Research Journal of Biotechnology and Life Science
Volume 6, Issue 1, 2026 (pp. 1-18)
www.abjournals.org

BIOCORROSION INHIBITION OF BURIED CARBON STEEL USING *CHROMOLAENA ODORATA* EXTRACTS

Obichi E. A., Tari-Ukuta P. M.*, Uzor O. S., Oka J. F., Nwachukwu G. A.,

Oteri V. O., and Adewumi B. E.

South-South Zonal Centre of Excellence, National Biotechnology Development Agency.

Regional Centre for Biotechnology and Bioresources Research, University of Port Harcourt, Nigeria.

*Corresponding Author's Email: maureywyte@gmail.com

Cite this article:

Obichi, E. A., Tari-Ukuta, P. M., Uzor, O. S., Oka, J. F., Nwachukwu, G. A., Oteri, V. O., Adewumi, B. E. (2026), Biocorrosion Inhibition of Buried Carbon Steel Using Chromolaena Odorata Extracts. Research Journal of Biotechnology and Life Science 6(1), 1-18. DOI: 10.52589/RJBLS-SCTQXMPB

Manuscript History

Received: 7 Mar 2026

Accepted: 9 Apr 2026

Published: 1 May 2026

ABSTRACT: *Microbiologically influenced corrosion (MIC) threatens buried carbon-steel infrastructure, particularly in petroleum-impacted soils where sulfate-reducing and biofilm-forming bacteria accelerate metal deterioration. Although synthetic biocides are commonly applied, environmental toxicity, microbial resistance, and operational concerns necessitate green alternatives. The potential of Chromolaena odorata, a phytochemically rich plant, remains largely unexplored in microbial corrosion mitigation. This study evaluated the inhibitory effects of aqueous C. odorata extract on microbial communities and corrosion of carbon steel in produced-water-enriched soil. The research aimed to determine the extract's biocorrosion-inhibitory capacity using gravimetric and metagenomic approaches. Soil samples were enriched with 200 mL of produced water per 1 kg of soil, and carbon-steel coupons (5 × 2 × 0.1 cm, 50g initial weight) were buried for 28 days. Microbial profiles were characterized via 16S rRNA sequencing, and corrosion rates were assessed by weight loss. Results indicated that the extract substantially suppressed corrosion-associated bacteria, including Pseudomonas (15.32% → 0%), Salinispora (6.75% →1.3%), Comamonas (8.45% → 1.2%), Clostridium (4.76% → 0.8%), and Pseudomonas balearica (1.91% → 0%). Corrosion rate decreased from 30.35mm/year in untreated coupons to 4.92 and 4.33 mm/year in treated coupons for ethanolic and aqueous extracts of C. odorata, respectively, representing 83.89% and 85.97% inhibition efficiency. While unclassified taxa remained high (~32%), treated soils exhibited a less corrosive microbiome structure. In conclusion, C. odorata extract selectively inhibits key MIC organisms, significantly reducing biocorrosion in buried steel. Further optimization through phytochemical fractionation, dose refinement (100mg/mL), and field validation is recommended. Adoption of this green inhibitor offers sustainable corrosion management, reduces reliance on toxic biocides, and supports eco-friendly pipeline maintenance in petroleum and water-distribution systems.*

KEYWORDS: Biocorrosion; Buried Carbon Steel; Green Inhibitors; *Chromolaena odorata* Extracts; Corrosion-Associated Bacteria.

Article DOI: 10.52589/RJBLS-SCTQXMPB
DOI URL: https://doi.org/10.52589/RJBLS-SCTQXMPB

INTRODUCTION

Microbiologically influenced corrosion (MIC) remains one of the most destructive forms of corrosion affecting buried steel pipelines used in the petroleum, water distribution, and industrial sectors. The combined effects of electrochemical reactions and microbial metabolism accelerate metal deterioration beyond the rates typically associated with abiotic corrosion (Videla, 2002; Nasser, 2019). This challenge is particularly pronounced in petroleum-impacted environments, where sulfate-reducing bacteria (SRB), acid-producing bacteria, and iron-oxidizing organisms thrive under anaerobic soil conditions. SRB, especially species within the genus *Desulfovibrio*, reduce sulfate into hydrogen sulfide (H_2S), a highly corrosive metabolite that undermines the structural integrity of carbon steel (Rajasekar et al., 2010; Lin & Ballim, 2012).

Conventional corrosion control methods rely heavily on synthetic biocides such as glutaraldehyde, THPS, and quaternary ammonium compounds. Although they are widely used, these chemicals pose major drawbacks, including ecological toxicity, high cost, accumulation in effluent streams, and the increasing emergence of resistant microbial strains (Stewart & Costerton, 2001; Fraise, 2002). This has prompted extensive scientific interest in plant-derived alternatives that provide antimicrobial and metal-protective properties without the environmental burden posed by synthetic biocides.

Chromolaena odorata, a tropical aromatic shrub common in West Africa, contains bioactive phytochemicals such as flavonoids, phenolics, terpenoids, and tannins capable of inhibiting microbial growth and forming protective films on metal surfaces (Lavanya & Brahmaprakash, 2011; Vijayaraghavan et al., 2017). Previous studies have demonstrated its antimicrobial and antioxidant activities (Odutayo et al., 2017; Vijayaraghavan et al., 2018; Ogunniran et al., 2025; Phetburom et al., 2025) however, limited data exist concerning its efficacy as a natural inhibitor of biocorrosion in buried steel environments. Considering the abundance, low cost, and ecological safety of *C. odorata*, evaluating its potential as a biocorrosion inhibitor is scientifically and industrially relevant.

This study investigates the inhibitory performance of ethanol and aqueous extracts of *C. odorata* on buried carbon-steel coupons in produced-water-enriched soil. By integrating chemical and microbiological perspectives, this research provides a foundation for using *C. odorata* as a green, sustainable corrosion-control alternative in pipeline systems.

MATERIALS AND METHODS

Collection of Soil, Produced Water, and Plant Samples

Produced water was collected from Seplat Energy PLC at the Ohaji-Egbema Flow Station in Imo State, Nigeria, using sterile 4-L high-density polyethylene containers. Samples were immediately transported to the laboratory for physicochemical characterization and subsequent use in soil enrichment. Soil samples were collected from a depth of 1 meter using a stainless-steel soil auger (Eijkelkamp 04.15.SA, Netherlands) at the University of Port Harcourt Innovation Park. The soil type was clay-loam, and it was stored in sealed plastic containers to preserve its native microbial load.

Article DOI: 10.52589/RJBLS-SCTQXMPB
DOI URL: https://doi.org/10.52589/RJBLS-SCTQXMPB

Fresh *Chromolaena odorata* leaves were harvested from wild vegetation surrounding the University of Port Harcourt. The samples were authenticated at the Department of Plant Science and Biotechnology Herbarium, where they were assigned voucher numbers UPH/P/412 and Accession No. 001. After verification, the leaves were cleaned with distilled water and transported for extraction procedures.

Preparation of Carbon-Steel Coupons

Carbon-steel coupons (composition: 0.1% C, 0.4% Mn, 0.03% S, 0.06% P, and 99.41% Fe) were fabricated at the University of Port Harcourt Science and Engineering Workshop. The coupons dimension measured 4 cm × 3 cm × 1.7 cm. Surface preparation followed NACE Standard RP0775 (2005). Each coupon was polished sequentially with 400-, 600-, and 1200-grit abrasive papers (Matador®, Germany) to obtain a smooth surface, followed by rinsing in deionized water and degreasing in absolute ethanol (Sigma-Aldrich, Germany). Rust removal was achieved by immersion in 20% hydrochloric acid. After drying, each coupon was weighed using an Adam Equipment PW254 analytical balance (United Kingdom), with readability of 0.0001g. The initial weight of each coupon (Wi) was recorded before the corrosion experiment.

