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Inhibitory Potential of Blended *Parkia biglobosa and Delonix regia* Extracts on Corrosion of AISI 1007 Steel in 1.0 M Hydrochloric Acid Medium

Yusuf L. SHUAIB-BABATA[1*], Kabiru S. AJAO[2], Yusuf O. BUSARI[3], Ibrahim O. AMBALI[4], Toheeb A. NURUDEEN[5], John A. OKOLO[6], Gabriel A. LONGE[7]

[1*,2,3,4,5,6,7]Department of Materials and Metallurgical Engineering, University of Ilorin, Ilorin, Nigeria

[1*]sylbabata@unilorin.edu.ng, [2]ajao.ks@unilorin.edu.ng, [3]busari.oy@unilorin.edu.ng, [4]ambali.io@unilorin.edu.ng, [5]abioduneniola5@gmail.com, [6]okolojohn7@gmail.com, [7]gabrielalongemme@gmail.com

Abstract

The development of sustainable corrosion inhibitors for mild steel in acidic environments remains a significant challenge. This study evaluates the individual and synergistic inhibition performance of Parkia biglobosa peel extract (PBPE) and Delonix regia pod extract (DRPE) in 1.0 M HCl using weight loss, gasometric, electrochemical polarization, and electrochemical impedance spectroscopy (EIS) techniques. Results from mass loss and gasometric measurements reveal that PBPE accelerates corrosion, whereas DRPE exhibits high inhibition efficiency. Hybrid formulations (PBPE:DRPE = 3:1, 1:3, 2:1, 1:2, 1:1) demonstrate enhanced performance, with DRPE-rich systems (1:3 and 1:2) showing superior inhibition efficiency. Polarization studies indicate mixed-type inhibition behaviour, while EIS results show increased charge transfer resistance and reduced double layer capacitance with increasing inhibitor concentration, confirming adsorption-driven protective film formation. This work uniquely identifies the antagonistic behaviour of PBPE and the dominant inhibitory effect of DRPE, and demonstrates that optimized hybridization significantly improves corrosion resistance. The findings provide a novel approach for designing efficient, eco-friendly inhibitor systems through strategic combination of plant extracts.

Keywords: *Corrosion, Hydrochloric Acid, Inhibitor, Plant extracts, Potential.*

1.0 Introduction

Corrosion inhibitor is a mixture of materials added in lower amounts to protect the exposed metallic surface from a corrosive environment. It lessens or completely stops metal corrosion [1]. Due to the increasing awareness on sustainable environment and environmental regulation on the toxic nature and high cost of some organic inhibitors, green corrosion inhibitors which are derived from bio-waste, also biodegradable and do not contain toxic compound serves as an effective alternative for corrosion inhibitors [2],[3],[4].

Corrosion of metallic materials, particularly mild steel, in acidic environments remains a major challenge in industrial processes such as acid pickling, descaling, and oil well acidizing. This degradation leads to significant economic losses and safety concerns across multiple sectors. The use of corrosion inhibitors remain one of the most effective mitigation strategies in the control or prevention of corrosion in many environments [1]. However, conventional synthetic inhibitors, such as chromates and phosphates, are associated with toxicity, high cost, and environmental hazards, leading to increasing regulatory restrictions and the need for sustainable alternatives [5].

Green corrosion inhibitors derived from plant extracts and bio-waste have gained considerable attention due to their biodegradability, eco-friendliness, availability, and low toxicity [3],[4]. It has been discovered through studies that plant extracts contain bioactive phytochemicals such as tannins, flavonoids, alkaloids, and polyphenols, which possess heteroatoms (N, O, S) and π-electron systems capable of adsorbing onto metal surfaces and forming protective films [6]. These compounds inhibit corrosion by blocking active sites, reducing charge transfer, and limiting the diffusion of aggressive ions. Consequently, plant-based inhibitors have demonstrated inhibition efficiencies often exceeding 60–90% depending on concentration and system conditions [6],[7].

The growing research interest in plant-derived inhibitors has been further shown in literature, highlighting the rapid expansion of green inhibitor research due to environmental regulations and the need for sustainable corrosion protection strategies[6],[7]. Several plants extracts have been investigated as corrosion inhibitors, which include *Carica papaya* [10],[11]; *Musa acuminata* [9]; *Azadirachta indica* [10]; [11]; *Prosopis africana* [12]; *Parkia biglobosa* [13],[14],[15],[16],[17] and *Delonix regia* [18]. While these studies confirm their corrosion inhibition potential, the efficiency of individual plant extracts varies significantly.

Some green corrosion inhibitors from various plant extracts have demonstrated high inhibition efficiencies during some experimental studies, such as *Citrulluslanatus*, *Prosopis Africana, Chrysophyllum albidum,*

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Cucumber, Phoenix dactylifera and other bio-based systems [1],[7],[8],[9],[10],[11],[19]. This quality reinforces their potential as viable alternatives to toxic inhibitors. Despite these advances, challenges remain regarding variability in performance, optimization of concentration, and consistency of inhibition efficiency across different plant sources.

There is an indication through findings that *Parkia biglobosa* pulp acts as an effective green inhibitor for mild steel corrosion in both acidic and alkaline environments, with potential applications in sustainable corrosion protection[20]. Previous studies have shown the effectiveness of *Parkia Biglobosa and Delonix Regia* extracts in inhibiting corrosion through adsorption mechanisms in acidic environment[21],[22]. This is an indication that bioactive compounds (such as alkaloids, tannins, and flavonoids) in *Parkia Biglobosa* and *Delonix Regia* may similarly adsorb onto metal surfaces, forming protective layers[21],[23].

Parkia biglobosa has been reported to exhibit relatively low inhibition efficiency [13], whereas *Delonix regia* demonstrates higher efficiency that improves with increasing concentration [18]. This inconsistency highlights a key limitation of single-component green inhibitors. Meanwhile, despite promising inhibiting effectiveness of *Delonix Regia* extracts detailed comparative data is still limited[24].

Through experimental studies, it has been proved that the organic inhibitors that form protective films on metal surfaces to control corrosion rates through formation of protective adsorbed layers differently or fill the gaps in other protective layer formed [25],[26],[27],[28],[29]. Some Researchers 30],[31],[32],[33],[34],[35],[36] through their studies discovered the effective corrosion inhibition of mild steel in acidic environments using each of *Parkia biglobosa* and *Delonix regia* extracts like some other plant extracts through adsorption and protective film formation. The studies showed the strong protective layer and adsorbed molecular film formed by *Parkia biglobosa* and *Delonix regia* extracts, respectively.

