

Performance Evaluation of *Mucuna Solanica* and Periwinkle Shell Inhibitors as Anti-Coating Agents for Corrosion Inhibition

Obiukwu David Nduji, Chinwuba Kevin Igwilo, Nnaemeka Uwaezuoke, Chukwuebuka Francis Dike*,
Federal University of Technology Owerri, Owerri, Nigeria

Abstract

In the oil and gas industry, pipelines composed predominantly of refined metals are inherently susceptible to degradation when exposed to corrosive environments such as atmospheric oxygen, saline solutions, or microbial activity. Conventional mitigation strategies—including material selection optimization, protective coatings, cathodic protection, and chemical inhibition—often rely on costly and environmentally detrimental synthetic inhibitors. This has necessitated the exploration of sustainable, cost-effective alternatives derived from natural sources. This study evaluates the corrosion inhibition efficacy of three bio-based coating materials formulated from locally sourced periwinkle shells (*Littorina littorea*), *Mucuna solanica* (MS) plant extract, and a hybrid composite (MPS) integrating both materials. A weight loss methodology was employed to assess corrosion rates under simulated acidic (HCl), saline (3.5 wt.% NaCl), and microbial (sulfate-reducing bacteria) conditions, reflecting common oilfield operational environments. Results demonstrated that the MPS hybrid inhibitor exhibited superior corrosion inhibition efficiency, achieving the lowest corrosion rates of 1.838×10^{-6} mm/year (acidic), 2.016×10^{-6} mm/year (saline), and 6.226×10^{-6} mm/year (microbial), outperforming standalone PS and MS inhibitors. These findings highlight the potential of composite bio-inhibitors as eco-friendly, high-performance alternatives for pipeline integrity management in petroleum production and transportation systems.

Introduction

Corrosion poses significant economic and safety challenges in the oil and gas industry due to the inherently corrosive impurities in crude oil and natural gas. This degradation manifests across three critical operational domains: production, transport/storage, and refining. Key corrosive agents in oilfield environments include carbon dioxide (CO₂), hydrogen sulfide (H₂S), and free water, which exacerbate metal dissolution in pipelines and wellbore infrastructure (Paul et al. 2014). The prevalence of sweet (CO₂-rich) and sour (H₂S-laden) crudes, coupled with operational extremes in temperature, pressure, and aqueous media—ranging from seawater to produced water—further accelerates corrosion kinetics (Schweitzer 2013).

Carbon and low-alloy steels, the primary materials for onshore/offshore structures such as pipelines and desalination plants, exhibit inherent susceptibility to generalized or localized corrosion (Malik et al. 1999). Despite their enhanced strength and moderate corrosion resistance, these alloys thermodynamically favor oxidation to their native oxide states. Corrosion rates are modulated by environmental variables, including dissolved salts, acidic species, microbial activity, flow velocity, and temperature gradients (Schweitzer 2007).

To mitigate these challenges, industry-standard strategies such as optimized material selection (Callister and Wiley 2007), protective coatings (Schweitzer 2013), cathodic protection, and corrosion inhibitors are widely employed. Among these, coatings have emerged as a versatile solution, functioning via three primary mechanisms:

Copyright © the author(s). This work is licensed under a Creative Commons Attribution 4.0 International License.

Improved Oil and Gas Recovery

DOI: 10.14800/IOGR.1359

Received January 19, 2025; revised February 10, 2025; accepted March 14, 2025.

*Corresponding author: dike.chukwuebuka@futo.edu.ng

(1) electrochemical inhibition, (2) barrier formation to isolate substrates from corrosive agents, and (3) sacrificial protection (Popoola et al. 2014). Advanced coatings now integrate passive-active dual functionality, combining barrier properties with active passivation to form protective interfacial layers (e.g., Cr_2O_3 or Al_2O_3). Material classes span metallic (e.g., Zn or Al alloys for cathodic protection; Buchheit et al., 2002), ceramic (e.g., TiO_2 or SiO_2 for microbial corrosion resistance; Krishnamurthy et al., 2013), polymeric (e.g., epoxy or polyurethane for impermeability; Lee et al. 2009), and hybrid systems that synergize adhesion, self-healing, and thermal stability (Dolan and Carson 2007).

Despite their efficacy, conventional coatings such as fusion-bonded epoxy (FBE), coal tar enamel (CTE), and three-layer polyolefins entail high costs and environmental liabilities, particularly in resource-constrained regions like Nigeria (Thompson and Saithala 2015). This study investigates sustainable, locally sourced alternatives: *Mucuna solanifera* (MS), a tropical legume (subfamily Papilionaceae) with high proteinaceous content, and periwinkle shell (PS, *Littorina littorea*), a calcareous agricultural waste. Prior applications of MS include rheology modification in drilling fluids (Duru et al., 2020) and cementitious extenders (Igwilo et al. 2020a), while PS has been repurposed as a partial cement substitute (Agbede and Manasseh 2009). Their hybrid composite (MPS) is hypothesized to synergize organic-inorganic interactions, leveraging MS's polymeric matrix for adhesion and PS's CaCO_3 -rich structure for pH buffering and barrier enhancement. By evaluating these materials under simulated oilfield conditions—acidic (HCl), saline (3.5 wt.% NaCl), and microbial (sulfate-reducing bacteria) environments—this work advances the development of low-cost, eco-friendly inhibitors tailored to tropical resource economies.

