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Determination of the Corrosion Inhibition Efficiency of *Senna Alata* on Mild Steel In H_2SO_4 Acid Solution

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ABSTRACT

The inhibition efficiency of ethanolic extract of *Senna alata* on the corrosion of mild steel in sulphuric acid solution was studied using gravimetric (at 30^0C) and gasometric (at 30^0C, 45^0C and 60^0C) methods. The results obtained show that the inhibitive properties of *Senna alata* extract was found to increase with increase in the extract concentrations and decrease with increase in temperature. The extract acted as a good inhibitor at 30^0C, 45^0C and 60^0C but have a better efficiency at 30^0C than at 45^0C. A slight increase in efficiency was observed from 45^0C to 60^0C, this is due to the chemical adsorption of the extract on the metal surface. The adsorption of *Senna alata* extract obeys Langmuir adsorption isotherm.

Keywords: Corrosion, *Senna alata,* Adsorption, Inhibition efficiency, Sulphuric acid, Mild steel.

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1. INTRODUCTION

Present trend in research on environmentally friendly corrosion inhibitors is taking us back to exploring the use of natural products as possible sources of cheap, non-toxic, and ecofriendly corrosion inhibitors. These natural products are either synthesized or extracted from aromatic herbs, spices, and medicinal plants. Of increasing interest is the use of medicinal plants extracts as corrosion inhibitors for metals in acidic solutions. Thus, is because these plants serve an incredibly rich sources of naturally synthesized chemical compounds that are environmentally acceptable, inexpensive, readily available, and renewable resources of materials (Okafor *et al.,* 2012). Due to the usefulness of organic inhibitor in various industries, the study of the organic inhibition is now an alternative field of research. Most of the well-known acid inhibitors are organic compounds containing nitrogen, sulphur, oxygen, and multiple bonds in the molecules. The lone pair of electrons available on the atoms allows the easy adsorption into the metal surface (Uwah *et al.,* 2013). Coating the metal with a millimeter thick impervious non corroding coating is a way by which the latter can be done. The effect of this may not be stable despite the fact that they have wide spread use because of break in the coating over time. The process for which the equipment is used might interfere with coating in some systems like a change in the transfer of heat properties (Ofem, 2010).

The majority of metals in nature appear in the form of sulphides and oxides. A lot of energy is required to get them in the form of a pure metal. That means they are thermodynamically unstable in nature, and the process of transforming back into their original form is spontaneous. Corrosion of metals is therefore inevitable. Among the various methods of controlling corrosion, the use of inhibitors is one of the most practical ways for protecting metals and alloys against corrosion, especially in acidic environment (Landolt, 2007).The aim of this study includes; to determine the corrosion inhibition efficiency of mild steel in H_2SO_4 acid solution by ethanolic extract of *Senna alata* using gravimetric (weight loss) and gasometric (hydrogen evolution) techniques. To know the effect of plant extract in corrosion of metals. The use of inhibitors is one of the best options of protecting metals against corrosion. Inhibitors are often added in industrial processes to secure metal dissolution from acid solution.

The past few years have witnessed tremendous advancements in scientific research based on plant extract as corrosion inhibitors. Husaini M. *et al.* (2020) studied the effect of aniline as an organic inhibitor on the corrosion of aluminum in HCl acid solution at different temperature using weight loss method. The results of the study reveal that aluminum corrosion was inhibited at different concentrations of the inhibitor, while the inhibition efficiency increased with increasing inhibitor concentration but decreased with rising temperature. Adsorption of the inhibitor on aluminum surface was found to be consistent with Langmuir adsorption isotherm. Inhibitory action of *Phyllanthus amarus* extracts on the corrosion of mild steel in acidic media using gravimetric and gasometric techniques was studied by Okafor *et al*, (2008). It was found that inhibition efficiency increases with increase in concentration of the extract, while the adsorption followed Langmuir adsorption isotherm and Temkin isotherm. Abiola *et al*, (2004) studied the inhibitory action of fruit juice of *Citrus paradise* on corrosion of mild steel in acidic medium and reported that inhibition efficiency increased with increase in concentration of the inhibitor, and physical adsorption of the phytochemical components of the plant on the metal was proposed as the mechanism of inhibition. The adsorption followed the Langmuir and Temkin isotherm. The inhibitive effect and adsorption behavior of *Ocimum basilium* extract for the corrosion of aluminum in HC1 and KOH solutions were investigated and it was reported that the inhibition efficiency increased with extract concentration and decreased with rise in temperature in both corrodents (Oguzie *et al.,* 2006).

