



Gravimetric Study of *Clerodendrum volubile* (Yorùbá Bógòlì) Leaf Extract as a Green Corrosion Inhibitor for Carbon Steel in Crude Oil-Contaminated Acidic Medium

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Abstract: The persistent degradation of industrial metals in petroleum-related acidic environments poses a major challenge to infrastructure integrity and environmental sustainability. This study evaluates the efficacy of an aqueous leaf extract of *Clerodendrum volubile* as a plant-derived protective agent for carbon steel in a simulated dual-phase medium containing 1.0M hydrochloric acid and crude oil. Using the weight loss technique over immersion durations up to 96 hours, corrosion inhibition was found to be concentration-dependent, with maximum efficiency reaching 78% at 400 ppm. Adsorption behavior conformed to the Langmuir isotherm, indicating monolayer coverage, while thermodynamic analysis revealed a negative standard free energy of adsorption (ΔG°_{ads}), suggesting a spontaneous and physically driven surface interaction. The results demonstrate that the extract's phytochemical constituents effectively hinder metal dissolution, even in hydrocarbon-rich environments, supporting its potential as a non-toxic, biodegradable alternative to conventional chemical inhibitors. This study expands the functional application of indigenous biomaterials in industrial corrosion mitigation and offers a cost-effective strategy for greener pipeline protection.

1. Introduction

Corrosion is an electrochemical process that results in the deterioration of metals when they interact with aggressive environments, particularly those containing acids. In the oil and gas industry, the challenge of corrosion is more complex due to the presence of oil-contaminated acidic media, where hydrocarbons and strong acids co-exist. Such conditions, commonly encountered during acidizing, descaling, and cleaning of pipelines, significantly accelerate the corrosion of carbon steel, a metal widely used in structural and industrial applications due to its strength, affordability, and workability (Obot *et al.*, 2009; Zarrouk *et al.*, 2012; Hmamou *et al.*, 2018; Umoren and Solomon, 2015; Verma *et al.*, 2018; Zehra *et al.*, 2020; Ech-Chihbi *et al.*, 2022; Timoudan *et al.*, 2024).

Traditional corrosion mitigation strategies often rely on the use of synthetic inhibitors such as chromates, amines, and phosphates. Although effective, these compounds are associated with toxicity, environmental persistence, and high disposal costs (Quraishi *et al.*, 2003; Bouklah *et al.*, 2004; Verma

et al., 2018). These concerns have driven the global search for safer and sustainable alternatives, giving rise to the concept of green inhibitors and eco-friendly substances derived from renewable natural sources such as plants. Green inhibitors are typically biodegradable, readily available, and non-toxic, offering a safer option for corrosion protection without compromising environmental health (Paulekat *et al.*, 1982; Hammouti *et al.*, 1995; Rani and Basu, 2012; Aourabi *et al.*, 2021).

Plant extracts have been widely recognized for their corrosion inhibition potential due to the presence of phytochemicals such as flavonoids, tannins, saponins, alkaloids, and phenolic compounds (Oguzie, 2005; Lrhoul *et al.*, 2023). These bioactive molecules can adsorb onto metal surfaces through π -electrons or lone pairs of heteroatoms, forming protective films that reduce the rate of metal dissolution (El-Etre, 2003; Ebenso *et al.*, 2010; Ou-ani *et al.*, 2024). The efficiency of a plant-based inhibitor depends on the nature and concentration of these compounds as well as the structure of the metal and the aggressiveness of the medium (Okonji K.S, 2025).

Clerodendrum volubile, locally known as Yorùbá Bógòlì, is a climbing shrub commonly found in the rainforests of West Africa. It has a rich history in traditional medicine, where it is used to treat inflammation, pain, and infections. Recent phytochemical investigations reveal that its leaves contain a high concentration of flavonoids, phenols, alkaloids, and terpenoids, compounds known for their antioxidant and metal-chelating properties (Akinmoladun *et al.*, 2010; Farombi *et al.*, 2012). The pharmacological potentials of *C. volubile*, such as anticancer, antioxidant, antiviral, antimicrobial, anti-inflammatory, hepatoprotective, antidiabetic, and anti-hypertensive properties were studied (Okaiyeto *et al.*, 2021). However, its application as a corrosion inhibitor remains unexplored, particularly in the context of oil-polluted acidic environments.

