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CORROSION MITIGATION IN OIL PIPELINES: THE ROLE OF GMELINA ARBOREA AND WIRE CROTON EXTRACTS

Chinedu Ifeanyi Okoro and Mariam Oluwaseun Adebayo
[1]Department of Petroleum Engineering, Rivers State University, Nkpolu-Oroworukwo, Port Harcourt, Nigeria.
[2]Department of Chemical & Petrochemical Engineering, Rivers State University, Nkpolu-Oroworukwo, Port Harcourt, Nigeria.
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Abstract
This research explores the sustainable application of Gmelina arborea and Wire Croton plant extracts as green corrosion inhibitors for oil pipeline infrastructure. Steel samples were exposed to different corrosive environment (acidic, alkaline, saline, and neutral) to simulate the diverse conditions faced by pipelines. Three different concentration ratios of the extract (50:50, 60:40, and 40:60) were applied into the corrosive environment to determine their efficacy in inhibiting pipeline corrosion. Gas Chromatography-Mass Spectrometry (GC-MS) was used to identify the phytochemicals responsible for corrosion inhibition in the Gmelina arborea and Wire Croton plant extracts. Additionally, surface morphology changes were evaluated using Scanning Electron Microscopy (SEM) to assess the protective layers formed by the inhibitors on the steel surface. The results reveal that the 60:40 ratio combination of Gmelina arborea and Wire Croton significantly reduces corrosion rates with highest inhibition efficiency, offering a sustainable ecofriendly alternative for corrosion control in the oil and gas industry. By mitigating corrosion, this study addresses not only environmental concerns but also provides a cost-effective solution, reducing maintenance costs and extending the lifespan of oil pipeline infrastructure. It underscores the potential of bio-based inhibitors as a viable approach to enhancing the longevity and safety of pipeline systems, ultimately lowering the economic burden on the industry.

Keywords: *Plant Extracts, Green corrosion inhibitor, Steel sample, sample media, Phytochemicals*

1. INTRODUCTION

Petroleum pipelines are an integral part of the oil and gas industry, transporting crude oil and petroleum products over long distances. These pipelines play a critical role in the transportation and distribution of oil and gas from production sites to refineries, terminals and distribution centers (Ijaola et al., 2020). Petroleum pipelines are designed to operate at high pressure, thus the pipes widely used in petroleum pipelines are typically made of steel or plastic, and they come in various diameters and thicknesses to withstand the pressure and corrosive nature of the petroleum products (Al-Amiery et al., 2023). The advancement of modern society and industry has increased the demand for engineers with specialized knowledge in corrosion as this will aid in developing effective corrosion prevention and control strategies. Corrosion is a natural process that involves the deterioration or degradation of materials usually metals due to environmental and other chemical factors (Rakesh & Kumar, 2021). Corrosion can cause significant damage to structures, equipment and other materials, leading to safety risks, aesthetic problems and economic losses (Aljibori et al., 2023).

Pipeline integrity is the ability of the pipeline to perform its intended function safely and reliably over time. To maintain pipeline integrity, pipeline companies may opt for preventive measures such as installing corrosion-resistant materials, regularly conducting maintenance checks and tests such as pigging and pressure testing and monitoring changes in pipeline performance (Mingjiang & Zhigang, 2018). Corrosion of pipelines results in the loss of both functional integrity and aesthetic appeal. Pipeline corrosion can have a wide range of negative effects on pipeline systems and the environment (Kumar & Yadav, 2021). Corrosion can result in the weakening of pipeline integrity, leading to failures, leaks and ruptures, increasing the risk to human health and safety, environmental degradation and economic losses (Sabara et al., 2025).

The presence of the corrosion inhibitor in the pipeline or wellbore creates a uniform protective barrier that minimizes the contact between the corrosive media and the metal surface (Zhang et al., 2023). This offers a dependable and efficient way to control and adjust the concentration of the inhibitor to match the required optimal conditions, enabling a reduction in corrosion levels throughout the pipeline system's lifetime (Hassan et al., 2023). Additionally, chemical inhibitors can be used in combination with cathodic protection methods and coating systems, increasing the pipeline's protection further. Combining these methods gives increased corrosion mitigation potential, prolonging pipelines and wellbores' useful lifespan while minimizing maintenance requirements and system downtime (Askari et al., 2021).