Ezeh E.M. and Chinedu Agu P., (2023) studied the corrosion inhibitory potential of *Chromolaena odorata* leaf extract (COL) on mild steel in HCl medium, the result shows that COL extract effectively inhibits corrosion in 1M HCl. Using gravimetric and gasometric techniques, the inhibitory action of *Allium cepa* and *Allium sativum* on the corrosion of mild steel in hydrochloric acid was studied, it was reported that the inhibition efficiency increased with increase of the concentration of the extract, while the adsorption followed the Langmuir isotherm. Similar inhibition efficiency behavior was exhibited by the extract which signifies that there is similarity in the composition of inhibitive compounds (Okafor *et al,* 2006). *Musa sapientum* peels extract was used as a corrosion inhibitor on mild steel in concentrated H_2S0_4 using weight loss method. The results of the study showed that as the concentration of the produced inhibitor increases, the rate of corrosion decreases. It also showed that as the concentration of the inhibitor increases, the inhibitor efficiency also increases up to an optimum of approximately 71% for 0.8g/l extract in 2.0M H_2S0_4 which is encouraging (Salami *et al,* 2012). Corrosion of mild steel in hydrochloric acid and nitric acid solution was studied by weight loss and thermometric methods in presence of *Ocimun sanctum* extract. From weight loss data, it was observed that the inhibition efficiency increases with the increase in the concentration of the extract of stem in HC1 and $HN0_3$ solutions as compared to extract of leaves of *Ocimum sanctum.* Maximum inhibition efficiency was found (98.67%) in 0.5M HC1 acid with 1.2% stem extract. The corrosion rate was found to decrease with the increase in concentration of extract while inhibition efficiency increases with increasing concentration of extract of *Ocimum sanctum* in HC1 and $HN0_3$ solution (Nutan *et al,* 2012). The inhibition potentials of lignin extract of *Tithonia diversifolia was* investigated by evaluating the corrosion behavior of medium carbon low alloy steel immersed in 1M H_2SO_4 solution containing varied concentration of the extract. Mass loss, corrosion rate, and adsorption characterization were utilized to evaluate the corrosion inhibition and adsorption properties of the extract. The results revealed that the lignin extract is an efficient inhibitor of corrosion in mild steel immersed in 1M H_2S0_4. The corrosion rates were observed to decrease with increase in concentration of lignin extract but increased with temperature. The activation energies and the negative free energy of adsorption obtained from the adsorption studies indicate that the lignin extract is physically adsorbed on the surface of the steel and that the adsorption is strong, spontaneous, and fit excellently with the assumptions of the Langmuir adsorption isotherm (Aleneme and Olusegun, 2012). Using weight loss method and quantum chemical calculation the inhibition performance and adsorption effect of ethanolic extract of Honeycomb propolis (HP) on the corrosion of mild steel in 0.5M H_2SO_4 was studied. The results showed that the inhibition efficiency was at optimum concentration of 5000ppm and efficiency increased with increase in extract concentration and decrease with rise in temperature. Adsorption behavior showed to be physisorption and closely Freundlich adsorption isotherm (Idris *et al* 2022). Inhibitive and adsorption properties of ethanol extract of *Colocasia esculenta* for the corrosion of mild steel in H_2S0_4 were investigated using weight loss, hydrogen evolution, and IR methods of monitoring corrosion. The results obtained indicates that ethanol extract of *Colocasia esculenta* is a good inhibitor for the corrosion of mild steel in H_2S0_4 and its inhibitive action is attributed to its phytochemical constituents, which aided its adsorption on the surface of mild steel. Calculated values of activating energy and inhibition efficiency at 303k and 333k revealed that the mechanism of adsorption of ethanol extract of *Colocasia esculenta* on mild steel surface is physical adsorption. Also, the adsorption of the inhibitor on mild steel surface is physical adsorption. Also, the adsorption of the inhibitor on mild steel surface was found to be spontaneous, endothermic, and consistent with the assumptions of Langmuir adsorption isotherm (Eddy, 2009). The Inhibitive effect of *Balanites aegyptiaca* leaves extract on mild steel in 1M HCL solution using gravimetric method is found to increase with increase in concentrations of the inhibitor and decrease with rise in temperature (Abubakar M.S. and Usman B, 2019).