To address this limitation, recent research trends have shifted toward the development of synergistic inhibitor systems, where the combination of multiple plants extracts enhances adsorption behaviour, surface coverage, and overall inhibition efficiency. Synergistic interactions between phytochemical constituents can lead to improved protective film formation and more stable adsorption on metal surfaces. However, despite growing interest in hybrid green inhibitors, there is limited research on the combined use of *Parkia biglobosa* and *Delonix regia*, particularly in optimizing their ratio for maximum inhibition performance. Therefore, the novelty of this study lies in the systematic investigation of the synergistic corrosion inhibition performance of blended *Parkia biglobosa* and *Delonix regia* extracts at varying ratios. Thus necessitate the formation of the blended *Parkia biglobosa* and *Delonix regia* extracts to be examined as an inhibitor in acidic medium. This study thereby seeks to experimentally validate the efficacy, optimal concentration and mechanism of the blended *Parkia biglobosa* and *Delonix regia* extracts in real-world conditions.

The optimization of the *Parkia Biglobosa plant extract with Delonix Regia* to obtain an optimal inhibitory potential efficiency is therefore deemed necessary in this study. This study investigates the inhibitory potential of blended *Parkia Biglobosa* and *Delonix Regia* on corrosion of local carbon steel in an acidic solution of Hydrochloric acid (HCl).

This work aims to evaluate the extent to which hybridization enhances inhibition efficiency compared to individual extracts and to elucidate the underlying inhibition mechanisms. The corrosion behaviour of local carbon steel in 1.0 M HCl is assessed using weight loss measurements, gasometric analysis, electrochemical polarization, and electrochemical impedance spectroscopy (EIS). This study provides new insights into the design of efficient, eco-friendly corrosion inhibitors through strategic combination of plant extracts, contributing to the advancement of sustainable corrosion control technologies.

2.0 Materials and Methods

2.1 Materials

The various materials that were used in this study include low carbon steel, *Parkia Biglobosa* (African locust bean pod), *Delonix Regia* (Flamboyant pod), hydrochloric acid and n-Hexane. The low carbon steel was obtained from a commercial steel vendor along Taiwo Road, Ilorin, Kwara State, Nigeria, while hydrochloric acid (sp. Gr. 1.8; % purity of 37% and Density of 1.19 g/cm^3) and n-Hexane were commercially sourced from Omega Chemical Store, Taiwo Road, Ilorin, Nigeria. Additionally, *Parkia Biglobosa* and *Delonix Regia* pods were obtained within the University of Ilorin campus where they were dumped as wastes. These materials are integral to the successful execution of the project's objectives and experimentation.

2.2 Preparation of plant extracts

The pods of *Parkia Biglobosa* and *Delonix Regia* were thoroughly cleaned, air-dried, and pulverized into fine particles. The extraction of oils from the pulverized pods were carried out at the Department of Chemistry Laboratory, University of Ilorin, Ilorin, Nigeria. The extraction process was carried out using the distillation column with n-hexane as the solvent, using the ratio of 6:1 (fine powder: solvent) which depended on the oil

content. Though, the is no stipulated single universal ratio for the process (extraction) of a pulverized pod using n-hexane, but it depends on oil content, particle size, and equipment [37],[38],[39],[40],[41],[42],[43].

(a) (b) (c) (d)

Figure 1(i): (a) Plucked *Parkia Biglobosa* fruit (b) separated seeds from the pods (c) *Parkia Biglobosa dried pod* (d) *Parkia Biglobosa* pod extracts

(a) (b) (c)

Figure 1(ii): (a) *Delonix Regia* pod (b) pulverized *DelonixRegia* pod (c) *Delonix Regia* pod extract.

Figure 1: The stages of preparation of the inhibitor extracts

2.3 Mild steel specimen

The mild steel rods used in this study was obtained in the local steel market at Taiwo, Ilorin, Kwara State, and was analyzed to obtain its elemental composition at MidWal Engineering Service Limited at Lekki, Lagos, Nigeria using Spectromaxx LMF06 Spectrometer. The 2.3 x 1.5 x 0.16 cm steel specimens for the weight loss (gravimetric) method were prepared in accordance with ASTM G1 -03 [44] and G4 standards [45] which were further polished, degreased in acetone, dried with heat dryer and immediately immersed in the corrosion medium. For this study, distilled water was used to prepare a Hydrochloric acid solution with a specific gravity of 1.19 to obtain 1.0 molarity.

2.4 Weight Loss (Gravimetric) Method

This is the simplest technique that is used in determining the rate of corrosion and the inhibition efficiency. The specimens were pre-weighed before being submerged in a 200 ml solution of a blank corrosive media and a medium with varying concentrations of the inhibitor extract at STP. The extract of *Parkia Biglobosa* and *Delonix Regia* were further added in the ratio of 2:1, 1:2, 3:1, 1:3, and the system was vacuumed to prevent the interaction with the environment using the NACE/ASTM G31-12a[46] guidelines. The specimens were submerged in the medium between 24 and 2160 hours in accordance with the ASTM G1 standard [44]. The specimen were removed from the medium after 24 hours, washed in distilled water, rinsed in acetone, dried and reweighed using an electronic weighing balance (HX 302 with 0.01g accuracy). The process was repeated for the other specimens in the medium till the period of 2160 hours. Equation (1) [19],[44] was used to determine the rate of corrosion.

$$\text{Corrosion rate (mpy)} = \frac{kW}{DAT} \quad (1)$$

Where W is the mass loss (g), A is surface area of the specimen in cm^2, K is constant = 3.45 x 10^6 mils per year (mpy), D is density of the steel (g/cm^3) and T is the time of exposure (hours).

The corrosion rate inhibition efficiency was determined using Equation (2) [17],[47].

$$I.E(\%) = \frac{CR_{Blank} - CR_{Inh}}{CR_{Blank}} x100 \quad (2)$$

Where CR_{Blank} is corrosion rate in the absence of inhibitor, CR_{Inh} corrosion rate in the presence of inhibitor.