This study investigates the inhibitory effect of *Clerodendrum volubile* leaf extract on the corrosion of carbon steel in oil-contaminated 1.0 M hydrochloric acid. Using the weight loss method, the corrosion rates and inhibition efficiencies at varying concentrations and immersion periods are evaluated. The results aim to establish *C. volubile* as a viable green inhibitor, offering an environmentally sustainable and cost-effective solution to industrial corrosion challenges, particularly in regions where the plant is indigenous and abundant.



Figure 1. *Clerodendrum volubile* (Yorùbá Bógòlì) Leaf

2. Methodology

2.1. Carbon Steel Coupons

Carbon steel specimens were mechanically cut into rectangular dimensions of 2 cm × 2 cm × 0.1 cm, polished using successive grades of emery paper (from 320 to 1200 grit), washed with distilled water, greased with ethanol, dried, and stored in a desiccator prior to use.

2.2. Preparation of Oil-Contaminated Acidic Medium

A 1.0 M solution of hydrochloric acid (HCl) was prepared by diluting concentrated HCl with distilled water. To simulate an oil-polluted industrial environment, 10 mL of crude oil was added to 100 mL of 1.0 M HCl and stirred vigorously for 5 minutes to form a heterogeneous mixture. This mixture served as the corrosive medium.

2.3. Plant Material and Extract Preparation

Fresh leaves of *Clerodendrum volubile* (Yorùbá Bógòli) were harvested from cultivated plants grown in the author's private garden in Ado-Ekiti, Ekiti State, Nigeria (approximate coordinates: 7.623° N, 5.220° E). Only healthy, mature leaves were selected for the study. Fresh leaves of *Clerodendrum volubile* were collected, washed thoroughly with distilled water, and shade-dried for 7 days. The dried leaves were then ground into fine powder using a mechanical grinder. Fifty grams (50 g) of the powdered leaves were soaked in 500 mL of distilled water for 48 hours with occasional stirring. The mixture was filtered using Whatman No. 1 filter paper. The filtrate was concentrated using a water bath at 50 °C to yield a thick greenish-brown extract, which was stored in airtight containers at 4 °C and used for further analysis.

The extract was reconstituted in 1.0 M HCl to obtain test solutions of concentrations 100 ppm, 200 ppm, 300 ppm, and 400 ppm, each mixed with a fixed volume of crude oil to maintain oil contamination.

2.4. Weight Loss (Gravimetric) Method

Pre-weighed carbon steel coupons were immersed in 100 mL of the test solutions (HCl + crude-oil + extract) in labeled beakers. One control setup containing only oil-contaminated acid (no inhibitor) was included. Coupons were suspended vertically in the solutions using nylon thread tied to retort stands, avoiding contact with the beaker walls. The immersion times were 24, 48, 72, and 96 hours. After each exposure period, the coupons were retrieved, cleaned with distilled water, scrubbed gently to remove corrosion products, rinsed in ethanol, dried, and reweighed. The corrosion rate (CR) in mg/cm²/hr was calculated using the equation:

$$CR = \frac{\Delta W}{A \times t}$$

Where:

ΔW = weight loss (g)

A = surface area of coupon (cm²)

t = exposure time (hours)

Inhibition Efficiency (IE%):

The inhibition efficiency of the extract was calculated using the following equation:

$$IE\% = \frac{W_o - W_i}{W_o} \times 100$$

Where:

W_o = weight loss in blank solution (without inhibitor)

W_i = weight loss in the presence of inhibitor

2.5. Adsorption Isotherm Studies

To gain insight into the mechanism of inhibition and the interaction between the *Clerodendrum volubile* extract and the carbon steel surface, the experimental data were analyzed using the Langmuir adsorption isotherm model. This model assumes that adsorption occurs on a homogeneous surface with uniform binding sites and no interaction between adsorbed species. The Langmuir isotherm is expressed as:

$$\frac{C}{\theta} = \frac{1}{K_{ads}} + C$$

Where:

C = Inhibitor concentration (ppm)

θ = surface coverage, calculated as $\theta = \frac{IE\%}{100}$

K_{ads} = equilibrium constant of adsorption (L/mg)

A plot of C/ θ against C should yield a straight line if the adsorption follows the Langmuir isotherm. The slope and intercept of the linear plot are used to calculate the adsorption parameters:

The slope indicates the extent of surface coverage consistency

The intercept is equal to:

$$1/K_{ads} \text{ From which } K_{ads} \text{ is determined}$$

The value of K_{ads} provides an indication of the strength of the adsorption process. Higher values suggest stronger interactions between the inhibitor molecules and the metal surface, which may imply chemical adsorption (chemisorption), while lower values may suggest physical adsorption (physisorption).

