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Evaluation of *Rauvolfia vomitoria* Extracts as Green Corrosion Inhibitor for Concrete in Domestic Sewers

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ABSTRACT

Biogenic sulfuric acid generated by sulfur-oxidizing bacteria *Acidithiobacillus thiooxidans* damages concrete in sewers, resulting in loss of concrete mass and deterioration. An evaluation of the biocorrosion inhibition of sewer concrete using extracts of *Rauvolfia vomitoria* plants was studied. Concrete coupons samples were exposed to biogenic sulfuric acid in sewer waters for 26 months. Microbial induced concrete corrosion of samples was measured in terms of variation in sulfate concentration, weight loss, changes in chemical composition and formation of corrosion by-products within the corroding concrete matrix. Weight loss measurements observed corrosion rates to have varied between 0.17722 mpy- 1.373457 mpy before coating with plant extracts. Changes in concrete morphology and the formation of corrosion by-products were observed using SEM and X-ray diffraction. GC-MS analysis of *Rauvolfia vomitoria* ethanolic extracts analysis, which identified 76 compounds. Extracts coated concrete samples were evaluated for biocorrosion control in sewer waters. Results showed a decrease in corrosion rates with extracts coating (0.002687mpy-0.003594mpy). A boost in the efficiency with increase in extract concentration was observed (68.3% - 88.9%), with 50% extract concentration giving the highest inhibition efficiency. A significant reduction in the formation of corrosion by-products was observed after coating. Statistical analysis indicated that extract concentration had the biggest impact on the inhibitory qualities of the extracts.

Keywords: *Acidithiobacillus thiooxidans*; Biocorrosion; Biogenic; Concrete; Extracts; Inhibitor; MICC; *Rauvolfia vomitoria*; SOB; SEM.

1. Introduction

Plant extracts have shown potential as green corrosion inhibitors for biocorrosion control in concrete infrastructures. These extracts offer environmentally friendly alternatives to toxic chemical inhibitors, aligning with the principles of green chemistry. The use of plant extracts can help preserve human health and the environment while minimizing the use of commercially available toxic inhibitors (de Souza Morais, *et al*, 2023, Thakur *et al*, 2023, Sheydaei, 2024).

The exploration of plant extracts as corrosion inhibitors is on the rise and very promising, with excellent performance reported in scientific literature and patents. They have been found to slow corrosion rates and prevent the development of corrosion byproducts. Plant extracts have been shown to have inhibitory efficiency above 80%, and even above 90% in some circumstances (Murungi and Sulaimon, 2022, Eddy *et al*, 2022, William-Porbeni *et al*, 2023, 2022, Mamudu *et al*, 2024).

The potential economic implications of using plant extracts for biocorrosion control compared to chemical inhibitors, include its cost-effectiveness, as these extracts are renewable, low-cost, and widely available. Thus making them economically feasible for large-scale application. Overall, plant extracts have showed promise as a viable and cost-effective technique for biocorrosion management (Akrom, 2022, Ienascu *et al*, 2023, Barbu *et al*, 2025).

The utilization of plant extracts as corrosion inhibitors is in line with the principles of environmental sustainability, as plants and plant-based products are considered green. The phytochemicals present in plant extracts, such as alkaloids, lipids, phenolic acids, saponins, and terpenoids, allow for their active participation in the adsorption process on the metallic surface, functioning as progressive corrosion inhibitors (Furtado and Nacimento, 2021, Mahesh *et al,* 2025, Al Otaibi and Hammud, 2021).

In concrete structures plant extracts have been applied in corrosion control (Bhattarai *et al,* 2021, Naderi, *et al,* 2022, Okeniye *et al,* 2014, Kumar *et al,* 2025).