2.5 Hydrogen gas evolution (Gasometric) measurement

The volume of hydrogen gas evolved from steel coupon when immersed in the test solution was measured using the gasometric measurement. A 200 mL of the test solution was put in a two necked flask with one end of the flask kept closed and the other end connected to a tube connected to the base of a burette. The burette was filled with an initial volume of water of 50 mL. Bubbles of hydrogen were formed as a result of reaction between the solution and the steel coupon which reduce the volume of water in the burette. The setup was tightly closed so as to prevent gases escaping from the medium. The readings were taking at 30 minutes intervals and the downward displacement of the water in the burette was measured for a total period of 300 minutes. The process was carried out for the solution without and with inhibitor with different concentration of

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the blended *Parkia Biglobosa* pod extract (PBPE) *and Delonix Regia* pod extract (DRPE). The inhibition efficiency (I.E%) from the hydrogen evolution measurement was determined using Equation (3)[48].

$$I.E(\%) = 1 - \frac{CR_{Inh}}{CR_{Blank}} x100\% \quad (3)$$

2.6 Tafel polarization technique

The Potentiodynamic Polarization Method assesses material corrosion in acidic environments. It involves a three-electrode cell with a working electrode (the material), a reference electrode, and a counter electrode. Voltage is applied to the working electrode while measuring current flow to create a polarization curve, revealing corrosion potential and corrosion current density. The AUTOLAB PGSTAT 204N instrument was used for this study. Metal samples were prepared according to ASTM G3-14 standards [49], attached to the working electrode, and immersed in the solution. Corrosion potential and current density are calculated from the intersection of anodic and cathodic Tafel slopes. Inhibition efficiency and corrosion rate are determined using equation (4) and (5)[50],[51],[52],[53] respectively. The inhibition efficiency ($\eta(\%)$) was determined by comparing the corrosion current density without the inhibitor with the corrosion current density in the presence of the inhibitor.

$$\eta(\%) = \frac{I_{corr,blank} - I_{corr\,(inh)}}{I_{corr}} \; x\,100 \quad (4)$$

Where: $I_{corr,blank}$ is the corrosion current density without the inhibitor and $I_{corr\,(inh)}$ is the corrosion current density with the inhibitor

$$\text{Corrosion Rate (CR)} = \frac{I_{corr}\; x\; K\; x\; EW}{ƥ} \quad (5)$$

Where:

I_{corr} The corrosion current density ($\frac{\mu A}{cm^2}$)

ƥ: Density of the metal ($\frac{g}{cm^3}$) = 7.85 $\frac{g}{cm^3}$

K is a constant (3.27 x 10^{-3} mm/year)

EW ≈ weight of the metal

3.0 Results and Discussion

3.1 Elemental composition analysis

The weight percentage result of element presents in the mild carbon steel as determined from the elemental composition analysis is shown in Table 1.

Table 1*:* Elemental composition of mild steel sample

Elements	**%wt**	**Elements**	**%wt**	**Elements**	**%wt**
Fe	98.400%	C	0.203%	Mn	0.612%
Si	0.174%	Cu	0.148%	S	0.045%
Cr	0.188%	Ni	0.072%	Sn	0.009%
V	0.037%	P	0.027%	Al	0.0005%

The results justifies the classification of this steel as AISI 1007 by showing that it conforms to the specified range of elements typical for AISI 1007 steel based on its chemical composition [2],[54],[55],[56].

3.2 Phytochemical analysis

The phytochemical (Qualitative and Quantitative) analysis results for *Parkia Biglobosa* pod and *Delonix Regia* pod are shown in Tables 2 and 3, respectively.

Table 2*:* Phytochemical analysis result of *Parkia Biglobosa* pod

Element	**Qualitative**	**Quantitative**
Alkaloids	+	49.68
Steroids	+	9.02
Triterpenoids	+	59.53
Glycoside	+	99.97

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Table 3*:* Phytochemical analysis result of *Delonix Regia* pod

Element	Qualitative	Quantitative
Alkaloids	+	19.00
Steroids	+	1.50
Triterpenoids	+	33.58
Glycoside	+	99.83

Tables *2* and 3 presents the active element presents in both *Parkia Biglobosa* pod extract and *Delonix Regia* pod extract, respectively. The elements include alkaloids, steroids, triterpenoids, and glycoside. The (+) shows that the constituent is actively present in the extract and the (-) indicates the absence of the constituent in the plant extract. The quantitative analysis indicates the amount of this constituent in the extract with glycoside having the highest constituent in the extract. The presence of these phytochemicals in the *Parkia Biglobosa* and *Delonix Regia* pod extract suggests that the extract have the potential to act as a natural corrosion inhibitor for metals [57],[58],[59],[60],[61],[62]. It was observed that the effectiveness of the extract as a corrosion inhibitor would depend on factors such as the concentration of these compounds in the extract.

3.3 Weight loss (Gravimetric) method

The results of the corrosion rates are plotted against the time of exposure for each inhibitor extracts and the hybrid concentration of the inhibitors for varied ratios of PBPE and DRPE (100%, 1:1, 1:2, 2:1, 1:3, 3:1) as shown in Figures 2 - 8. While the calculated corrosion efficiency against the time of exposure for all the specimens are displayed in Figures 9 – 14.

