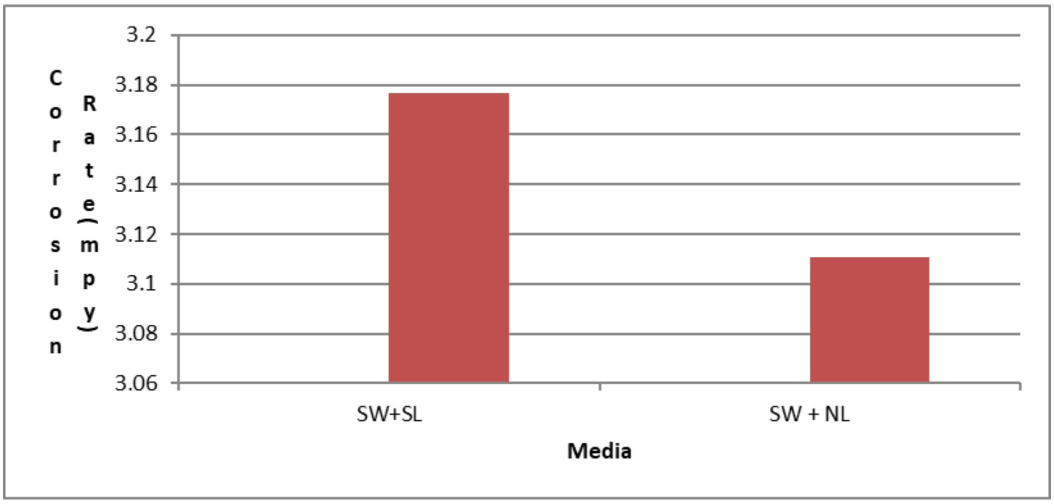

Figure 2 Average Corrosion Rate of MS C-1026 in Seawater with different Corrosion Inhibitors

3.3. Inhibition Efficiency (IE %) of different Corrosion Inhibitors on MS C-1026 in Seawater

Fig. 3 shows that when the MS C-1026 coupons were immersed in the Seawater containing different natural green extract inhibitors for 2400 hours (100 days), the coupon in Neem Leaf solution had the highest Average Corrosion Inhibition Efficiency, IE of 96.82%, while Scent Leaf had 96.54%. The Neem Leaf might be more efficient because it contains tannin and has a bitter taste. Tannin as a secondary metabolic constituent extracted from plants posses the ability to inhibit corrosion on the metal surfaces by forming a protective film. The inhibition efficiency of some plant extracts in a number of cases has been attributed to the presence of tannin in their chemical component. In addition as related with the presence of tannin in the plant extracts, is the bitter taste in the bark and /or leaves of plants [37]. Neem plant is bitter in taste and its bitterness is because of the complex compounds arrangement called "triterpenes" or more specifically "limonoids" [8, 37, 38].

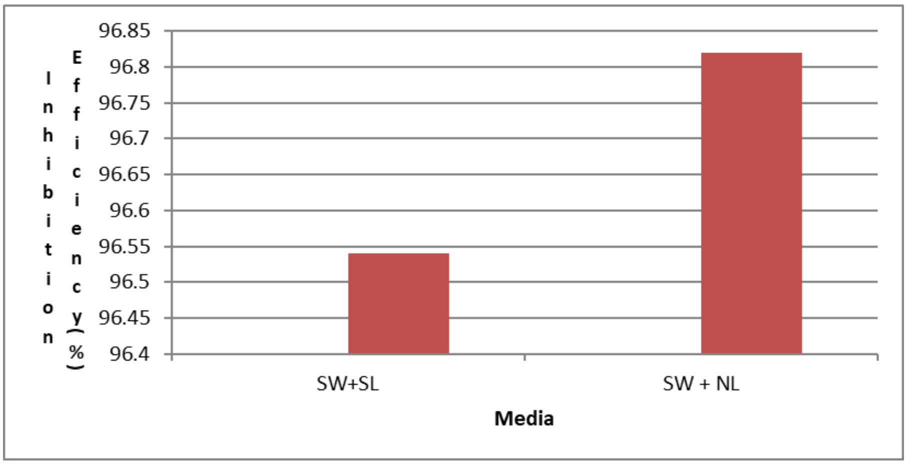

Figure 3 Inhibition Efficiency (IE %) of Corrosion Inhibitors on MS C1026 in Seawater

3.4. Surface Roughness Analysis

Table 1 shows the surface roughness breakdown of the various coupons. From the study, it revealed that Seawater, SW (Con) had the highest surface roughness value of 5.576mµ, Control sample (Pol) with 5.621mµ, Control sample (Unpol) was 5.576mµ, NL was 3.718mµ, while SL was with the least roughness value of 1.737mµ. The SW (Con) with the greatest surface roughness perhaps is due to the coarse macrocrystalline grain boundary that contributed too much corrosion on the MS coupon which is without inhibitor, while the SW with SL coupon having least surface roughness is evident to the microcrystalline grain boundary on the Mild Steel which is much dense because of the adsorption of the inhibitory properties on the surface [8].