Rauvolfia vomitoria is a shrub that is about 5m in height. The stem is glabrous, rigid, and upright. The older sections of the plant do not contain any latex. The nodes are lumpy and swollen, and the branches are whorled (Orwa *et al,* 2009). It grows naturally in forests; however, it is usually found in forest regrowth where fallow periods are protracted. It is a medicinal plant found in the humid tropical secondary and lowland forests of Africa and Asia (Olatokunboh *et al,* 2009). *Rauvolfia vomitoria* is a common ornamental plant that has traditionally been used to treat a variety of diseases. The roots, barks, and leaves are the pieces that are widely used for herbal remedies (Emencheta *et al,* 2020, Ojo *et al,* 2012, Okereke *et al,* 2017). *Rauvolfia vomitoria* Afzel is a hermaphroditic shrub species with three whorls of oval or oblong shining green leaves. Poison devil's pepper, African serpent wood, and other common names for the plant include Asofeyeje (Yoruba), Ira or Akanta (Igbo), and Wadda (Hausa). In nature, the shrub can be found all over the world (Yorkum & Okenwa, 2019). The presence of flavonoids, tannins, alkaloids, steroids, terpenoids, and saponins has been demonstrated by phytochemical study of *Rauvolfia vomitoria* leaf extracts (Emencheta *et al,* 2020, Johnson *et al,* 2020). This study is to explore the effectiveness of *Rauvolfia vomitoria* on concrete biocorrosion control in sewer environments. By investigating the corrosion inhibition potential of these natural extracts, this study seeks to contribute to the development of sustainable and environmentally friendly strategies for preserving concrete infrastructure.

1.1. Study Objectives

The following are the objectives of this study:

(1) Extraction, qualitative analysis and GC-MS of Rauvolfia vomitoria leaves extract. (2) Microbial induced concrete corrosion study of concrete in sewer wastewater. (3) Biogenic acid corrosion inhibition study on concrete using plant extracts. (4) To study the effects of plant extracts on sewer pH and sulfate concentration. (5) To study concrete morphology changes using SEM and XRD.

2. Methodology

The detailed experimental procedures for concrete preparation and sampling, microbial and chemical analysis of raw sewer water, corrosion study and weight loss measurement, plant extraction, phytochemical analysis of *Rauvolfia vomitoria* extracts and concrete coating with modified epoxy resins as well as corrosion inhibition studies are described in previous publications (William-Porbeni *et al* 2023a., William-Porbeni and Gumus, 2021a, 2021b).

3. Results and Discussion

Previously reported are the initial findings from the chemical analysis of the sample sewer wastewater as well as the identification and isolation of the main sulfur-oxidizing bacteria found in the sample sewer wastewater (William-Porbeni and Gumus, 2021a, 2021b).

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3.1. Analysis of *Rauvolfia vomitoria* Extracts

Qualitative analysis of *Rauvolfia vomitoria* ethanolic extracts showed the existence of tannins, saponins, flavonoids, alkaloids, terpenoids produced in plant tissues with the absence of cardiac glycosides. GC-MS analysis showed the presence of 76 compounds. The major constituents of the extracts was found to be Decane, 3,8,-dimethyl (8.9911% Peak area), 2,4-Di-tert-butylphenol (7.86% peak area),Oxacyclotetradecane2,11-dione (5.204% peak area), Heptane, 2,6-dimethyl- (4.7476% Peak area), Oxalic acid (4.2447 % Peak area) in addition to 7 other different but close compounds with Decane. The compound with the lowest constituents was found to be oleic acid (0.0431% Peak area).

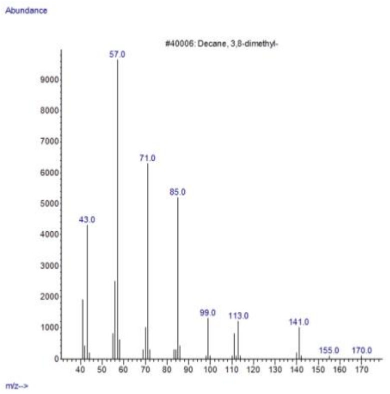

Figure 1. Decane, 3, 8,-dimethyl

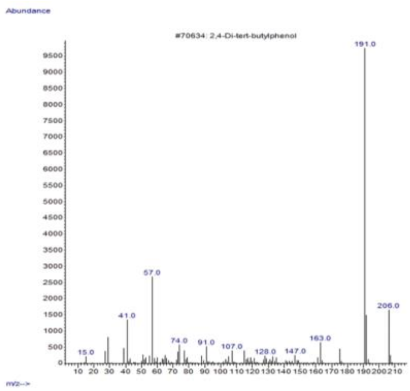

Figure 2. 2, 4-Di-tert-butylphenol

Figures 1 and 2 shows the GC-MS chromatogram of Rauvolfia vomitoria showing Decane and 2,4-Di-tert-butylphenol. Decane was identified as the major constituents in the extracts with a percentage of 8.99%. This was followed by 2,4-di-tert-butylphenol with 7.886%. 2, 4-Di-tert-butylphenol has been reported to be toxic and has shown excellent antibacterial activity towards a wide range of micro-organisms such as *Serratia marcensis* and *pseudomonas aeruginosa* by disrupting the growth and formation of biofilms.