Among the various methods of controlling corrosion, the use of green inhibitors is currently receiving the most attention. An inhibitor is generally defined as a chemical substance that when added in small concentrations to an environment reduces or prevents corrosion. While inorganic substances such as phosphates, chromates, dichromates and arsenates have been effective as corrosion inhibitors, their major drawback is the presence of heavy metals, which are harmful to health and constitute harm to the environment (Al-Amiery et al., 2023). Green inhibitors are considered rich reservoirs of natural chemical compounds due to their unique characteristics, such as strong affinity, good solubility and high adsorption capability. The extracts are considered as the promising eco-friendly corrosion inhibitors that have a significant effect on the physical and chemical processes of electrochemical corrosion behaviors by promoting the formation of a protective layer on the metal surface (Moubarak et al., 2023).

Singh et al. (2015) studied the effect aloe vera gel on mild steel corrosion, this study examined the impact of Aloe Vera gel on the corrosion of mild steel in a 1M HCl medium using various techniques such as weight loss, electrochemical impedance spectroscopy, and Tafel polarization. The selection of Aloe Vera gel was based on its abundance of organic molecules. Tafel polarization measurements pointed out that Aloe Vera gel extract functions as a mixed inhibitor, with the activation parameters indicating that the inhibitor binds to the metal surface through both physical and chemical interactions. The inhibitor demonstrated a high corrosion inhibition efficiency of more than 90% and the lowest corrosion rate at an optimal concentration of 200 ppm, which was supported by the observations obtained from atomic force microscopy (AFM) and scanning electron microscopy (SEM). Using the decoction method, Haiqin et al. (2024) utilized extract from pumpkin leaves as an eco-friendly and non-toxic copper inhibitor in 0.5M H_2SO_4 corrosion media. In order to assess the composition and protective ability of this extract, several methods including Fourier infrared spectroscopy, electrochemical testing, XPS, AFM, and SEM were employed. Results showed that the pumpkin leaf extract (PLE) proved to be an effective cathode corrosion inhibitor, particularly when exposed to specific temperature ranges. At a concentration of 800mg/L, the corrosion inhibition efficiency of PLE against copper was found to be 89.98%. Additionally, the corrosion protection efficiency of the PLE on copper remained above 85% even as temperature and soaking time increased. Results of the morphology analysis indicated that the PLE provided equally effective protection for copper despite varying temperature conditions. Furthermore, XPS analysis revealed that the PLE molecules were adsorbed and formed an adsorption film, findings which were consistent with Langmuir monolayer adsorption. Molecular dynamics simulations and quantum chemical calculations of the main components found within the PLE were conducted to gain further insight into its inhibitive behavior. Noyelvictoria et al. (2015) in their study investigated the potential of alcoholic Psidium guajava (guava) leaf extract as an inhibitor against corrosion of mild steel in a 1M phosphoric acid medium, using weight loss, potentiodynamic polarization, and electrochemical impedance spectroscopy methods. Results showed that the inhibition efficiency of the extract increased with its concentration up to 800 ppm, with a slight decrease observed at 1200ppm. The adsorption of the extract was found to be consistent with both Langmuir and Temkin adsorption isotherm equations, and its kinetic and thermodynamic parameters were studied and discussed. Chemisorption dominated the comprehensive-type adsorption, and potentiodynamic polarization studies indicated that the extract acted as a mixed-type inhibitor. The potential use of Pawpaw leaves extract as an anticorrosion agent for aluminum in a hydrochloric acid medium was investigated by Omotioma and Onukwuli (2017). Fourier transform infrared spectroscopy (FTIR) was utilized to analyze the extract and the corrosion product. Thermometric, gravimetric, potentiodynamic polarization, and scanning electron microscopic methods were employed as well. Response Surface Methodology (RSM) of Design Expert Software 9 was used to optimize the inhibition efficiency, with inhibitor concentration (0.2g/l – 1.0g/l), temperature (303K – 333K), and time (1 hour - 5 hours) as the considered factors. The study revealed that the stretched C-H and O-H functional groups were predominantly responsible for the corrosion inhibition process, and adsorption of the extract on the aluminum surface followed physical adsorption mechanisms. A quadratic model was deemed sufficient to describe the inhibition process, and optimal inhibition efficiency of 80.58% was achieved at an inhibitor concentration of 0.961 g/l, temperature of 311.459 K, and time of 3.932 hours. This extract proves to be a mixed-type inhibitor that can effectively control both cathodic and anodic corrosion.