Table 1 Surface Roughness Analysis

S/No	Name of MS Coupon	Roughness (mµ)
1	Control (Unpol.)	5.576
2	Control (Pol.)	5.621
3	SW	5.777
4	SW with SL	1.737
5	SW with NL	3.718

3.5. Phytochemical Analysis

Table 2 shows the result of Quantitative Phytochemical Analysis on the natural green plant extracts. It was evident that Tannin was abundant in Neem leaf extracts, while Alkaloid, Tannin, Flavonoid and Phenol present in Scent Leaf. Alkaloid, Tannin, Saponin and Flavonoid were present in Neem leaf, and there was no Saponin and Phenol bioactive component in both Scent leaf and Neem leaf [4, 8].

Table 2 Phytochemical Qualitative Analysis of Scent Leaf, Cassava Leaf and Neem Leaf

Sample	Alkaloid	Tannin	Saponin	Flavonoid	Phenol
Scent Leaf	+ +	+ +	-	+	+
Neem Leaf	+	+ + +	+	+ +	-

KEY: + = Less, + + = More, + + + = Abundant and - = None

3.6. Fourier Transform Infrared Spectroscopy

3.6.1. Seawater

Fig. 4: shows the FTIR spectrum of Mild Steel C-1026 in Seawater. Wave numbers and intensities of adsorption in terms of height of the different peaks, assembled from the FTIR spectrum of SW as well as vibration type and functional groups are presented on Table 3. From the results obtained, C=C bending of alkene at 984.0 cm^{-1} and alkene, monosubstituted stretching at 1638.3 cm^{-1}, O–H phenol bending at 1375.4 cm^{-1}, stretching of hydrogen bonded carboxylic acids at 2922.2 and alcohol stretching at 3280.1 cm^{-1}, C–H bending of alkane, methylene group at 1457.4 cm^{-1}, N–O stretching of nitro compound at 1578.7 cm^{-1}, C=C=C stretching of alkene at 1990.4 cm^{-1}, N=C=S stretching isothiocyanate at 2113.4 cm^{-1}, N–H stretching of amine salt at 2851.4 cm^{-1} [8].

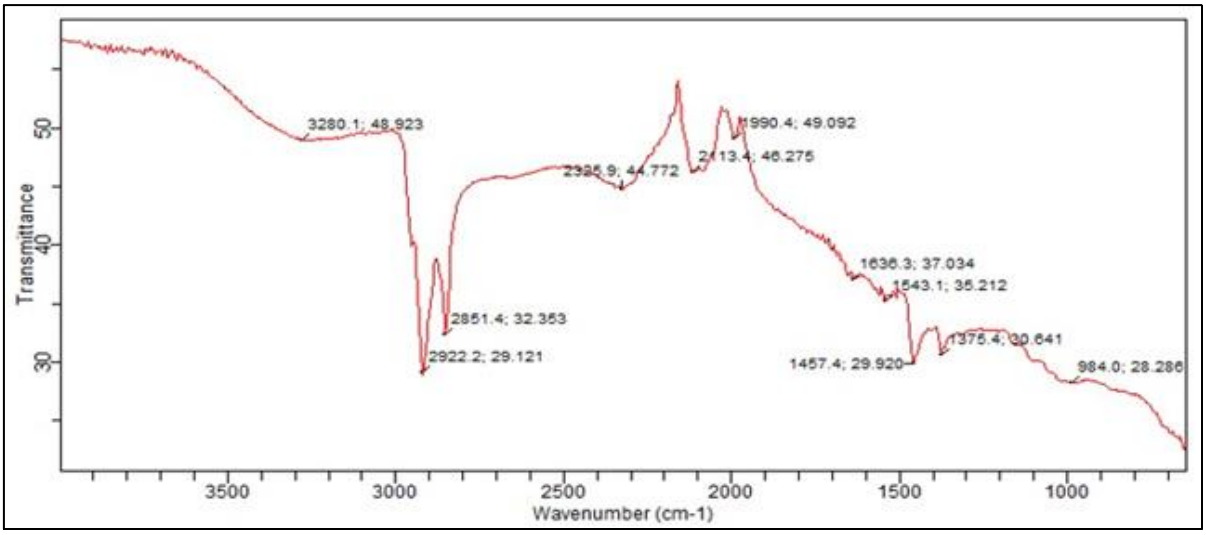

Figure 4 FTIR spectrum of film on Mild Steel surface without corrosion inhibitor in Seawater [8]