The feasibility and spontaneity of the adsorption process can be evaluated by calculating the standard free energy of adsorption (ΔG°_{ads}) using the relation:

$$\Delta G^{\circ}_{ads} = -RT \ln (K_{ads} \times 55.5)$$

Where:

R = universal gas constant (8.314 J/mol-K)

T = temperature in Kelvin

55.5 = concentration of water in mol/L (used to standardize aqueous systems)

A negative value of ΔG°_{ads} confirms that the adsorption process is spontaneous.

3. Results

3.1. Weight Loss Measurements

The weight loss of carbon steel coupons immersed in crude oil-contaminated 1.0 M HCl, with and without *Clerodendrum volubile* leaf extract, was monitored over immersion periods of 24, 48, 72, and 96 hours. **Table 1** presents the initial and final weights of the steel coupons, from which the weight loss (WL) values were derived.

Table 1. Weight loss values of carbon steel in crude oil-contaminated acidic medium with and without *C. volubile* extract.

Concentration (ppm)	Time (hrs)	Initial Weight (g)	Final Weight (g)	Weight Loss (g)
Blank (0 ppm)	24	4.833	4.697	0.136
	48	4.833	4.690	0.143
	72	4.833	4.645	0.188
	96	4.833	4.638	0.195
100 ppm	24	4.833	4.776	0.057
	48	4.833	4.761	0.072
	72	4.833	4.758	0.075
	96	4.833	4.735	0.098
200 ppm	24	4.833	4.794	0.039
	48	4.833	4.776	0.057
	72	4.833	4.765	0.068
	96	4.833	4.751	0.082
300 ppm	24	4.833	4.796	0.037
	48	4.833	4.780	0.053
	72	4.833	4.775	0.058
	96	4.833	4.759	0.074
400 ppm	24	4.833	4.803	0.030
	48	4.833	4.788	0.045
	72	4.833	4.780	0.053
	96	4.833	4.775	0.058

From Table 1, it is evident that weight loss decreased progressively with increasing extract concentration at each time point, indicating enhanced corrosion inhibition. The blank sample exhibited the highest weight loss throughout, reflecting severe corrosion in the absence of an inhibitor.

3.2. Corrosion Rate and Inhibition Efficiency

The corrosion rate (CR) values were calculated using the gravimetric data, and the inhibition efficiency (IE%) of the extract was determined relative to the blank sample. The results indicate that corrosion rate decreases consistently with higher extract concentrations and that inhibition efficiency increases with both extract dosage and exposure time, reaching a maximum of ~78% at 400 ppm after 24 hours. Figure 2. shows variation of weight loss with immersion time for carbon steel in crude oil-contaminated 1.0 M HCl solution at different concentrations of *Clerodendrum volubile* leaf extract.

Table 2. Corrosion rates and inhibition efficiencies of *C. volubile* extract at different concentrations and immersion times

Conc. (ppm)	Time (hrs)	Corrosion Rate (mg/cm ² /hr)	Inhibition Efficiency (%)
0 (Blank)	24	2.83	—
	48	1.49	—
	72	1.30	—
	96	1.14	—
100	24	1.19	57.96
	48	0.75	49.66
	72	0.52	60.00
	96	0.57	50.00
200	24	0.81	71.38
	48	0.59	60.40
	72	0.47	63.85
	96	0.48	57.89
300	24	0.77	72.79
	48	0.55	63.09
	72	0.40	69.23
	96	0.43	62.28
400	24	0.63	77.74
	48	0.47	68.46
	72	0.37	71.54
	96	0.34	70.18

(Note: Surface area = 8 cm², t in hours, and mass change converted to mg)