3.2. Corrosion Rate and Inhibitor Efficiency

The weight loss of concrete during coating and immersion was calculated as a metric to assess how well extracts controlled concrete deterioration. The findings of the corrosion rate calculations before coating and five weeks after coating and wastewater immersion are shown in Table 1.

Table 1. Corrosion Rates Before and After Extracts Coating

Concentration	CR without extract (mpy)	CR with extract (mpy)	% IE
RV 10%	0.17722	0.002687	68.33
RV 25%	0.15396	0.003376	79.61
RV 50%	1.373457	0.003594	85.94

Corrosion rates of the corroded concrete was estimated using weight loss measurements. Pre-corroded samples were air dried to remove moisture. The dried samples were thereafter weighed to determine the weight loss. Microbial induced corrosion of concrete is a slow process with rates ranging from 1mm/yr to 5mm/yr. (Mori *et al*, 1991). Corrosion rates of concrete in this study before coating with inhibitor were within the range of 0.17722mpy - 1.373457mpy.

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This corrosion rates is likely due to the presence of biogenic sulfuric acid produced by the action of sulfur oxidizing bacteria. Additionally, the low pH maintained during the course of study allowed for conditions favorable to the growth of acidophillic micro-organisms (G. Padilla *et al*, 2010, Wang *et al*, 2023, Li and Jiang, 2023). Corrosion rates after coating varied between 0.002687mpy, 0.003376mpy, 0.003594mpy for 10%,25% and 50% extract concentration. At 50% extract concentration the inhibitor efficiency of the extracts almost approximates that of the commercial biocide glutaraldehyde. This is evidence that at higher extract concentration plant extracts have the potential of been as effective as commercial biocide in microbial corrosion control.

3.3. Sewer pH Variation

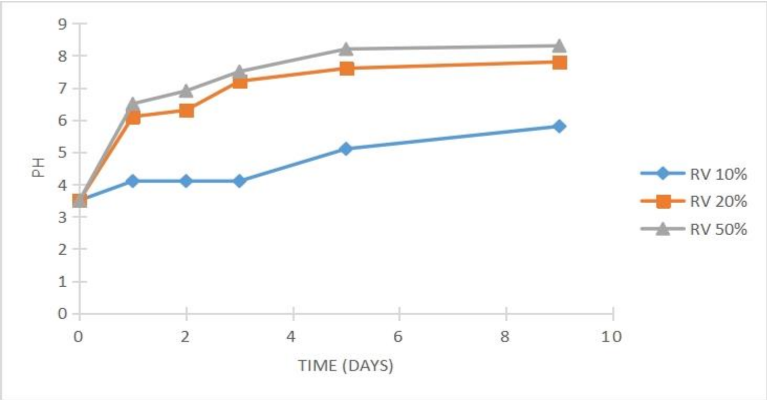

Figure 3. pH Variation in extract Coated Concretes

Figure 3 shows variations in pH of the *Rauvolfia vomitoria* extracts coated concrete sample. At all concentration of extracts a gradual increase in pH with time was observed.

3.4. Effects on Sulfate and Sulfur Oxidizing Bacteria

Sulfate in wastewater systems is a product of biotic and abiotic activities within the sewers. Profiles of the measured concentrations of sulfate in sewer waters with extract modified epoxy coating are presented in figure the figures below.