Materials and Methods

Materials. The materials employed in this study were *Mucuna solanifera* (abbreviated as MS), periwinkle shell (abbreviated as PS), thinner, water, and a neutral binder (alkyl resin). Additionally, zinc oxide (ZnO), an anti-skin agent, and a mixed dryer were used. The apparatus included API 5L X52 carbon steel pipes, a painting brush, an analytical weighing balance (Mettler Toledo ME204E with 0.1 mg precision), a Hamilton mixer, and a beaker.

Sourcing of Materials. *Mucuna solanifera* was procured from a market in Enugu. Periwinkle shell was sourced from a market in Imo State. The thinner, ZnO, anti-skin agent, mixed dryer, and the neutral binder (alkyl resin) were all obtained from an industrial store.

Material Processing. In the material processing stage, *Mucuna solanifera* and periwinkle shells underwent similar yet distinct processing procedures. For *Mucuna solanifera*, the collected samples were thoroughly washed with deionized water to remove surface impurities. Subsequently, the washed samples were placed in a Memmert UN 55 laboratory oven with a temperature accuracy of $\pm 1^\circ\text{C}$ and dried at 50°C for 4 hours. After drying, the *Mucuna solanifera* was pulverized using a Hamilton HBL500 industrial blender. The pulverized samples were sieved through a 250-mesh sieve to obtain powder with a uniform particle size. Finally, the sieved powder was stored in an airtight container to prevent moisture absorption and contamination. The processing of periwinkle shells was similar. First, the shells were soaked in deionized water and gently scrubbed to remove adhering organic matter. Then, they were also dried in the oven at 50°C for 4 hours. After that, the dried shells were crushed using the industrial blender, and the crushed particles were sieved through a 250-mesh sieve. The resulting powder was stored in an airtight container for subsequent experiments.

Methods. Sample Characterization. Sample characterization is a crucial step to precisely identify the elements present and understand the inherent features of the samples. In this study, characterizing *Mucuna solanifera* and periwinkle shell was of utmost importance. This process aimed to determine their elemental compositions and potential characteristics, ensuring their suitability for the research within the context of petroleum engineering corrosion inhibition. As per previous research, Igwillo et al. (2020b) have conducted similar characterizations on *Mucuna solanifera* and periwinkle shell, providing a valuable reference for our study. This prior work not only

validates the relevance of our chosen materials but also offers insights into the expected outcomes of our own characterization efforts.

Inhibitor Formulation. For the formulation of corrosion-inhibiting coatings, three distinct types of inhibitors were designed. These include a mucuna solannie-based (MS-based) inhibitor, a periwinkle shell-based (PS-based) inhibitor, and a mucuna solannie-periwinkle shell hybrid (MS-PS hybrid) system. The specific formulations of these inhibitors are presented in **Table 1**. This approach allows for a comprehensive evaluation of the individual and combined effects of mucuna solannie and periwinkle shell in corrosion inhibition, which is highly relevant to the challenges faced in petroleum engineering, such as protecting pipelines and equipment from corrosion in harsh oil and gas environments.

Table 1—Inhibitor formulation for MS.

S/N	Materials	MS-based	PS-based	MS-PS hybrid
1	Neutral Binder	40g	40g	40g
2	Periwinkle Shell	0g	40g	40g
3	Mucuna Solanie	40g	0g	40g
4	Thinner	15g	15g	15g
5	ZnO	4g	5g	4g
6	Anti-Skin	1g	1g	1g
7	Mixed Dryer	3g	3g	3g

Corrosion Test. Corrosion evaluation was carried out using the weight-loss method. The weight-loss approach was selected because of its capability to capture various types of corrosion by delving into the minute details of corrosion events. This method provides a comprehensive understanding of the corrosion process, which is crucial for accurately assessing the effectiveness of corrosion inhibitors in a petroleum engineering context. In this study, a total of 18 pipe specimens were employed for corrosion rate (CR) evaluation. Prior to any testing, the diameter and length of each pipe were precisely measured. Subsequently, these pipes were divided into two main groups: 9 pipes served as control specimens (CR Control pipes), and the other 9 were used as coated specimens (CR Coating pipes). The grouped pipes were further subdivided according to different environmental conditions relevant to the corrosion inhibition study. The specific details of these environmental conditions are presented in **Table 2**. This systematic approach allows for a detailed comparison of corrosion rates under various scenarios, enabling a more in-depth analysis of the performance of the inhibitors in different oil and gas-related environments.

Table 2—Environmental conditions for the corrosion inhibition study.

S/N	Assumption	MS	PS	MS-PS
1	Acid (Control)	MS-Control-Acid	PS-Control-Acid	MS-PS-Control-Acid
2	Acid (Coating)	MS-Coating-Acid	PS-Coating-Acid	MS-PS-Coating-Acid
3	Salt (Control)	MS-Control-Salt	PS-Control-Salt	MS-PS-Control-Salt
4	Salt (Coating)	MS-Coating-Salt	PS-Coating-Salt	MS-PS-Coating-Salt
5	Microbial (Control)	MS-Control-Microbial	PS-Control-Microbial	MS-PS-Control-Microbial
6	Microbial (Control)	MS-Coating-Microbial	PS-Coating-Microbial	MS-PS-Coating-Microbial

Results

Sample Characterization. Sample characterization was conducted to identify the elemental features of the specimens. This step was crucial for determining whether the materials possess essential elements capable of reducing or mitigating corrosion. According to Igwillo et al. (2020b), periwinkle shell was found to contain 79.48% calcium, along with 8.83% silicon, 2.13% silver, 2.13% yttrium, 1.55% niobium, 1.11% iron, 1.04% potassium, 0.95% chlorine, 0.86% sulfur, 0.58% aluminum, 0.42% oxygen, 0.33% carbon, 0.21% phosphorus, 0.13% sodium, 0.13% magnesium, and 0.13% titanium. *Mucuna solan*, on the other hand, had 39.18% potassium, 14.71% carbon, 7.89% phosphorus, 6.37% zinc, 5.11% iron, 5.05% sulfur, 4.55% calcium, 3.54% yttrium, 3.06% titanium, 2.7% chlorine, 2.08% oxygen, 1.95% silicon, 1.77% aluminum, 1.17% magnesium, and 0.86% sodium. As the results indicate, periwinkle shell is predominantly composed of calcium, while *mucuna solan* mainly consists of potassium and carbon.