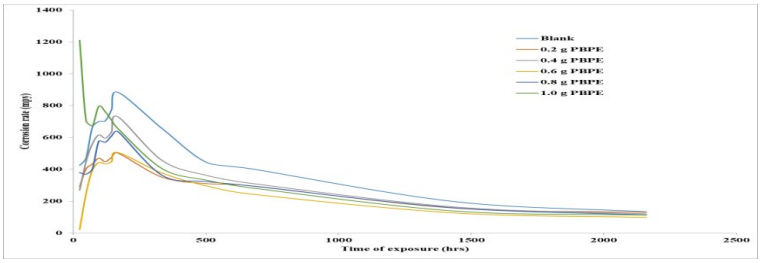

Figure 2: Corrosion rate (mpy) for the 100% PBPE concentration ratio

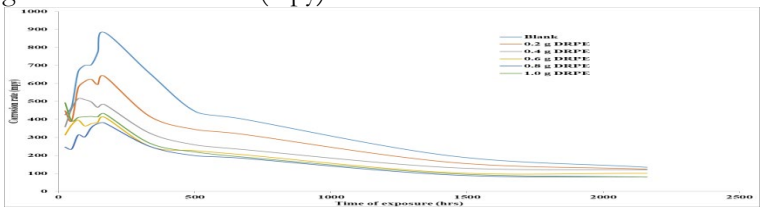

Figure 3: Corrosion rate (mpy) for the 100% DRPE concentration ratio

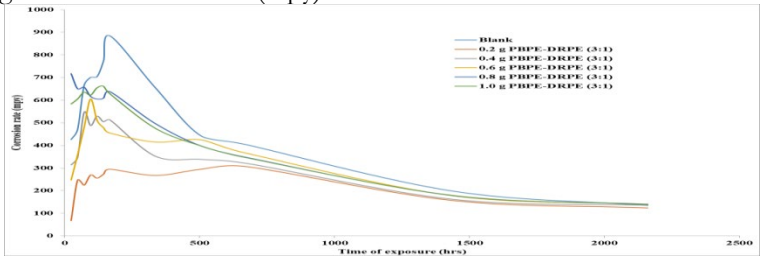

Figure 4: Corrosion rate (mpy) for the 3:1 concentration ratio of PAPE : DRPE

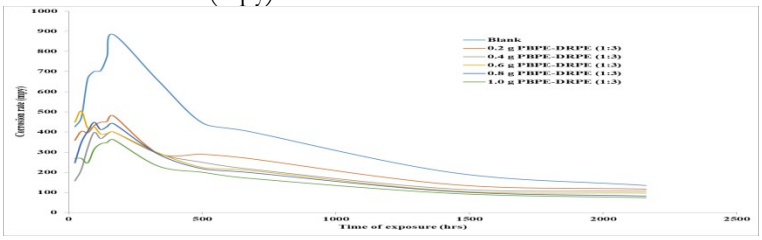

Figure 5: Corrosion rate (mpy) for the1:3 concentration ratio of PAPE: DRPE

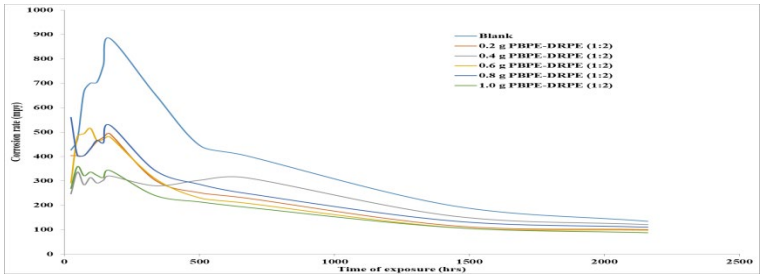

Figure 6: Corrosion rate (mpy) for the 1:2 concentration ratio of PAPE:DRPE

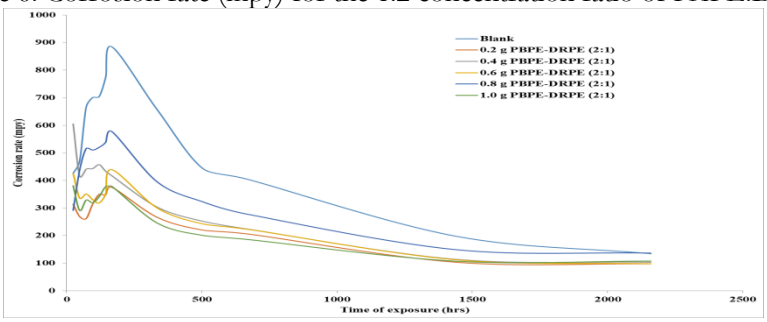

Figure 7: Corrosion rate (mpy) for the 2:1 concentration ratio of PAPE:DRPE

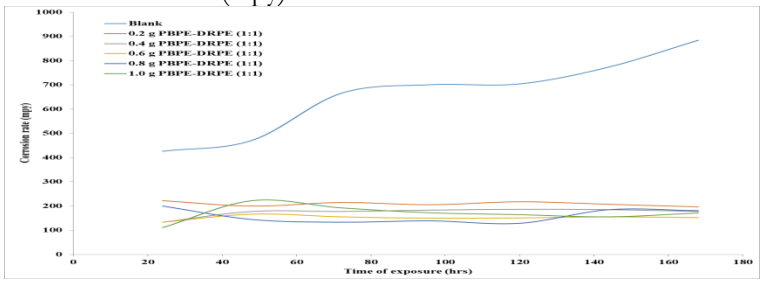

Figure 8: Corrosion rate (mpy) for the 1:1 concentration ratio of PAPE:DRPE

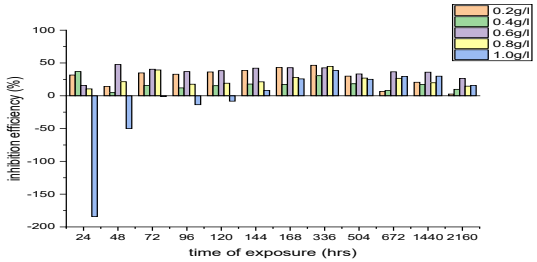

Figure 9: Inhibition efficiency (IE%) for the 100% PBPE concentration ratio

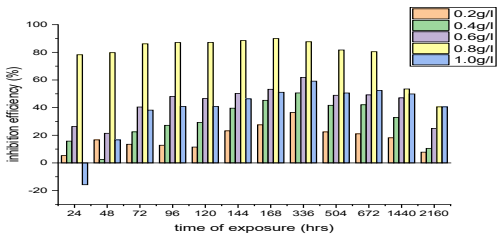

Figure 10: Inhibition efficiency (IE%) for the 100% DRPE concentration ratio

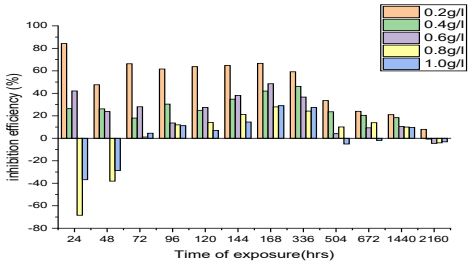

Figure 11: Inhibition efficiency (IE%) for the 3:1 of PBPE: DRPE concentration ratio

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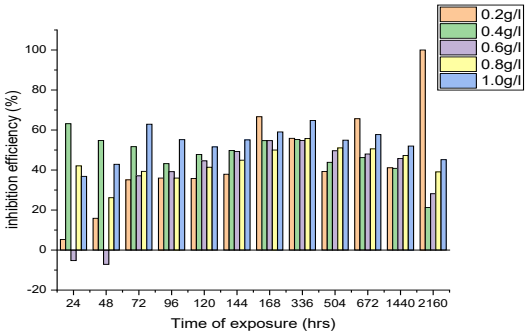