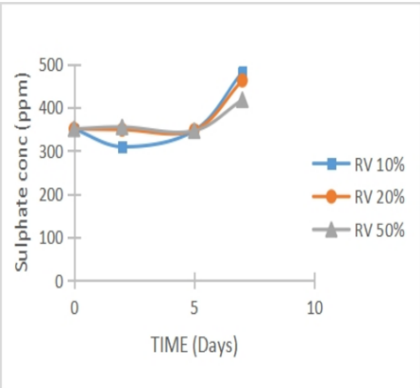

Figure 4. Sulfate variation for coated concrete

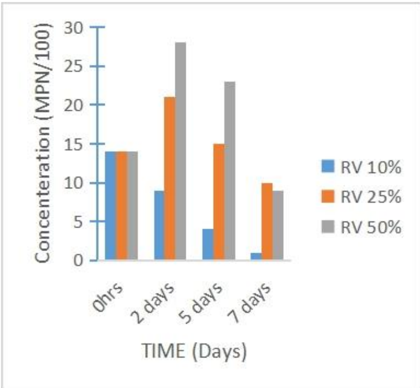

Figure 5. SOB Variation in coated concrete

Figure 4 shows the variation in sulfate concentration with time for *Rauvolfia vomitoria* extract coated concrete samples. For *Rauvolfia vomitoria* coated concrete samples, at 10% extract concentration a decrease in sulfate from

35.0mg/l to 30.8mg/l was observed. However by day 7 an increase to 48.1mg/l was observed. Similarly, for the 25% extracts concentration sulfate was observed to have decreased within the first 24hrs and increased thereafter. For 50% a slight initial increase was observed within the first 24hrs followed by a decrease and an increase by day 7.

Figure 5 shows the variation in SOB population with time for *Rauvolfia vomitoria* extract coated concretes. For the 10% extracts coated concrete, a decline in SOB population was observed within the first 48hrs with a decline in SO_4. This decline continued for the period observed. For the 25% and 50% extracts coated concretes an initial increase in SOB population with increase in SO_4 was observed. This increase was followed by a gradual decline with immersion time.

3.5. Morphology and Inhibition Mechanism

SEM analysis was done on the concrete before and after coating to access the microstructural properties of the coated concrete. Results in addition to providing additional topographical analysis of the concrete also gives a compositional analysis of the coated concrete.

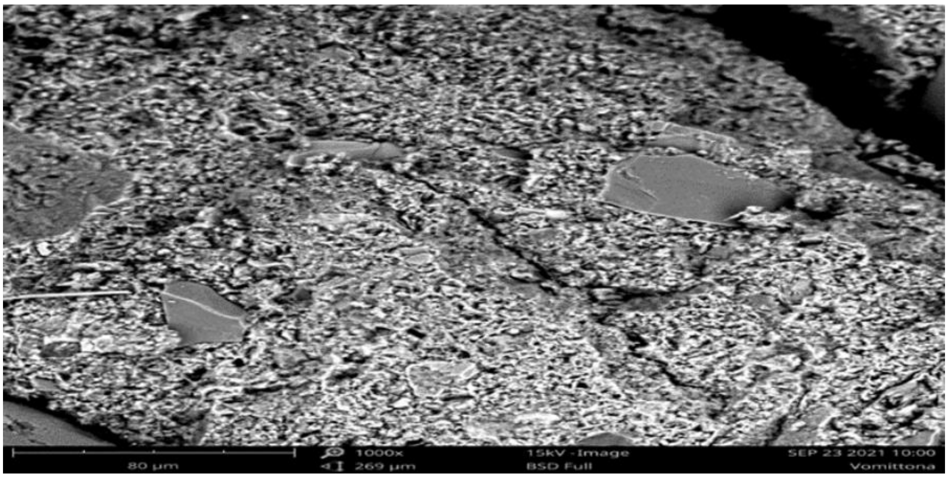

Figure 6. SEM for *Rauvolfia vomitoria* coated concrete

Microstructural image of the *Rauvolfia vomitoria* extract coated concrete showed a concrete matrix that is denser and more compacted when compared to precorroded uncoated concrete. A close observation of the SEM image Figure 6, shows the absence of corrosion by-products gypsum and ettringite within the concrete matrix, in its place was the appearance of the dense fibrous, crystalline and whitish compounds.

These compound formed acts as pore blockers preventing the ingress of corrosive media into the concrete. It has been speculated that the microcrystalline compounds are formed by chemical reactions of the plant extracts and loosely bound corrosion by-products in the concrete matrix and below the coating layers.