Table 3 Frequency Range or Wave Number and intensities of FTIR of corrosion product of Mild Steel in Seawater

Frequency Range or Wave number (cm-1)	Height Or Transmittance	Type of Compound or Functional Group	Bond	Intensity
3280.1	48.923	Alcohol (Stretching)	O–H	Strong
2922.2	28.121	Hydrogen-bonded carboxylic acids (Stretching)	O–H	Broad
2851.4	32.353	Amine salt (Stretching)	N–H	Strong
2325.9	44.7723	Carbon dioxide (Stretching)	O=C=O	Strong
2113.4	46.275	Isothiocyanate (Stretching)	N=C=S	Strong
1990.4	49.092	Alkene (Stretching)	C=C=C	Strong
1638.3	37.034	Alkene, monosubstituted (Stretching)	C=C	Medium
1576.7	35.212	Nitro Compound (Stretching)	N–O	Strong
1457.4	29.92	Alkane, Methylene group (Bending)	C–H	Medium
1375.4	30.641	Phenol (Bending)	O – H	Medium
984.0	28.285	Alkene (Bending)	C=C	Strong

3.6.2. Seawater with Scent Leaf Bath

Fig. 5 shows the FTIR spectrum of Mild Steel C-1026 coupon in Seawater with Scent Leaf extract. Wave numbers and intensities of adsorption in terms of height of the different peaks, collected from the FTIR spectrum of Seawater with Scent Leaf as well as of vibration type and functional groups are presented on Table 4. From the results obtained, C–H 1, 4 – disubstituted bending at 868.5 cm^{-1}, C–O stretching of primary alcohol at 1025.0 cm^{-1} and alkane stretching at 2855.1 cm^{-1}, O–H phenol bending at 1375.4 cm^{-1} and hydrogen bonded carboxylic acids stretching at 3280.1 cm^{1}, C=O conjugated anhydride stretching at 1786.6 cm^{-1}, C=C=C alkene stretching at 1990.4 cm^{-1}, C≡C alkyne, monosubstituted stretching at 2102.2 cm^{-1} and N–H amine salt stretching at 2922.2 ccm^{-1} [8].

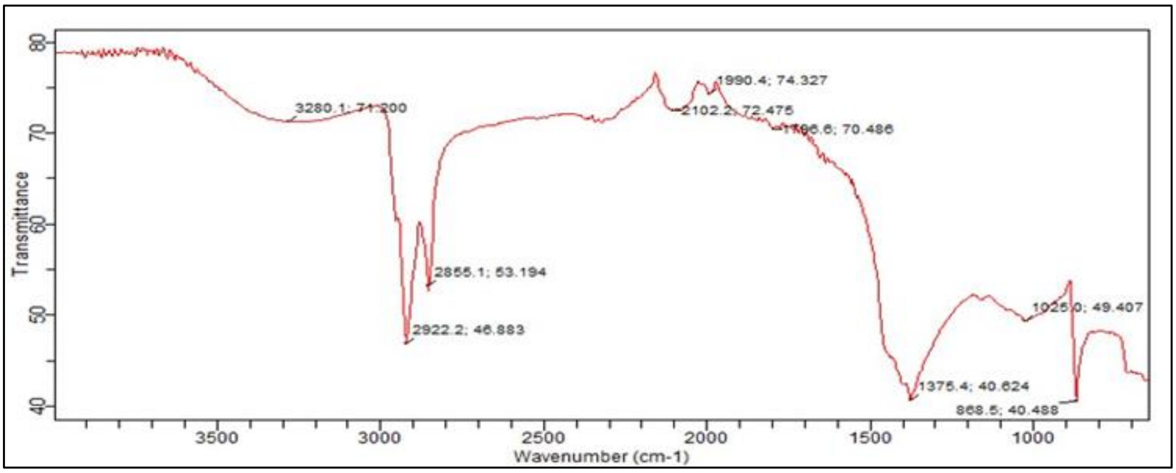

Figure 5 FTIR spectrum of film on Mild Steel surface after immersion in Seawater with Scent Leaf extract [8]

