

Effects of Neem Seed and Wire Croton Extracts on Mild Steel in Salt and Fresh Water Media Using Electrochemical – SEM – GCMS and FTIR

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Abstract:

Corrosion inhibition of mild steel remains a major challenge in industrial and environmental systems, necessitating the development of effective, economical, and environmentally sustainable corrosion inhibitors. Thus, plant extracts from neem seed and wire croton were prepared using standard extraction techniques and characterized, confirming the presence of key phytochemical constituents from both neem seed and wire croton plant extracts in the GC/MS analysis of Cembranoid (over 11.95%), Labdanes (over 15.48%), Hexadecanoic acid Ethylester over (11.41%), 1,2,4-Trithiolane,3,5-diethyl (over 9.36%) and Methyl,8-Methyl-nonanoate for Wire Croton while Azadirone (over 18.54%), 2-Furancarboxaldehyde (over 11.13), Meliantriol (over 10.89%), Epoxyazadiradione (over 9.67%), Ammonium acetate (over 9.54%), Salannol (over 9.42%), for Neem Seed. The plant extracts were characterized for FT-IR, EIS and SEM EDX result with neem seed extract exhibiting relatively higher concentrations of active components. Scanning electron microscopy was used to characterize the surface morphology of uninhibited and inhibited mild steel specimens and the results show a remarkable inhibition of the corrosion process in the presence of the inhibitor. Analysis of the peaks of Fourier Transform-Infrared Spectrum (FT-IR) of the inhibitors indicated presence of functional groups containing Phosphorus, Oxygen, Nitrogen, -OH and -COOH while the peaks of the Gas Chromatography – Mass Spectrometry (GC-MS) analysis is in agreement with the results of the FT-IR and indicate the presence of corrosion inhibiting compound such as Terpenes, Tannin, Alkaloid, Flavonoid and Phytate in different appreciable concentrations.

Keywords: Azadirachta indica, Bonplandia, Mild Steel, Green Inhibitor, Functional Group

1. Introduction

Mild steel is a widely used construction and engineering material due to its mechanical properties, availability, and affordability (Jamel & Sathiq, 2010). However, it is highly susceptible to corrosion, especially when exposed to aggressive environments such as acidic solutions, saline water, and even untreated freshwater. Corrosion leads to structural degradation, operational failure, and economic losses in various industries, including oil and gas, water treatment, transportation, and construction (Fontana, 2005). Traditionally, synthetic organic and inorganic compounds have been used as corrosion inhibitors to minimize the deterioration of metals in corrosive

environments. Although effective, many of these inhibitors contain toxic and non-biodegradable chemicals such as chromates, nitrates, and phosphates, which pose significant environmental and health hazards (Raja & Sethuraman, 2008). The growing environmental concerns and the need for sustainable alternatives have prompted researchers to explore natural plant-based extracts as green corrosion inhibitors. Plant extracts contain phytochemicals such as alkaloids, tannins, flavonoids, and saponins, which have been shown to form protective films over metal surfaces, thereby reducing the rate of corrosion (Okafor *et al.*, 2008). These bioactive compounds can adsorb onto the metal surface, creating a barrier that limits contact with corrosive agents. Neem seed (*Phyllanthusemblica*) has been widely studied for its antimicrobial, antifungal, and antioxidant properties (Okpala *et al.* 2022). It is rich in compounds like azadirachtin, nimbolide, and salannin, which contribute to its effectiveness in corrosion inhibition (Umoren & Ebenso, 2008). Similarly, Wire Croton (*Codiaeumvariegatum*), a lesser-known medicinal plant, contains terpenoids and polyphenolic compounds with potential corrosion-inhibiting properties, although it has not been as extensively studied as neem. Evaluating the effectiveness of these plant extracts across different corrosive media such as fresh water and salt water is essential to understanding their performance under variable environmental conditions (Abiola *et al.*, 2010). While chloride ions in saltwater can cause pitting and localized corrosion. The variation in media simulates real-world conditions, thereby helping to assess the practical applicability of these green inhibitors (Ezzat, 2024).

Metal corrosion challenges must be handled and confronted because of environmental and human safety. Corrosion can be reduced or control through a good strategy such as inhibitive substance application to stop reactions of both cathodic and anodic or each (Raja & Sethuraman 2005). Corrosion inhibitors are more popular among the various methods of corrosion prevention and control because these inhibitors are compounds that are organic in nature that contains some atoms such as nitrogen oxygen and sulfur atom. Due to the expensiveness, toxic and hazardous nature of most of the chemical inhibitors to human being and the environment as well, their usage have been limited (Halambek *et al.*, 2010). In order to attain sustainable greenness to the eco system or the environment, the search for eco-friendly and environmental friendly corrosion inhibitor as a substitute for the inorganic and organic inhibitors harmful to human being and environment. Different parts of plant extracts contain these alternative less expensive, renewable and eco-friendly inhibitors (Oguzie, 2005; Okafor *et al.*, 2008). Thus, Mild steel is an indispensable material in many industrial applications due to its mechanical strength, formability, and low cost. However, its high susceptibility to corrosion, especially in aggressive environments such as acidic, saline, and freshwater media, significantly limits its long-term utility (Rajeswari *et al.*, 2022). Corrosion not only reduces the structural integrity of mild steel but also leads to increased maintenance costs, frequent replacements, safety hazards, and environmental pollution due to the release of metal ions into ecosystems (Sharma & Sharma, 2014). Although several studies have investigated the inhibition efficiency of various plant extracts (Sheydaei. (2024)), the corrosion-inhibiting capabilities of Neem seed and Wire croton have not been comprehensively compared, particularly in fresh water and salt water corrosive environments. Therefore, this research is focused on examining and evaluating the inhibitive performance of these plant extracts (Neem seed and Wire Croton) on mild steel corrosion in fresh and salt water media., via the preparation, extraction and characterization of Neem seed and Wire croton extracts, determination of the inhibitive components of the plant extracts, and characterization of mild steel coupon surface structure with inhibitors.