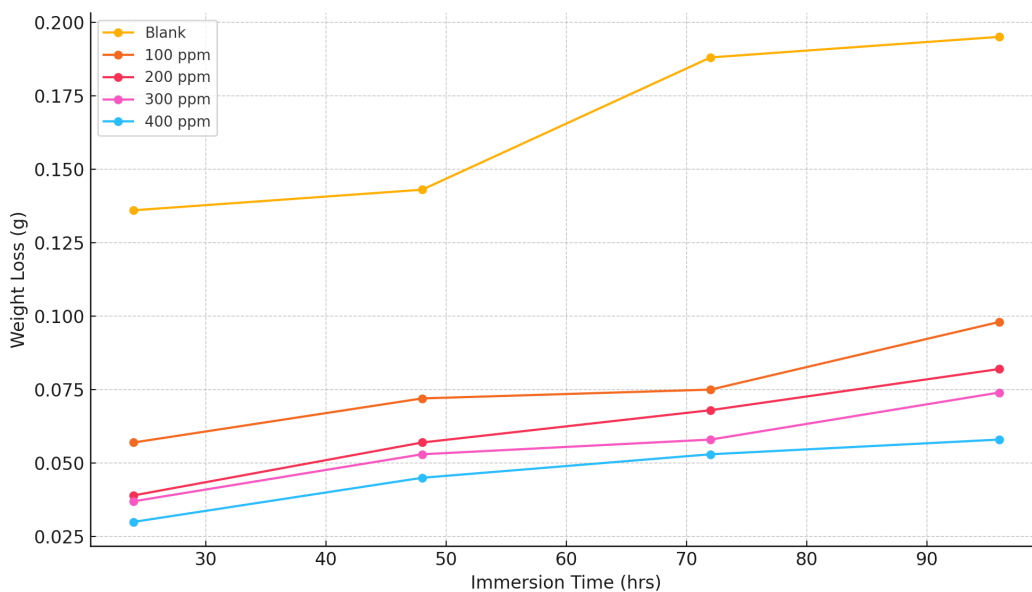


Figure 2. Weight Loss of Carbon Steel vs Time

The blank sample (0 ppm) shows the highest weight loss, while the 400 ppm extract exhibits the lowest, indicating increased corrosion inhibition with extract concentration, and Figure 3. illustrates Inhibition efficiency (%) of *Clerodendrum volubile* leaf extract on carbon steel corrosion in crude oil-contaminated acidic medium over time. The inhibition efficiency increases with extract concentration, reaching a maximum at 400 ppm. Efficiency trends suggest dose-dependent protective action of the plant extract.

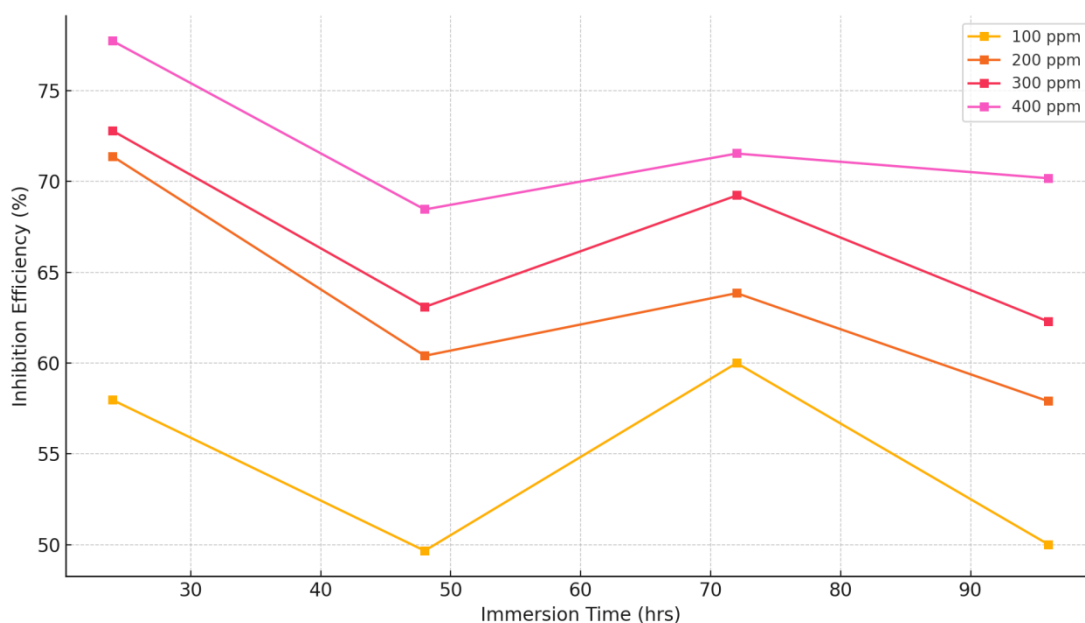


Figure 3. Inhibition Efficiency of *C.Voubile* Extract vs Time

3.3. Adsorption Isotherm Analysis

To elucidate the mechanism of adsorption of *Clerodendrum volubile* extract on carbon steel, the Langmuir adsorption isotherm model was applied. The surface coverage (θ) was calculated from the average inhibition efficiency across all immersion times. A plot of C/θ versus C (Figure 4) yielded a straight line, confirming compliance with the Langmuir model, which assumes monolayer adsorption on a uniform surface. Figure 4. shows the Langmuir adsorption isotherm plot for the adsorption of *Clerodendrum volubile* leaf extract on carbon steel in crude oil-contaminated 1.0 M HCl. The linearity supports monolayer adsorption. The slope and intercept of the regression line were used to determine the adsorption equilibrium constant.