Table 4 Frequency Range or Wave Number and intensities of FTIR of corrosion product of Mild Steel in Seawater with Scent Leaf as corrosion inhibitor

Frequency Range or Wave number (cm^{-1})	Height or Transmittance	Type of Compound or Functional Group	Bond	Intensity
3280.1	71.200	Hydrogen-bonded carboxylic acids	O–H	Broad
2922.2	46.883	Amine salt (Stretching)	N–H	Strong
2855.1	53.19	Alkane (Stretching)	C–H	Medium
2102.2	72.475	Alkyne, monosubstituted (Stretching)	C≡C	Weak
1990.4	74.327	Alkene (Stretching)	C=C=C	Medium
1786.6	70.486	Conjugated anhydride (Stretching)	C=O	Strong
1375.4	40.624	Phenol (Bending)	O–H	Medium
1025.0	49.407	Primary alcohol (Stretching)	C–O	Strong
868.5	40.488	1, 4 – disubstituted (Bending)	C–H	Strong

3.6.3. Seawater with Neem Leaf Bath

Fig. 6 shows the FTIR spectrum of Mild Steel C-1026 coupon in Seawater with Neem Leaf extract. Wave numbers and intensities of adsorption in terms of height of the different peaks, gathered from the FTIR spectrum of Seawater with Neem Leaf as well as vibration type and functional groups are presented on Table 5. From the results obtained, C–H 1, 3 – disubstituted bending at 782.7 cm^{-1}, 1, 3 – disubstituted bending at 872.2 cm^{-1}, aromatic compound, overtone bending at 1871.1 cm^{-1} and alkane stretching 2855.1 cm^{-1}, C–O stretching of primary alcohol at 1080.9 cm^{-1}, O–H phenol bending at 1375.4 cm^{-1}, alcohol, intramolecular bonded stretching at 3198.1 cm^{-1} and alcohol, free, stretching at 3670.8 cm^{-1}, C=O conjugated anhydride stretching at 1786.8 cm^{-1}, C=C=C alkene stretching at 1985.7 cm^{-1}, C≡C alkyne, monosubstituted stretching at 2019.7 cm^{-1} and N–H amine salt stretching at 2922.2 cm^{-1} [8].

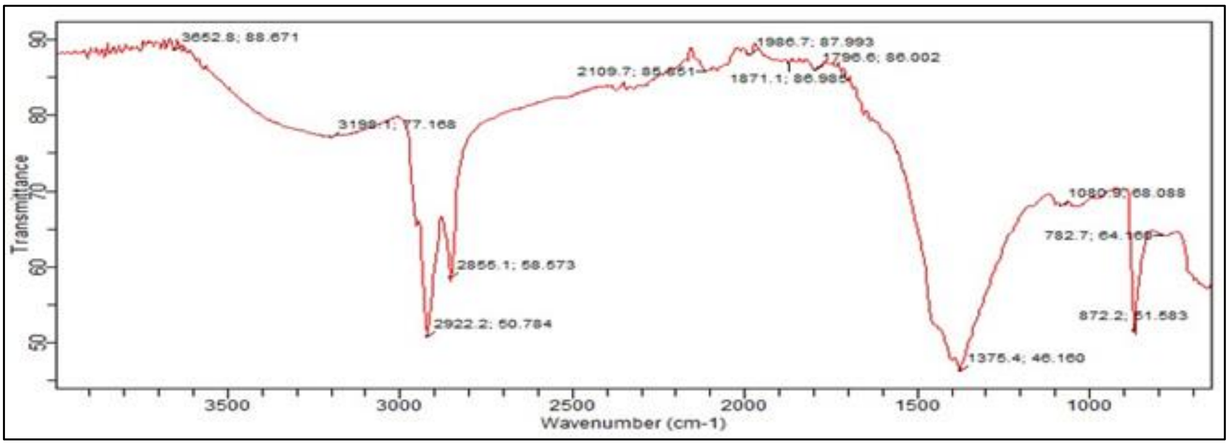

Figure 6 FTIR spectrum of film on Mild Steel surface after immersion in Seawater with Neem Leaf extract [8]

Table 5 Frequency Range or Wave Number and intensities of FTIR of corrosion product of Mild Steel in Seawater with Neem Leaf as corrosion inhibitor