2.0 Materials and Method

2.1 Materials

Neem Seed used was bought at Rumuokoro market in Obio/Akpor local government areaa while Wire Croton leaves used was gotten at the Rivers State University, Port Harcourt. Acetone were bought from a Chemical Shop in Port Harcourt while Mild Steel, Salt and Fresh Water were gotten in Rivers State. The mild steel coupon with its composition is shown thus



Plate 1: Mild Steel Couple Sample

Table 1: Chemical Composition of Mild Steel

Element	Composition (%)
Carbon	0.017
Silicon	0.007
Manganese	0.196
Phosphorous	0.009
Nikel	0.013
Molybdenum	0.015
Chromium	0.043
Sulphur	0.014
Iron	99.686

The density of the mild steel used is 7.86g/cm^3

2.2 Extraction and Characterization of Neem Seed and Wire Croton

Wire Croton leave of 1.5kg was weight into a reactor and later poured in a fine crushing mortal for size reduction. After crushing the wet wire croton leave, it was poured into a 75um sieve mesh. The wire croton wet leave was poured into the sieve mesh and was properly squeezed to extract the natural lipid without contamination and adulteration. The recovered Wire Croton lipid was bottled and immediately kept in a refridgerator to prevent it from losing concentration before its application as corrosion inhibitor.



Plate 2: Wire Croton Plant Extract, Harvested Wire Croton and Wire Croton Extract

Also, 1.5kg of the Neem Seeds was weighed into a reactor and crushed into fine size by crushing mortal. After crushing, the wet Neem Seed was poured into a 75um sieve mesh. The neem seed cake was poured into the sieve mesh and properly squeezed with hand to extract the natural lipid without contamination or adulteration. The recovered neem seed lipid was bottled and immediately reffridgerated to prevent concentration lost or degradation prior to its application as corrosion inhibitor.



Plate 3: Natural Neem Seeds Plant, Harvested Neem Seeds and Neem Seeds Extract

2.3 Characterization of Samples

2.3.1 GC-MS Chromatography

Sample was extracted with petroleum ether using the Soxhlet method. Approximately 5 g of dried and 80mL of petroleum ether (60–90°C) were used in each Soxhlet extraction, which was realized at 80°C for 8 hours. After the extraction procedure, the solvents were evaporated under vacuum, and the samples were subsequently stored at 4°C. Lipids obtained after the extraction of the samples were converted to the corresponding FAMES. In this procedure, 40μL of extracted lipid was placed into 10mL centrifuge tubes to which 0.7mL of KOH (10M) solution and 5.3mL of methanol were added. The operation was performed at 55°C for 1.5 hours with mixing for 5 seconds every 20 minutes. After cooling to room temperature, 0.58mL of sulfuric acid (10 M) solution was added and the process continued at 55°C for 1.5hours with mixing for 5 seconds every 20 minutes. After cooling to room temperature, 3 mL of n-hexane was added and mixed for 5 minutes. Subsequently, the tubes were centrifuged for 5 minutes and the extracts were removed for GC analysis.

2.3.2 Fourier Transform Infrared Spectroscopy (FT-IR)

Fourier Transform Infrared Spectroscopy is an analytical technique that identifies organic and inorganic materials, measures the infrared radiation absorption of the materials against the length of wave number thereby identifying the functional group in the molecular components. The principle upon which FTIR operates is that within the path of the optical, an infrared light which comes from the source passes through Michelson interferometer and this equipment is fitted with mirrors.

2.4 Characterization of Mild Steel Coupon Surface Structure with Inhibitors

2.4.1 Electrochemical Impedance Spectroscopy (EIS) Measurement

The electrochemical analysis was done in conventional three electrode cell with a Gamry Reference 3000 advanced electrochemical workstation. The reference electrode used was saturated calomel electrode (SCE), The counter electrode was platinum electrode and the working electrode was metal (mild steel) with an exposed surface area of 1 cm². The electrolytes were the test solutions of Salt water and Fresh water in the presence and absence of different concentrations of the Neem Seed and Wire Croton extract. To get a steady state for accurate reading at open circuit potential (OCP), the metal electrode was immersed in the test solution for 3 hrs. Measurements of Electrochemical Impedance Spectroscopy (EIS) were carried out over a frequency of 60 Hz, with a 10 mV amplitude sinusoidal voltage. The corrosion behavior of mild steel in Salt water in presence and absence of Wire Croton and Neem Seed plant extracts were investigated by EIS after immersion.

2.4.2 Scanning Electron Microscopy with Energy Dispersive X-ray Spectroscopy

The SEM uses an electron beam instead of a beam of light, which moved directed towards the specimen under examination where the electron gun is located at the top of the device, shoot out a beam of highly concentrated electrons. There are two main types of electron guns used by SEM. The first, thermionic guns that heat a filament until electrons stream away and field emission guns, other popular choice rip electrons away from their atoms by generating a strong electrical field. The SEM usually requires a vacuum chamber to function, as the electron beam must not be obstructed as the microscope. Small particle could deflect the electrons onto the specimen itself when observing the results. When a specimen is hit with electrons incident beam, it emits X-rays and three kinds of electrons namely; Primary backscattered electrons, Secondary electrons and Auger electrons. The SEM uses primary backscatter electrons and secondary electrons. An electron recorder picks up the rebounding electrons and records their imprint. This information is translated onto a screen which allows three dimensions images to be represented clearly. One of the SEM's greatest advantages is its ability to reproduce a texture information in a consistent and coherent manner.