Physicochemical Analysis of Soil and Produced Water

Physicochemical properties were analyzed following AOAC (1990) and UNEP (2011) standard procedures. Soil pH was measured using a Hanna Instruments HI2211 digital pH meter (USA) after preparing a 1:2 soil-to-water suspension and allowing equilibrium. Moisture content was determined using a Memmert UF55 drying oven (Germany) at 105^0C for 6 hours. Salinity and chloride were quantified by titrating the soil extract with 0.02N $AgNO_3$ (BDH Chemicals, UK) using potassium chromate indicator. Sulfate and phosphate concentrations were evaluated using a Hach DR2800 spectrophotometer (USA) with reagent pillows. Heavy metals, including Cadmium (Cd), Iron (Fe), Zinc (Zn), and Lead (Pb) were measured using a PerkinElmer AAnalyst 400 Atomic Absorption Spectrophotometer (USA). These analyses were essential for confirming the soil's suitability for SRB enrichment and biocorrosion simulation.

Soil Enrichment and Biocorrosion Simulation

To stimulate sulfate-reducing bacterial activity, produced water was mixed thoroughly with the collected soil and incubated anaerobically for 21 days at room temperature. The enriched soil was then divided into experimental units and labelled S1, S2, S3, and S4 for the corrosion study. Where S1 represents the soil from baseline setup containing buried coupons at Day 0, S2 represents soil from setup containing buried coupons without any treatment at Day 28 (Control setup), S3 represents soil from setup containing coupons treated with aqueous extracts of *C. odorata,* and S4 represents soil from setup containing buried coupons treated with ethanol extracts of *C. odorata*.

***Chromolaena odorata* Processing and Extract Formulation**

The cold extraction method was employed for the extraction, according to the methods of Umar et al. (2016) and Amise et al. (2016), but with slight modification using fresh *Chromolaena odorata* leaves. Randomly growing *C. odorata* leaves were harvested from a bush nearby, rinsed under running water, spread on a table to dry with the aid of an air-blower. After drying, the plants were macerated into small pieces and pulverized with a locally fabricated grinder

Article DOI: 10.52589/RJBLS-SCTQXMPB
DOI URL: https://doi.org/10.52589/RJBLS-SCTQXMPB

into fine powder, then put in their separate plates and labelled accordingly. (Miralrio & Vázquez, 2020). The powdered material was weighed for extract formulation using an Adam PW254 balance. 400g/mL of aqueous extract was prepared by submerging 100g of *C. odorata* powder in 250 mL of distilled water, likewise ethanol extract (400g/mL) was prepared using the same mass-to-volume ratio with analytical-grade absolute ethanol (Merck, Germany). All two mixtures were kept to stand for 24 hours at ambient temperature and agitated intermittently. The extracts were gotten by percolation technique filtered through Whatman No. 1 filter paper, producing *C. odorata* aqueous extract (CoAE) and *C. odorata* ethanolic extract. (CoEE). The extracts were stored in sterile airtight amber bottles at 4^0C until required (Briggs et al., 2019).

Phytochemical Profiling Using HPLC–MS

Phytochemical identification was conducted using an Agilent 1290 Infinity II High-Performance Liquid Chromatography system coupled with an Agilent 6470 Triple Quadrupole Mass Spectrometer (USA). Chromatographic separation was achieved using an Agilent ZORBAX Eclipse Plus C18 column (4.6 × 150 mm, 5 µm). The mobile phase consisted of Solvent A (water + 0.1% formic acid) and Solvent B (acetonitrile + 0.1% formic acid). A gradient elution from 10% to 95% Solvent B over 35 minutes was applied at a flow rate of 0.4 mL/min. The injection volume was 5 µL, and the detector was set to 280 nm.

Mass spectrometry was performed in electrospray ionization (ESI) mode using both positive and negative ion scans. Operating parameters included a capillary voltage of 3.5 kV, drying gas temperature of 300^0C, gas flow rate of 11 L/min, and nebulizer pressure of 35 psi. Phytochemicals were identified by matching retention times and fragmentation patterns with reference standards and METLIN and HMDB databases. Quantification followed the procedures of Briggs et al. (2019) and Ighodaro et al. (2016).

Conditioning and Burying of Metal Coupons

The pre-cleaned carbon-steel coupons were submerged for 24 hours in either ethanol or aqueous extracts of *C. odorata* at concentrations of 400g/L for extract conditioning. Control coupons were immersed in distilled water. After conditioning, the coupons were buried in the designated enriched soil (S2, S3 and S4) contained within plastic bioreactors. The setups were stored under anaerobic conditions for 28-day burial periods, following the protocol described by Adindu et al. (2017) and Briggs et al. (2019).

Gravimetric Corrosion Analysis

The level of corrosion in the system and the efficacy of the treatment biocides on the coupons were examined using gravimetric corrosion analysis. After the 28 days, each coupon was retrieved from the soil, washed, and cleaned to remove corroded spots and reweighed in triplicates, with an average weight recorded as the final weight (W_f). Metal weight loss by corrosion (Wi – Wf) of the coupons was calculated, and corrosion rate (CR) was calculated using the Rohrback Cosasco Systems (1999) equation I:

$$CR = \frac{22{,}300\,(Wi - Wf)}{D \times A \times T} \quad \text{(I)}$$

Where D is the metal density, A is the exposed area, and T is the exposure time.

Article DOI: 10.52589/RJBLS-SCTQXMPB
DOI URL: https://doi.org/10.52589/RJBLS-SCTQXMPB

Inhibition efficiency (IE) and surface coverage (Θ) of the extracts were calculated using equations II and III, respectively, following Immanuel et al. (2016). Adsorption behavior of the extracts on the coupons was assessed using the Langmuir isotherm.

$$(IE) = 100\,[1 - (CR2/CR1)] \quad (II)$$

Where CR1 is the corrosion rate in the absence of the inhibitor, and CR2 is the corrosion rate in the presence of the inhibitor.

$$\Theta = IE/100 \quad (III)$$

Metagenomic Analysis

To evaluate the microbial community responses to the extract biocides applied on the coupons, soil samples from baseline (day 0), control (day 28), and treated setups were subjected to bacterial DNA extraction using Zymo Research Quick-DNA Fungal/Bacterial MiniPrep Kits. Sequencing of 16S rRNA amplicons was conducted on an Illumina MiSeq platform in paired-end read mode (Illumina Inc., USA), to track microbial community population in the biocorrosion ecosystems and the evolution of the microbiomes in reaction to the *C. odorata* extracts. Bioinformatic analysis for Taxonomic Assignment and determination of microbial community structure and diversity, respectively, was performed using QIIME2 version 2021.8 bioinformatic pipeline following Nasser (2019). The Operational Taxonomic Unit (OTU) picking was carried out with the de novo OTU picking method of QIIME2.

Gravimetric corrosion analysis, phytochemical profiling, and metagenomic evaluation were applied to elucidate the mechanisms by which the plant extract suppresses microbial activity and reduces corrosion rates.

Statistical Analysis

Data from the gravimetric analysis were processed using SPSS version 25 to ascertain degrees of significance. One-way ANOVA examined the effects of the two treatments and the control on the percentage weight loss of metals during the 28-day biocorrosion investigation and determined statistical significance ($p < 0.05$). Tukey HSD was applied for post-hoc comparisons among the treatments.

RESULTS

The physicochemical analysis of the soil from The University of Port Harcourt Innovation Park used for this study revealed a clayey-loam texture with an acidic pH of 5.8 and temperature of 26.8^0C. Moisture and salinity content were 14.4% and 120mg/kg respectively, indicating a high moisture and low salinity content. Phosphate, nitrate and sulphate contents were 1.89mg/kg, 39.63mg/kg and 104mg/kg, respectively. Heavy metals analysis revealed low Cd, Fe, Zn and Pb values of 0.03mg/kg, 4.20mg/kg, 0.56mg/kg and 0.27mg/kg respectively.

The phytochemical constituents in the aqueous and ethanolic extracts of *C. odorata* is presented in Table 1.