X-ray diffraction (XRD) analysis gives a qualitative analysis of the minerals within the concrete. X-ray analysis was done to determine and analyze the presence of the crystalline compounds formed within the concrete matrix. It was used to identify the intensity and structure of crystalline compounds formed in *Rauvolfia vomitoria* extract coated concrete.

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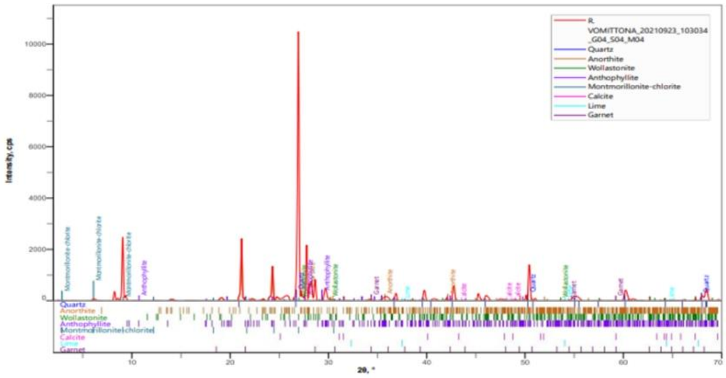

Figure 7. XRD FOR *Rauvolfia vomitoria* Coated Concrete

Figure 7 give the XRD graph drawn between 2θ and intensity. The XRD spectra shows the presence of quartz, anorthite, wollanstonite and montmorrilonite-chlorite. The first peak was observed was that of montmorrilonite-chlorite at 2θ = 9.8 (approx.) and a second peak at 2θ =22. The highest peak at 2θ = 27.

These results suggest that the microcrystalline compounds formed penetrates the concretes, acts as a passivation layer preventing inflow of biogenic acid into the concrete thus improving the inhibitory and coating efficiency of the plants extracts. It has been suggested that the ability of extracts to inhibit corrosion in concrete could be as a result of enhanced cement hydration due to the curing process within the concrete matrix leading to reduction in capillary pores as well as the pore blocking role played by green extracts in coated samples (Ghoreishiamiri *et al*, 2020, Chen *et al*, 2021, William-Porbeni *et al*, 2023).

4. Statistical Analysis

To explore the corrosion variables that meaningfully affected the corrosion rates after coating, regression analysis with analysis of variance (ANOVA) was done. Independent parameters considered for analysis to have significantly affected the corrosion rate were pH, concentration of extracts and time. The corrosion rate was represented by CR in the model equation, and the response component can be stated by the equation beneath: CR = $f\ (A, B, C)$, where A is the pH, B is the inhibitor concentration and C is the time. Inhibitor concentration (In_c) and Sulfate concentration ($SO4-$) are considered functions of corrosion rate. Analysis of variance (ANOVA) was used to examine the significance of the variables and their interactions. To determine how process variables affected the extract-coated samples' rate of corrosion, an ANOVA and a linear regression equation were employed.

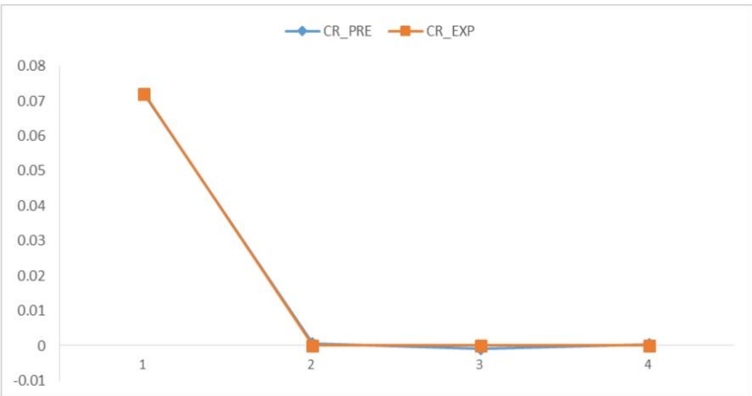

Figure 8. Regression plot for *Rauvolfia vomitoria* coated concrete

Table 2. Results of ANOVA

Plants	Df	Sum of Square	Mean of Square	F	Significance F	R^2
Rauvolfia vomitoria	2	0.003885	0.001942	1445.687	0.018594	0.9996

The quotient of explained deviation to total variance is defined as the coefficient of determination (R^2). When the R^2 value nears unity, a superior response model that fits the real experimental data is obtained. For extracts studied, the R^2 value calculated for this model was 0.9996%. This indicates a strong correlation with experimental values. This confirms that the model explains the relationship between the independent variables and responses quite well. For statistically significant parameters, the F-values for the models should be less than 0.05.