3.0 Results and Discussion

3.1 Analysis of Gas Chromatography and Mass Spectrometry

The results of Gas Chromatography and Mass Spectrometry of plant extract observed as molecular phytochemical properties of corrosion inhibition in composition of Wire Croton are Cembranoid (over 11.95%), Labdanes (over 15.48%), Hexadecanoic acid Ethylester over (11.41%), 1,2,4-Trithiolane,3,5-diethyl (over 9.36%) and Methyl,8-Methyl-nonanoate. The Wire Croton are well-known inhibitors that enhance surface coverage due to bulky structure, adsorption on metal surface, formation of a protective organic film, electron donation via heteroatoms (O, S) and blocking anodic and cathodic reaction site especially in saline and fresh water environments (Izisionwuru *et al.*, 2021; Madawa *et al.*, 2025). Also, the results of Gas Chromatography and Mass Spectrometry of plant extract observed as molecular phytochemical properties of corrosion inhibition in composition of Neem seed are Azadirone (over 18.54%), 2-Furancarboxaldehyde (over 11.13), Meliantriol (over 10.89%), Epoxyazadiradione (over 9.67%), Ammonium acetate (over 9.54%), Salannol (over 9.42%), for Neem Seed. The Molecular phytochemical properties for Neem Seed are eco-friendly ("green") inhibitors and effectiveness on metal type, corrosion

medium, concentration and Temperature. The molecular phytochemical properties contain heteroatoms (O) π -electrons systems, absorb onto metal surface (Steel, mild steel, aluminum), form a protective film that reduces metal dissolution and act mainly as mixed-type inhibitors (both anodic and cathodic) while 2-Propen-1-one (over 54.12%), Dodecanoic acid (over 8.14%), Bis(2-ethylhexyl) Phthalate (over 4.37%), Squalene (3.47%) Cyclododecanol (3.34%) and Pivalamide (over 3.30%) for Blended Neem Seed and Wire Croton Extract. The 2-Propen-1-one (Iziorwuru *et al.*, 2021; Madawa *et al.*, 2025). Molecular phytochemical properties observed in Blended Neem Seed and Wire Croton Extract are effective corrosion inhibitors for metals like mild steel coupon in saline and fresh water environments, working by adsorbing onto the metal surface to form a protective film, with efficiency boosted by heteroatoms (O, N, S) and π -electrons using electrochemical techniques. (with Neem seed extract exhibiting relatively higher concentrations of active constituents) Past work on green inhibitors have established molecular phytochemicals components capability in corrosion rate inhibition of metal samples in contact with corrosive environments. Extensive literature review and research have shown that these molecules and hence functional groups are capable of inhibiting the rate at which corrosion takes place on metal surfaces in salt water and fresh water media where the use of metals and other substances that corrode (Iziorwuru *et al.*, 2021; Madawa *et al.*, 2025)

3.2 Fourier Transform Infrared Spectroscopy

The Fourier Transform Infrared (FT-IR) Spectroscopy of the plant extracts of wire croton, neem seed and its blended sample are highlighted in Table.2, Table 3 and Table 4 respectively. Also presented are infrared spectrums interpretation of the control or blank which are the fresh and salt water following Spectrums Practical guideline articulated by Coates in 2000 (REFERENCE)

Table 2: Fourier Transform Infrared (FT-IR) Spectroscopy of Neem Seed Extract

Compound Class	Functional Group	Appearance	LC FTIR Spectra Peaks
Amines	N-H bend	Medium	1638
Alkynes	-C(triple bond)C-Stretch	Weak	2122
Amines amides	N-H Stretch	Medium	3267

The Infrared spectrum of the plant extracts of neem seed base stock corrodent are presented along with the interpretation of the spectrums following the practical guidelines articulated in (Iziorwuru *et al.*, 2021). The interpretation of the infrared spectrum of neem seed corrodent shown in Figure 1 is detailed in Table2. Thus, the neem seed possess weak (w) but broad (r) COOH dimmers and medium C = C aromatic stretch indicating the presence of Phenol, and N - H stretch and variable N - H bend present in amines, thereby suggesting presence of heteroatoms like nitrogen. In addition, it can be deduced that these constituents contribute to the inhibiting property exhibited by neem seed. This is in agreement with (Iziorworu *et al.*, 2021a) whose report was corroborated by (Ukpaka *et al.* 2023) that heteroatoms in functional groups play a prominent role in the inhibition process of crude extracts

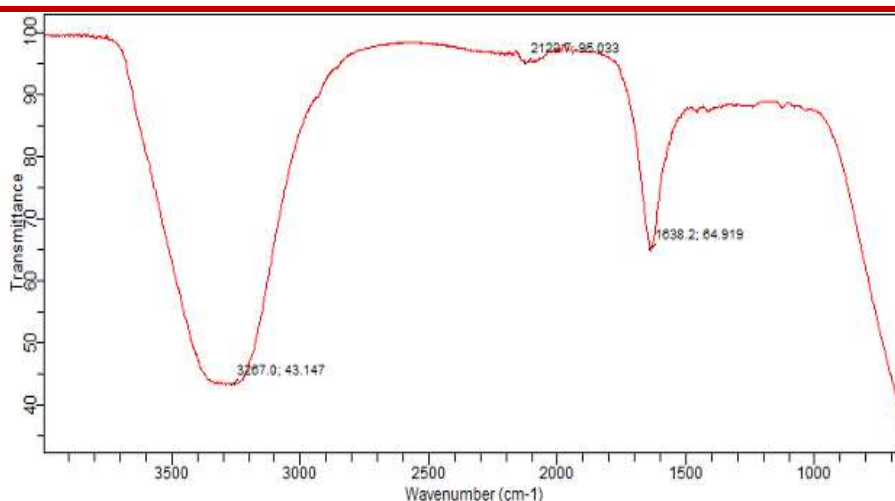


Figure 1: Fourier Transform Infrared (FT-IR) Spectroscopy for Neem Seed

Besides, the infrared spectrum of the plant extracts of wire croton base stock corroder are presented along with the interpretation of the spectrums following the practical guidelines articulated in (Izionwuru *et al.*, 2021). The interpretation of the infrared spectrum wire croton corroder depicted in Figure 2 as shown in Table 3. It can be deduced that wire croton have C - N stretch that suggests the presence of Aliphatic Amines, weak (w) but broad (r) COOH dimmers and medium C = C aromatic stretch indicating the presence of Phenol, and variable N - H bend present in amines suggesting presence of heteroatoms like nitrogen.

Table 3: Fourier Transform Infrared (FT-IR) Spectroscopy of Wire Croton Extract

Compound Class	Functional Group	Appearance	LC FTIR Spectra Peaks
Aliphatic Amines	C-N stretch	Medium	1043
Aromatics	C-C stretch(in ring)	Medium	1412
Primary amines	N-H bend	Medium	1636
Alkanes	-C(triple bond)C-H:C-H Stretch	Medium	3281

Therefore, it can be posited that these constituents contribute to the inhibiting property exhibited by wire croton, which is in tandem with (Izionworu *et al.*, 2021a) whose report was corroborated by Ukpaka *et al.* (2023) that heteroatoms in functional groups play a prominent role in the inhibition process of crude extracts.