Frequency Range or Wave number (cm^{-1})	**Height or Transmittance**	**Type of Compound or Functional Group**	**Bond**	**Intensity**
3852.8	88.671	Alcohol, Free (Stretching) Sharp	O–H	Medium
3198.1	77.168	Alcohol, intramolecular bonded (Stretching) Broad	O–H	Weak
2922.2	50.784	Amine salt (Stretching)	N–H	Strong
2855.1	58.673	Alkane (Stretching)	C–H	Medium
2109.7	85.851	Alkyne, monosubstituted (Stretching)	C≡C	Weak
1985.7	87.993	Alkene (Stretching)	C=C=C	Medium
1871.1	86.985	Aromatic compound, Overtone (Bending)	C–H	Weak
1786.8	86.002	Acid halide (Stretching)	C=O	Strong
1375.4	46.160	Phenol (Bending)	O–H	Medium
1080.9	68.088	Primary alcohol (Stretching)	C–O	Strong
872.2	51.683	1, 3- disubstituted (Bending)	C–H	Strong
782.7	64.160	1, 3- disubstituted (Bending)	C–H	Strong

3.7. Microstructure or Morphological Studies

Fig. 7a, 7b and 7c show the Scanning Electron Microscopy of the MS in SW and the various natural green extract corrosion inhibitors. From the study, Table 1 and Fig. 7a shows that the rough surface morphology of the coupon in Seawater solution in the absence of inhibitor was very high. This factor was also affirmed by Madawa, et al., 2021 and Cetin et al., 2009 [4, 39]. Inferring from Table 1 of the surface roughness analysis, Seawater, SW coupon was observed to had 5.777μm, Scent Leaf, SL coupon had 1.737μm, and Neem Leaf, NL coupon had 3.718μm. Comparing the results derived from the study, it provided an evidence that the green plant extracts prevented corrosion on Mild Steel through adsorption of the inhibitor molecules on the surface [2, 35]. In addition, it was evident that Scent Leaf extracts molecules were assumed to be more efficiently adsorbed on the MS surface on the surface roughness analysis. SW coupon was observed to corrode most might be due to the Cl^- ions that are contain in SW which are the principle driving force of corrosion on MS [2,13,14]. Significantly, when MS is dip in SW, it causes loss on the metal quality and threatens impending failure [4, 8]. Table 6 and Table 7 shows the various elements contained in each MS in the presence of the green plant extracts. All these elements also contributed in their respective capacities to the effective inhibition of corrosion on MS.

3.8. Corrosive Media

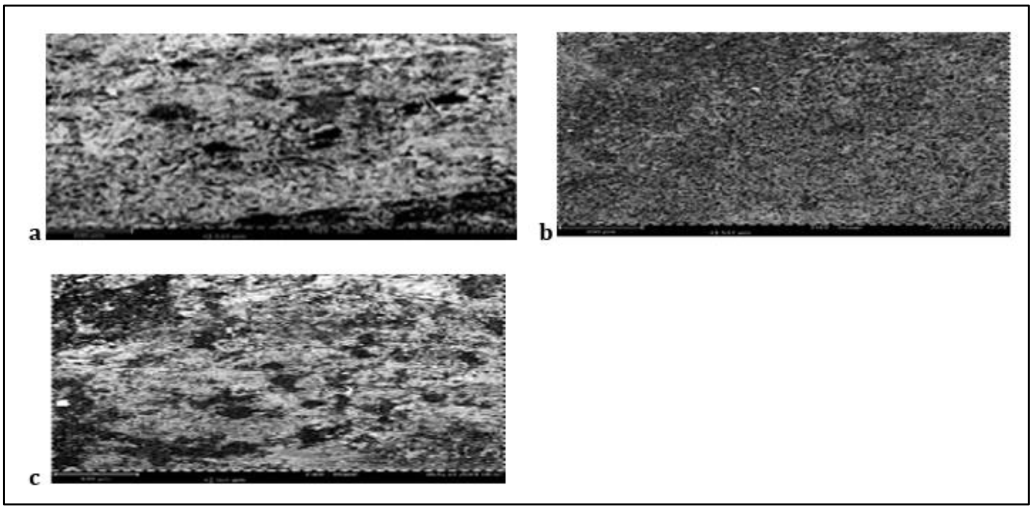

Figure 7 SEM analysis of MS C-1026 corroded in a. SW, b. SW with Scent Leaf extract and c. SW with Neem Leaf extract

3.8.1. Corrosive Media and Corrosion Inhibitors

Table 6 and Table 7 show the different elements embedded in the various MS coupons which also attributed to the proficiency in the corrosion inhibition on Mild Steel. They are the products of the Seawater and green plant corrosion inhibitors. The elements, atomic concentrations and weight concentrations vary from one another contributing to their difference effectiveness.