According to the World Corrosion Organization, the annual global cost of corrosion is estimated at US$2.5trillion, which is over 3.4 percent Gross Domestic Product (GDP) of industrialized countries. It has been further estimated by the World Corrosion Organization that around 20% of this loss could be prevented through better application of existing knowledge in corrosion protection and this is true as the

cost of corrosion control in Nigeria between 2004-2008 was found to be far less compared to the estimated cost of oil spillage in 1978 alone, which is over $38 billion (Obike et al., 2020). Also, according to Nigeria Extractive Industries Transparency Initiative
(NEITI) over 27 million barrels of national commercial crude oil products was lost between 20162020 at an estimate revenue loss of $14.6 billion due to Corrosion, operational cost and other factors. Therefore, deploying appropriate ecofriendly strategies for infrastructural corrosion management and control is not only the best sustainable infrastructural development but smart investment preventing high expensive industrial failures. This highlights the need for applied research, education, information dissemination and technological development. In addition to the financial cost, safety risks and environmental pollution caused by corrosion is of great concerns. Structural fractures, pressure tank failures and leaks in containers holding toxic, corrosive, or flammable liquids can lead to personnel injuries. Corrosion-control measures are essential across virtually all industries and aspects of daily life, from energy production at power plants and wastewater treatment facilities, oil and gas industries down to the transportation sector. The potential usage or application of Gmelina Arborea and Wire Croton leaf extracts for corrosion prevention is in tandem with the recent trend of the environment-friendly corrosion inhibitors concept. Hence, this research study investigates Gmelina Arborea and Wire Croton extracts as biobased corrosion inhibitors is closely tied to the current trend of eco-friendly corrosion inhibitor concepts. This study highlights the potential of these natural extracts to serve as efficient and environmentally friendly alternatives to synthetic inhibitors in combating metal corrosion by studying the inhibition and corrosion mechanism behind the deterioration of the functional integrity of petroleum pipeline, deduction of the corrosion rate of steel in different environment, determination and optimization of the inhibition efficiency of Wire croton and Gmelina extracts on steel pipeline in different environment and at various concentration, identify the phytochemicals and molecular compounds of the plant extracts using Gas chromatography-mass spectrometry (GC-MS) and photochemical analyses, and examine the surface morphologies of steels using Scanning electron microscope (SEM).

2. METHODS

2.1 Preparation of Acid Solution

740ml distilled water measured and poured into a volumetric flask and 60ml of concentrated HCL was carefully measured and infused into the volumetric flask and stirred making the solution a total of 800ml. The solution was thoroughly mixed to assure the complete dissolution of the hydrochloric acid in the water. The pH of the solution was taken using litmus paper and a pH meter to investigate the acidity of the solution. The blue litmus paper turned red confirming the solution as Acidic, while using the pH meter the concentration of the hydrogen ions was high resulting to a pH value below 7

2.2 Preparation of Alkaline Solution

A clean and dry flask was taken, and 15g of sodium hydroxide was weighed using a weighing balance. Distilled water was then added to the flask to bring the total volume up to 800ml and the solution was stirred. Care was taken while adding the water to avoid generating heat which is a byproduct of the NaOH and water reaction. The solution was thoroughly mixed to ensure that the dissolved NaOH was well distributed in the water. The pH of the solution was taken using a pH meter to investigate the basicity of the solution.