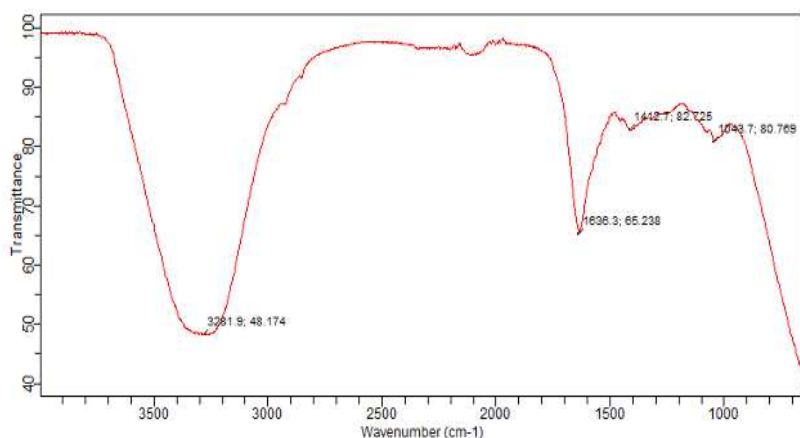


Figure 2: Fourier Transform Infrared (FT-IR) Spectroscopy for Wire Croton

In addition, the Infrared spectrum of the plant extracts of blended neem seed and wire croton base stock corrodent are presented along with the interpretation of the spectrums following the practical guidelines articulated in (Izionwuru *et al.*, 2021). The interpretation of the infrared spectrum of blended neem seed and wire croton corrodent shown in Figure 3 and Table 4 respectively. It shows that blended neem seed and wire croton have C = H stretch that suggests the presence of Tannin (a compound in plants), weak (w) but broad (r) COOH dimmers and medium C = C aromatic stretch indicating the presence of Phenol, and variable N - H bend present in amines suggesting presence of heteroatoms like nitrogen.

Table 4: Fourier Transform Infrared Spectroscopy of Blended Plant Extracts of Neem Seed and Wire Croton

Compound Class	Functional Group	Appearance	LC FTIR Spectra Peaks
Alkyl halide	C-Cl stretch	Strong	782.7
Aromatics	C-H stretch	Strong	887.1
Aliphatic amines	C-N stretch	Medium	1006
Aliphatic amines	C-N stretch	Medium	1230
Aromatic amines	C-N stretch	Strong	1271
Asymmetric	C-O Asymmetric stretch	Strong	1319
Aromatics	C-C stretch (in ring)	Medium	1420
Alkanes	-C=C- stretch	Medium	1658
Nil	Nil		1886
Nil	Nil	Nil	1986
Alkynes	-C(triple bond)C- stretch	Weak	2124
Aldehydes	H-C=O:C-H stretch	Medium	2579
Aldehydes	H-C=O:C-H stretch	Medium	2657
Alkanes	C-H stretch	Medium	2821
Alkanes	H-C=O:C-H stretch	Medium	2866
Alkanes	C-H stretch	Medium	2989
Alkanes	C-H stretch	Medium	3082

Thus, it can be deduced that these constituents contribute to the inhibiting property exhibited by blended neem seed and wire croton based on results of Izionworu *et al.*, 2021a and supported by Ukpaka *et al.* (2023) that heteroatoms in functional groups play a prominent role in the inhibition process of crude extracts.

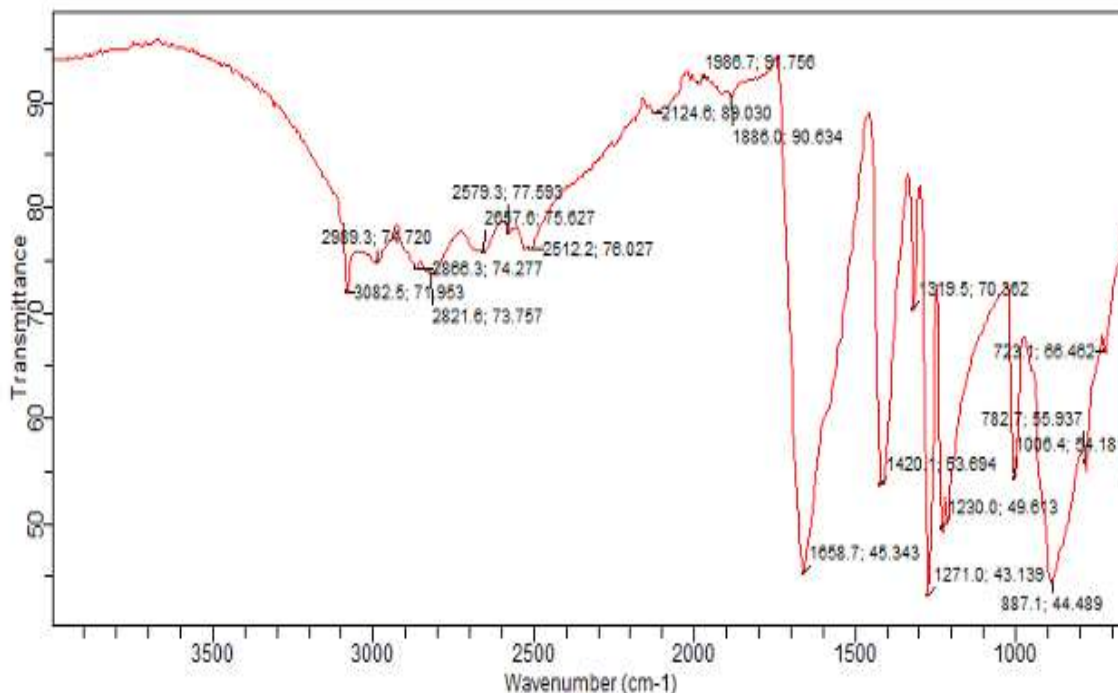


Figure 3: Fourier Transform Infrared (FT-IR) Spectroscopy for Blended Wire Croton-Neem Seed

3.3 Electrochemical Impedance Spectroscopy Measurement

The graphical representation of Nyquist plots, Bode plot and Theta plot of mild steel (coupon) in uninhibited and inhibited Salt and Fresh solutions containing concentrations of Wire Croton and Neem Seed plant extract are displayed in Figures 4, 5 and 6 respectively.