Article DOI: 10.52589/RJBLS-SCTQXMPB
DOI URL: https://doi.org/10.52589/RJBLS-SCTQXMPB

Table 1: Phytochemical Constituents of *C. odorata* Extracts

Phytochemical Constituents	CoAE	CoEE
Phytate (%)	3.717	3.057
Tanin (%)	1.892	3.764
Oxalate (%)	1.957	1.609
Saponin (%)	1.479	0.947
Trypsin-inhibitor (%)	1.734	2.285
Total Alkaloids (g/100g)	12.583	15.370
Total Glycosides (g/100g)	3.879	3.616
Total Flavonoids (g/100g)	43.215	54.864
Total Phenolics (g/100g)	242.824	259.953

LEGEND: CoAE – *C. odorata* Aqueous Extract; CoEE – *C. odorata*

Ethanolic Extract

The corrosion rate (mm/year), inhibition efficiency (%), and surface coverage (Θ) calculated using data from the metal weight loss of coupons buried in the simulated soil setups in the presence (400g/L concentration) and absence of the inhibitors are presented in Table 2. The corrosion rate (CR) for the control setup without any inhibitor extract (S2), as seen in Table 2, is 30.35mm/year, while the corrosion rate of the aqueous extract of *C. odorata* setup (S3) is 4.92mm/year; the inhibition efficiency (IE) and the surface coverage are 83.89% and 0.84, respectively. Likewise, the CR, IE, and surface coverage of the ethanolic extract of *C. odorata* setup (S4) are 4.33mm/year, 85.97%, and 0.86, respectively.

Table 2: Corrosion Rate, Inhibitor Efficiency, and Surface Coverage for Biocorrosion Experiment with 400g/L Inhibitor Concentration.

Setup	Concentration (g/L)	Corrosion Rate (mpy)	Inhibitor Efficiency (%)	Surface Coverage (Θ)
S2	0	30.35		
S3	400	4.92	83.89	0.84
S4	400	4.33	85.97	0.86

LEGEND: S2 – Control setup without any inhibitor extract; S3 - Treatment with *C. odorata* aqueous extract; S4 – Treatment with *C. odorata* ethanol extract

The one-way ANOVA, which examined the treatments' effects on weight loss percentages compared to the control (without treatment), demonstrated that there was a statistically significant difference in the mean percentage of weight loss between two groups ((F (4, 15) = [12.662], p = 0.000) and (F (4, 15) = [10.604], p = 0.000)), respectively, indicating that there is no chance that such large F-values could be an accident. Post hoc (multiple comparison) analysis using the Tukey HSD test revealed that the mean value of % weight loss was significantly different between control and the treatments for CoAE (p = 0.001, 95% C.I. = [0.4010, 1.4804]); and CoEE (p = 0.001, 95% C.I. = [0.3339, 1.4133]). However, there was no significant difference between the individual samples, indicating the effectiveness of both aqueous and ethanolic extracts of *C. odorata* in inhibiting the biocorrosion of the buried carbon steel.

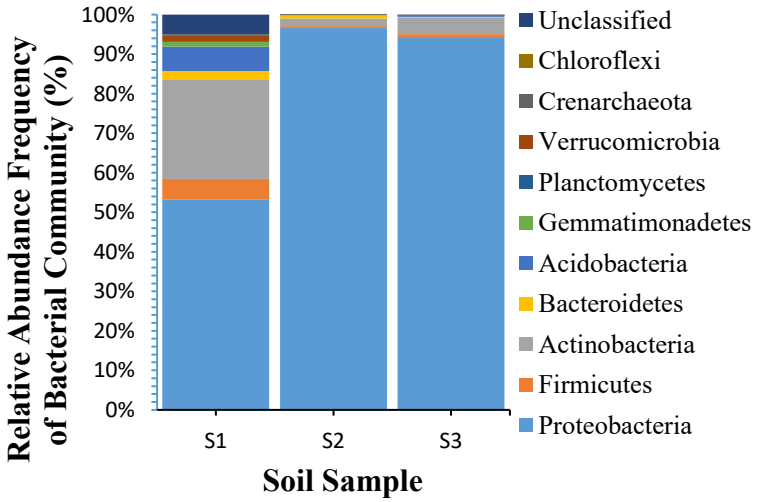
Article DOI: 10.52589/RJBLS-SCTQXMPB
DOI URL: https://doi.org/10.52589/RJBLS-SCTQXMPB

The metagenomic results presented in Figures 1 through 6 and the quantitative data in Table 3 collectively show the shifts in microbial community composition following treatment of the coupons (S3) with the aqueous extract of *Chromolaena odorata*. The baseline sample (S1) in Figures 1–6 was dominated by unclassified organisms, accounting for 99.192% of all detected species, as shown in Table 3, indicating a highly diverse but largely unresolved microbial population. In contrast, the untreated control sample at 28 days (S2) showed a reduction in unclassified taxa to 95.837%, with notable increases in identifiable species such as *Ochrobactrum intermedium* at 2.201% and *Pseudomonas balearica* at 1.907%, demonstrating microbial proliferation in the absence of treatment.

In the treated sample (S3), Figures 1–6 illustrate a distinct reduction in the relative abundance of several taxonomically resolved groups. Table 3 shows that unclassified organisms remained high at 97.652%, but the extract-treated sample contained markedly lower proportions of species commonly associated with biofilm formation and biocorrosion. For example, *Pseudomonas balearica*—present at 0.337% in the baseline sample and 1.907% in the control-was eliminated in the treated sample, registering 0% abundance. Similarly, *Faecalibacterium prausnitzii*, which appeared at 0.337% in the baseline and 0.002% in the control, dropped to 0.024% in the treated sample. *Streptomyces lanatus* increased slightly from 0.060% in baseline to 0.083% in the treated sample, while *Prevotella copri* declined from 0.067% in baseline to 0.012% in the treated environment. *Ochrobactrum intermedium*, a species detected at 2.201% in the control, remained at a similar value of 2.234% in the treated sample, suggesting selective non-inhibition of this organism.

Across the taxonomic levels depicted in Figures 1–6—Phylum (Figure 1), Class (Figure 2), Order (Figure 3), Family (Figure 4), Genus (Figure 5), and Species (Figure 6)—the treated sample displayed a clear suppression of multiple genera known for corrosive activities. The aqueous extract of *Chromolaena odorata* inhibited genera such as *Pseudomonas*, *Salinispora*, *Sphingomonas*, *Comamonas*, *Pseudoxanthomonas*, *Enterobacter*, *Clostridium*, *Rhodanobacter*, *Marinobacter*, *Ochrobactrum*, *Cupriavidus*, *Bosea*, *Sphinopyxis*, *Mycoplana*, *Kribbella*, *Phenylobacterium*, *Dokdonella*, *Chitinophaga*, *Azospirillum*, and *Geosporobacter/Thermotalea*, all of which are visible in the genus-level distribution of Figure 5.