2. MATERIALS AND EXPERIMENTAL METHODS

2.1. Materials and Preparation of the Plant Extract

The mild steel used for this investigation was obtained from a metal shop in Calabar, Cross River State. The sheet of the mild steel has a thickness of 0.08cm. The sheet was cut into coupons with dimension 2cm x 4cm for the gasometric method and 4cm x 4cm for the weight loss method. The metal coupons were polished with emery paper, degreased in ethanol, and dried with acetone before each batch of the corrosion studies. The sample of *S. alata* used was obtained from farmlands in Ebendo community, Kwale, Delta State, it was identified by the Taxonomy unit of the Department of Botany, Delta State University (DELSU), Abraka, Delta State, Nigeria.

The apparatus used in the course of this study are: Weighing balance, Oven, Gasometric assembly, Water Bath, Erlenmeyer flask, Spatula, Funnel, Stop watch, Retort stand, Emery paper (varius grits), Round bottom flask, Volumetric flasks, Measuring cylinder and Beaker. All the reagents and chemicals used were of analytical; Sulphuric acid, Ethanol, Acetone and Distilled water.

Bulk of the *S. alata* plant was collected, spread on a mat and air dried to prevent fermentation. After serval days of air drying, it was oven dried at a temperature range of 50^0C – 60^0C. The oven dried sample was blended using a manual laboratory blender to powder and them stored in a sample bottle.

The Soxhlet extraction assemblage was set up. The Soxhlet extractor was filled with wool before the introduction of the sample. A condenser with a cold-water inlet and a hot water outlet was connected above the Soxhlet extractor to facilitate condensation of the extracting solvent (Ethanol). A quick fit round bottom flask was filled with 250mL of ethanol; this was connected to the bottom of the Soxhlet extractor after the addition of anti-bumping chips in the flask. The round bottom flask was placed on a heating mantle that is connected to an electrical source; the extraction process proceeded batch-wisely. The ethanol in the siphon tube of the extractor must turn colorless (showing completion), before a new sample is introduced.

The extract was evaporated in a beaker to remove the ethanol content until the solid and oil sample of the extract was obtained and recorded using the following steps:

Weight of dried beaker =105.0kg

Weight of breaker + dried sample = 148.3g

Weight of sample = 148.3g – 105.0g = 43.3g

The sample was stored in a sample bottle.

2.2. Preparation of Solution

The sulphuric acid used has a density of 1.84gml^{-1} and is of 98% wt/wt composition. 0.5M H_2SO_4 was needed for the purpose of this research; this was obtained using the following steps;

There are 98g of H_2SO_4 in 100g of solution.

Specific gravity (s.g) of solution = 1.84gcm^{-3}

$$s.g = \frac{mass}{volume}$$

Taking 1dm^3 of solution, to get the mass of solution:

Mass of solution = s.g x volume

= 1.84 x 1000 = 1840g

⇨ 1dm^3 of solution weighs 1840g

Mass of H_2SO_4 in 1840g of solution = $\frac{98 \times 1840}{100}$ = 1803.2g

Number of moles of H_2SO_4 in 1dm^3 of solution = $\frac{1803.2g}{98g/mol}$ = 18.4moles

⇨ Molarity = 18.4M; for the bottle.

Dilution;

Given; C_b= Concentration of H_2SO_4 in bottle = 18.4M

C_P = Concentration of H_2SO_4 solution prepared = 0.5M

V_b = Vol. of H_2SO_4 in bottle needed = ? cm^3

V_p = VOL. of H_2SO_4 solution prepared = 1000cm^3

Using dilution law: $C_b C_b$ = $C_P V_P$

V_b = $\frac{C_p V_p}{cb}$ = $\frac{0.5 \times 1000}{18.4}$

V_b = 27cm^3

Hence, the volume of 98% H_2SO_4 used to prepare 0.5M H_2SO_4 is 27cm^3. Some amount of distilled water was turned into a clean 1000ml volumetric flask, 27cm^3 of the concentrated H_2SO_4 was added, more distilled water was added up to the 1000ml mark of the flask, and shaken thoroughly before emptying it into a clean reagent bottle, labeled "Blank 0.5M H_2SO_4 solution"

To prepare the stock inhibitor solution, the above process was repeated with 5g *S. alata* leaf extract dissolved in 1000cm^3 of 0.5M H_2SO_4 solution. This is emptied into a clean reagent bottle and then left for 24 hours for through mixing. This was labeled "Stock solution of 0.5M H_2SO_4 solution"

2.3. Preparation of Metal Samples

The coupons of mild steel were polished with emery paper, degreased with ethanol, and dried in acetone. The coupons were weight in the gravimetric analysis.