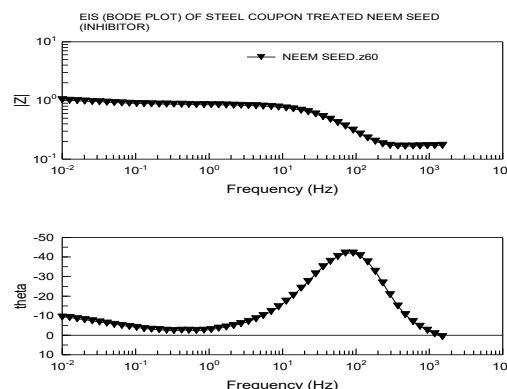
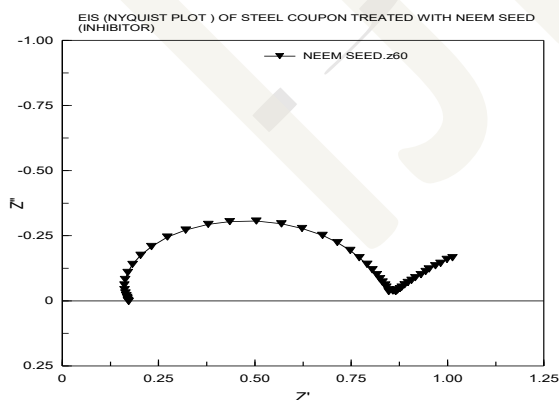


Figure 4: Electrochemical Impedance Spectroscopy for Neem seed

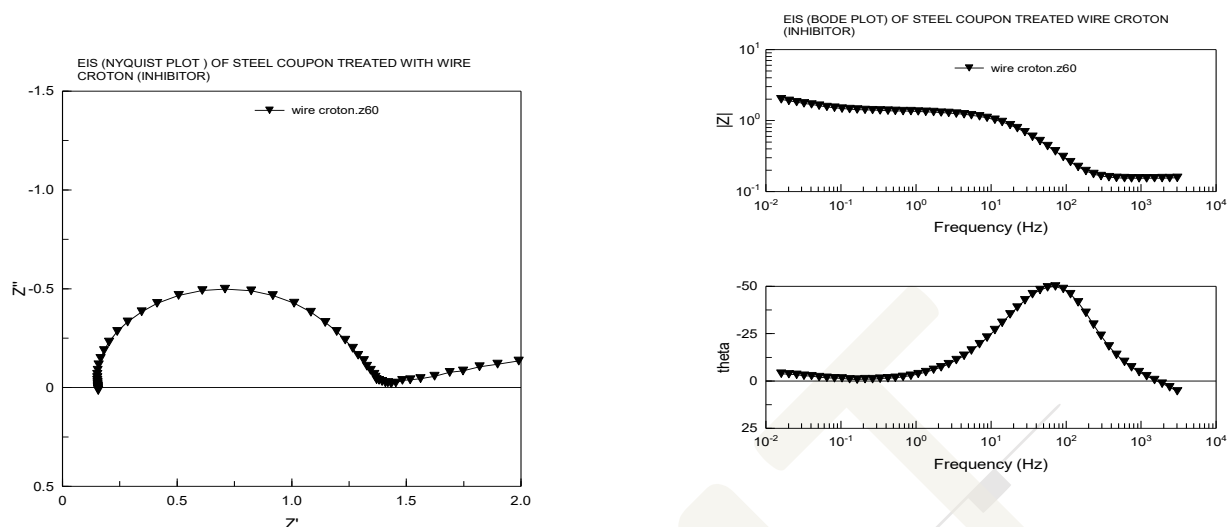


Figure 5: Electrochemical Impedance Spectroscopy for Wire Croton

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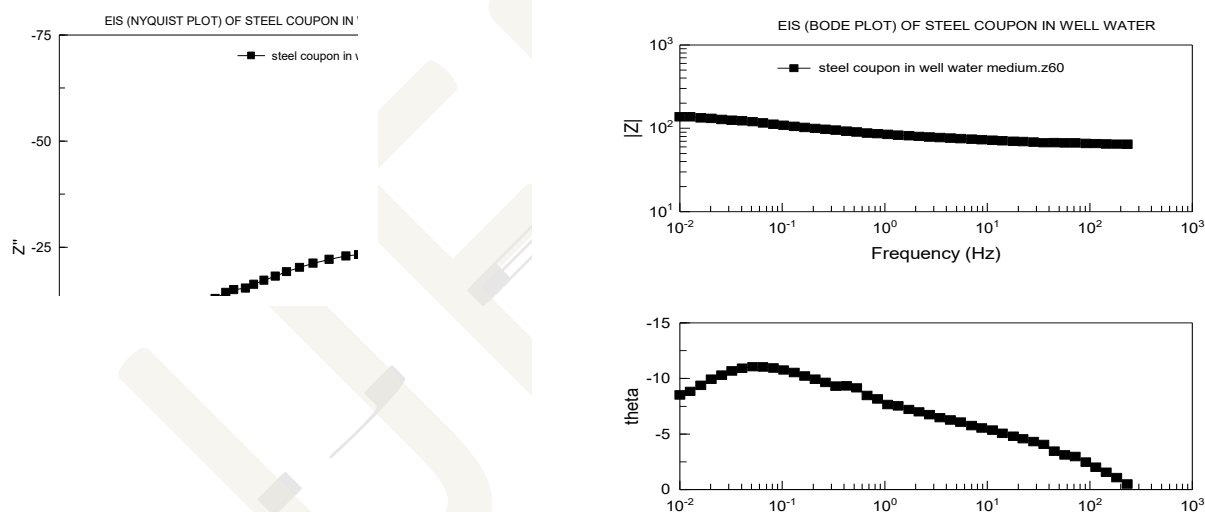


Figure 6: Electrochemical Impedance Spectroscopy for Fresh Water.

