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Research article

Comparative Studies of Corrosion Inhibition of Ethanol Extract of Nymphaeaceae and *Aloe barbadenis* on Mild Steel in H_2SO_4

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ABSTRACT

Ethanol extracts of *Nymphaeaceae* and *Aloe barbadenis* were used to evaluate the corrosion inhibition of mild steel in 1M H_2SO_4 by adsorption isotherm experiments using the gravimetric method. *A. barbadenis* demonstrated a greater percentage of inhibition efficiency (%IE), and it was observed that for an increase in immersion period and inhibitor concentration, the corrosion rate of mild steel coupons decreases with the plant extracts presence (0.5–1.5 w/v%). The result has reportedly shown an increase in the inhibitor's inhibitory efficacy of up to 343K, pointing to extract adsorption onto the surface of mild steel. The Langmuir and Temkin adsorption isotherm were found to be followed by the adsorption on mild steel.

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1. INTRODUCTION

Corrosion is the process through which materials corrode and subsequently deteriorate when exposed to the environment. The fundamental properties of a material are destroyed through corrosion. Corrosion control is of economic, environment and aesthetic importance (Adejo et al., 2014). For many years, inhibitors have been used effectively to protect materials, particularly metals, from the devastating effects of corrosion. To that end, synthetic inhibitors with outstanding inhibitive function are no longer allowed in use due to their adverse effects on humans and the environment, cost aside (Adejo et al., 2014);(Fouda et al., 2017). As a result, emphasis has switched to non-toxic and environmentally friendly inhibitors. Many studies have been conducted on plant extracts since they have been discovered to have the required features of non-toxicity, bio-degradability, cheap cost, renewability, and ease of availability, as well as simple extraction procedures (Rajendran et al., 2005). To contribute to the ongoing interest in environmentally acceptable corrosion inhibitors, an ethanol extract of *Nymphaeaceae* leaves and *Aloe barbadenis* was examined and found to inhibit mild steel corrosion in a sulphuric acid medium (Adejo et al., 2014);(Okafor et al., 2008). Mostly, the acid corrosion inhibitors are nitrogen, oxygen and sulfur-containing organic compounds (Khalid Hasan & Sisodia, 2011). Adsorption isotherms employing surface coverage, at various concentrations and temperatures may provide fundamental details on the inhibitor-metal surface interaction (Uwah et al., 2013). Opuntia extract was studied for the corrosion of aluminium in acid medium, and vanillin for the corrosion of mild steel in acid medium (Sribharathy et al., 2013). In previous studies, different temperatures and *Heterophragma adenophyllum* (HA) extract concentrations were shown to significantly affect the corrosion behavior of low C steel in 0.5M HCl, according to (Pahuja et al., 2020). Also, they believe that the polarisation curve's shape can be utilised to evaluate how well HA inhibits corrosion. When using a larger HA concentration, the anodic-cathodic current densities decrease to lower values, making HA an effective GCI. This result proved that the HA could withstand both cathodic and anodic branch reactions. Moreover, temperature has an impact on how well HA inhibits corrosion. According to their findings, an elevated temperature would reduce the inhibitory effectiveness of HA because it would cause the molecules that form up the protective layer to desorb from the metal surface (Palaniappan et al., 2020).

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The current study reports on inhibition of corrosion and adsorption assessments of *Nymphaeaceae* leaves and *Aloe barbadenis* extracts as an environmental inhibitor on corrosion of mild steel in 1M H_2SO_4 solution using gravimetric analysis (Khalid Hasan & Sisodia, 2011).

2. MATERIALS AND METHODOLOGY

2.1 Materials

The coupons of the mild steel utilised in this study were obtained at Hassan Usman Katsina Polytechnic, Katsina State from the Department of welding and fabrication. The water lily leaves and aloe vera plant were obtained from Ajiwa dam site at Ajiwa water treatment plant, Batagarawa Local Government, Katsina State and authenticated at biology research laboratory, Umaru Musa Yardua University, Katsina Nigeria.

2.2 Metal preparation for the experiment

Prior to the commencement of the weight loss experiment, the metals of 3cm by 3cm sizes were holed at the top and exposed to chemical treatments. The mild steel materials were washed and cleaned by immersion in acetone, then dried. The dried samples were weighed using an analytical weighing balance and stored in desiccators before being immersed in the acid media (Okafor et al., 2008).