2.4. Gasometric (Hydrogen Evolution) Method

The volume of hydrogen evolved was determined using the procedure as describe by Umoren *et al.,* (2011). A 100ml 0f 0.5M H_2SO_4 solution was introduced into a reaction vessel connected to a burette through delivery tubes. The technique involves the measurement of the volume of hydrogen gas evolved from the surface of a corroding metal in the system. The hydrogen gas evolved displaces the paraffin oil in the gasometric setup, and this is a function of the corrosion rate. The displacement of the oil is read directly from the burette.

The gasometric analysis was carried out by measuring 100ml of the corrodent into a round bottle quick flask and introducing it into the reaction chamber, connected to a burette through a delivery tube. The mild steel coupon was dropped into the solution in the chamber, and the reaction vessel was quickly corked to avoid escape of hydrogen gas. The volume of hydrogen gas evolved was monitored by the depression (in $cm^{3)}$ in the paraffin oil level and recorded every 60 seconds (1 min) for a period of 45 minutes at 30°C room temperature.

This sample experiment was repeated in the presence of the inhibitor with concentrations of $1.0gl^{-1}$, $2.0gl^{-1}$ $4.0gl^{-1}$ and $5.0gl^{-1}$ respectively of the *S. alata* extract. The above procedures were repeated at elevated temperature of 45°C and 60°C.

Table 2.1. Volume of stock and blank used for gasometric study.

S/N	Concentration (gl-1	Stock(ml)	Blank (ml)
1	0	0	100
2	1	20	80
3	2	40	60
4	3	60	40
5	4	80	20
6	5	100	0

2.5. Gravimetric (Weight Loss) Method

Sixteen beakers (250ml) were used for the gravimetric study. Test on blank, 1.0gl^{-1}, 3.0gl^{-1} and 5gl^{-1} were carried out. Four beakers were used for blank and 4 each for 1.gl^{-1}, 3.gl^{-1} and 5gl^{-1}, respectively. These beakers were labeled according to their various inhibitor concentrations. The mild steel coupons (4cm X 4cm) were polished with emery paper, degreased in ethanol, dried in acetone, weight and their weight recorded before they were suspended in each beaker with the aids of hooks.

After 24 hours, 4 coupons (one from blank and one each from 1.gl^{-1}, 3.gl^{-1} and 5gl^{-1} solutions. The retrieved coupons were washed in ethanol, dried in acetone, reweighed and recorded. The retrieval of coupons was repeated at intervals of 120 hours (5 days) for 15 days at room temperature (30°C).

The weight loss of each coupon was determined using the formula;

$$\Delta W = W_2 - W_1$$

Where; ΔW = Weight loss, W_2 = Initial weight, and W_1 = Final weight

The corrosion rate (CR) was calculated using the formula;

$$CR = \frac{\Delta W}{A.t}$$

Where; A = Area of the metal coupon (cm^2) and t = Time (hours)

Table 2.2. Volume of Stock and blank solutions used for Gravimetric Study.

S/N	Concentration (5gl^{-1})	Stock (ml)	Blank (ml)
1	0	0	250
2	1	50	200
3	3	150	100
4	5	250	0

2.6. Inhibitor Efficiency

The inhibition efficiency was determined using the formula;

$$\%I.E = \frac{R_{HO} - R_{Hi}}{R_{HO}} X\ 100$$

Where; %I.E = Inhibition efficiency.

R_{HO} and R_{Hi} are the rates of hydrogen evolution per surface area in the absence and presence of inhibitor molecules, respectively.

For weight loss measurements, R_{ho} and R_{Hi} were repeated with R_o and R_i which represents the corrosion rates in the absence and presence of the inhibitor molecules, respectively (Ikpi *et al.,* 2012).

3. RESULTS AND DISCUSSION

3.1. Effect of Time on the Corrosion Rate Of Hydrogen Evolution Of Mild Steel In 0.5M H_2S0_4 Solution (Gasometric Method)

It was observed that as time increases, the hydrogen gas evolved per surface area increased also, this reaction was based on the fact that the corrodent was constantly attacked with time. Introducing *Senna alata extract* led to a decrease in hydrogen evolution as the concentration of *Senna alata* extract increases in the acid solution, as shown in fig 3.1 (a), (b), and (c). This indicates that the extracts have a good inhibitive property on mild steel in H_2S0_4 media. The rate of hydrogen evolution increased at higher temperature of 45°C and 60°C which is in agreement with (Okafor *et al,* 2006).