The impedance spectra of mild steel in fresh water in the absence and presence of Wire croton and Neem seed plant extracts are depicted in the Nyquist plots (Figures 4, 5, and 6). For the uninhibited fresh water (blank), the plot exhibits a nearly perfect semicircle, indicating that the electrochemical reaction is predominantly controlled by the charge transfer process. The charge transfer resistance corresponds to the difference along the real impedance axis between the low- and high-frequency regions (Inzunza *et al.*, 2012; Zulkifli *et al.*, 2022). The semicircular response observed across the sample Nyquist plots further confirms that the corrosion process operates under charge transfer control (Thirumoolan *et al.*, 2022). Wire Croton and Neem seed extracts to the fresh water solution,

the charge transfer resistance increased significantly, reflecting an increase in overall impedance with higher inhibitor concentrations (Ghelichkhah *et al.*, 2021). In addition, the electrochemical characteristics of the system were further evaluated using Bode plots to gain detailed insights into the frequency response behavior (Matad *et al.*, 2014; Nugroho *et al.*, 2018; Zulkifli *et al.*, 2022). Bode plots demonstrated that at low frequencies, a higher impedance modulus corresponds to enhanced corrosion resistance with the maximum phase angle (theta) peak increased progressively with inhibitor addition. Therefore, maximum phase angle peaks reached approximately 50° for wire Croton extract and 45° for Neem seed extract in comparison with 12° for the fresh water blank. This notable increase indicates superior passivation performance, which aligns closely with the Nyquist findings. This phase angle behavior illustrates the stability of the protective adsorbed film and clarifies the charge transfer mechanism occurring at the metal–electrolyte interface (Zulkifli *et al.*, 2017; Zulkifli *et al.*, 2022). Thus, these deductions confirm that optimal corrosion inhibition is achieved at higher extract concentrations (Aziz *et al.*, 2014). The strong consistency between the Bode and Nyquist plots provides robust evidence that the inhibition mechanism is predominantly driven by the adsorption of organic molecules onto the steel surface, forming a barrier layer that restricts charge transport and mitigates ongoing corrosion (Pourzarghan & Fazeli-Nasab, 2021; Qiang *et al.*, 2020, 2021).

Furthermore, the impedance spectra of mild steel in saltwater in the absence and presence of wire Croton and Neem seed extracts are illustrated in Figures 4, 5, and 7 respectively. For the uninhibited saltwater solution (blank), the Nyquist plot displays a nearly perfect semicircle, indicating that the electrochemical process is predominantly controlled by charge transfer. The charge transfer resistance corresponds to the difference in real impedance measured at the low- and high-frequency limits. The semicircular response observed across the sample plots further confirms that the electrochemical reactions remain under charge transfer control.

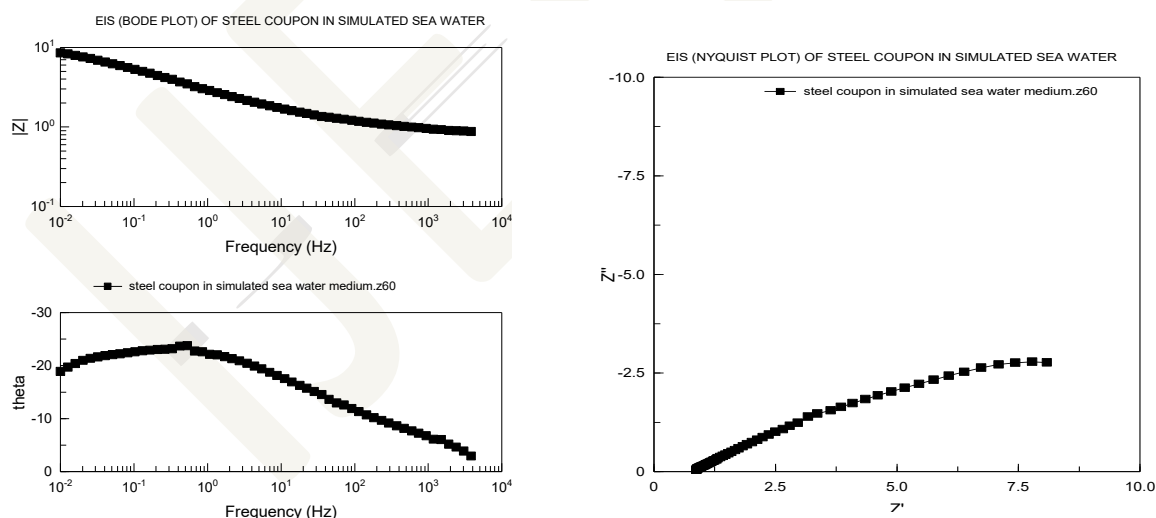


Figure 7: Electrochemical Impedance Spectroscopy for Salt Water

The Wire Croton and Neem seed plant extracts into the saltwater solution, the charge transfer resistance increased significantly, reflecting a rise in overall impedance with increasing inhibitor concentration. To complement the Nyquist analysis, the frequency response behavior was further evaluated using Bode plots. In the low-frequency region of the Bode plot, a higher impedance

modulus signifies enhanced corrosion resistance with maximum phase angle (θ) gradually increased with the addition of plant extracts. The maximum phase angle reached approximately 50° for the Wire Croton extract and 45° for the Neem seed extract in comparison with 22° for the uninhibited saltwater blank. This marked increase in phase angle demonstrates superior passivation performance and aligns with the higher impedance values observed in the Nyquist plots. This comparative analysis demonstrates the stability of the protective adsorbed layer and clarifies the charge transfer mechanism occurring at the metal–electrolyte interface, thereby confirming the inhibitor's efficacy. Thus, it can be posited that optimal inhibition efficiency is achieved at higher extract concentrations, in tandem with the Bode and Nyquist responses. This consistency confirms that the inhibition mechanism is governed by the physical or chemical adsorption of organic plant molecules onto the mild steel surface, creating a protective barrier that restricts charge transport and mitigates ongoing corrosion (Pourzarghan & Fazeli-Nasab, 2021).