2.3 Gravimetric method (weight loss method)

The surfaces of the coupon samples were smoothened with an emery paper, cleaned and dried metal coupons were weighed before immersion into respective test solutions of 1M H_2SO_4 using analytical weighing balance. The tests were carried out with different concentrations of inhibitor (Oguzie, 2008). The measured samples were immersed in a beaker containing 200 ml of the test solution, which was prepared by mixing 100 ml of 1M H_2SO_4 with 100 ml of different concentrations of the inhibitors (Dahiya et al., 2016). The beakers were covered with aluminium foil and inserted into a thermo-stated oven maintained a temperature 30, 50 and 70^{0}C. The coupons were removed from the beakers after 1hr, washed with distilled water, rinsed with acetone, dried and reweighed again. The differences in weight between initial and final weight was taken as the weight lost and the corrosion rate (Khalid Hasan & Sisodia, 2011).

$$CR\ (gm/cm^3hr) = \frac{weight\ loss\ (g)}{A\ X\ T} \quad 1$$

$$\theta = \frac{(Wi - Wf)}{Wi} \quad 2$$

$$\%IE = \frac{(Wi - Wf)}{Wi}\ x\ 100 \quad 3$$

Where Wi and Wf are the weight loss of Mild steel coupons before and after immersion in the media, CR is the corrosion rate (mgcm-2h-1), θ is the degree of surface coverage of the inhibitor, IE is the percentage efficiency of inhibition (%IE), A is the area of the coupon, t is the time after immersion (hours).

2.4 Adsorption Isotherms

Adsorption isotherm studies explain how organic substances (inhibitors) adhere to metal surfaces. Effective establishment of the adsorption isotherm model of the water lily leaves and aloe vera extracts on mild steel in 1M H_2SO medium (Akinbulumo et al., 2020). By inclusion of corrosion rate, CR, and inhibitor surface coverage degree, θ (which is the inverse of inhibition efficiency) in different linear forms of adsorption isotherms models (Langmuir and Temkin):

The Langmuir adsorption isotherm model:

$$\frac{C}{\theta} = \frac{1}{K} + C \quad 4$$

Temkin adsorption isotherm model:

$$\theta = \ln C + K_{ads} \quad 5$$

Where,

C =Concentration of inhibitor

θ = the Degree of surface coverage

Kads is the adsorption equilibrium constant obtained from the isotherm.

Free energy of adsorption

The free energy of adsorption of inhibitors will be computed using the following equation:

$$\Delta Gads = -RT\ ln(K55.5) \quad 6$$

3. RESULTS AND DISCUSSION

3.1 Weight loss analysis

The results for Nymphaeaceae leaves and Aloe barbadenis surface coverage (θ), inhibition efficiency (%IE), and corrosion rate (CR) of the extracts obtained from weight loss analysis in the presence of 1M H_2SO_4 are presented below in table 1 and 2.

Table 1. *Nymphaeaceae* leaves extract corrosion rate and percentage inhibition efficiency in 1M H_2SO_4.

Temp.	Inhibitor Conc. (w/v%)	ΔW(g)	CR(g/cm²hr)	θ(cm²)	%IE
303K	blank	0.33	0.012222		
	0.5	0.08	0.002963	0.757576	75.75758
	1.0	0.03	0.001111	0.909091	90.90909
	1.5	0.01	0.00037	0.969697	96.9697
323K	Blank	1.01	0.336667		
	0.5	0.47	0.156667	0.534753	53.46535
	1.0	0.25	0.083333	0.752475	75.24752
	1.5	0.20	0.066667	0.801980	80.19802
343K	blank	1.5	0.5		
	0.5	1.32	0.44	0.62	62
	1.0	1.0	0.333333	0.833333	83.3333
	1.5	0.8	0.266667	0.966667	96.6667

Table 2. *Aloe barbadenis* extract corrosion rate and percentage inhibition efficiency in 1M H_2SO_4.

Temp. (K)	Inhibitor (w/v%)	Δw	CR(g/cm²hr)	Ɵ	%IE
303K	Blank	0.4	0.133333		
	0.5	0.03	0.01	0.325	32.5
	1.0	0.02	0.006667	0.35	35
	1.5	0.01	0.003333	0.375	37.5
323K	Blank	1.02	0.34		
	0.5	0.55	0.183333	0.480784	48.07843
	1.0	0.21	0.07	0.814118	81.41176
	1.5	0.13	0.043333	0.892549	89.2549
343K	Blank	1.5	0.5		
	0.5	1.2	0.4	0.7	70
	1.0	0.91	0.303333	0.893333	89.33333
	1.5	0.77	0.256667	0.986667	98.66667

Adsorption isotherm parameters (slope, R^2, ΔG_{ads} and K_{ads}) for the adsorption of *Nymphaeaceae leaves* and *Aloe barbadenis* onto mild steel surfaces in the presence of 1M H_2SO_4 acid are presented in table 3 and 4 below.