3.8.2. Scent Leaf and Corrosive Media

Table 6 Elemental Composition of MS C-1026 in Seawater and Scent Leaf media

Element Number	Element Symbol	Element Name	Atomic Conc.	Weight Conc.
6	C	Carbon	79.58	52.3
20	Ca	Calcium	9.44	20.69
26	Fe	Iron	5.6	17.1
12	Mg	Magnesium	1.55	2.05
47	Ag	Silver	0.28	1.68
16	S	Sulfur	0.68	1.19
15	P	Phosphorus	0.62	1.05
14	Si	Silicon	0.61	0.93
25	Mn	Manganese	0.28	0.85
13	Al	Aluminium	0.5	0.74
11	Na	Sodium	0.55	0.69

19	K	Potassium	0.24	0.51
22	Ti	Titanium	0.08	0.21

3.8.3. Neem Leaf and Corrosive Media

Table 7 Elemental composition analysis of MS C-1026 in Seawater and Neem Leaf media

Element Number	Element Symbol	Element Name	Atomic Conc.	Weight Conc.
6	C	Carbon	76.85	44.46
26	Fe	Iron	16.00	43.05
20	Ca	Calcium	1.28	2.46
47	Ag	Silver	0.40	2.09
12	Mg	Magnesium	1.28	1.49
14	Si	Silicon	0.97	1.32
16	S	Sulfur	0.80	1.23
25	Mn	Manganese	0.41	1.09
13	Al	Aluminium	0.62	0.80
15	P	Phosphorus	0.47	0.70
11	Na	Sodium	0.60	0.66
19	K	Potassium	0.24	0.45
22	Ti	Titanium	0.09	0.20

4. Conclusion

The natural green plant extracts as alternative corrosion inhibitors on Mild Steel in the various engineering fields has advanced tremendously. The two green plants extracts utilized in this study displayed improved corrosion efficiency on the Mild Steel. So, from the investigation, it was observed that Neem Leaf extract performed most efficiently in the inhibition of corrosion on the MS in Seawater environment.

Furthermore, the FTIR study revealed that, the different coupons in the various green plant extract solutions were composed of varying functional groups, such as Hydrogen-bonded carboxylic acids (Stretching), Amine salt (Stretching), Alkane (Stretching), etc. These functional groups also contributed to the efficiency of corrosion inhibition on Mild Steel.

Moreover, the SEM analysis also testifies the efficiency of these inhibitors. It was disclosed that the elements composed in the various coupons vary from one to another gave them the necessary physical and chemical properties to withstand the corrosion rate and satisfy the corrosion inhibition assignment. Therefore, the effectiveness of the natural green plant extracts as corrosion inhibitors was attributed to the various bioactive compounds, functional groups as well as the elements embodied in them. The application of the alternative source as corrosion inhibitor is recommendable with more research to be conducted on the vast naturally endowed resources surrounding us.

Compliance with ethical standards

Acknowledgments

Without reservation, we whole heartedly appreciate Engr. Prof. Tolumoye J. Tuaweri and Engr. Prof. (Mrs.) Rhoda Gumus for their enormous contributions to the completion and success of this investigation.

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Priyadarshini B., Stella S. M., Stango A. X., Subramanian B. and Vijayalakshmi U. (2015). Corrosion Resistance of Mild Steel in Acidic Environment; Effect of Peltophorum ptetocarpum Extract. International Journal of Chem Tech Research, 2014-2015, 7(2): 512-525.

[2] Diah R. G., Emriadi, A. A. and Mai E. (2017). Corrosion Inhibition of Ethanol Extract of Cassava (Manihot Esculenta) Leaves on Mild Steel in Sulfuric Acid. International Journal of Chem Tech Research. CODEN (USA): IJCRGG, ISSN: 0974-4290, ISSN (Online):2455-9555. Vol, 10 No.2, pp163-171.

[3] Karthikeyan, S. (2016). Drugs/Antibiotic as Potential Corrosion Inhibitors for Metals – A Review, International Journal of Chem Tech Research, 2016, 9(6): 251-259.