3.4 Surface Morphological Studies of the Inhibition on the Surface of Mild Steel Coupon

The results of Scanning Electron Microscopy with Energy Dispersive X-ray Spectroscopy (SEM/EDX) of plant extracts from Neem Seed, Wire Croton and Blended Neem Seed and Wire Croton extracts observed the characterization of morphology of the corroded mild steel coupon use in presence and absence of the inhibitors in composition of Iron (over 84.97 of Atomic Concentration and 90.31 of weight concentration) and of (over 7.83 of Atomic Concentration and 1.79 of weight concentration) for Wire Croton, (over 84.03 of Atomic Concentration and 91.67 of weight concentration) and chlorine of (over 6.30 of Atomic Concentration and 4.36 of weight concentration) for Neem seed (over 90.33 of Atomic Concentration and 93.72 of weight concentration) and carbon of (over 7.83 of Atomic Concentration and 1.79 of weight concentration) for blended Neem Seed-Wire Croton Extract .

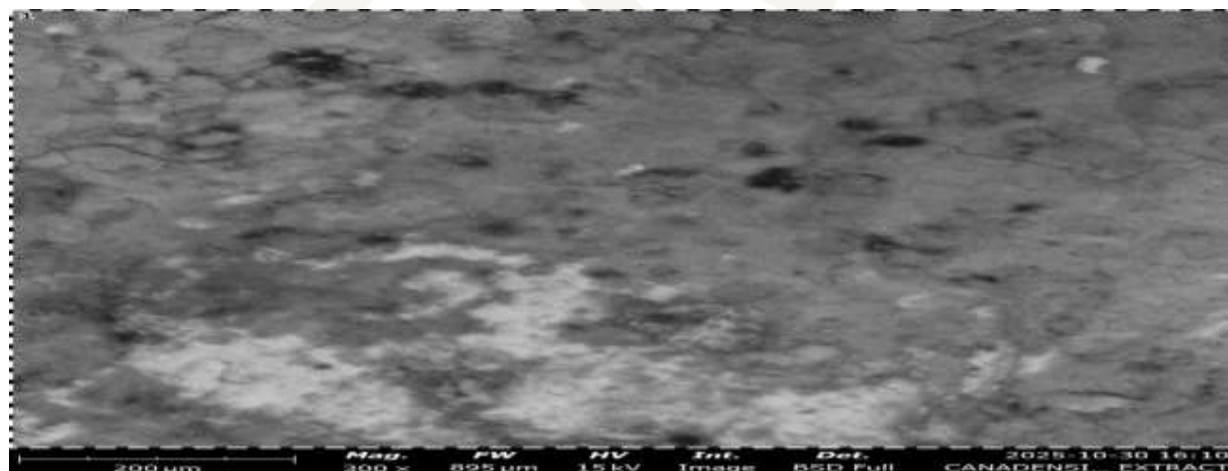


Plate 4: (SEM/EDX) of Plant Extract from Wire Croton

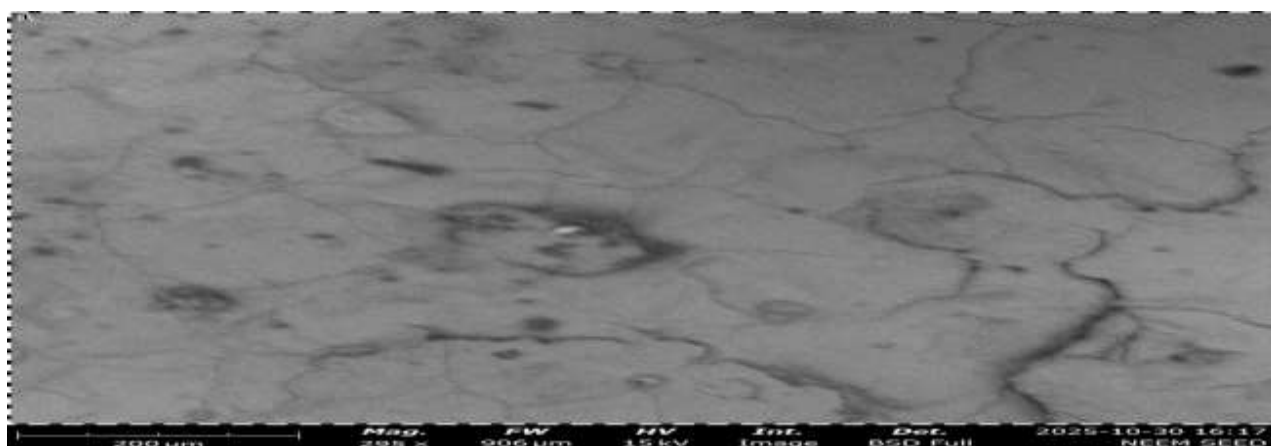


Plate 5: (SEM/EDX) of Plant Extract from Neem Seed

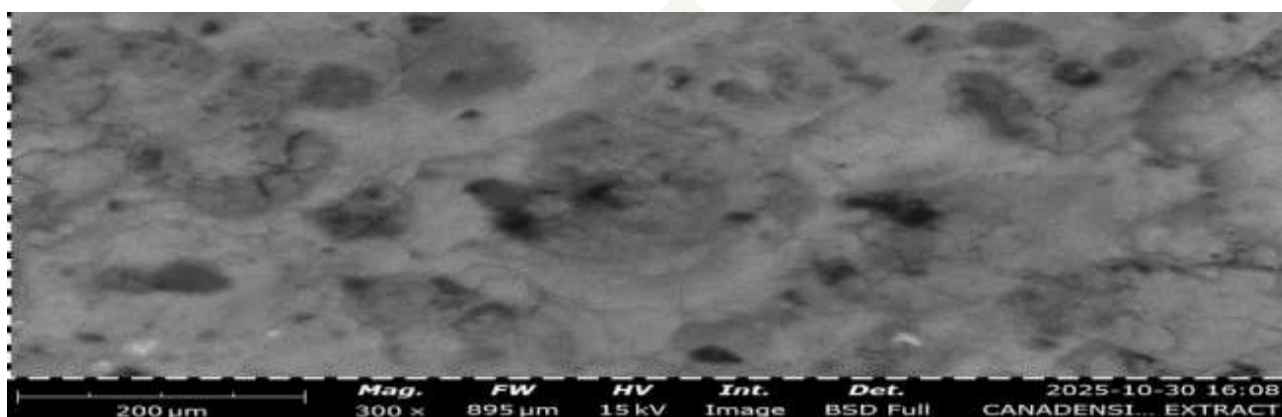


Plate 6: SEM/EDX Image of Mild Steel in Blended Neem Seed/ Wire Croton Solution after 9hrs of Immersion at 298k