2.3 Preparation of Saline Solution

A clean and dry beaker was weighed, and the beaker weight was noted down. The collected sea water was poured into the beaker. The beaker was weighed again to determine the weight of the sea water. The difference between the weight of the beaker with and without the sea water was calculated to obtain the mass of the sea water, which was 600ml. To prepare saline solution using the sea water, 3g of sterile sodium chloride was added to the beaker based on the mass of the collected sea water. The beaker and the contents (sea water and sodium chloride) were stirred gently to dissolve the sodium chloride. Distilled water was added to the beaker, using a measuring cylinder, to bring the total volume up to 800 ml. The mixture was stirred again to ensure complete dissolution of the sodium chloride in the sea water.

2.4 Preparation of Plant Extract

Fresh leaves were harvested and carefully weighed using an electronic balance. The weight was recorded. The leaves were washed and cleaned thoroughly with distilled water to remove any surface impurities. The cleaned leaves were then chopped into small pieces using a sterile blade. The chopped leaves were then transferred into a manual grinder and grinded until a paste-like consistency was formed. 600g of each of the leaf paste was placed in a clean beaker and diluted with 1200ml of distilled water The beaker was covered with aluminum foil and allowed to stand for 5 hours to allow the active compounds to dissolve in the water. After 5 hours, the solution was filtered using a muslin cloth to remove solid particles. The resulting extract was collected in a clean beaker and stored in a refrigerator.

2.5 Metal Sample Preparation

The metals were cut into coupons (5cm x 5cm x 0.06cm) with the metal perforated to create a tiny hole. The coupons were cleaned followed by polishing with emery paper to expose shining polished surface. To remove any oil and organic impurities, the coupons were degreased with acetone and finally washed with distilled water, dried in air and then stored in desiccators. Accurate weight of each coupon was taken using electronic weighing balance and the initial weight was recorded. The coupons were labeled in a manner to avoid any mix up.

3. CHARACTERIZATION OF THE PLANT EXTRACTS

3.1 Gas Chromatography Mass Spectrometer Analysis of the Plant Extracts

The plant extracts were subjected to GC-MS analysis. This involved injecting a small amount of the extract into the GC-MS instrument, which separates the individual components of the extract based on their molecular weights and chemical properties. During the GC analysis, the plant extract was heated and separated into its constituent substances. These separated substances were then transported through a column using an inert gas. After passing through the column opening, the separated substances were directed into the MS for identification. The Mass Spectrometer identified the compounds present in the plant extract based on the mass of the analyte molecule. The resulting chromatogram was analyzed to identify the specific compounds present in the extract. This information was compared to existing databases of known compounds to determine the identity and quantity of each component. The GC-MS analysis provided valuable insight into the chemical composition of the plant extracts, which can be used to better understand their potential applications and effects.

3.2 Scanning Electron Microscopy (SEM) Analysis of Metals

Scanning electron microscopy (SEM) was used for monitoring the surface morphological changes. In this study, polished metal coupons were immersed in 1 M acidic, alkaline and saline media respectively in the absence and presence of the 0.21.0g/l of the inhibitor for 8hrs. Then the specimen were cleaned with distilled water, dried in acetone and used for the analysis. Scanning Electron Microscope was used for this investigation.

3.3 Phytochemical Identification using Qualitative Analysis

Qualitative analysis for plant extracts is a process of determining the presence or absence of various classes of compounds, such as alkaloids, flavonoids, tannins, and steroids. The purpose of qualitative analysis is to provide a preliminary understanding of the bioactive compounds that exist in a given plant extract. These tests involve adding a few drops of specific reagents to the plant extract solution, observing for changes in color, appearance of a precipitate or gas, or change in pH. The results of these tests indicate the presence or absence of a particular class of compounds in the plant extract. Based on the test results, the possible presence of a certain compound can be determined

3.4 CORROSION RATE AND INHIBITION EFFICIENCY

The corrosion rate and inhibition efficiency of this research study are evaluated as highlighted in Equation 1 and 2 respectively.