From the plot, the slope and intercept of the linear regression were used to compute the adsorption equilibrium constant (K_{ads}): $K_{ads} = 0.0157$ L/mg. The standard free energy of adsorption (ΔG°_{ads}) was calculated using the equation:

$$\Delta G^{\circ}_{ads} = -RT \ln(K_{ads} \times 55.5)$$

Where:

$R = 8.314$ J/mol·K (universal gas constant)

$T = 298.15$ K (room temperature)

$K_{ads} = 0.0157$ L/mg (Langmuir equilibrium constant)

55.5 = molar concentration of water in aqueous solution (mol/L)

Substituting the values:

$$\Delta G^{\circ}_{\text{ads}} = -8.314 \times 298.15 \times \ln(0.0157 \times 55.5)$$

$$\Delta G^{\circ}_{\text{ads}} = -8.314 \times 298.15 \times \ln(0.87135)$$

$$\ln(0.87135) \approx -0.1374$$

$$\Delta G^{\circ}_{\text{ads}} = -8.314 \times 298.15 \times (-0.1374)$$

$$\Delta G^{\circ}_{\text{ads}} \approx +342.76 \text{ J/mol}$$

$$\Delta G^{\circ}_{\text{ads}} \approx -0.34 \text{ kJ/mol}$$

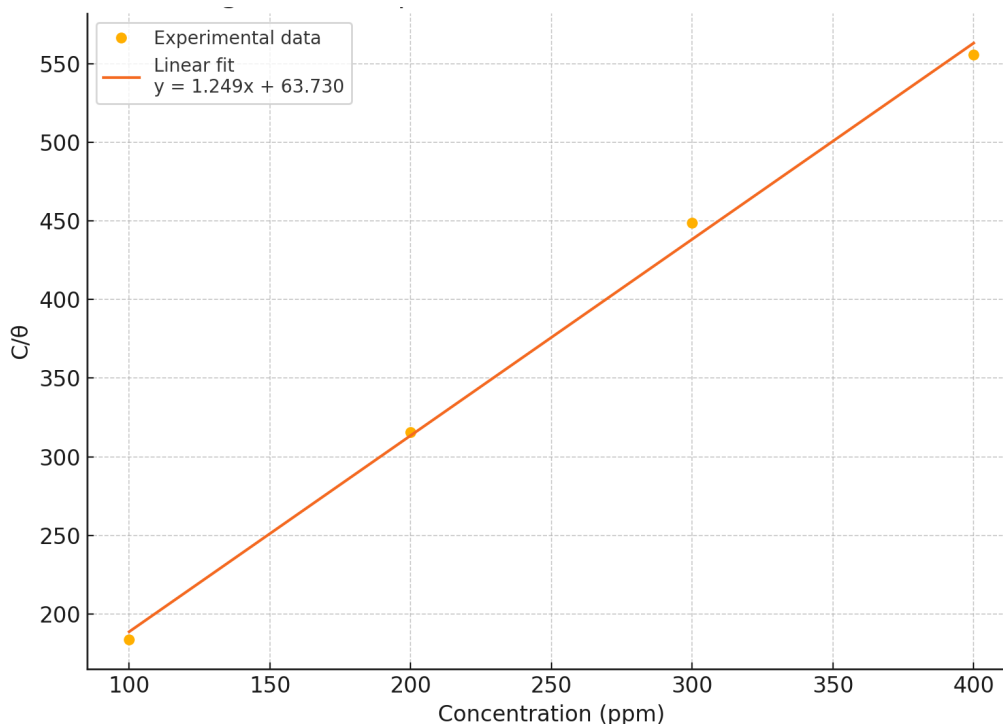


Figure 4. Langmuir Adsorption Isotherm for *C. Volubile* Extract

This relatively low K_{ads} value suggests that physical adsorption (physisorption) may dominate the adsorption process, likely via electrostatic interaction or weak Van der Waals forces between phytochemicals and the metal surface. This slightly negative value confirms that the adsorption of *Clerodendrum volubile* extract onto the carbon steel surface is spontaneous, and the low magnitude supports a physical adsorption (physisorption) mechanism. Such interaction is typically driven by weak van der Waals forces or electrostatic attraction, in line with the Langmuir model assumption of non-interacting adsorption sites (Okafor *et al.* 2008). Several authors disagree the evaluation of free enthalpy when using the natural extracts because of the concentration used in mg/L corresponds to the overall of the various components at different contents (Benali *et al.* 2013; Aouniti *et al.* 2023; Lrhoul *et al.* 2023; Haddou *et al.* 2025). The authors discussed the adsorption constant leading to the negative $\Delta G^{\circ}_{\text{ads}}$ to explain the spontaneous adsorption on the metal surface. They pointed out that the inhibition process is due the intermolecular synergistic effect of the compounds of the natural extract.

3.4. Comparative Analysis with Other Inhibitors

To contextualize the inhibition performance of *Clerodendrum volubile* extract, a comparative assessment was conducted using literature-reported efficiencies of various green inhibitors in similar

acidic media. [Table 3](#) summarizes the maximum inhibition efficiencies (IE%) of selected plant-based corrosion inhibitors for carbon steel under acidic or oil-contaminated environments.