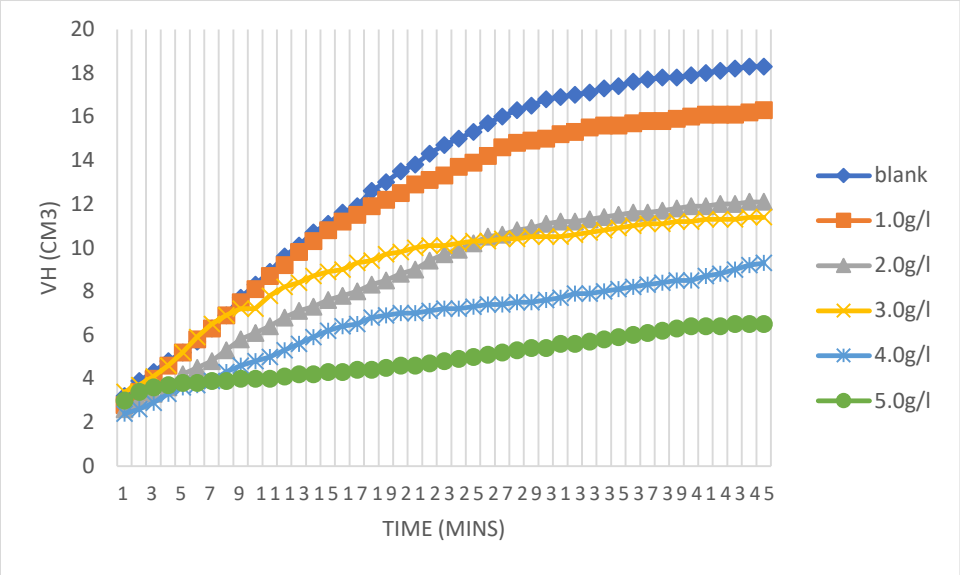

Figure 3.1(a). Variation of volume of hydrogen evolved with time for mild steel in 0.5M H_2SO_4 solutions containing plant extract of S. *alata* at 30^0C.