Table 3. Effect of the Parameters for *Rauvolfia vomitoria* Extract (95% confidence level)

Parameters	Coefficients	Standard Error	T	P	95% (Lower)	95% (Upper)
Intercept	0.134641	0.002458	54.77408	0.011621	0.103408	0.165875
RV	-0.0047	0.05647	-0.08321	0.947147	-0.72221	0.712814
$[SO_4^-]^{0.5}$	-0.00703	0.000172	-40.7908	0.015604	-0.00922	-0.00484

A general model equation describing the corrosion behavior of the concrete in the sewer environment under biogenic acid corrosion in the extracts can be expressed as:

$CR = A + [\ ] + [SO4-]^{0.5}$

where $A - intercept, B\ and\ C - parameter\ coefficients.$

As shown in the above table, the ANOVA computation was assessed at a 95% confidence level, or a significance level of α=0.05. According to the results, the biggest statistical influence on corrosion control is the inhibitor concentration.

5. Conclusion

This study investigated the effects of *Rauvolfia vomitoria* leaf extract on concrete corrosion inhibition. The study's findings were as follows:

1. *Rauvolfia vomitoria* coated concrete had a significant effect on sulfate concentration, sewer pH, and fluctuations in the sewer's SOB populations.

2. Compared to the commercial biocide glutaraldehyde, the extract inhibitor of *Rauvolfia vomitoria* demonstrated tolerance to corrosive sewage environments.

3. Significant decrease in rates of corrosion was observed for *Rauvolfia vomitoria* extracts coated concrete.

4. The development of thick fibrous, crystalline, and whitish compounds was visible in SEM images of extract-coated concrete. These compound formed acts a pore blockers preventing the ingress of corrosive media into the concrete.

6. Recommendations

To control the rates of sewer corrosion, it is necessary to not only protect surfaces from coming in contact with the corrosive media but also to minimize the growth and metabolism of the micro-organism producing the corrosive environment. It is thus suggested that:

a) The bactericidal as well as the acid neutralization capacity of the phytochemicals in the plants extracts needs to be fully understood.

b) Future work should include mechanistic modeling to quantify adsorption energetic and extract-cement interaction pathways

c) Uptake mechanism of micro-organism of plant phytochemicals should be studied to give an enhanced comprehension of the biocidal activity of extracts as well as an understanding of selectivity of SOB to plants extracts.

d) Modification of concrete mix designs using different plant extracts to observe corrosion inhibition activity on coated samples.

Declarations

Source of Funding

This study received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Competing Interests Statement

The authors declare that they have no competing interests related to this work.

Consent for publication

The authors declare that they consented to the publication of this study.

Availability of data and materials

Supplementary information is available from the authors upon reasonable request.

Ethical Approval

Not applicable for this study.

Informed consent

Not applicable for this study.

References

[1] AlOtaibi, N., & Hammud, H.H. (2021). Corrosion inhibition using Harmal leaf extract as an eco-friendly corrosion inhibitor. Molecules, 26: 7024. https://doi.org/10.3390/molecules26227024.

[2] Barbu, C.A., Fierascu, I., Semenescu, A., & Cotrut, C.M. (2025). Critical review regarding the application of plant extracts as eco-friendly corrosion inhibitors: A sustainable interdisciplinary approach. Molecules, 30: 3722. https://doi.org/10.3390/molecules30183722.

[3] Bhattarai, J., Somai, M., Acharya, N., Giri, A., Roka, A., & Phulara, N.R. (2021). Study on the effects of green-based plant extracts and waterproofers as anti-corrosion agents for steel-reinforced concrete slabs. E3S Web of Conferences, 302: 02018. https://doi.org/10.1051/e3sconf/202130202018.

[4] Chen, S.C., Lin, W.T., Huang, R., & Hsu, H.M. (2021). Performance of green concrete and inorganic coating materials. Materials, 14: 832. https://doi.org/10.3390/ma14040832.