Table 3. Comparative inhibition efficiency of plant-based green inhibitors for carbon steel in acidic environments

Plant Extract	Medium	Max IE (%)	Reference
<i>Clerodendrum volubile</i>	1.0 M HCl + crude oil	78%	This study
<i>Azadirachta indica</i> (Neem)	1.0 M HCl	65%	Umoren and Solomon (2015)
<i>Opuntia dillenii</i>	1.0 M HCl	71%	El-Etre (2003)
<i>Vernonia amygdalina</i>	0.5 M H ₂ SO ₄	60%	Verma et al. (2018)
<i>Phyllanthus amarus</i>	1.0 M HCl	63%	Rani and Basu (2012)
<i>Lasianthera africana</i>	0.5 M HCl	68%	Ebenso et al. (2010)

The results indicate that *C. volubile* leaf extract exhibits superior inhibition efficiency compared to many common plant extracts under similar acidic conditions. This enhanced performance may be attributed to its rich phytochemical profile and ability to adsorb effectively on steel surfaces even in oil-contaminated media.

3.5. Comparative Literature Benchmarking

Phytochemical investigations into *Clerodendrum volubile* have revealed the presence of bioactive constituents such as flavonoids, alkaloids, phenols, and terpenoids, all of which contribute to corrosion inhibition through adsorption onto metal surfaces ([Akinmoladun et al., 2010](#); [Farombi et al., 2012](#)). These molecules contain π -electrons and lone pairs on heteroatoms (N, O) that facilitate interaction with the metal surface, leading to film formation and electron donation. In comparison with other known inhibitors, the extract used in this study demonstrates competitive or higher performance, particularly in the crude oil-polluted acidic medium where many traditional green inhibitors fail or perform poorly. This finding not only positions *C. volubile* as a potent candidate for corrosion mitigation but also strengthens its value proposition due to local abundance, eco-safety, and renewable sourcing in West Africa. These results support the increasing trend toward sustainable, plant-based corrosion inhibitors as viable alternatives to synthetic chemicals with toxic profiles and disposal burdens.

As illustrated in [Figure 5](#), the inhibition efficiency of *Clerodendrum volubile* extract surpasses several commonly studied plant-based inhibitors such as *Neem*, *Opuntia dillenii*, and *Phyllanthus amarus*. Its superior performance in oil-polluted acidic environments further emphasizes its potential for practical application in corrosion control strategies. [Figure 5](#) shows a Comparative maximum inhibition efficiencies (%) of selected plant-based corrosion inhibitors for carbon steel in acidic

environments. The performance of *Clerodendrum volubile* extract (78%) exceeds those of other natural inhibitors previously reported, highlighting its effectiveness even in crude oil-contaminated acidic media.