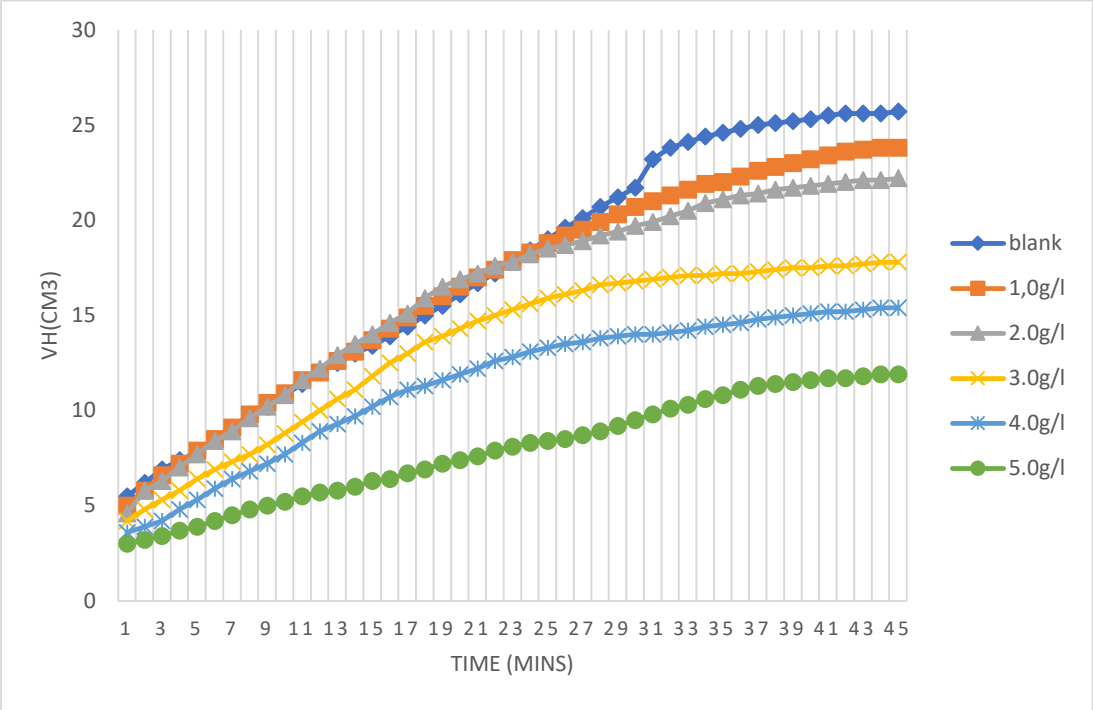

Figure 3.1(b). Variation of volume of hydrogen evolved with time for mild steel in 0.5M H_2SO_4 solutions containing plant extract of S. *alata* at 45^0C.

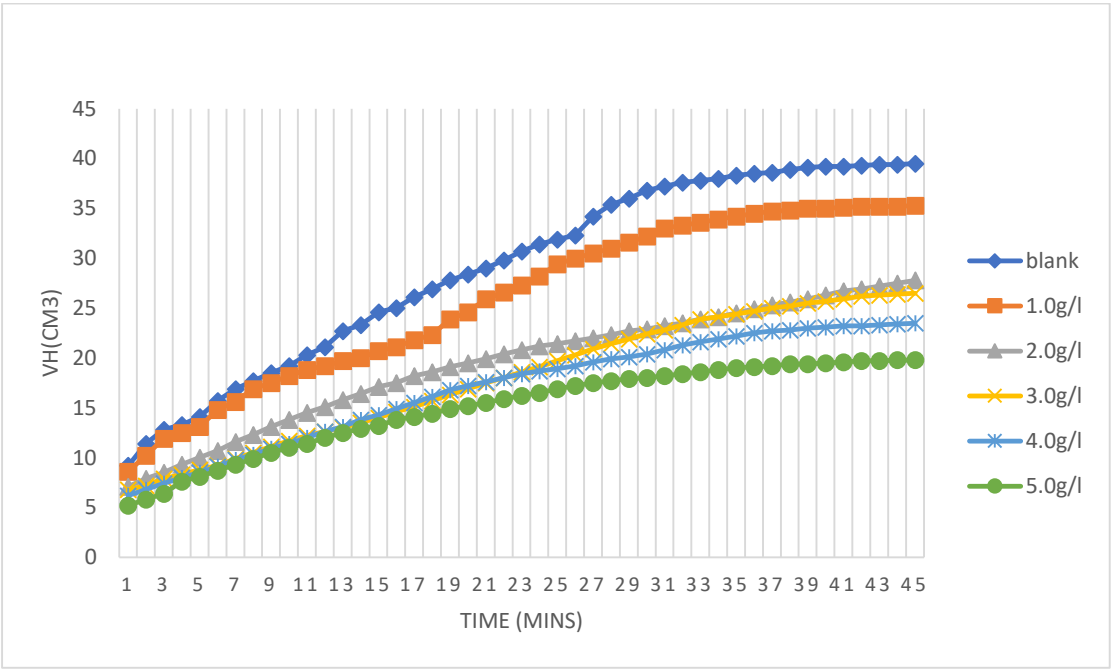

Figure 3.1(c). Variation of volume of hydrogen evolved with time for mild steel in 0.5M H_2SO_4 solutions containing plant extract of S. *alata* at 60^0C.

3.2. Effect of Time on the Corrosion Rate of Mild Steel In 0.5M H_2S0_4 Solution (Gravimetric Method)

The weight loss of mild steel was observed to increase with increase in immersion time in 0.5M H_2S0_4 solutions containing different concentrations of *Senna alata* extract and decreases with an increase in the concentration of the inhibitor, as shown in figure 3.2.