Corrosion Inhibition Study. Acid Environment. Figures 1 to 3 illustrate the corrosion rates of pipes coated with *mucuna solan* (MS), periwinkle shell (PS), and the *mucuna solan*-periwinkle shell hybrid (MPS) in an acid environment. As shown in Figure 1, the MS-coated pipe in the acid environment did not show any signs of corrosion for the first 12 weeks. On the 15th week, it recorded a corrosion rate of 3.27×10^{-6} mm/year. After another 3 weeks, the corrosion rate decreased by 16.5% to 2.73×10^{-6} mm/year. On the 21st week, the corrosion rate increased by 71.4% to 4.68×10^{-6} mm/year. Comparing the final corrosion rate of the coated pipe with that of the uncoated pipe, the application of the MS coating reduced the corrosion rate by 77.9%.

In Figure 2, the PS-coated pipe in the acid environment did not corrode for the first 6 weeks. At the 9th week of observation, it recorded a corrosion rate of 4.23×10^{-6} mm/year. This corrosion rate decreased by 2.51% and 1.99% at the 12th and 15th weeks of observation, respectively. At the 18th week of observation, the corrosion rate increased by 66.5%, and then dropped by 13.9% at the 21st week of observation. Comparing the final corrosion rate of the coated pipe with the uncoated pipe, the introduction of the PS coating reduced the corrosion rate by 82.8%.

As depicted in Figure 3, the MPS-coated pipe in the acid environment did not corrode for 18 weeks. At the 21st week, it recorded a corrosion rate of 1.83×10^{-6} . Comparing the final corrosion rate of the coated pipe with the uncoated pipe, the application of the MPS coating reduced the corrosion rate by 91.3%.

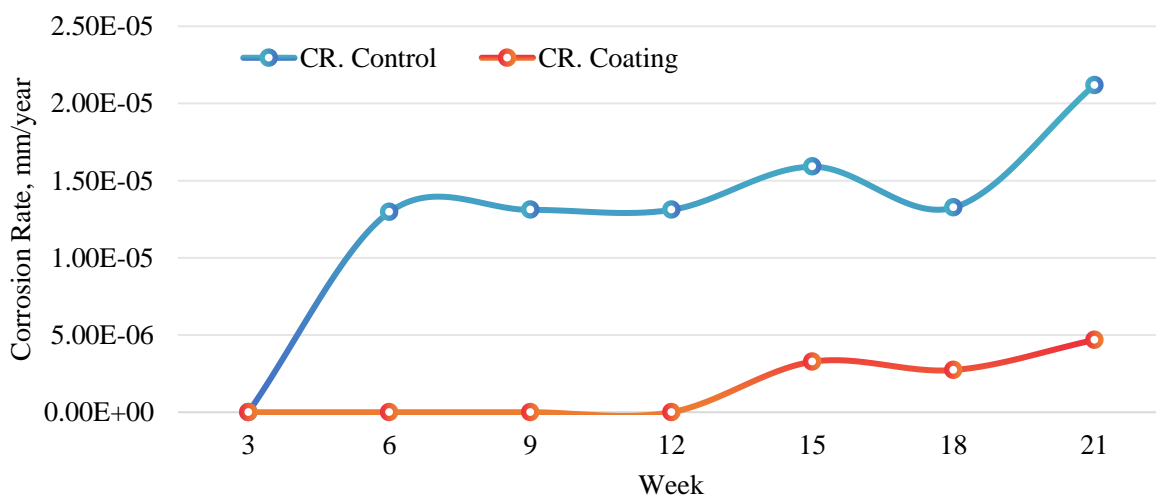


Figure 1—Corrosion rate of mucunie solan inhibitor in acid environment.

When comparing the corrosion rates of the pipes before and after inhibition, it is evident that the MS, PS, and MPS coatings all reduced the corrosion rates of the pipes. This can be attributed to their functional groups, which

facilitate the formation of complexes with metal surfaces and ions, thereby occupying a large surface area and protecting the metals from corrosive agents (Rajendran et al. 2005). The inhibitive power of these polymers is also associated with heteroatoms (oxygen and nitrogen) and cyclic rings, which are major adsorption sites (Arthur et al. 2013). Comparing Figures 1 through 3, the MPS-coated pipe exhibited the best corrosion inhibition performance, reducing the corrosion rate by 91.3%. As shown in Figures 1 to 3, the control pipe showed a continuous increase in corrosion rate. This is due to the ability of the acid to dissociate the metals and the decrease in hydrogen ions as the sole cathodic reaction, which is consistent with the findings of Aria et al. (2019).