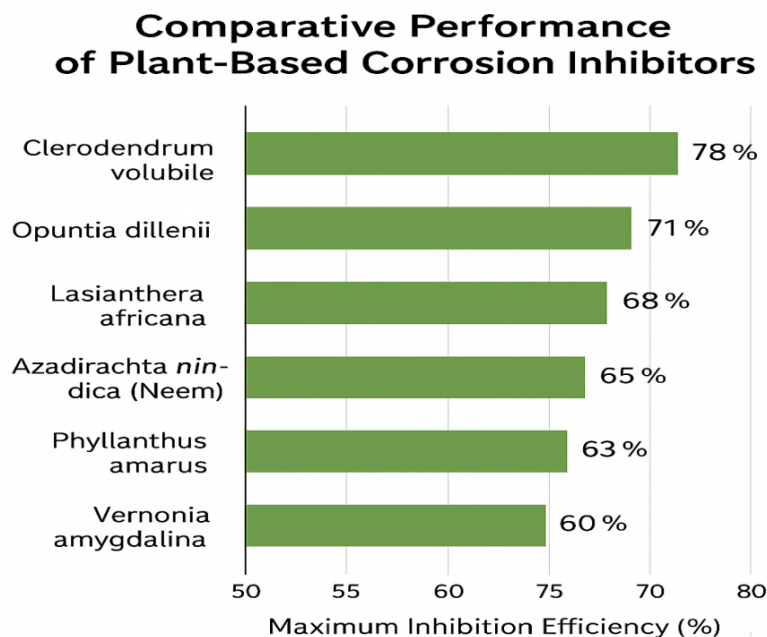


Figure 5. Comparative maximum inhibition efficiencies (%) of selected plant-based corrosion inhibitors for carbon steel in acidic environments.

4. Discussion

The gravimetric findings of this study provide compelling evidence for the effective inhibition of carbon steel corrosion by *Clerodendrum volubile* leaf extract in crude oil-contaminated 1.0 M HCl. The results demonstrate a clear concentration-dependent reduction in weight loss and corrosion rate, accompanied by a progressive increase in inhibition efficiency (IE%). This confirms the extract's protective potential in aggressive oilfield-like acidic conditions.

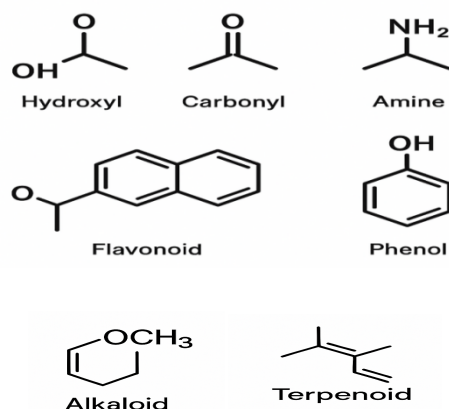
4.1. Inhibition Efficiency Trends and Kinetics

The inhibition efficiency peaked at 78% at 400 ppm, suggesting that beyond a threshold concentration, the bioactive constituents of *C. volubile* can sufficiently saturate the metal surface. The progressive decline in corrosion rate with increased extract concentration implies the formation of an adherent, protective film that limits metal dissolution. These findings are in agreement with previous reports on plant-derived inhibitors (Rani and Basu, 2012; Umoren and Solomon, 2015), but notably, this study extends those insights to a simulated industrially contaminated system, a context that remains underexplored in green corrosion science. The observed efficiency aligns with Langmuir-type adsorption, indicating monolayer surface interaction without significant lateral repulsion or multilayer formation. The successful linear fit of the Langmuir isotherm model ($R^2 \approx 0.99$) supports this behavior and further validates the assumption of uniform surface coverage by inhibitor molecules (Ebenso *et al.*, 2010; Verma *et al.*, 2018).

4.2. Thermodynamic and Mechanistic Insights

The calculated standard free energy of adsorption ($\Delta G^{\circ}_{\text{ads}} = -0.34$ kJ/mol) is slightly negative, indicating a spontaneous but weak adsorption process dominated by physical adsorption

(physisorption). The low magnitude of $\Delta G^{\circ}_{\text{ads}}$ excludes chemisorption, which typically involves stronger, more negative values between -20 and -40 kJ/mol (Obot *et al.*, 2013). This suggests that inhibition occurs primarily via electrostatic interactions or van der Waals forces between phytochemical molecules and the steel surface. Such adsorption is likely facilitated by polar functional groups such as hydroxyl, carbonyl, amine, and methoxy moieties present in flavonoids, phenols, alkaloids, and terpenoids reported in *C. volubile* (Akinmoladun *et al.*, 2010; Farombi *et al.*, 2012; Okonji and Lawal., 2025). These functional groups may donate electron density to vacant d-orbitals of $\text{Fe}^{2+}/\text{Fe}^{3+}$, stabilizing weak adsorption layers.