[5] DeSouzaMorais, W.R., DaSilva, J.S., Queiroz, N.M.P., DePaivaESilvaZanta, C.L., Ribeiro, A.S., & Tonholo, J. (2023). Green corrosion inhibitors based on plant extracts for metals and alloys in corrosive environment: A technological and scientific prospection. Applied Sciences, 13: 7482. https://doi.org/10.3390/app13137482.

[6] Eddy, N.O., Ibok, U.J., Garg, R., Iqbal, A., Amin, M., Mustafa, F., Egilmez, M., & Galal, A.M. (2022). A brief review on fruit and vegetable extracts as corrosion inhibitors in acidic environments. Molecules, 27: 2991. https://doi.org/10.3390/molecules27092991.

[7] Emencheta, S.C., Enweani, B.I., Oli, A.N., Ibezim, E.C., & Imanyikwa, I.E.O. (2020). Antimicrobial evaluation of plant parts of *Rauwolfia vomitoria*. Journal of Complementary and Alternative Medical Research, 12: 11–20. https://doi.org/10.9734/jocamr/2020/v12i130197.

[8] Furtado, L.B., & Nascimento, R. (2021). Plant extracts as green corrosion inhibitors. In Sustainable corrosion inhibitors II: Synthesis, design, and practical applications, Pages 19–77, American Chemical Society. https://doi.org/10.1021/bk-2021-1404.ch002.

[9] Ghoreishiamiri, S., Raja, P.B., Ismail, M., & Karouei, S.F.H. (2020). Properties of contaminated reinforced concrete added by *Areca catechu* leaf extract as an eco-friendly corrosion inhibitor. Journal of Bio- and Tribo-Corrosion, 6: 134. https://doi.org/10.1007/s40735-020-00430-2.

[10] Gutierrez-Padilla, M.G.D., Bielefeldt, A., Ovtchinnikov, S., Hernandez, M., & Silverstein, J. (2010). Biogenic sulfuric acid attack on different types of commercially produced concrete sewer pipes. Cement and Concrete Research, 40: 293–301. https://doi.org/10.1016/j.cemconres.2009.10.002.

[11] Ienașcu, I.M.C., Căta, A., Chiș, A.A., Ștefănuț, M.N., Sfîrloagă, P., Rusu, G., Frum, A., Arseniu, A.M., Morgovan, C., Rus, L.L., & Dobrea, C.M. (2023). Some Brassicaceae extracts as potential antioxidants and green corrosion inhibitors. Materials, 16: 2967. https://doi.org/10.3390/ma16082967.

[12] Johnson, C.E., Etim, E.I., Udoh, A.E., & Bassey, U.S. (2020). Analysis of the constituents of *Rauvolfia vomitoria* ethanol root extract using GC-MS. World Journal of Innovative Research, 9: 32–34.

[13] Kumar, N., Noor, I.S.M., Yahya, M.Z.A., & Prakash, S. (2025). Botanical corrosion inhibitors in reinforced concrete: Material sustainability assessment and analysis. Zastita Materijala, 66: 40–55. https://doi.org/10.62638/zasmat1092.

[14] Li, X., & Jiang, G. (2023). Characterization of corrosion microbial communities. In G. Jiang (Eds.), Microbiologically influenced corrosion of concrete sewers, Engineering Materials, Springer, Cham. https://doi.org/10.1007/978-3-031-29941-4_5.

[15] Mahesh, R., Jain, A., Kumar, Y.S., & Raghu, A.V. (2025). Plant extracts and green nanocomposites as sustainable corrosion inhibitors: A comprehensive review. Sustainable Chemistry One World, 100132. https://doi.org/10.1016/j.scowo.2025.100132.

[16] Mamudu, U., Santos, J.H., Umoren, S.A., Alnarabiji, M.S., & Lim, R.C. (2024). Corrosion inhibition of ethanolic extract of *Dillenia suffruticosa* leaves on mild steel in hydrochloric acid medium. Corrosion Communications, 15: 52–62. https://doi.org/10.1016/j.corcom.2023.10.005.

[17] Mori, T., Koga, M., Hikosaka, Y., Nonaka, T., Mishina, F., Sakai, Y., & Koizumi, J. (1991). Microbial corrosion of concrete sewer pipes: H_2S production from sediments and corrosion rate determination. Water Science and Technology, 23: 1275–1282. https://doi.org/10.2166/wst.1991.0579.