Figure 12: Inhibition efficiency (IE%) for the 1:3 of PBPE: DRPE concentration ratio

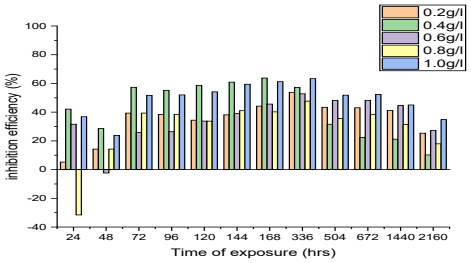

Figure 13: Inhibition efficiency (IE%) for the 1:2 of PBPE: DRPE concentration ratio

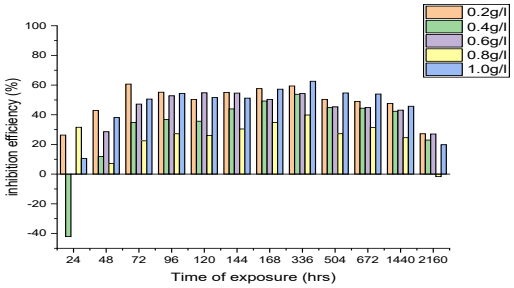

Figure 14: Inhibition efficiency (IE%) for the 2:1 of PBPE: DRPE concentration ratio

The electrochemistry of metal involves the cathodic hydrogen evolution and anodic dissolution of the metal, as shown in the following chemical reactions

Anode chemical reaction $Fe \rightarrow Fe^{2+} + 2e^-$

Cathode chemical reaction $2H^+ + 2e^- \rightarrow H_{2(g)}$

Overall reaction $Fe + 2H^+ \rightarrow Fe^{2+} + H_2$

From the overall redox reaction above, the rate of corrosion can be determined by employing the gravimetric methods, by the measurement of the weight loss of the metal.

The differences in the weight loss as obtained in the AISI 1007 steel at different concentrations of PAPE:DRPE in 1.0 M hydrochloric medium at different immersion time are shown in Figures 2 – 8. The specimens during the electrochemical reaction tests performed using a 1.0 M acidic media were observed with and without the corrosion inhibitor (0.0 g/l). The results showed that the specimen in a blank medium corroded at a higher rate. As the concentration of the plant extract was increased, the corrosion rate for the DRPE reduced significantly. However the corrosion rate slightly increased for the PBPE. The reduction in the corrosion rate could be seen as an effect of the phytochemicals adsorbing unto the surface of the metal, forming a barrier between the metal surface and the corrosive medium[17].

At 100% PBPE green inhibitor, after 2160 hours, 1.0 g/L recorded a 300mpy. Also in Figure 4, the trend for the corrosion was observed and the corrosion rate was seen to reduce drastically for 100% of DRPE. Figure 5, PBPE:DRPE when mixed with the formulation of 3:1, it showed that the corrosion rate was increased when exposed for about 2160 hours. However when a concentration of 1:3 of PBPE:DRPE, the result (Figure 6) shows a drastic decrease in corrosion rate with time exposure up to 2160 hours.

The calculated %IE graphs (Figures 9 - 15) revealed the effectiveness of the hybridized plant extracts in inhibiting the corrosion of the steel in the HCl medium. The hybridized specimen comprising of 1:3 PBPE:DRPE exhibited better corrosion effectiveness (optimization), especially with the concentration of 1.0 g/l at 336 hours of exposure (64.79% IE). This implies that the inhibiting efficiency of the plant extract (PBPE) can be optimized with the DRPE at the ratio of 1:3 (PBPE:DRPE).

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The good performance of plant extracts as an inhibitor can be attributed to the presence of phytochemical constituents that are capable of interacting with the mild steel surface as a result of the adsorption ability of the extracts. The adsorption on the mild steel surface is being facilitated by the presence of the bioactive compounds (tannin, alkaloids, flavonoids and tannins) in the plant extracts (as revealed in Tables 2 and 3) that enhances surface coverage and formation of stable adsorbed layer [12],[63],[64],[65],[66],[68]. Higher concentration of the inhibitor in the medium is another that can be attributed to the higher inhibition efficiency attained, since higher concentration directly increases the surface coverage of the inhibitor on the metal surface, thereby making it a key factor attributed to higher inhibition efficiency [12],[69]. Corrosion rate reduces as concentration increases by making available more inhibitor molecules to adsorb onto the metal/solution interface that lead to creation of a denser, more stable protective barrier that reduces corrosion rates.

Effective corrosion inhibition of mild steel was achieved as a result of the adsorption of bioactive compounds discovered in the plants extracts as shown in Tables 2 and 3. The wealth of tannins, alkaloids, flavonoid in the bioactive compounds in the inhibitor is responsible for the adsorption onto the mild steel that prevent corrosion [69]. The compounds contain heteroatoms (like Nitogen and Oxygen) and conjugated bonds that facilitate the process.

3.4 Hydrogen gas evolution (Gasometric) technique

The volume of hydrogen gas that was evolved both in the absent and present of varied concentration of the hybrid extract are shown in Figures 16-27.

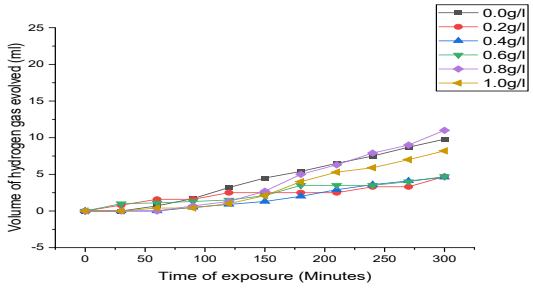

Figure 16: Rate of hydrogen gas evolution in 1 M HCL of 100% PBPE

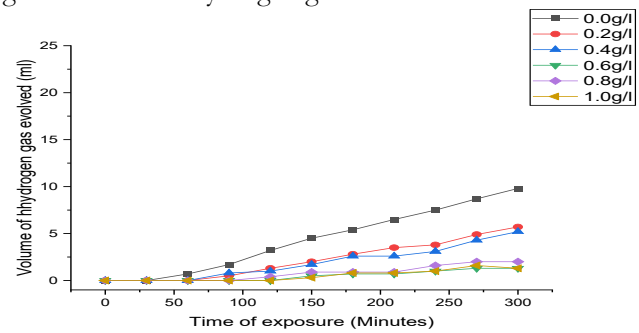

Figure 17: Rate of hydrogen gas evolution in 1M HCL of 100% DRPE

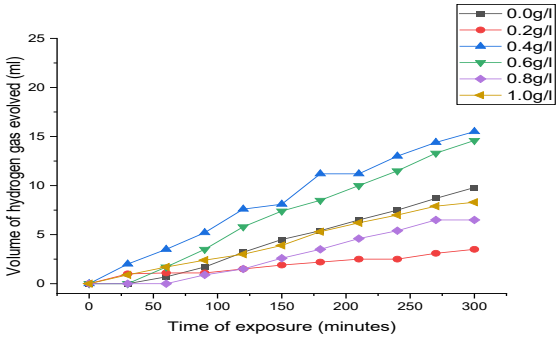

Figure 18: Rate of hydrogen gas evolution in 1M HCL at different concentrations of the 3:1 PBPE: DRPE