[4] Madawa, N. C., Tuaweri, T. J., Mebine, P. and Onyemaobi. O. O. (2021). Corrosion Inhibition of Mild Steel C1026 Pipeline in Na_2SO_4 using Green Inhibitors. International Journal of Engineering Science Invention (IJESI), Vol.10 (01), 2021, PP15-22. Journal DOI-10.35629/6734

[5] Thangavelu, M., Umarani, P. P., Raymond and Sekar, M. (2011): Eco-Friendly Inhibitor System for Corrosion Inhibition of Carbon Steel in High Chloride Media. 4 (2), 2011, 245-250.

[6] Bulicek, M., Malek, J., and Prusa, V. (2019: Thermodynamics and Stability of Non-Equilibrium Steady States in Open Systems. Published in Entropy, Volume 21, Issues 7, Article 704

[7] Corrosion – Wikipedia free encyclopedia.

[8] Madawa, N. C., Tuaweri, T. J. and Abdulkareem B. (2024). Effect of Green Corrosion Inhibitors on the Corrosion of Mild Steel C-1026 Pipeline in Seawater. *International Journal of Engineering and Science Invention (IJESI) ISSN (Online): 2319-6734, ISSN (Print): 2319-6726 www.ijesi.org ||Volume 13 Issue 8 August 2024 || PP 01-11*

[9] Satapathy, A. K., Gunasekaran G., Sahoo, S. C., Amit K. and Rodignes, R. V. (2009). Corros. Sci. 51, 2009, 63.

[10] Ameena, M. A. (2015). Corrosion Inhibition on Carbon Steel in Hydrochloric Acid Solution by Senna-Italica Extract. 22, 2015, 49-63.

[11] Tuaweri, T. J. and Ogbonnaya, E. A. (2017). Corrosion Inhibitive Characteristics of Vernonia amygdalina (Bitter Leaf) on Mild Steel in Seawater. 4(11), 2017, 6-13.

[12] Suleiman, I. Y., Salihu, S. A., Emokpaire, O. S., Ogheneme, O. C. and Shuaibu L. (2017): Evaluation of Grewa Venusta (Wild Juta Tree) as corrosion Inhibition for Mild Steel in Acidic Environment. 2017.

[13] Subramanyam B. and Kumar R. P. (2016). Corrosion Inhibition Using Water Hyacinth. International Journal of Chem Tech Research, 2016, 9(5):558-562.

[14] Yumana J. and Anthony N. (2015): Citrus Sinensis Leaf Extract as an Efficient Green Corrosion Inhibitor for Mild Steel in Aqueous Medium. International Journal of Chem Tech Research, 2014-2015, 7(1):37-43.

[15] Yetri, Y., Emriadi, J. N. and Guna W. (2015). Corrosion Inhibitor of Mild Steel by Polar Extract of Theobroma Cacao Peels in Hydrochloric Acid Solution. Asian Journal of Chemistry, 2015, 27(3), 875-880.

[16] Ndukwe, A. I. (2017). Corrosion Inhibition of Mild Steel in Acidic Media by Some Plant Leaf Paste. P 6-20, 29-31, 33- & 57.

[17] Tuaweri, J. T. and Ogbonnaya, E. A. (2017). Corrosion Inhibition Characteristics of Vernonia amygdaline (Bitter Leaf) on Mild Steel in Seawater. https://www.serip.org

[18] Nasibi, M., Zaarei, D., Rashed, G. and Ghasemi, E. (2013). Chem. Eng. Comm., 200 (2013) 367.

[19] Nagarajan, P, and Sulochana, N. (2006). Natural product extracts as eco-friendly corrosion inhibitors for commercial mild steel in 1 M HCl. J. Ind. Chem. 23 (2), 51 – 55.

[20] Sivaraju, M. and Kannan, K. (2010). Inhibitive properties of plant extract (Acalypha indica L.) on mild steel corrosion in 1M Phosphoric acid. Int. J. Chem. Tech. Res. 2(2), 1243 – 1253.

[21] Bouyanzer, A., Hammouti, B. and Majidi, I., (2006). Pennyroyal oil from Mentha pulegium as corrosion inhibitor for steel in 1M HCl. Material Lethers, vol. 60, no. 23, pp. 2840-2006.

[22] Rehan, H. H. (2003), "Corrosion control by water soluble extracts from leaves of economic plants." Materialwissenschaft und Werkstofftechmik, vol. 34, no. 2, pp. 232-237.