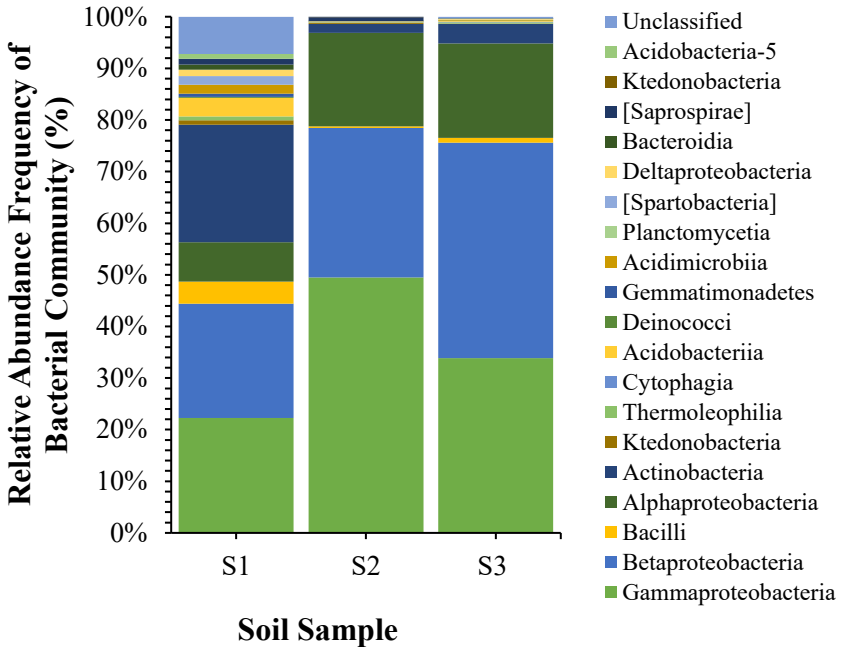
Figure 1: Relative Abundance of Bacterial Community Phylum Taxa



LEGEND: S1- Baseline soil sample (Day 0); S2- Control soil sample (No extract treatment); S3- Treated (with *C. odorata* aqueous extract) coupons soil sample

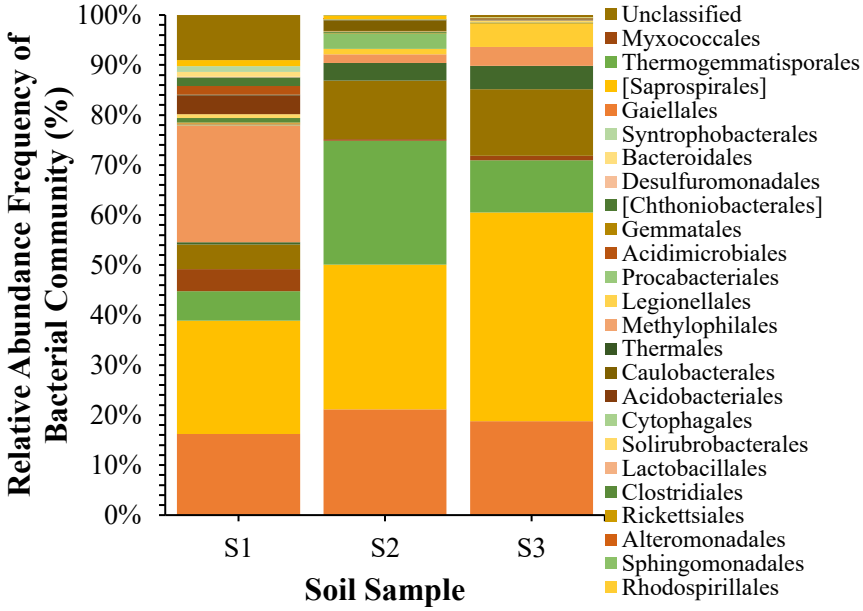
Article DOI: 10.52589/RJBLS-SCTQXMPB
DOI URL: https://doi.org/10.52589/RJBLS-SCTQXMPB

Figure 2: Relative Abundance of Bacterial Community Class Taxa



LEGEND: S1- Baseline soil sample (Day 0); S2- Control soil sample (No extract treatment); S3- Treated (with *C. odorata* aqueous extract) coupons soil sample

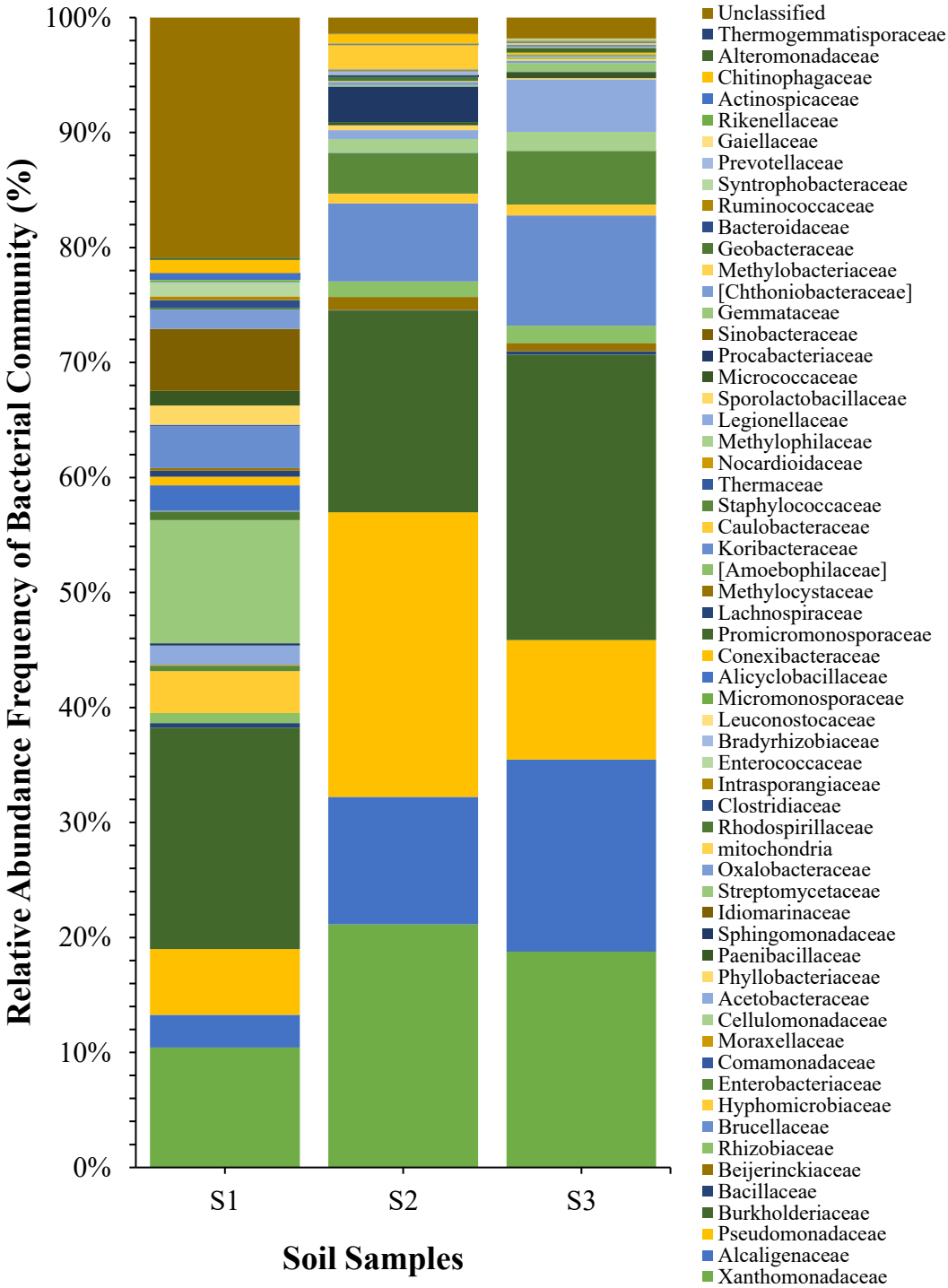
Figure 3: Relative Abundance of Bacterial Community Order Taxa



LEGEND: S1- Baseline soil sample (Day 0); S2- Control soil sample (No extract treatment); S3- Treated (with *C. odorata* aqueous extract) coupons soil sample

Article DOI: 10.52589/RJBLS-SCTQXMPB
DOI URL: https://doi.org/10.52589/RJBLS-SCTQXMPB