[18] Akrom, M. (2022). Experimental investigation of natural plant extracts as a green corrosion inhibitor in steel. Journal of Renewable Energy and Mechanics, 5: 1–15. https://doi.org/10.25299/rem.2022.8887.

[19] Murungi, P.I., & Sulaimon, A.A. (2022). Ideal corrosion inhibitors: A review of plant extracts for metal surfaces. Corrosion Reviews, 40: 127–136. https://doi.org/10.1515/corrrev-2021-0051.

[20] Naderi, R., Bautista, A., Velasco, F., Soleimani, M., & Pourfath, M. (2022). Green corrosion inhibition for carbon steel reinforcement using *Urtica dioica* extract. Journal of Building Engineering, 58: 105055. https://doi.org/10.1016/j.jobe.2022.105055.

[21] Ojo, O.O., Ajayi, S.S., & Owolabi, O.L. (2012). Phytochemical screening and antimicrobial activities of *Rauvolfia vomitoria* and *Peperomia pellucida* extracts. International Research Journal of Biochemistry and Bioinformatics, 2: 127–134.

[22] Olatokunboh, A., Kayode, Y.O., & Adeola, O.K. (2009). Anticonvulsant activity of *Rauwolfia vomitoria*. African Journal of Pharmacy and Pharmacology, 3: 319–322.

[23] Oluwasina, O.O., Olagboye, S.A., Olaiya, A., & Hassan, F.G. (2017). Phytochemical quantification and antimicrobial activity of *Rauvolfia vomitoria* extracts. FUTA Journal of Research in Sciences, 13: 10–16.

[24] Okereke, S.C., Ijeh, I.I., & Arunsi, U.O.I. (2017). Bioactive constituents of *Rauvolfia vomitoria* roots using GC-MS and FT-IR. African Journal of Pharmacy and Pharmacology, 11: 25–31. https://doi.org/10.5897/ajpp2016.4712.

[25] Okeniyi, J.O., Loto, C.A., & Popoola, A.P.I. (2014). Corrosion inhibition performance of *Rhizophora mangle* bark extract on reinforced concrete steel. International Journal of Electrochemical Science, 9: 4205–4216.

[26] Orwa, C., Mutua, A., Kindt, R., Jamnadass, R., & Simmons, A. (2009). Agroforestry database: A tree reference and selection guide, version 4.0. http://www.worldagroforestry.org/sites/treedbs/treedatabases.asp.

[27] Sheydaei, M. (2024). The use of plant extracts as green corrosion inhibitors: A review. Surfaces, 7: 380–403. https://doi.org/10.3390/surfaces7020024.

[28] Thakur, A., Assad, H., Kaya, S., & Kumar, A. (2023). Plant extracts as bio-based anticorrosive materials. In Handbook of biomolecules, Pages 591–618, Elsevier.

[29] Wang, D., Guan, F., Feng, C., Mathivanan, K., Zhang, R., & Sand, W. (2023). Review on microbially influenced concrete corrosion. Microorganisms, 11: 2076. https://doi.org/10.3390/microorganisms11082076.

[30] William-Porbeni, D., Ogbereyo, S., & Gumus, R.H. (2023). Effects of extracts of *Alchornea cordifolia* on biocorrosion control on sewer concrete. International Journal of Advances in Scientific Research and Engineering, 9: 17–28. https://doi.org/10.31695/ijasre.2023.9.5.2.

[31] William-Porbeni, D., & Gumus, R.H. (2021a). Identification and characterization of microorganisms from a domestic sewer. Journal of Multidisciplinary Engineering Science Studies, 7: 4007–4013.

[32] William-Porbeni, D., & Gumus, R.H. (2021b). Microbiologically induced corrosion of concrete in sewer wastewater. International Journal of Advances in Scientific Research and Engineering, 7: 9–17. https://doi.org/10.31695/ijasre.2021.34075.

[33] Yorkum, L.K., & Okenwa, C.A. (2019). Phytochemical analysis of aqueous leaf extract of *Rauvolfia vomitoria*. European Journal of Biomedical and Pharmaceutical Sciences, 6: 100–103.