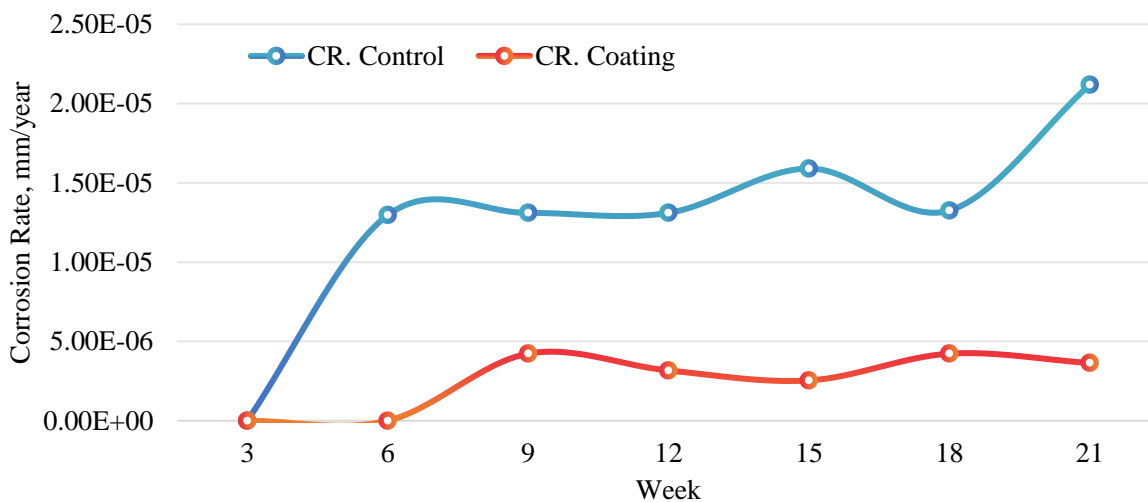


Figure 2—Corrosion rate of periwinkle shell inhibitor in acid environment.

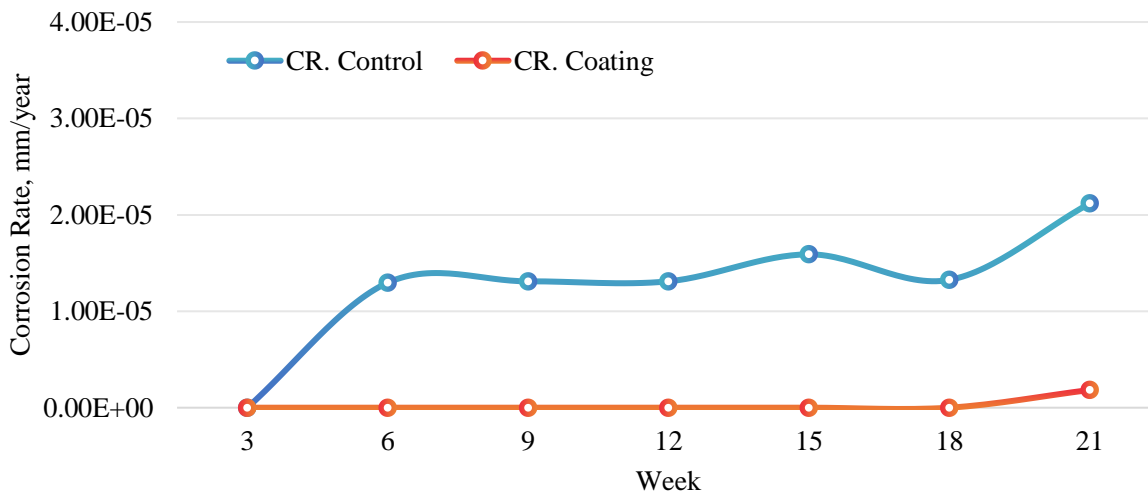


Figure 3—Corrosion rate of mucuna solannie-periwinkle shell inhibitor in acid environment.

Salt Environment. Figures 4 to 6 show the corrosion rates of pipes coated with MS, PS, and MPS in a salt environment. In Figure 4, the MS-coated pipe in the salt environment did not corrode for the first 3 weeks. After 6 weeks, it recorded a corrosion rate of 3.448×10^{-5} mm/year. This corrosion rate increased by 88.8% to 6.51×10^{-5} mm/year at the 9th week. It then decreased by 8.9% to 5.928×10^{-5} mm/year at the 12th week and increased by 45.9% to 8.649×10^{-5} mm/year at the 15th week. Further investigation in the 18th and 21st weeks showed increases in the corrosion rate of 5.4% and 5.5%, respectively. Comparing the final corrosion rate of the coated pipe with the uncoated pipe, the introduction of the MS coating increased the corrosion rate by 421%.

The PS-coated pipe in the salt environment did not corrode for 6 weeks. During the 9th week of observation, it recorded a corrosion rate of 4.6×10^{-6} mm/year. This corrosion rate decreased by 25% to 3.45×10^{-6} at the 12th week of observation. During the 15th week of observation, the corrosion rate increased by 52.8% to 5.27×10^{-6} mm/year. Further investigation in the 18th and 21st weeks showed decreases in the corrosion rate of 17.1% and 9.38%, respectively. As shown in Figure 5, comparing the final corrosion rate of the coated pipe with the uncoated pipe, the introduction of the PS coating reduced the corrosion rate by 396%.