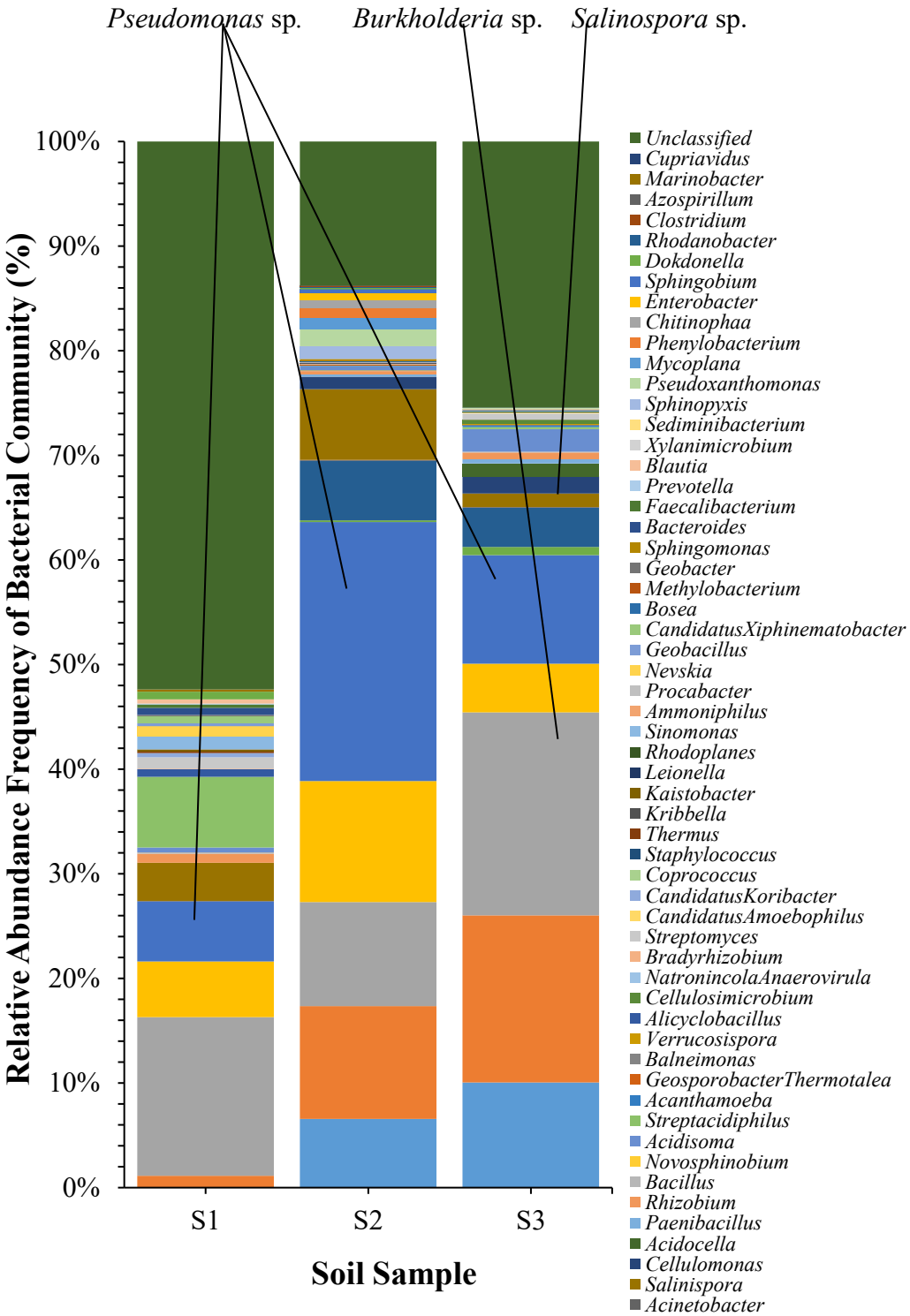
Figure 4: Relative Abundance of Bacterial Community Family Taxa



LEGEND: S1- Baseline soil sample (Day 0); S2- Control soil sample (No extract treatment); S3- Treated (with *C. odorata* aqueous extract) coupon soil sample

Article DOI: 10.52589/RJBLS-SCTQXMPB
DOI URL: https://doi.org/10.52589/RJBLS-SCTQXMPB

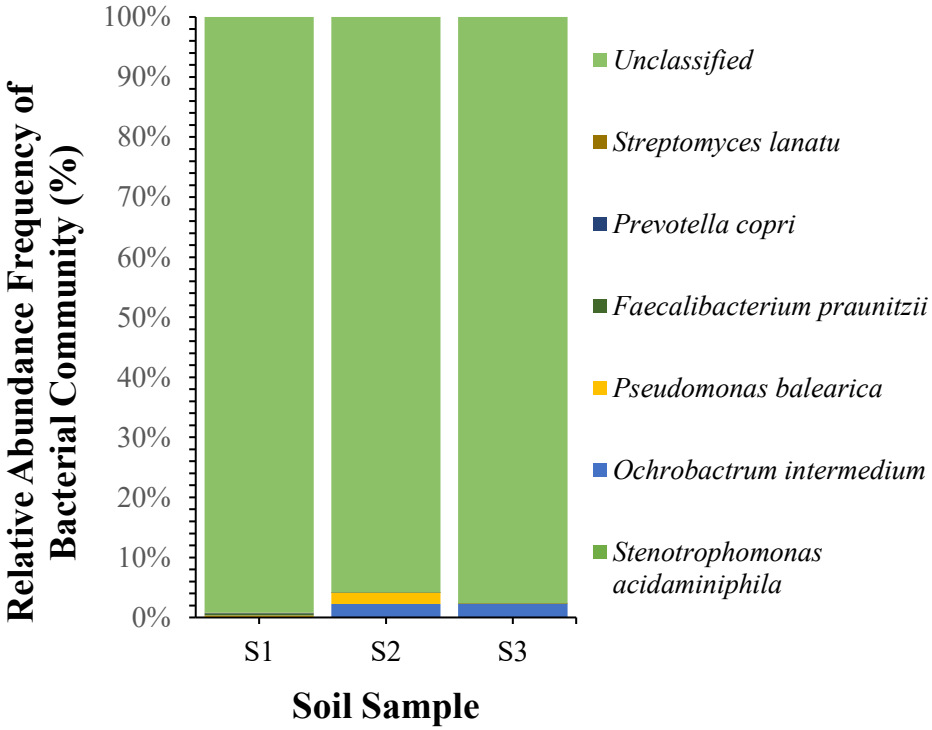
Figure 5: Relative Abundance of Bacterial Community Genus Taxa



LEGEND: S1- Baseline soil sample (Day 0); S2- Control soil sample (No extract treatment); S3- Treated (with *C. odorata* aqueous extract) coupons soil sample

Article DOI: 10.52589/RJBLS-SCTQXMPB
DOI URL: https://doi.org/10.52589/RJBLS-SCTQXMPB

Figure 6: Relative Abundance of Bacterial Community Species Taxa



LEGEND: S1- Baseline soil sample (Day 0); S2- Control soil sample (No extract treatment); S3- Treated (with *C. odorata* aqueous extract) coupons soil sample

Table 3: Relative Percentage Abundance (%) of Classified and Unclassified Species

S/N	Species	S1	S2	S3
1	*Stenotrophomonas acidaminiphila*	0	0	0.028
2	*Ochrobactrum intermedium*	0	2.234	2.201
3	*Pseudomonas balearica*	0.337	1.907	0
4	*Faecalibacterium praunitzii*	0.337	0.002	0.024
5	*Prevotella copri*	0.067	0.005	0.012
6	*Streptomyces lanatus*	0.06	0.015	0.083
7	Unclassified	99.192	95.837	97.652

LEGEND: S1- Baseline soil sample (Day 0); S2- Control soil sample (No extract treatment); S3- Treated (with *C. odorata* aqueous extract) coupons soil sample

DISCUSSION

The findings of this study reveals the environmental conditions of the soil within which the pipeline material is buried and the complex interactions which occur in the field, contributing to the diversity, abundance and activities of the microbial community in the ecosystem. The acidic pH (5.8) of the soil in this study is critical because both low and slightly acidic pH values are known to influence corrosion rates significantly. The corrosion behavior of metals are significantly impacted by pH fluctuations which occur with a high concentration of microbes