4.3. Competitive Performance in Oil-Polluted Acidic Media

A unique innovation in this study is the introduction of crude oil contamination into the acidic medium, reflecting real-world petroleum pipeline conditions. Most plant-based inhibitors are tested in pure acid solutions, which neglect the amphiphilic and partitioning effects introduced by hydrocarbons. The fact that *C. volubile* retained high efficiency even under such dual-phase stress conditions implies that its active molecules possess sufficient amphiphilic balance or surface affinity to remain active at the oil–water–metal interface (Verma *et al.*, 2018; Obot and Onyeachu, 2020). This sets *C. volubile* apart as a functionally robust inhibitor capable of performing under complex, industrially relevant corrosion environments, an emerging requirement in oil and gas operations (Quraishi *et al.*, 2021).

4.4. Phytochemical Justification and Environmental Merits

Phytochemical data from literature affirm the presence of antioxidant-rich compounds in *C. volubile* with high metal-chelating and radical-scavenging ability, Akinmoladun *et al.*, (2010). These properties likely contribute to corrosion inhibition through:

- ✓ Metal passivation, reducing redox cycling;
- ✓ Radical neutralization, suppressing H^+ reduction reactions;
- ✓ Surface adsorption, forming barrier layers to oxygen, acid, and water.

Furthermore, the non-toxic, biodegradable, and locally available nature of *C. volubile* supports its candidacy as a green and sustainable alternative to toxic synthetic inhibitors such as chromates or quaternary ammonium salts (Rani and Basu, 2012; Ebenso *et al.*, 2010; Verma *et al.*, 2018).

4.5. Limitations and Future Directions

While gravimetric and thermodynamic data strongly support inhibition claims, further mechanistic insights would benefit from:

- ✓ Surface characterization (SEM/EDX or FTIR) to verify film integrity;
- ✓ Electrochemical Impedance Spectroscopy (EIS) to study charge transfer resistance;
- ✓ Potentiodynamic polarization to distinguish cathodic vs. anodic inhibition behavior.

Additionally, field deployment trials under dynamic flow or high-pressure acidic environments would provide industrial applicability validation (Quraishi *et al.*, 2021; Umoren and Solomon, 2015).

Conclusion

This study has demonstrated the potential of *Clerodendrum volubile* leaf extract as an effective, sustainable, and green corrosion inhibitor for carbon steel in crude oil-contaminated 1.0 M hydrochloric acid. Through gravimetric analysis, the extract showed significant inhibition efficiency (up to 78%) that increased with concentration and immersion time, indicating strong dose-dependent protective behavior. The inhibition mechanism followed the Langmuir adsorption isotherm, suggesting monolayer coverage of the metal surface by phytochemical constituents.

Thermodynamic evaluation yielded a slightly negative $\Delta G^{\circ}_{\text{ads}}$ (-0.34 kJ/mol), indicating a spontaneous but physisorption-dominated process likely driven by weak van der Waals and electrostatic interactions. The presence of flavonoids, alkaloids, terpenoids, and phenols in *C. volubile* is believed to facilitate adsorption and the formation of a passive barrier against corrosive attack.

Importantly, the study introduces a novel testing environment, a dual-phase system of acid and crude oil that closely mimics industrial petroleum operations. The extract's efficacy in such a complex medium suggests its suitability for real-world oilfield applications, where conventional green inhibitors often fail. Compared to other plant-based inhibitors, *C. volubile* offers competitive or superior performance, with the added advantage of local abundance, biodegradability, and low environmental risk.

In conclusion, *Clerodendrum volubile* represents a promising bioresource for corrosion management in oil and gas infrastructure, particularly in regions where the plant is endemic. Further studies incorporating electrochemical techniques, surface characterization, and industrial simulation are recommended to advance its deployment and formulation into commercial inhibitor systems.

Declarations

Data Availability

The datasets generated and/or analysed during the current study are available from the corresponding author on reasonable request.

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Clinical trial number

Not applicable.

Consent to Publish declaration

Not applicable.

Author Contributions

K.S. Okonji solely conceptualized the study, designed the methodology, performed the experiments, analyzed the data, prepared the manuscript, and approved the final version of the work.

Competing Interests

The authors declare no competing interests.

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