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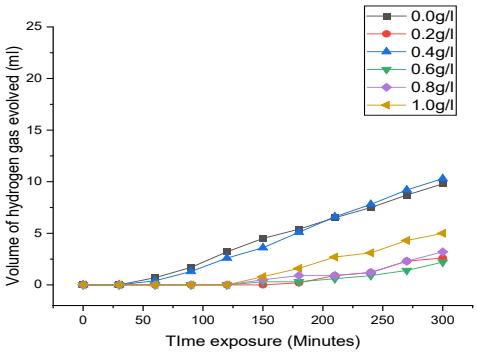

Figure 19: Rate of hydrogen gas evolution in 1M HCL at different concentrations of the 1:3 PBPE: DRPE

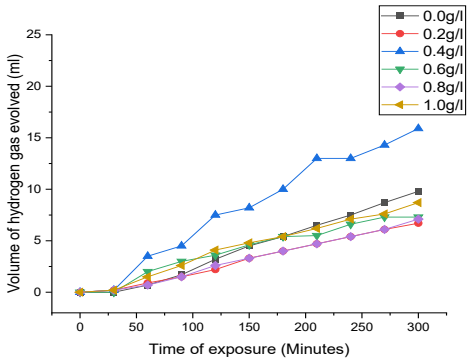

Figure 20: Rate of hydrogen gas evolution in 1M HCL at different concentrations of the 2:1 PBPE: DRPE

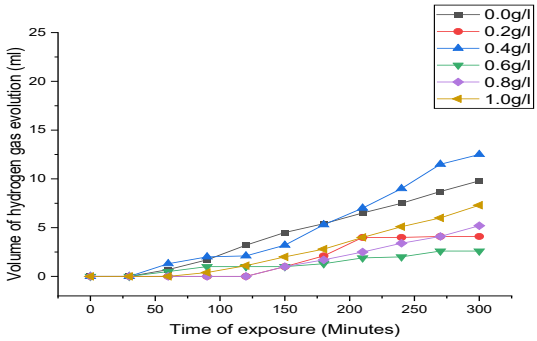

Figure 21: Rate of hydrogen gas evolution in 1M HCL at different concentrations of the 1:2 PBPE:DRPE

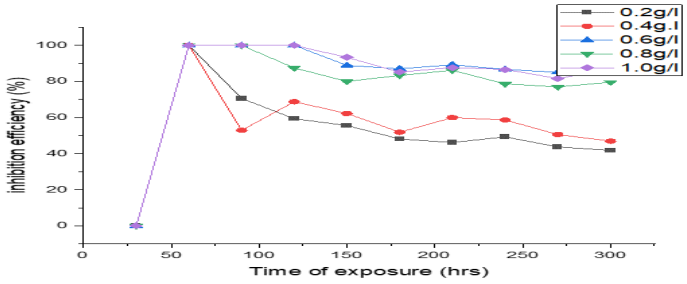

Figure 22: Variation of inhibition efficiency vs. time of exposure of DRPE concentrations

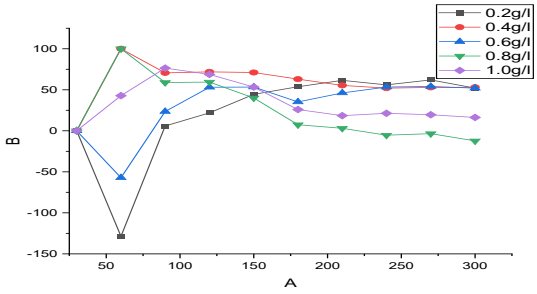

Figure 23: Variation of inhibition efficiency vs. time of exposure of PBPE concentrations

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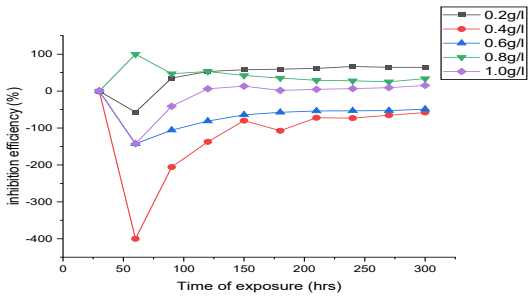

Figure 24: Variation of inhibition efficiency vs. time of exposure for 3:1 of PBPE:DRPE concentrations

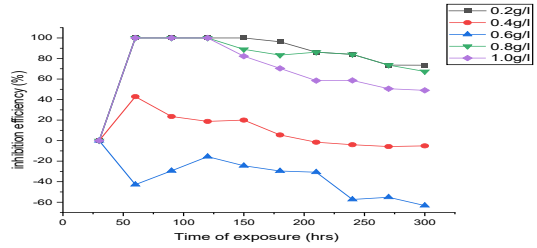

Figure 25: Variation of inhibition efficiency vs. time of exposure for 1:3 of PBPE:DRPE concentrations

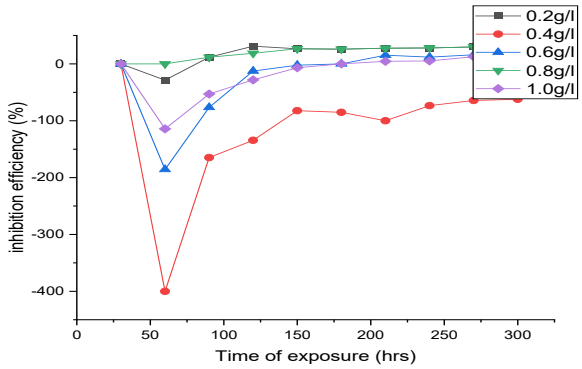

Figure 26: Variation of inhibition efficiency vs. time of exposure for 2:1 of PBPE: DRPE concentrations