Article DOI: 10.52589/RJBLS-SCTQXMPB
DOI URL: https://doi.org/10.52589/RJBLS-SCTQXMPB

and electrochemical processes such as solubility of metal ions, production of corrosive byproducts and increased microbial activity. Research by Hou et al. (2016) and Wu et al. (2010) shows that a lower pH might accelerate corrosion by making the surrounding environment more hostile and promoting metal breakdown. While a very acidic or basic pH can point to a corrosive environment, it's important to remember that corrosion is complex and that several other variables hasten the deterioration of underground pipes. Although the temperature of the soil environment used in this study was minimal (26.8^0C), higher soil temperature enhances chemical reactions and microbial activity which speed up the degradation of buried metals, thereby increasing corrosion rates. While this study did not investigate the effects of varying temperatures on buried pipelines, research by Li et al. (2017) and Immanuel et al. (2016), shows that there is a positive link between temperature and corrosion rates. When soil moisture levels are high, underground ferrous metal pipes are more likely to corrode (Wasim et al., 2018). The ideal moisture level for any particular soil varies from one soil type to another. The clayey-loam soil used in this study which has higher water retention because of its tiny pore spaces may have contributed to the increased corrosion of the metals, as corrosion rate and mass loss both rise with increasing moisture levels, reaching a maximum at 15-20% water content. This corroborates with the results of other studies (Song et al. 2017; Qin et al. 2018). Even though high salinity levels are known to accelerate biofilm formation and biocorrosion, the low salinity (120mg/kg) of the soil in this study suggests that microbial activities, including those of SRB, were likely limited. It is possible that other factors, such as the presence of specific nutrients or environmental conditions that are more favorable to microbial growth, played a more prominent role in influencing corrosion in this study. Additionally, the lack of high salinity may have hindered the formation of dense SRB biofilms, which are typically associated with increased corrosion rates in more saline environments. The presence of nitrate, sulfate, and phosphate in the soil can significantly influence microbial corrosion, known as microbiologically influenced corrosion (MIC), and may alter the behavior of corrosion-influencing bacteria and fungi. Specifically, studies focusing .on the synergistic effects of nitrate, sulfate, and phosphate, along with their relationship to microbial biofilm formation and the production of corrosive byproducts, could shed light on how these ions influence corrosion rates.

The HPLC-MS phytochemical screening of the aqueous and ethanol extracts of *C. odorata* revealed that various plants secondary metabolites such as alkaloids, flavonoids, tannins, glycosides, phenolics, phytates, saponins, oxalates, are present in the two extracts, but in varying concentrations (Table 1). Other researchers have reported the presence of these phytochemicals in other green plant corrosion inhibitors (Buchweishaija, 2009; Umar et al., 2016; Miralrio & Vázquez, 2020; Pourmohseni et al., 2024). According to many studies (Stanley et al., 2016; Agarry et al., 2018; Briggs et al., 2019), naturally occurring compounds, including plant extracts, which are considered ecologically benign, have shown to be very effective in preventing and managing biocorrosion. Based on the results of this investigation (Table 2), the phytochemicals discovered in the aqueous and ethanolic extracts of *C. odorata* effectively prevented biocorrosion on the buried metal steels. Table 1 shows that the *C. odorata* extracts used had significant amounts of phytochemicals, which may explain why the inhibitors worked so well. Rao and Mulky (2023) observed that the phytochemicals in *Phyllanthus amarus*'s aqueous extract had a high concentration of tannins, alkaloids, and phenolic compounds, indicating its bio-potency and antibacterial properties, which is in agreement with our findings. Secondary metabolites can interact with the microbial community in the soil, altering the balance of microbial populations and reducing the overall activity of

Article DOI: 10.52589/RJBLS-SCTQXMPB
DOI URL: https://doi.org/10.52589/RJBLS-SCTQXMPB

microorganisms that promote biocorrosion (Stanley et al., 2016, Rao & Mulky, 2023). Phenolics and flavonoids can act as chelating agents, binding with metal ions and reducing their availability for corrosion reactions, while alkaloids exhibit antimicrobial and antioxidative properties in biocorrosion inhibition. Tannins and flavonoids can also form complexes with metal surfaces, creating a protective layer that shields the steel from further corrosion (Al-Amiery et al., 2023).

The findings of the metagenomic analysis demonstrate that the aqueous extract of *Chromolaena odorata* caused significant shifts in the microbial community structure of the treated soil (S3), resulting in a clear reduction of several genera commonly associated with microbiologically influenced corrosion (MIC). These results are consistent with earlier reports indicating that phytochemical-rich plant extracts possess broad antimicrobial and corrosion-inhibitory properties. According to Vijayaraghavan et al. (2017), *C. odorata* contains potent secondary metabolites—such as flavonoids, tannins, saponins, and phenolic acids—that exert strong antimicrobial effects against bacteria capable of biofilm formation and metal deterioration. The suppression of multiple corrosive genera in the present study, including *Pseudomonas*, *Comamonas*, *Clostridium*, *Marinobacter*, *Sphingomonas*, and *Enterobacter*, therefore aligns with the biochemical potential previously attributed to this plant.

The complete elimination of *Pseudomonas balearica* in the treated soil further supports the inhibitory action of *C. odorata* against organisms with established biofilm-forming capability. According to Lin and Ballim (2012), species within the *Pseudomonas* genus are among the most persistent contributors to biofilm-mediated corrosion, enhancing electron transfer and accelerating pitting in buried steel structures. Their disappearance in the treated soil (from 1.907% in the control to 0%) suggests that the extract may have directly inhibited their growth or disrupted their ecological competitiveness. Similar suppression of *Pseudomonas* spp. by plant-based inhibitors was reported by Eddy and Ebenso (2010), who demonstrated that phytochemical-rich extracts significantly impair the metabolic activities of biofilm-producing bacteria.

The extract also inhibited several other microbial genera that contribute to MIC through various mechanisms. Members of *Pseudomonas, Clostridium*, *Salinispora*, *Comamonas*, *Sphingomonas, Geosporobacter*, *Phenylobacterium, Kribbella*, *Cupriavidus*, and *Dokdonella*—all detected in the untreated control but significantly reduced in the treated soil—are recognized for fermentative, acid-producing, or metal-respiring processes associated with corrosion of buried oil pipelines. The decline of these groups corresponds to the extract's broad-spectrum antimicrobial effect and explains the reduced representation of many classified taxa in the S3 (treated) relative to the S2 (untreated). According to Rajasekar et al. (2010), such organisms accelerate electron transfer reactions and modify soil chemistry in ways that promote steel deterioration. The broad-spectrum inhibition effects observed here agree with previous findings by Immanuel et al. (2016), who reported that plant extracts with high concentrations of phenolics inhibit diverse microbial groups involved in MIC through membrane disruption, enzyme inhibition, and biofilm interference.

The relative abundance of unclassified microbial taxa remained high in all samples, including the treated soil (97.652%). This is typical of environmental microbiomes, where a substantial proportion of soil microorganisms remain unculturable or poorly annotated. According to Vartoukian et al. (2010), up to 99% of soil microbes are unculturable under laboratory conditions, meaning that changes in classified taxa may underestimate the full ecological

Article DOI: 10.52589/RJBLS-SCTQXMPB
DOI URL: https://doi.org/10.52589/RJBLS-SCTQXMPB

impact of the treatment. Nonetheless, the reduction in key corrosive genera strongly indicates that *C. odorata* extract altered the soil microbiome in ways that reduced its overall corrosive potential. The high percentage of unclassified sequences, especially in the baseline (99.192%) and treatment setups, underscores the complexity of microbial communities in such environments and the challenges of fully characterizing them through metagenomic approaches.

The persistence of *Ochrobactrum intermedium* at similar levels in both the treated soil (2.234%) and the control (2.201%) suggests selective non-inhibition of this organism. According to Oshiki et al. (2013), some soil bacteria may possess natural tolerance to plant-derived antimicrobials depending on their membrane composition and metabolic flexibility. However, since *Ochrobactrum* is not a primary driver of sulfate reduction or metal-adjacent corrosion processes, its persistence does not undermine the inhibitory effectiveness of the extract.