[23] El-Etre, A. Y., Abdallah, M. and El-Tantawy, Z. E. (2005). Corrosion inhibition of some metals using Lawsonia extract, Corrosion Science, vol. 47, no. 2. pp. 385-395.

[24] Umoren, S. A. and Eduok, U. M. (2006). Inhibitive and adsorption characteristics of Cassava leaf extract on corrosion of mild steel in acidic media. Journal of Taibah University for Science, 10(6), pp. 794-804.

[25] Meryem H., Abderrahim A., Ali O., Lahoucine B., Jamal A., Imane E.; Mohamed A.; Hafid A. and Rachid L. M. (2022). Inhibitive Properties of Date Seed Extracts (Phoenix Dactylifera L.) on Mild Steel Corrosion in 1M HCl Solution: Experimental and DFT Studies. Biointerface Researching Applied Chemistry. Open- Access Journal (ISSN 2069-5837)

[26] Emregul, K.C. and Hayvey, M. (2005). Studies on the Effect of a Newly Synthesized Schiff Based Compound from Phenazone and Vanillin on the Corrosion of Steel in 2M HCl, corrosion Science 2006, 48, 797-812,https://doi.org/10.1016/j.corsci.2005.03.001.

[27] Moretti, G., Guidi, F. and F. Fabris. (2013). Corrosion Inhibition of the Mild Steel in 0,5M HCl by 2-Butyl-Hexahydropyrrolo [1.2-b][1,2] Oxazole. Corrosion Science 2013, 76, 206-218,https://doi.org/10.1016/j.corsci.2013.044.

[28] Williams Raphael de Souza Morais, Soares de Silva J., and Queiroz, N.M.P. (2023). Green Corrosion Inhibitors Based on Plant Extracts for Metals and Alloys in Corrosive Environment: A Technological and Scientific Prospection. Applied Sciences.

[29] Abdelaziz. (2021). Green corrosion inhibition of mild steel in HCl medium using leaves extract of Arbutus unedo L. plant: An experimental and computational approach (Colloids and Surfaces A: Physicochemical and Engineering Aspect

[30] Raja, P. B., Mehran, F., Ahmad, K. Q., Afidah, A. R., Hasnah, O., Mart, L., and Khalijah, A. (2013). Evaluation of green corrosion inhibition by alkaloid extracts of Ochrosia oppositifolia and isoresrpiline against steel in 1 M HCl medium. Industrial & Engineering Chemistry Research.

[31] Umoren, S. A., Zuhair, M. G., and Ime, B. O. (2013). Natural products for material protection: inhibition of mild steel corrosion by date palm seed extracts in acidic media. Industrial & Engineering Chemistry Research.

[32] Anyanwu, S. I., Eseonu O. and Nwosu, H. U. (2014). Studies on Corrosion Characteristics of Carbon Steel Exposed to Na_2CO_3, Na_2SO_4 and NaCl Solutions of Different Concentrations. 3(10), 2014, 48-60.

[33] Rolf N. (2005). Controlling Internal Corrosion in Oil and Gas Pipelines. Business Briefing; Explanation and Production; The Oil and Gas Review. 2, 2005, 70 – 74.

[34] Loto, C. A. (2003). The effect of Bitter Leaf extract on the inhibition of Mild Steel in HCl and H_2SO_4. Corrosion Prev and Control. 50 2003, 43-49.

[35] Tuaweri, T. J., Ogbonnaya, E. A. and Onyemaobi, O. O. (2015). Corrosion Inhibition of Heat Treated Mild Steel with Neem Leave Extract in a Chloride Medium. 04(06), 2015, 404-409.

[36] Ejieh, C. and Ejimofor, R. A. (2012): Inhibition of Corrosion on Mild Steel Using Piper Guineense (Uziza) Extract in Sulphuric Acid in Varying pH Value.

[37] Loto, C. A. (2003). The Effect of Bitter Leaf Extract on the inhibition of Mild Steel in HCl and H_2SO_4, Corrosion Prev and Control, 50(1)3:43-49. Neem Foundation. 2001. www.neemfoundation.org.March20

[38] Hello. Helloiniya.com/neem/chemical corporation. Html. 2011, 3:20.

[39] Cetin B., Ozer H., Cakir A., Mete E, Tosun M., Ozturk E., Polat T. and Kandemir A. (2009). Chemical composition of hydrodistilled essential oil of Artemisia incana (L.) Druce and Antimicrobial activity against food borne microorganisms. Chem Biodiverse 6(12):2302-10.2009.