The corrosion rate of steel pipeline is described as

$$C_R = K \times \left(\frac{W}{DAT}\right) \qquad (1)$$

The inhibition efficiency of green corrosion inhibitors are deduced as

$$IE = \frac{W^c - W^i}{W_c} \times 100 \qquad (2)$$

4. RESULTS AND DISCUSSION

4.1 Variation of Inhibitors Concentration

At the 50:50 ratio, Gmelina Arboreal and Wire Croton are present in equal amounts, the performance of the inhibitors becomes more balanced but less effective overall. **Table 1: Test Setup for 50:50 Concentration**

Sample	Initial Weight (g)	Final Weight (g)	Weight Loss (g)	Corrosion Rate (mm/year)	Inhibition Efficiency (%)

Acidic	12.3	11.99	0.36	5.23 x 10^{-5}	85.00
Alkaline	14.48	14.29	0.19	3.93 x 10^{-5}	86.40
Saline	12.42	12.19	0.28	4.79 x 10^{-5}	84.40
Neutral	13.10	13.01	0.11	1.50 x 10^{-5}	87.77

Gmelina Arboreal and Wire Croton competes for adsorption onto the metal surface since both inhibitors are present in equal quantities, thereby interfering with each other's ability to effectively adsorb onto the surface and form a continuous film, resulting in less effective inhibition. Without one component playing a dominant role, the inhibitors might not interact as effectively to form a stable and cohesive barrier. Consequently, this could lead to a more fragmented or less protective film on the metal surface.
Gmelina Arboreal is the dominant component in the 60:40 ratio, which is likely the key factor for its higher efficiency compared to other ratios.

Table 2: Test Setup for 60:40 Concentration

Sample	Initial Weight (g)	Final Weight (g)	Weight Loss (g)	Corrosion Rate (mm/year)	Inhibition Efficiency (%)
Acidic	12.90	12.70	0.20	4.66 x 10^{-5}	91.66
Alkaline	12.50	12.39	0.11	2.62 x 10^{-5}	92.14
Saline	14.75	14.59	0.16	3.25 x 10^{-5}	91.11
Neutral	13.90	13.83	0.07	1.49 x 10^{-5}	92.22

The higher corrosion inhibition at this ratio suggests that Gmelina Arboreal may possess strong adsorption properties and a high affinity for binding to the metal surface, creating a dense, stable film that prevents corrosive agents (water, oxygen, or chloride ions) from reaching the metal. Wire Croton may not be the primary inhibitor in this ratio, its presence at 40% likely supports the adsorption and stability of the protective film formed by Gmelina Arboreal. The interaction between the two inhibitors at this ratio may be synergistic, with Wire Croton reinforcing the film formed by Gmelina Arboreal, contributing to its stability and robustness.

Table 3: Test Setup for 40:60 Concentration

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Sample	Initial Weight (g)	Final Weight (g)	Weight Loss (g)	Corrosion Rate (mm/year)	Inhibition Efficiency (%)
Acidic	13.85	13.45	0.40	5.80×10^{-5}	83.33
Alkaline	13.40	13.12	0.28	4.31×10^{-5}	80.00
Saline	11.80	11.48	0.32	6.25×10^{-5}	82.22
Neutral	14.55	14.44	0.09	1.84×10^{-5}	90.00

For the 40:60 ratio in which Wire Croton is the dominant inhibitor, the efficiency is the lowest. This suggests that Wire Croton is less effective as the primary corrosion inhibitor compared to Gmelina Arboreal. Although Wire Croton may still offer some level of protection, its mechanisms might not be as efficient in forming a stable protective layer or in preventing corrosive agents from attacking the metal. Hence, its protective film could be more porous or less adherent, allowing more aggressive species to reach the metal surface and accelerate corrosion especially under harsh environmental conditions thereby reducing the overall inhibition performance. **Table 4: Test Setup for Control Samples**

Sample	Initial Weight (g)	Final Weight (g)	Weight Loss (g)	Corrosion Rate (mm/year)	Inhibition Efficiency (%)
Acidic	13.50	11.10	0.40	6.39×10^{-4}	83.33
Alkaline	13.40	13.12	0.28	3.58×10^{-4}	80.00
Saline	11.80	11.48	0.32	4.30×10^{-4}	82.22
Neutral	14.55	14.44	0.09	2.41×10^{-4}	90.00