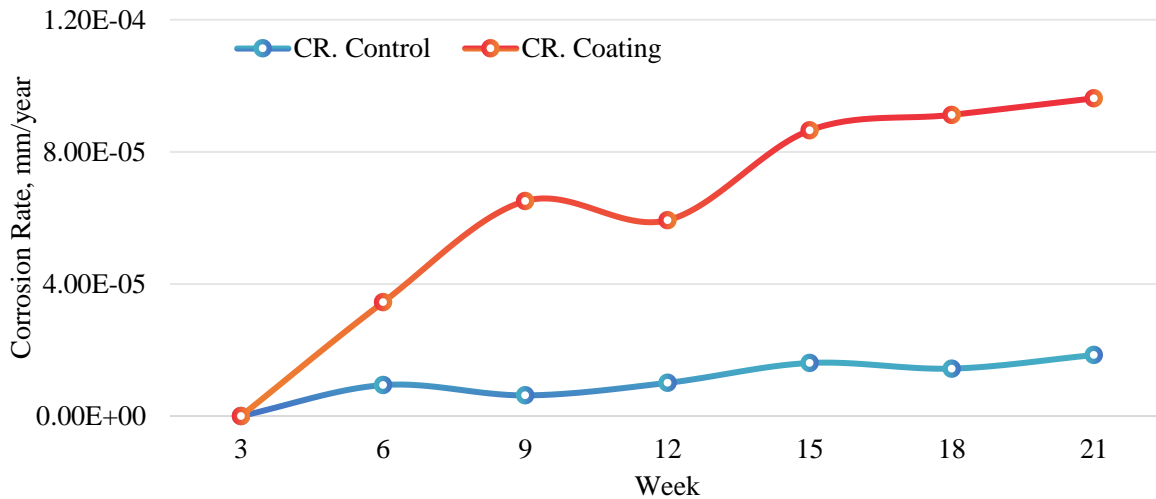


Figure 4—Corrosion rate of mucuna solanifolia inhibitor in salt environment.

The MPS-coated pipe in the salt environment did not corrode for the first 15 weeks. At the 18th week, it recorded a corrosion rate of 2.32×10^{-6} . From the 18th week to the 21st week, the corrosion rate decreased by 13.3%. As shown in Figure 6, the corrosion rate of the corrosion-inhibited pipe remained zero for 15 weeks before increasing to 4.37×10^{-6} mm/year and then dropping to 3.96×10^{-6} mm/year. As observed from Figures 4 to 6, the corrosion rate of the uncoated pipe increased over time compared to the coated pipes.

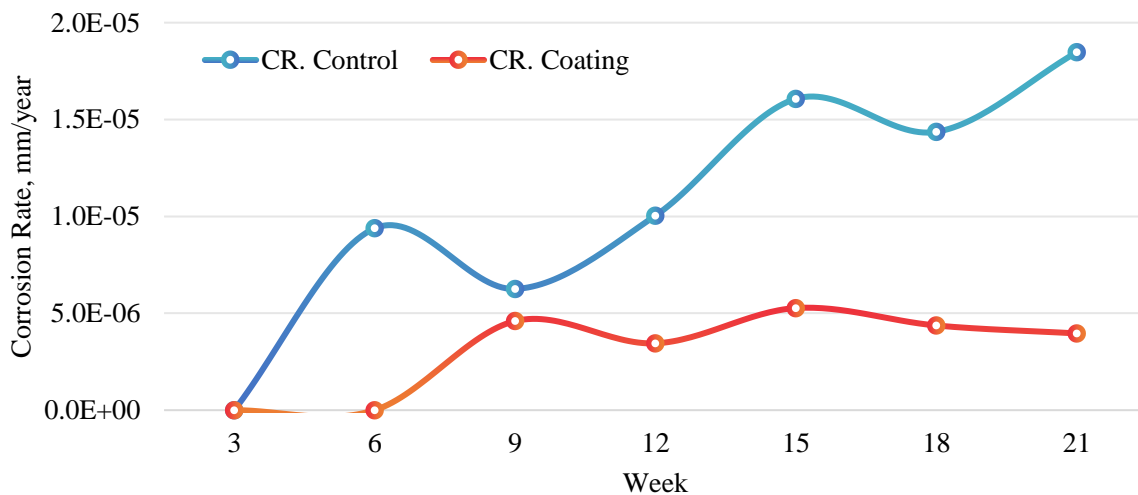


Figure 5—Corrosion rate of periwinkle shell inhibitor in salt environment.

Microbial Environment. Figures 7 to 9 present the corrosion rates of pipes coated with MS, PS, and MPS in a microbial environment. In Figure 7, the MS-inhibited pipe showed an increase in corrosion rate to 2.805×10^{-4} and 3.3334×10^{-4} mm/year after 3 and 6 weeks, respectively. However, the corrosion rate continuously declined

until it reached 2.822×10^{-4} mm/year after the 21st week. Comparing the corrosion rates of the coated and uncoated pipes, the corrosion rate of the coated pipe was higher, indicating that mucuna solannie is not a suitable inhibitor in a microbial environment.

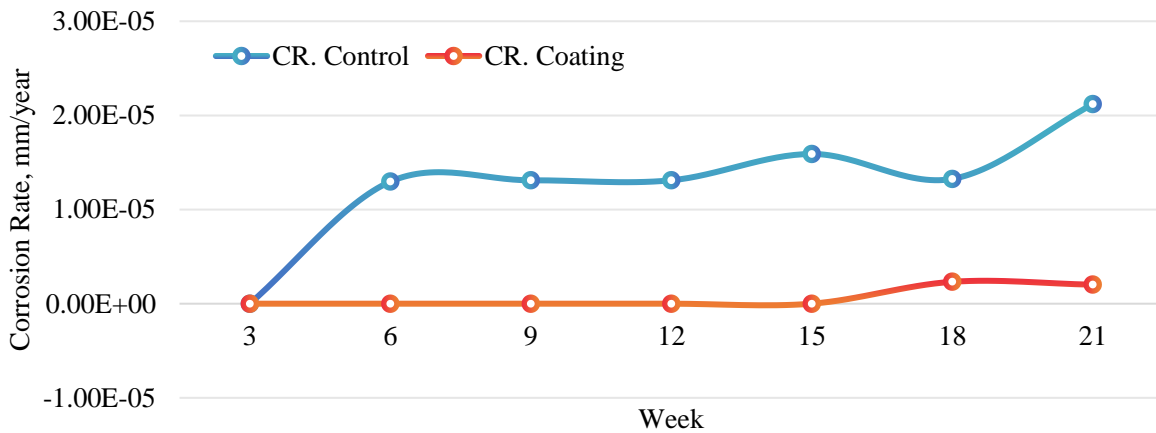


Figure 6—Corrosion rate of mucuna solannie-periwinkle shell inhibitor in salt environment.