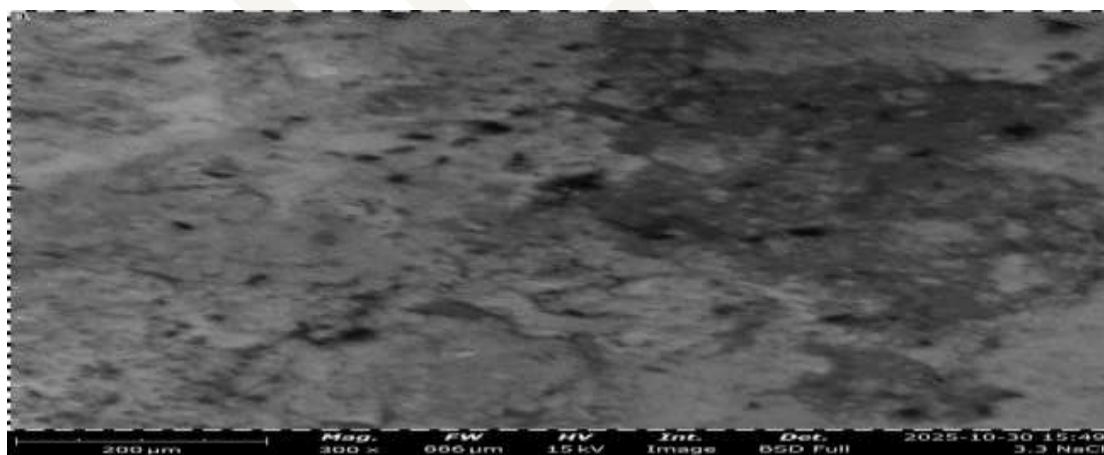


Plate 7: SEM/EDX Image of Mild Steel in Salt Water Solution after 9hrs of Immersion at 298k

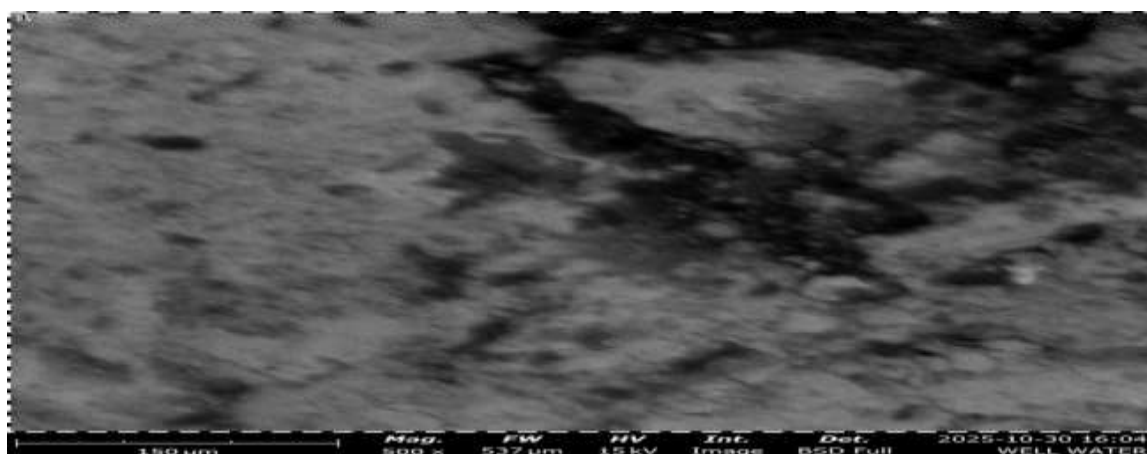


Plate 8: SEM/EDX Image of Mild Steel Fresh Water Solution After 9hrs of Immersion at 298k

Extensive researches on green inhibitors have established molecular phytochemicals components capability in corrosion rate inhibition of metal samples in contact with corrosive environments. These researches have shown that these molecules and hence functional groups are capable of inhibiting the rate at which corrosion takes place on metal surfaces in salt water and fresh Water media where the use of metals and other substances that rust or corrode as posited by Izionwuru *et al.*, 2021 and Oguzie *et al.*, 2013

4.0 Conclusion

The Neem seed and wire croton extracts were successfully prepared and characterized, revealing the presence of alkaloids, tannins, flavonoids, phenolics, and saponins. Characterization results confirmed that neem seed extract contained relatively higher concentrations of active constituents, indicating stronger potential for metal surface adsorption and corrosion inhibition. This trend confirmed the strong influence of chloride ions on metal dissolution and established salt as the most aggressive test environment. The results indicated that both extracts suppressed corrosion by forming protective films on the steel surface, thereby reducing metal dissolution over the exposure period. Comparative analysis demonstrated that neem seed extract consistently outperformed wire croton across all media, and this higher performance was attributed to its richer phytochemical composition and stronger adsorption capability on the mild steel surface. Results confirmed that both extracts are eco-friendly, biodegradable, and non-toxic, with low production costs due to simple extraction and local availability. Surface characterization results showed that mild steel samples treated with blended inhibitors exhibited smoother surfaces with minimal pitting and corrosion damage. Also, in comparison with uninhibited samples, the blended extracts provided improved surface coverage, indicating enhanced protective film formation. Characterization results confirmed that the developed corrosion inhibitor formed a stable, adsorbed protective layer on the mild steel surface, as functional group interactions between plant extract constituents and coupon validated the inhibitor's effectiveness, stability, and suitability for corrosion protection applications.

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