The microbial shifts observed in this study are strongly correlated with the corrosion-inhibition mechanisms documented for plant extracts. According to Al-Amiery et al. (2024), phytochemicals inhibit corrosion through multiple pathways, including adsorption onto metal surfaces, formation of protective films, and direct antimicrobial effects against corrosion-inducing microbes. These mechanisms align with the present findings, where the extract reduced the abundance of several organismal groups known to facilitate MIC progression in buried steel environments. The consistency of these results with previous corrosion studies suggests that *C. odorata* possesses the necessary phytochemical profile for effective field-scale application.

Furthermore, the results complement earlier reports describing *C. odorata* as an effective inhibitor of chemical and microbial deterioration in metal systems. According to Lavanya and Brahmaprakash (2011), the strong antioxidant capacity of this plant's extracts helps neutralize reactive metabolites such as sulfide ions, thereby slowing the electrochemical processes that drive corrosion. The present study provides microbial-level evidence that supports this hypothesis by demonstrating that the extract not only influences chemical pathways but also reshapes the microbial ecology responsible for initiating and accelerating corrosion reactions.

CONCLUSION

The findings of this study clearly establish that the aqueous and ethanolic extract of *Chromolaena odorata* possesses substantial potential as a natural, eco-friendly inhibitor of microbiologically influenced corrosion in buried carbon-steel environments. By integrating gravimetric evaluation with high-resolution metagenomic profiling, the study provides compelling evidence that the extract acts through dual mechanisms: direct suppression of corrosion-associated microbial communities and indirect interference with corrosion-supporting biochemical pathways. Lower corrosion rates in the treatment setups as compared to higher corrosion rate in the control set up, with inhibition efficiency of 80% and above in the two treatments showed the efficacy of the extracts in inhibiting the corrosion of the buried metals.

The metagenomic results revealed that treatment with *C. odorata's* aqueous extract significantly altered the microbial ecology of the soil by reducing the abundance of multiple

Article DOI: 10.52589/RJBLS-SCTQXMPB
DOI URL: https://doi.org/10.52589/RJBLS-SCTQXMPB

genera widely recognized for promoting steel degradation, including *Pseudomonas*, *Clostridium*, *Comamonas*, *Sphingomonas*, and *Marinobacter*. This reduction in diversity and abundance of MIC-linked microorganisms demonstrates that the extract effectively disrupts microbial networks that drive sulfate reduction, acid production, and biofilm formation, key processes that accelerate underground metal corrosion. Notably, the complete elimination of *Pseudomonas balearica*—a known biofilm-forming organism- implies that the extract is highly effective against bacteria central to early-stage corrosion initiation.

The dominance of unclassified taxa across all samples, while typical of complex soil microbiomes, reinforces the significance of the selective inhibition observed among classified organisms. Even within this highly diverse microbial environment, *C. odorata* extract exerted measurable and targeted biological pressure on functionally important bacterial groups. This finding highlights the extract's biochemical potency and ecological relevance in modifying soil microbiota toward a less corrosive state.

Additionally, the persistence of a few neutral or weakly corrosive species such as *Ochrobactrum intermedium* suggests that the extract does not indiscriminately eliminate all microorganisms, but predominantly targets those with corrosion-enhancing characteristics. This selective inhibition supports the extract's potential for practical application, where complete sterilization is neither feasible nor desirable, and highlights an advantage over some synthetic biocides known for disrupting entire microbial ecosystems.

Overall, the study advances the understanding that *Chromolaena odorata* contains bioactive compounds capable of serving as effective natural corrosion inhibitors. It demonstrates not only microbiological efficacy but also practical relevance for pipeline-bearing environments where soil microorganisms significantly influence corrosion rates. Taken together, the results underscore the potential of *C. odorata* as a sustainable, low-toxicity alternative to conventional chemical biocides, offering a promising strategy for environmentally conscious corrosion management in the petroleum, water distribution, and civil engineering sectors.

RECOMMENDATION

Based on the inhibitory effects observed, it is recommended that *Chromolaena odorata* extract be further evaluated in field-scale corrosion-management programs, particularly in oil and gas pipeline corridors where microbial corrosion is prevalent. Future studies should incorporate electrochemical impedance spectroscopy (EIS), long-term burial tests, and phytochemical fractionation to isolate the specific bioactive constituents responsible for inhibition. A combination of *C. odorata* extract with existing corrosion-mitigation strategies may also enhance overall protection efficiency.

CONTRIBUTION TO KNOWLEDGE

This study contributes novel evidence demonstrating that *Chromolaena odorata* extract can restructure soil microbial communities by selectively inhibiting key corrosion-associated genera, as confirmed through metagenomic analysis. It is among the first documented works to link this plant's antimicrobial activity directly to MIC reduction in buried steel. Furthermore,

Article DOI: 10.52589/RJBLS-SCTQXMPB
DOI URL: https://doi.org/10.52589/RJBLS-SCTQXMPB

the methodological integration of DNA-based microbial profiling with corrosion-inhibition assessment provides a comprehensive framework for evaluating natural inhibitors in corrosion science.

REFERENCES

Adindu, C. C., Briggs, T., & Okafor, P. C. (2017). Evaluation of corrosion inhibition potentials of plant extracts on mild steel in an acidic environment. *International Journal of Scientific & Engineering Research*, *8*(6), 145–153.

Agarry, S. E., Oghenejoboh, K. M., Aworanti, O. A. & Arinkoola, A. O. (2018) Biocorrosion inhibition of mild steel in crude oil-water environment using extracts of *Musa paradisiaca* peels, *Moringa oleifera* leaves and *Carica papaya* peels as biocidal-green inhibitors: Kinetics and adsorption studies. *Chemical Engineering Communications, 206*(1), 98–124.

Al-Amiery, A. A., Al-Majedy, Y. K., Kadhum, A. A. H., & Mohamad, A. B. (2024). Green corrosion inhibitors and their prospects for future applications. *Corrosion Science*, *213*, 110–125.

Al-Amiery, A. A., Isahak, W. N. R.W. & Al-Azzawi, W. K (2023). Corrosion inhibitors: natural and synthetic organic inhibitors. *Lubricants, 11*, 174.

AOAC. (1990). *Official methods of analysis* (15th ed.). Association of Official Analytical Chemists.

Amise, A.F., Lennox, J.A. & Agbo, B.E. (2016). Antimicrobial potential and phytochemical analysis of *Dacryodes edulis* against selected clinical bacterial isolates. *International Journal of Pharmacognosy and Phytochemical Research*, *8*(11), 1795-1800.

Arriba-Rodriguez, M., Hernández, J. P., & Biezma, M. V. (2018). Corrosion of buried pipelines: Mechanisms, assessment, and mitigation. *Engineering Failure Analysis*, *89*, 89–108.

Briggs, T., Amadi, L. O., & Uwah, E. I. (2019). Phytochemical composition and anticorrosion activity of selected plant extracts on low-carbon steel. *Journal of Materials and Environmental Science*, *10*(3), 243–252.

Buchweishaija, J. (2009). Phytochemicals as green corrosion inhibitors in various corrosive media: A review. *Tanzanian Journal of Science*, *35*(1), 77-92.

Dutra, R., Silva, J. M. C., Barroso, R. C., & Coelho, L. C. B. B. (2023). Metagenomic insights into microbial communities associated with biocorrosion. *Frontiers in Microbiology*, *14*, 1134552.

Eddy, N. O., & Ebenso, E. E. (2010). Adsorption and inhibitive properties of ethanol extract of *Hibiscus sabdariffa* on mild steel in acidic medium. *Pigment & Resin Technology*, *39*(2), 77–83.

Fraise, A. P. (2002). Biocide abuse and antimicrobial resistance—a cause for concern? *Journal of Antimicrobial Chemotherapy*, *49*(1), 11–12.

Hou, Y., Deqing, L., Li, S., Yang, W. & Li, C. Q. (2016). Experimental investigation on corrosion effect on mechanical properties of buried metal pipes. *International Journal Corrosion,* Article ID 5808372, 1-13.