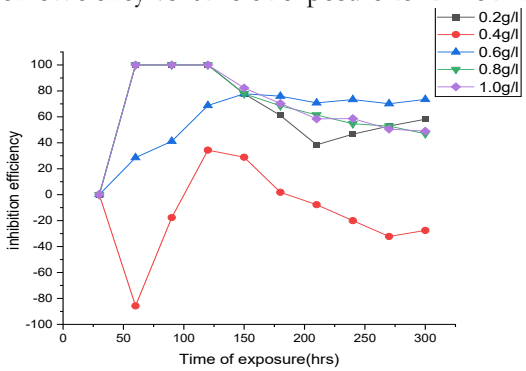

Figure 27: Variation of inhibition efficiency vs. time of exposure for 1:2 of PBPE: DRPE concentrations

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A protective and adherent coating layer that separates the sample surface from the corrosive medium leads to corrosion inhibition. The effectiveness of the corrosion resistant layer on the metal surface was influenced by the adsorption of the inhibitor concentration on the sample causing a barrier between the sample and the medium thus retarding the rate of corrosion.

The rate and volume of hydrogen gas that was evolved during the gasometric process both in the absence and presence of varied concentration of the plant hybrid extracts are presented in the figure below. The result showed that the volume of hydrogen gas that was evolved increases with increase in the time duration in which the mild steel was exposed to the 1M acidic medium. However, as the concentration of the inhibitor obtained from the plant extract was increased, the rate of hydrogen gas increases then begins to decline appropriately. The hydrogen gas evolution measurement was studied, with the highest and lowest data recorded for PBPE, DRPE, 1:1 of PBPE: DRPE, 1:2 of PBPE: DRPE, 2:1 of PBPE:DRPE, 1:3 of PBPE:DRPE, 3:1 of PBPE:DRPE.

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3.5 Tafel polarization

Tafel polarization technique determines the rate at which corrosion occur in a medium under electrochemical reactions. The potentiodynamic polarization data are shown as Tafel plots for AISI 1007 steel in 1.0 M HCl with the addition of various concentrations of PBPE and DRPE in Figures 28 – 31. For the electrochemical reaction under activation control, polarization curves showed a linear behavior in the corrosion potential (E_{corr}) vs log current density (I_{corr}) plots. The corrosion kinetic parameters such as corrosion potential, E_{corr} corrosion current density, $I_{corr,}$ anodic and cathodic Tafel slopes.

Furthermore, from the data obtained during the experiment, it showed that the PBPE Tafel polarization analysis showed that the corrosion potentials Ecorr shifted towards the negative potentials for the test samples in the PBPE inhibitor while the corrosion current density (Icorr) values decrease as the concentration of the extracts increases. However, the estimated inhibition efficiency (IE) of the inhibitor increases. The highest inhibition efficiency of 29.77% was achieved at 0.6 g. After taking the study of the DRPE inhibitor, the DRPE Tafel polarization analysis showed that the corrosion potentials Ecorr shifted towards the negative potentials for the test samples in the DRPE inhibitor while the corrosion current density (Icorr) values decrease as the concentration of the extracts increases. However, the estimated inhibition efficiency (IE) of the inhibitor increases. The highest inhibition efficiency of 96.78% was achieved at 0.6 g with respect to the blank. Furthermore, the Tafel polarization measurements of mild steel dissolution in 1.0 M of HCl in the absence and presence of various concentrations of hybrid inhibitors. In the presence of hybrid PBPE and DRPE, both anodic and cathodic current densities were reduced, which is used to show a mixed-type inhibitor activity[17]. The highest inhibition efficiency was obtained at 0.6 g/l of the hybrid inhibition of the ratio of PBPE:DRPE in ratios of 3:1,1:3,1:2, and 1:1 which gives the result of 86.06%, 92.9% and 97%.

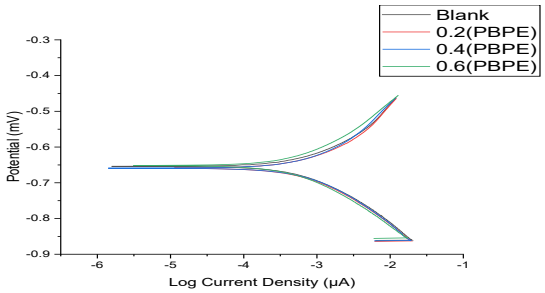

Figure 28: Corrosion potential plot against log current density (100% PBPE)

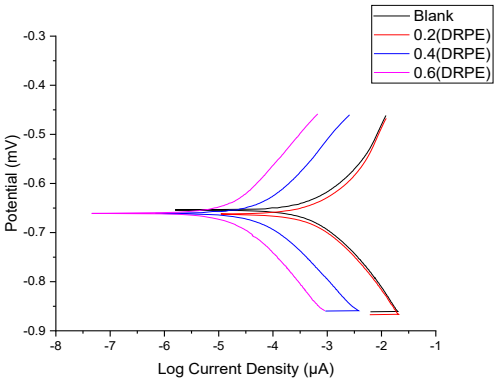

Figure 29: Corrosion potential plot against log current density (100% DRPE)

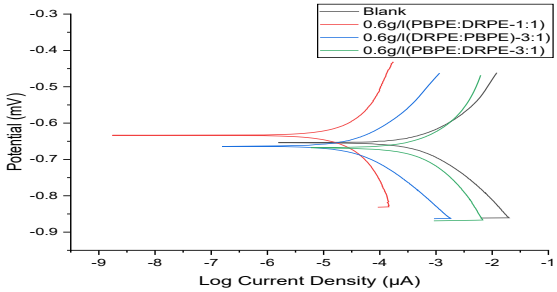

Figure 30: Tafel polarization curves of mild steel with and without both PBPE and DRPE inhibitor in the ratio of 3:1

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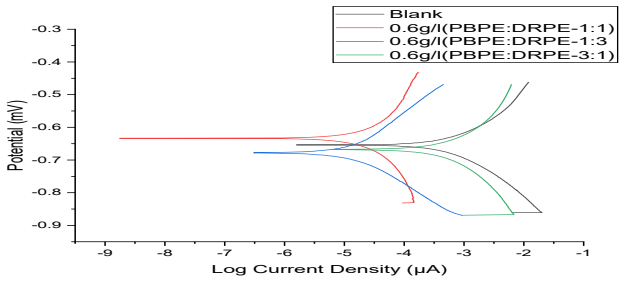