In Figure 8, the PS-coated pipe and the uncoated pipe had similar corrosion rates after 6 weeks of investigation. After that, the corrosion rate of the PS-coated pipe was higher for an additional 9 weeks. This trend reversed, and the corrosion rate of the PS-coated pipe became lower than that of the uncoated pipe, indicating the long-term suitability of this local corrosion inhibitor.

As shown in Figure 9, the corrosion rate of the MPS-coated pipe remained lower than that of the uncoated pipe, always indicating the suitability of the inhibitor in a microbial environment. Microorganisms promote corrosion by synthesizing oxidizing agents, which can be metabolic or end-products of their interaction with the metal (Iverson 1974). As observed in Figure 7, the higher corrosion rate of the coated pipe compared to the uncoated pipe can be attributed to the increased synthesis of oxidizing agents and the reduction of the pipe/environment barrier for liquid contaminants, which is consistent with Iverson’s (1974) study. In Figure 8, the similar corrosion rates of the coated and uncoated pipes can be attributed to the oxidation process, which reduces the weight of the iron. In Figure 9, the lower corrosion rate of the coated pipe compared to the uncoated pipe is due to the coating blend’s ability to inhibit the corrosion process, create an effective barrier between the substrate material and the environment, and act as a sacrificial material, which is in line with the findings of Popoola et al. (2014).

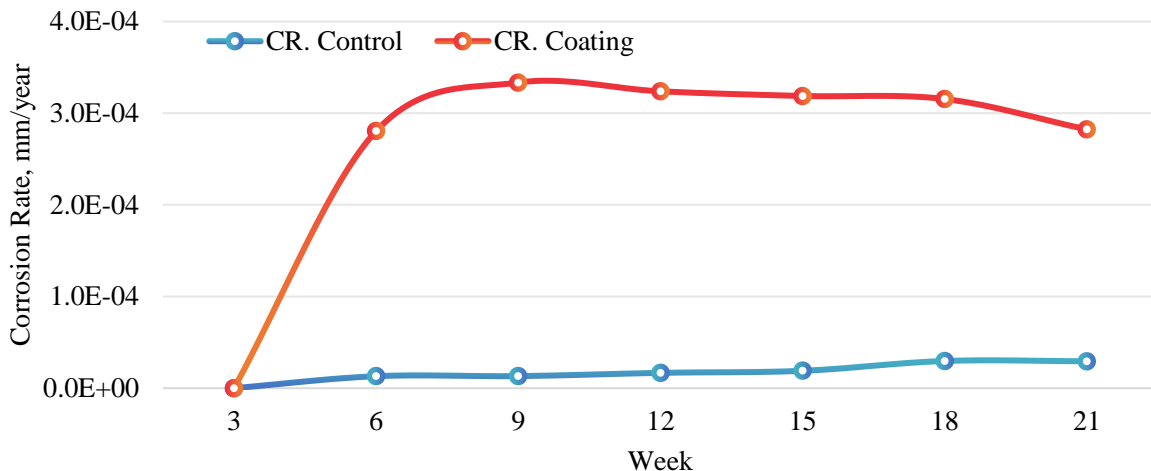


Figure 7—Corrosion rate of mucuna solannie inhibitor in microbial environment.

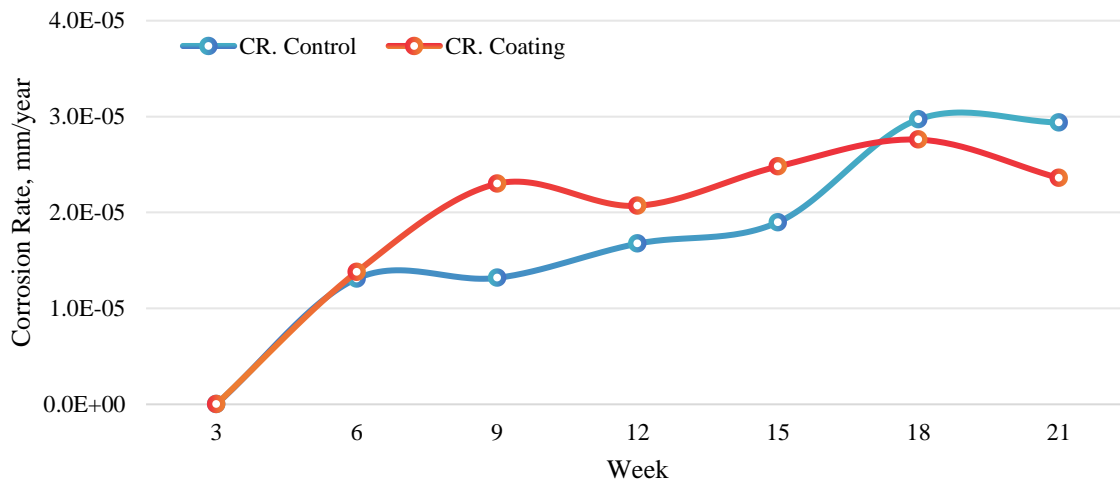


Figure 8—Corrosion rate of periwinkle shell inhibitor in microbial environment.