Ighodaro, O. M., Omole, J. O., & Adeosun, A. M. (2016). Phytochemical screening and antioxidant activities of selected Nigerian medicinal plants. *Journal of Pharmacy and Bioallied Sciences*, *8*(2), 104–109.

Article DOI: 10.52589/RJBLS-SCTQXMPB
DOI URL: https://doi.org/10.52589/RJBLS-SCTQXMPB

Immanuel, A. S., Otor, C., & Paul, E. (2016). Corrosion inhibition of mild steel by natural plant extracts in simulated environments. *Journal of Minerals and Materials Characterization and Engineering*, *4*(2), 125–138.

Kamagata, Y. (2015). Microbial ecology of oil-field corrosion. *Applied Microbiology and Biotechnology*, *99*(2), 6661–6671.

Khouzani, M. F., Melchers, R. E., & Kinsella, B. (2019). Long-term corrosion of buried carbon steel pipelines. *Corrosion Science*, *150*, 37–48.

Lavanya, M., & Brahmaprakash, G. P. (2011). Biological activities of *Chromolaena odorata*: A review. *Journal of Plant Sciences*, *6*(4), 220–228.

Li, X., Yang, T., Mbadinga, S. M., Liu, J. F., Yang, S. Z., Gu, J. D. & Mu, B. Z. (2017). Responses of microbial community composition to temperature gradient and carbon steel corrosion in production water of petroleum reservoir. *Frontiers in Microbiology*, *8*, 2379.

Lin, F., & Ballim, C. (2012). Microbial corrosion of steel in soil environments: Mechanisms and mitigation strategies. *Corrosion Reviews*, *30*(3–4), 125–135.

Mbah, C. M., Briggs, T., & Ubeh, R. (2023). Effect of soil physicochemical parameters on corrosion of buried pipeline steel. *Environmental Engineering Research*, *28*(5), 220–230.

Miralrio, A. & Vázquez, A. E. (2020). Plant extracts as green corrosion inhibitors for different metal surfaces and corrosive media: A Review. *Processes*, *8*, 942.

NACE International. (2005). *NACE RP0775: Preparation, cleaning, and evaluation of corrosion test coupons.* NACE International.

Nasser, A. (2019). Microbiologically influenced corrosion in oilfield environments: A metagenomics perspective. *International Biodeterioration & Biodegradation*, *143*, 104716.

Ngobiri, N. U., Oguzie, E. E., & Ogbobe, O. (2015). Corrosion inhibition of steel pipelines by plant extracts. *Industrial & Engineering Chemistry Research*, *54*(2), 842–852.

Odutayo, F., Ezeamagu, C., Kabiawu, T., Aina, D., & Mensah-Agyei, G. (2017). Phytochemical screening and antimicrobial activity of *Chromolaena odorata* leaf extract against selected microorganisms. *Journal of Advances in Medical and Pharmaceutical Sciences*, *13*(4), 1-9.

Ogunniran, A. O., Dauda, O. S., Adeleke, O. V., Omowaye, M. M., Okon, B. I., & Daramola, F. A. (2025). Assessment of the nutritional, antioxidant and antimicrobial properties of *Chromolaena odorata* leaves. *Biotechnology Journal International*, *29*(3), 1-14.

Okafor, P. C., & Ebenso, E. E. (2007). Adsorption characteristics and corrosion inhibition mechanisms of plant extracts on metal surfaces. *International Journal of Electrochemical Science*, *2*(1), 1–11.

Oshiki, M., Satoh, H., & Okabe, S. (2013). Ecology of microbial communities associated with microbiologically influenced corrosion. *Applied Microbiology and Biotechnology*, *97*(12), 5301–5311.

Phetburom, N., Bunthiang, T., Sunontarat, S., Chopjitt, P., Hatrongjit, R., Kerdsin, A., ... & Boueroy, P. (2025). Ethanolic *Chromolaena odorata* (Siam weed) leaf extract exhibits broad-spectrum antimicrobial, antibiofilm, antioxidant, and cell-disruptive activities against clinically relevant bacteria. *Veterinary World*, *18*(12), 3982-3993.

Pourmohseni, M., Rashidi, A. & Karimkhani, M. (2024). Preparation of corrosion inhibitor from natural plant for mild steel immersed in an acidic environmental: Experimental and theoretical study. *Science Reports, 14*, 7937.

Article DOI: 10.52589/RJBLS-SCTQXMPB
DOI URL: https://doi.org/10.52589/RJBLS-SCTQXMPB

Qin, F., Jiang, C., Cui, X., Wang, Q., Wang, J., Huang, R., Yu, D., Qu, Q., Zhang, Y. & Peng, P. D. (2018). Effect of soil moisture content on corrosion behavior of ×70 steel. *International Journal Electrochemical Science, 13*, 1603–1613.

Rajasekar, A., Maruthamuthu, S., & Ting, Y. P. (2010). Microbial corrosion in petroleum pipelines. *Journal of Petroleum Science and Engineering*, *72*(3–4), 210–215.

Rao, P. & Mulky, L. (2023). Microbially influenced corrosion and its control measures: A critical review. *Journal of Bio- and Tribo-Corrosion, 9*, 57.

Rohrback Cosasco Systems. (1999). *Corrosion rate calculation and corrosion monitoring guidelines.* Rohrback Cosasco.

Song, Y., Jiang, G., Chen, Y., Zhao, P. & Tian, Y. (2017). Effects of chloride ions on corrosion of ductile iron and carbon steel in soil environments. *Science Report*, *7*, 1–13.

Stanley, H. O., Abu, G. O. & Immanuel, O. M. (2016). Evaluation of the biocorrosion inhibition potential of ethanol extract of *Ganoderma tropicum*. *International Journal of Current Microbiology and Applied Sciences*, *5*(7), 609–618.

Stewart, P. S., & Costerton, J. W. (2001). Antibiotic resistance of bacteria in biofilms. *The Lancet*, *358*(9276), 135–138.

Umar, H. A., Suleiman, A., & Tijjani, M. (2016). Extraction and characterization of natural corrosion inhibitors from plant sources. *Journal of Chemistry*, Article 123456.

Umar, M. I. B., Mohammed, J. O., Oko, I. Y., Tafinta, A., Aliko, A. & Jobbi, D.Y. (2016). Phytochemical analysis and antimicrobial effect of lemon grass (*Cymbopogon citratus*) obtained from Zaria, Kaduna State, Nigeria. *Journal of Complementary and alternative Medical Research*, *1*(2), 1-8.

UNEP. (2011). *Environmental monitoring and assessment handbook.* United Nations Environment Programme.

Vartoukian, S. R., Palmer, R. M., & Wade, W. G. (2010). Strategies for culturing unculturable bacteria. *Journal of Applied Microbiology*, *109*(6), 1620–1628.

Videla, H. A. (2002). Prevention of MIC in industrial systems. *International Biodeterioration & Biodegradation*, *49*(4), 259–270.

Vijayaraghavan, K., Rajkumar, J., & Seyed, M. A. (2018). Phytochemical screening, free radical scavenging and antimicrobial potential of *Chromolaena odorata* leaf extracts against pathogenic bacterium in wound infections–a multispectrum perspective. *Biocatalysis and agricultural biotechnology*, *15*, 103-112.

Vijayaraghavan, K., Suribabu, J., & Venkatesan, R. (2017). Anticorrosion and antimicrobial activities of *Chromolaena odorata*. *Materials Today: Proceedings*, *4*(9), 10061–1006.

Wasim, M., Shoaib, S., Mubarak, N. M., Inamuddin & Asiri, A. M. (2018) Factors influencing corrosion of metal pipes in soils. *Environmental Chemistry Letters, 16*, 861–879.

Wu, Y. H., Liu, T. M., Luo, S. X., & Sun, C. (2010). Corrosion characteristics of Q235 steel in simulated Yingtan soil solutions. *Materialwissenschaft und Werkstofftechnik*, *41*(3), 142–146.

Article DOI: 10.52589/RJBLS-SCTQXMPB
DOI URL: https://doi.org/10.52589/RJBLS-SCTQXMPB