4.2 Comparative Analysis of Inhibition Mechanisms

As the concentration of Gmelina Arboreal decreases and Wire Croton increases, the overall efficiency declines indicating that Wire Croton is less effective as a primary inhibitor. This highlights the importance of finding the optimal balance between the two components to maximize corrosion inhibition efficiency. The inhibition efficiency of the Gmelina Arboreal and Wire Croton inhibitors is highly dependent on the corrosive nature of the media in which they are applied. In acidic and saline environments, where aggressive ions are present, the inhibitors struggle to form and maintain effective protective films, leading to lower efficiencies. Also, in less aggressive media such as alkaline and distilled water, the inhibitors can form more stable films and provide greater protection, resulting in higher inhibition efficiencies. This trend highlights the importance of selecting appropriate inhibitors based on the specific corrosive environment.

4.3 Qualitative Analysis for Phytochemical Identification

Wire croton contains a variety of phytochemicals that have shown potential in corrosion inhibition in different corrosive medias as shown in Table 5. These compounds adsorb onto metal surfaces, forming a protective layer that minimizes the interaction between the metal and corrosive agents. The phytochemicals in wire croton act as electron donors, reducing the rate of oxidation and metal degradation.

Table 5: Qualitative results for wire croton

Phytochemical components	Test	Results
Alkaloids	Dragendorffs	+
Tannins	Ferric chloride	++
Flavonoids	Shinoda	++
Saponins	Froth test	++
Phenolic acids	Ferric chloride	+
Terpenoids	Salkowski	++

(+) = moderate presence, (++) = strong presence

Similarly, phytochemicals in Gmelina arborea inhibit corrosion through several mechanisms. These include forming a protective layer on metal surfaces, acting as antioxidants to neutralize reactive species, chelating metal ions to reduce reactivity, and adsorbing onto metal surfaces to block corrosive agents. As highlighted in Table 6, compounds such as flavonoids, tannins, and phenolics are key players in these processes.

Table 6: Qualitative Results for Gmelina Arborea

Phytochemical Components	Test	Results
Coumarins	Uv fluorescence	++
Quinones	Borntrager	++
Glycosides	Keller-kiliani	++
Steroids	Liebermann-buchard	+
Terpenoids	Salkowiski	+
Iridoid glycosides	Borntrager	++
Saponins	Froth	++
Tannins	Ferric chloride	++
Alkaloids	Dragendorff	++
Flavonoids	Shinoda	++
Phenolic acids	Ferric chloride	+

(+) = moderate presence, (++) = strong presence

Besides, the analysis of chromatograph of Gmelina arborea extract with a focus on corrosion inhibition, the peaks as shown in Figure 1 represent different bioactive compounds such as Flavonoids, Tannins,

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Saponins, Phenolic compounds, Terpenoids and Triterpenoids, Alkaloids etc. in the extract that have the potential to inhibit corrosion. These compounds generally work by adsorbing onto the metal surface, forming a protective barrier, and preventing the metal from reacting with corrosive agents such as oxygen, water, or acids.