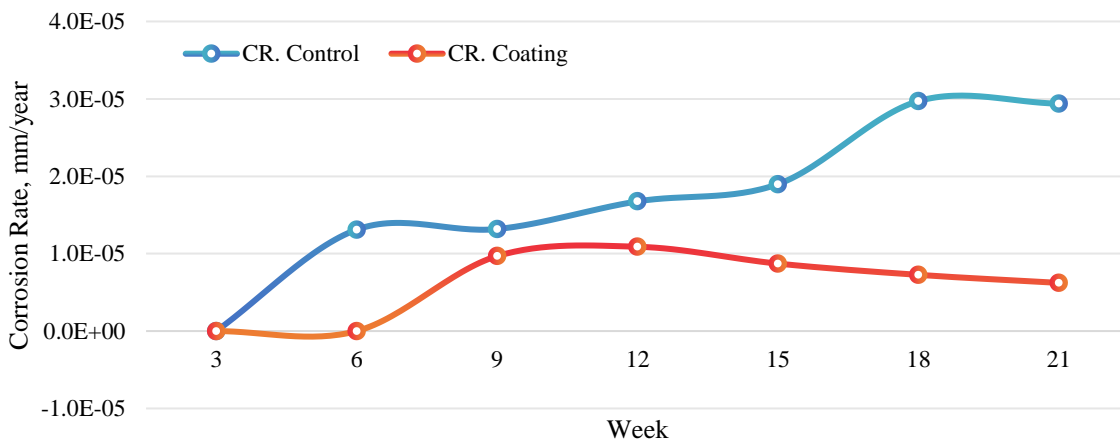


Figure 9—Corrosion rate of mucuna solanica-periwinkle shell inhibitor in microbial environment.

Conclusions

This study investigated the corrosion inhibition performance of locally sourced *Mucuna solanica* (MS), periwinkle shell (PS), and their hybrid composite (MPS) as eco-friendly coating materials for carbon steel pipelines in acidic, saline, and microbial environments. The key findings are summarized as follows:

1. The MPS hybrid coating demonstrated significantly enhanced corrosion inhibition compared to standalone MS and PS formulations across all tested environments. In acidic conditions, MPS achieved a 91.3% reduction in corrosion rate, outperforming PS (82.8%) and MS (77.9%). Similarly, in saline environments, MPS maintained zero corrosion for 15 weeks, with a final corrosion rate of 3.96×10^{-6} mm/year, while PS reduced corrosion by 396% compared to uncoated pipes. Under microbial exposure, MPS exhibited sustained protection, maintaining lower corrosion rates than uncoated pipes throughout the 21-week study. This superior performance is attributed to the synergistic interaction between PS (calcium-rich, barrier-forming) and MS (potassium/carbon-rich, adsorption-active), which collectively enhance passivation and barrier integrity.

2. The microbial environment posed the greatest challenge to inhibition performance, with MS-coated pipes exhibiting higher corrosion rates (up to 3.333×10^{-4} mm/year) than uncoated controls due to microbial synthesis of oxidizing agents. In contrast, MPS resisted microbial degradation, likely due to its composite structure limiting biofilm adhesion and metabolite penetration. Saline conditions also revealed material-specific vulnerabilities: MS coatings increased corrosion rates by 421%, whereas PS and MPS maintained protective efficacy, highlighting the importance of environment-specific inhibitor design.
3. The inhibition mechanism of PS and MPS aligns with their elemental composition. PS's high calcium content (79.48%) likely facilitated the formation of protective carbonate layers, while MS's heteroatoms (oxygen, nitrogen) and cyclic organic compounds enabled chemisorption onto steel surfaces, blocking active corrosion sites. The hybrid MPS combined these traits, creating a dual passive-active barrier that impeded corrosive ion diffusion and neutralized acidic/microbial agents.
4. The MPS hybrid presents a cost-effective, sustainable alternative to conventional inhibitors (e.g., FBE, CTE), particularly for resource-limited regions. Its efficacy in harsh environments (e.g., offshore saline, sour gas pipelines) underscores its potential for field applications. However, the poor performance of MS in microbial settings necessitates caution in environments prone to microbiologically influenced corrosion (MIC).

Future Work

The following future work was recommended:

1. Long-term stability studies under fluctuating temperature/pressure conditions.
2. Electrochemical analysis (EIS, polarization) to quantify adsorption efficiency and mechanistic pathways.
3. Field trials in operational oil/gas pipelines to validate scalability.

Conflicting Interests

The author(s) declare that they have no conflicting interests.