Table 3: Calculated values of slope, ΔGads, R2 and kads for the adsorption of *Nymphaeaceae* leaves extract onto mild steel surface in 1M H_2SO_4

Isotherms	Temp (K)	Slopes	ΔG_{ads} (Kjmol^{-1})	R^2	K_{ads}
Langmuir	303	0.886	-13.98	1.000	4.710
	323	19.30	-5.652	0.997	0.148
	343	0.762	-13.94	0.998	2.392
Temkin	303	0.450	-15.32	0.991	7.888
	323	-0.194	-11.36	0.961	1.241
	343	0.694	-16.97	0.998	6.918

Table 4: Calculated values of slope, ΔG_{ads}, R^2 and k_{ads} for the adsorption *of Aloe Barbadenis* extract onto mild steel surface in 1M H_2SO_4

Isotherms	Temp (K)	Slopes	ΔG_{ads}(Kjmol^{-1})	R^2	K_{ads}
Langmuir	303	2.66	-15.83	0.995	9.90
	323	0.640	-11.83	0.945	1.481
	343	0.993	-18.23	0.976	10.75
Temkin	303	0.102	-12.17	0.977	2.259
	323	0.889	-15.52	0.963	5.834
	343	0.605	-17.26	0.997	7.670

The tables 1 & 2 illustrate the variation of corrosion rates of the coupons in 1M H_2SO_4 with and without inhibitors concentration for an exposure time of 3 hours. Furthermore, it can be seen from the tables that the rate of corrosion decreases with the increase of the inhibitor concentration but increases with the increase of temperature. For example, (S. A. Umoren & Solomon, 2015) found that at all concentrations of coconut coir dust extract, the IE drops as temperature rises (Umoren *et al.*, 2019). The pattern is frequently seen as suggestive of physical absorption (Popova et al., 2003). Because plant extracts exhibit a decrease in surface coverage and an instability of protective layer at elevated solution temperatures, this trend is regarded as physical absorption (Raghavendra, 2018).

3.2 *Adsorption isotherms*

This study utilized two adsorption isotherms: Langmuir and Temkin isotherms, to determine the mode of adsorption and establish the best fit isotherms of *Nymphaeaceae leaves* and *Aloe barbadenis* extract. The correlation coefficients (R^2) values were used to determine the best fit isotherm among them. The adsorption isotherms (Langmuir and Temkin adsorption isotherm) also decrease with increase in concentration of the inhibitor (0.5 – 1.5w/v%) at 303K, 313K and 343 K in acid medium. Many scholars have hypothesized that the Langmuir adsorption isotherm has been explained by interactions between species that are absorbed on metallic substrates. Corrosion inhibitors generally slow down corrosion by regulating the interactions between the inhibitor and mild steel during the inhibitor's adsorption process on the metal's solid outer surface. To select the inhibition strategy and adsorption isotherm that best match the experimental data, it is essential to comprehend the nature of the inhibitor's adsorption (April, 2021). The Langmuir and Temkin adsorption isotherms, with R^2 values equal to unity and close to unity were found as the best fit for inhibitor/metal surface interaction, based on the correlation coefficients.

3.3 *Free Energy of Adsorption* ΔG_{ads}

The adsorption process of *Nymphaeaceae leaves* and *Aloe barbadenis* extracts on mild steel surfaces were found to be spontaneous, with the lowest free energy observed at -13.98 KJ/mol and the highest at -5.025KJ/mol, while for *Aloe barbadenis* extract in table 4 showed -21.17KJ/mol as the lowest and -7.495 KJ/mol as the highest indicating an exothermic interaction between the metal and inhibitor (Onyeachu et al., 2021).

4. CONCLUSION

Nymphaeaceae leaves and *Aloe Barbadenis extracts* inhibits the corrosion rates in 1M H_2SO_4 but *Aloe Barbadenis extract inhibit the corrosion rate more compared to Nymphaeaceae leaves extract at various conditions which they were exposed. At 323 K and 343 K Aloe barbadenis shows inhibition efficiency of 89.25 & 98.66% respectively while Nymphaeaceae leaves has 80.19 & 96.66%. As higher %IE were obtained from A. barbadenis it vividly shows that mild steel has safer environment in* 1M H_2SO_4 *with A. barbadenis extract as inhibitor than in Nymphaeaceae extract. The Langmuir and Temkin isotherms in* H_2SO_4 *medium similarly revealed a progressive trend with increasing temperature, indicating that higher inhibitor adsorption was obtained in A. barbadenis extract.* Additionally, the protective layers of this extract are seen to rise with increasing inhibitor concentration as a result of water molecule displacement from the metal's surface. Further, an increase in temperature affects the stability of the layer present on the metal surface (April, 2021).

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