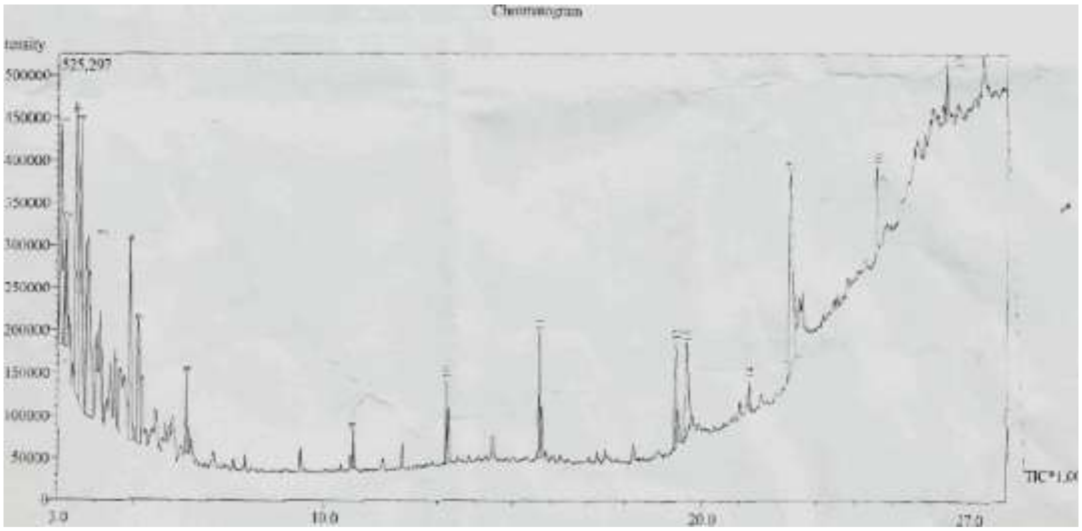

Figure 1: Chromatogram of Gmelina arborea Leaf Extract

4.4 Scanning Electron Microscopy

Scanning Electron Microscopy (SEM) is crucial for evaluating the effectiveness of corrosion inhibitors on steel. It provides high-resolution images to observe changes in surface morphology before and after treatment, revealing details like pitting, roughness, and corrosion products. SEM confirms the presence and uniformity of the protective layer formed by inhibitors and when paired with EDS, it can also analyze elemental composition. This makes SEM as essential tool for assessing both the physical condition of the steel and the performance of corrosion inhibitors in anti-corrosion strategies. In the presence of Gmelina arborea and Wire Croton inhibitors, SEM images show a significantly smoother surface. The pitting is reduced, and the surface degradation is minimal compared to the untreated samples. The inhibitors adsorb onto the steel surface, forming a protective barrier that limits the direct contact of the acid with the steel. This confirms the inhibitory effect of the plant extracts in acidic environments. Also, SEM images of inhibited steel samples in alkaline media display a marked improvement in surface condition. The presence of a protective film, attributed to the adsorption of organic molecules from Gmelina arborea and Wire Croton, is evident. The film prevents the hydroxide ions from reacting with the steel, significantly reducing surface roughness and pitting. The results show a substantial reduction in corrosion-related damage.

5. CONCLUSION

This research comprehensively explores the application of Gmelina arborea and Wire Croton extracts as green corrosion inhibitors, significantly enhancing the understanding of corrosion mechanisms and the practical implications for petroleum pipeline infrastructure. The study identifies the critical pathways through which corrosion compromises the functional integrity of pipelines, providing insights into how environmental factors influence corrosion rates across various metals. The systematic evaluation of corrosion rates in diverse corrosive environments underscores the necessity for tailored corrosion management strategies. The results indicate that Gmelina arborea and Wire Croton extracts effectively inhibit corrosion, particularly when optimized at specific concentration ratios (50:50, 60:40, and 40:60). This optimization process is crucial, as it reveals the extracts' maximum efficacy under varying environmental conditions, thereby providing actionable recommendations for their application in real-world settings. The Gas Chromatography-Mass Spectrometry identifies the phytochemicals and molecular compounds responsible for the observed corrosion inhibition. This approach not only enriches the understanding of the bioactive constituents within the extracts but also lays the groundwork for future research into the mechanisms of action that contribute to their effectiveness. The examination of surface morphologies using Scanning Electron Microscopy (SEM) further validates the protective layers formed on steel surfaces, indicating a promising approach to mitigating corrosion damage. These findings support the hypothesis that bio-based inhibitors can offer a sustainable solution to corrosion management, addressing environmental concerns while simultaneously reducing maintenance costs and extending the lifespan of pipeline infrastructure.

Thus, the research study advocates for the integration of innovative green corrosion inhibition methods in the oil and gas industry by utilizing natural plant extracts, thereby enhancing safety and reliability of pipeline operations and also contribute to broader environmental sustainability goals. Future researches should explore additional plant sources and refine application techniques to further improve the potential of bio-based corrosion inhibitors, fostering a more resilient and eco-friendly approach to managing the challenges of corrosion in critical oil and gas infrastructure

NOMENCLATURE

C_R	=	Corrosion rate (mm/y)
D	=	Metal Density mg/cm^3
A	=	Area of the Sample in cm^2
T	=	Time of exposure on the metal in hours
K	=	Constant (87.6)
IE	=	Inhibition efficiency
W_c	=	Weight loss control sample
W_i	=	Weight loss inhibited sample

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