Figure 31: Tafel polarization curves of mild steel with and without both PBPE and DRPE inhibitor in the ratio of 1:3

Table 4: Corrosion parameters for mild corrosion at various concentrations of DRPE as determined using the potentiodynamic polarization technique at 300 +/- 1 K

Conc. (g)	Tafel slope (mV/dec)		E_{corr} (mV)	I_{corr} (μA/cm^2)	η(%)
	β_a	β_c			
Blank	51.78	59.43	-654.99	211	-
0.2	47.3	48.9	-659.9	195.23	7.47
0.4	42.17	39.55	-660	169.37	19.72
0.6	51.73	46.28	-652.76	148.17	29.77

Conc. (g)	Tafel slope (mV/dec)		E_{corr} (mV)	I_{corr} (μA/cm^2)	η(%)
	β_a	β_c			
Blank	51.78	59.43	-654.99	211	-
0.2	48.94	45.65	-663.43	195	7.5
0.4	59.79	46.85	-661.82	23	89
0.6	55.79	49.66	-661.52	6.79	96.78

Table 5: Tafel polarization parameters for mild corrosion at an optimal quantity of 0.6g and varied concentrations of the hybrid ratio of PBPE:DRPE as determined using the potentiodynamic polarization technique at 300 +/- 1 K.

Conc. (g)	Tafel slope (mV/dec)		E_{corr} (mV)	I_{corr} (μA/cm^2)	η(%)
	β_a	β_c			
Blank	51.78	59.43	-654.99	211	-
0.6	55.94	51.54	-664.12	29.4	86.06
0.6	56.57	48.9	-664.58	14.8	92.9

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Table 6: Tafel polarization parameters for mild corrosion at an optimal quantity of 0.6g and varied concentrations of the hybrid ratio of PBPE:DRPE as determined using the potentiodynamic polarization technique at 300 +/- 1 K.

Conc. (g)	Tafel slope (mV/dec)		E_{corr} (mV)	I_{corr} (μA/cm²)	η(%)
	β_a	β_c			
Blank	51.78	59.43	-654.99	211	-
0.6	72.3	57.0	-678.83	6.25	97
0.6	57.3	63.8	-668.9	190	9.9

Table 7:: Tafel polarization parameters for mild corrosion at an optimal quantity of 0.6g and varied concentrations of the hybrid ratio of PBPE:DRPE as determined using the potentiodynamic polarization technique at 300 +/- 1 K.

Conc. (g)	Tafel slope (mV/ dec)		E_{corr} (mV)	I_{corr} (μA/cm²)	η(%)
	β_a	β_c			
Blank	51.78	59.43	-654.99	211	-
0.6	51.54	49.33	-666.3	40.02	81
0.6	63.80	58.26	-667.6	0.187	99.9

Electrochemical Impedance Spectroscopy

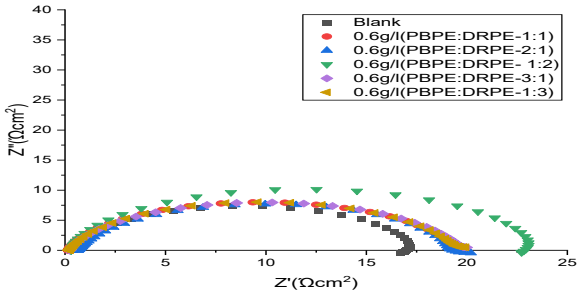

Figure 32: Nyquist plot of mild steel with and without both PBPE and DRPE inhibitor in the ratio of 1:2

The corrosion behaviour of AISI 1007 steel in 1.0 M HCl medium, in the absence and presence of various concentrations of hybridized PBPE and DRPE were investigated. The resultant Nyquist plot are shown in Figure 32. The existence of a single semicircle in each plot shows that there was only a single charge transfer process during the anodic dissolution of the AISI 1007 steel and remained unaffected in the presence of inhibitive molecules of the extract added into the acid medium. There was a gradual increase in the diameter of each semicircle of the Nyquist plot due to an increase in the number of inhibitive molecules in the extract. This is in alignment with the Patel *et al.* (2009)'s results that there was formation and gradual improvement of the barrier layer of the inhibitive molecules and as a result the acid corrosion rate of AISI 1007 steel gradually decreased[23], when the PBPE: DRPE concentration ratio was varied using (1:1, 1:2, 2:1, 1:3, 3:1) of 0.6g/l. It clearly reflected that at the ratio of 1:2 of 0.6g/l, formation and gradual improvement of the barrier layer of the inhibitive molecules took place, and as a result the acid corrosion rate of AISI 1007 steel gradually decreased.

Table 4 – 7 show various parameters such as R_t and the double layer capacitance, C_{dl}. There was a gradual decrease in the values C_{dl} with increase in the concentration of the extract. This change shows that the inhibitive molecules of the extracts had been adsorbed on the steel surface and decreased the roughness on the AISI 1007 steel surface.

4.0 Conclusion

This study evaluates the inhibitory potential of blended Parkia biglobosa and Delonix regia extracts on corrosion of AISI 1007 steel in Hydrochloric acid medium using different corrosion testing techniques. The analysis aimed to identify the appropriated proportion of the plant extracts to exhibit the higher corrosion

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inhibition efficiency and time of exposure in the medium. Results were interpreted to assess its performance The following conclusions were drawn from this study:

1. Increase in the inhibitor concentration causes gradual decline in the corrosion rate
2. Using gravimetric technique, the presence of *Parkia Biglobosa* pod extract as an inhibitor in the medium of exposure (HCl) reduces the corrosion rate of the steel between the hours of 144 and 2160. However, the presence of *Delonix Regia* pod extract as an inhibitor in the medium of exposure (HCl) reduces the corrosion rate of the steel between the hours of 72 and 2160.
3. Generally, irrespective of the corrosion techniques used, DRPE exhibited higher corrosion resistant when compared to PBPE.
4. Highest inhibitive efficiency of PBPE was attained at a concentration of 0.6 g/l, and the highest inhibitive efficiency of DRPE was attained at a concentration of 0.8 g/l.
5. The hybridized concentration of PBPE: DRPE showed highest inhibitory efficiency at a ratio of 1:2, and 1:3 with an efficiency of 96.78% and 92.9% respectively.

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