Reference

- Agbede, O.I. and Manasseh, J. 2009. Suitability of Periwinkle Shell as Partial Replacement for River Gravel in Concrete. *Leonardo Electronic Journal of Practices and Technologies* **14**(1): 59-66.
- Arthur, D.E., Jonathan, A., and Ameh, P.O., et al. 2013. A Review on the Assessment of Polymeric Materials Used as Corrosion Inhibitor of Metals and Alloys. *International Journal of Industrial Chemistry* **4**(2):1-20.
- Bhadra, S., Singha, N.K., and Khastgir, D. 2011. Polyaniline Based Anticorrosive and Antimolding Coating. *Journal of Chemical Engineering and Materials Science* **2**(1): 1-11.
- Buchheit, R.G., Mamidipally, S.B., and Schmutz, P., et al. 2002. Active Corrosion Protection in Ce-Modified Hydrotalcite Conversion Coatings. *Corrosion* **58**(1): 3-12.
- Callister, W.D. and Wiley, J. 2007. Materials Science, sixth edition. New York: John Wiley & Sons, Inc.
- Dolan, S.E. and Carlson, L.R. 2007. U.S. Patent No.775882.
- Durodola, B.M., Olugbuyiro, J.A.O., and Moshood, S.A., et al. 2011. Study of Influence of Zinc Plated Mild Steel Deterioration in Seawater Environment. *International Journal of Electrochemical Science* **6**(1): 5605-5616.
- Duru, U.I., Onyejekwe, I.M., and Isu, D.O., et al. 2020. Performance Evaluation of Mucuna solanica as a Drilling Fluid Additive in Water-Base Mud at Cold Temperature. *Journal of Petroleum and Gas Engineering* **11**(1): 1-8.
- Ekop, I.E., Adenuga, O.A., and Umoh, A.A. 2013. Strength Characteristics of Granite-Pachimalania aurita Shell Concrete. *Nigerian Journal of Agriculture, Food and Environment* **9**(2): 9-14.
- Hill, M. 2009. U.S. Patent No. 7534290.
- Igwilo, K.C., Uwaezuoke, N., and Okoro, E.E., et al. 2020a. Experimental Analysis of Mucuna solanica as Cement Extender Additive for Oil and Gas Well Cementing. *Journal of Petroleum Exploration and Production Technology* **10**(1): 3437-3448.

- Igwilo, K.C., Uwaezuoke, N., and Okoli, N., et al. 2020b. Beneficiation of Nigerian Bentonite Using Local Materials. *Journal of Petroleum Exploration and Production Technology* **12**(4):23-45.
- Igwilo, K.C., Uwaezuoke, N., and Onyekwere, R.K., et al. 2021a. Comparative Assessment of Mucuna solanica as an Alternative Fluid Loss Control Material in Synthetic Drilling Fluid Design. *Journal of Petroleum Exploration and Production Technology* **11**(1): 97-120.
- Iverson, W.P. 1974. *Microbial Corrosion of Iron*. New York: Academic Press.
- Kramer, T., Gillich, V., and Fuchs, R. 2007. U.S. Patent No. 782475.
- Krishnamurthy, A., Gadhamshetty, V., and Mukherjee, R., et al. 2013. Passivation of Microbial Corrosion Using a Graphene Coating. *Carbon* **56**(1): 45-59.
- Lee, J.H., Brady, B.K., and Fuss, R.L. 2009. U.S. Patent No. 7494734.
- Malik, A.U., Ahmad, S., and Andijani, I., et al. 1999. Corrosion Behavior of Steels in Gulf Seawater Environment. *Desalination* **123**(2): 205-213.
- Paul, S., Pattanayak, A., and Guchhait, S.K. 2014. Corrosion Behavior of Carbon Steel in Synthetically Produced Oil Field Seawater. *International Journal of Metals* **2014**(1): 1-11.
- Popoola, A., Olorunniwo, O.E., and Ige, O.O. 2014. Corrosion Resistance Through the Application of Anti-Corrosion Coatings. In *Developments in Corrosion Protection*, ed. M. Aliofkhaezrai, Chap. 12, 241-270. London, United Kingdom: IntechOpen Limited.
- Rajendran, S., Sridevi, S.P., and Anthony, N., et al. 2005. Corrosion Behavior of Carbon Steel in Polyvinyl Alcohol. *Anti-Corrosion Methods and Materials* **52**(2): 102-107.
- Schweitzer, P.A. 2007. *Fundamentals of Metallic Corrosion: Atmospheric and Media Corrosion of Metals, second edition*. Boca Raton, Florida: CRC Press.
- Schweitzer, P.A. 2013. *Fundamentals of Corrosion: Mechanisms, Causes, and Preventative Methods*. Cambridge: Cambridge University Press.
- Thompson, I. and Saithala, J.R. 2015. Review of Pipeline Coating Systems from an Operator's Perspective. *Corrosion Engineering, Science and Technology* **13**(2):81-104.
- Wessling, B. 1999. Scientific Engineering of Anti-Corrosion Coating Systems Based on Organic Metals (Polyaniline). *Journal of Corrosion Science and Engineering* **1**(1):15-32.

Kevin Chinwuba Igwilo is a Professor at the Department of Petroleum Engineering, Federal University of Technology Owerri with research interest in drilling engineering, completion engineering, drilling and completion fluids technology, reservoir simulation and corrosion. Igwilo holds a bachelor's degree and master's degree in petroleum engineering from University of Port Harcourt, PhD degree in Petroleum Engineering from Federal University of Technology Owerri, Nigeria.

Obiukwu David Nduji is master's student at the Department of Petroleum Engineering, Federal University of Technology Owerri with research interest in drilling engineering and corrosion. Obiukwu holds a bachelor's degree in petroleum engineering from Federal University of Technology Owerri, Nigeria.

Nnaemeka Uwaezuoke is a senior lecturer at the Department of Petroleum Engineering, Federal University of Technology Owerri with research interest in drilling and well engineering. Uwaezuoke holds a bachelor's degree in petroleum engineering from Federal University of Technology Owerri, master's degree in petroleum engineering from University of Stavanger, Norway, and a PhD degree in Petroleum Engineering from Federal University of Technology Owerri, Nigeria.

Chukwuebuka Francis Dike is a research technologist at the Department of Petroleum Engineering, Federal University of Technology Owerri with research interest in drilling fluids, enhanced oil recovery, reservoir engineering and flow assurance. Dike holds a bachelor's degree and master's degree in petroleum engineering from Federal University of Technology Owerri, Nigeria.