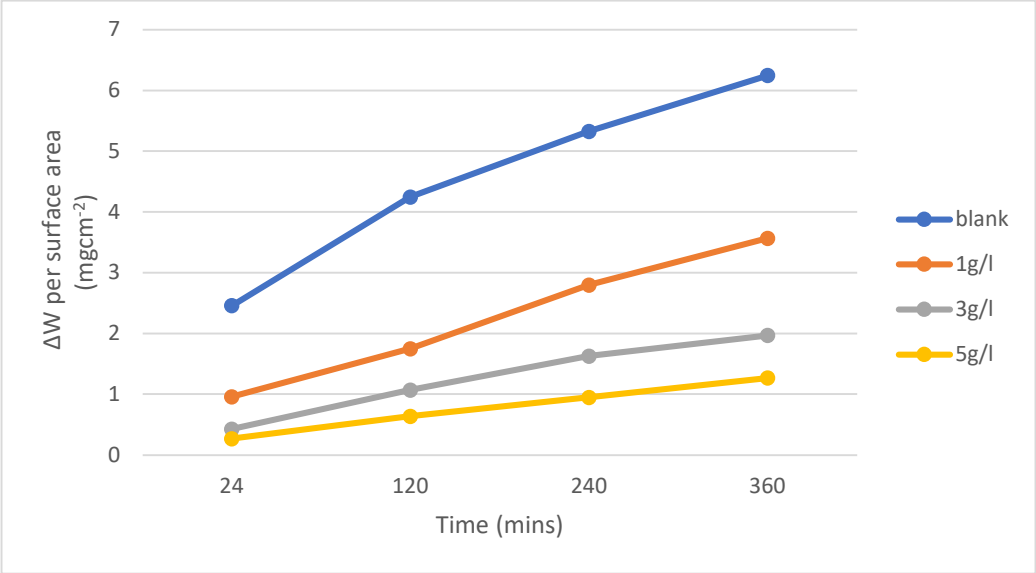

Figure 3.2. Variation of weight loss per surface area with time for mild steel in 0.5M H_2SO_4 solutions containing S. *alata extract at* 30^0C.

3.3. Effects of Extract Concentration In Inhibition Efficiency

Table 3.1 and 3.2 shows the calculated values of inhibition efficiency for gravimetric and gasometric methods at different temperature and inhibitor concentration. The values were calculated using equation 2.8. Inhibition efficiency increased with increase in inhibitor concentration, as shown in fig 3.3 and fig 3.4 and it is temperature dependent. The plant extract inhibits corrosion of mild steel in 0.5M H_2S0_4 solution to an appreciable extent. It is clear that the corrosion inhibition may be due to the increase in the adsorption of phyto-chemicals present in the plant on the metal surface. *Senna alata* extract acts as an inhibitor because of its phytochemical composition.

Table 3.1. Values of half-life ($t_{1/2}$), rate constant (k), corrosion rate ($mgcm^{-2}h^{-1}$), inhibition efficiency, surface coverage (Θ), for mild steel coupon in 0.5 H_2SO_4 solution containing *S. alata* extract using gravimetric analysis.

Concentration (g/I)	**Weight loss**	**Corrosion rate ($mgcm^{-2}h^{-1}$)**	**Surface Coverage (Θ)**	**Inhibitor efficiency (%)**	**Rate constant $10^{-3}(h^{-1})$**	**Half-life 10^{-1}(h)**
Blank	6.25	1.0047	-	-	1.5995	43.33
1.0	3.57	0.5739	0.4288	42.9	0.6895	100.51
3.0	1.97	0.3167	0.6848	68.5	0.3118	225.26
5.0	1.27	0.2041	0.7868	79.7	0.1970	351.78

Table 3.2. Values for activation energy (Ea), inhibitor efficiency, and surface coverage (Θ), for mild steel coupons in 0.5 H_2SO_4 solutions containing *S. alata* extract using gasometric method.

Concen traction (g/I)	**Rate of H2 evolution ($mlcm^{-2}min^{-1}$)**			**Surface coverage (Θ)**			**Inhibition efficiency (%)**			**Ea (Kjmol-1)**
	30^0C	45^0C	60^0C	30^0C	45^0C	60^0C	30^0C	45^0C	60^0C	
Blank	0.014	0.018	0.030							
1.0SA +0.5M H_2SO_4	0.010	0.016	0.023	0.286	0.111	0.233	28.60	11.10	23.30	52.77
2.0SA +0.5M H_2SO_4	0.008	0.015	0.019	0.429	0.167	0.367	42.90	16.70	36.70	52.87
3.0SA +0.5M H_2SO_4	0.006	0.011	0.017	0.538	0.389	0.433	53.80	38.90	43.30	51.30
4.0SA +0.5M H_2SO_4	0.005	0.010	0.015	0.615	0.444	0.500	61.50	44.40	50.00	51.05
5.0SA +0.5MH_2SO_4	0.003	0.008	0.013	0.769	0.556	0.567	76.90	55.60	56.70	48.15

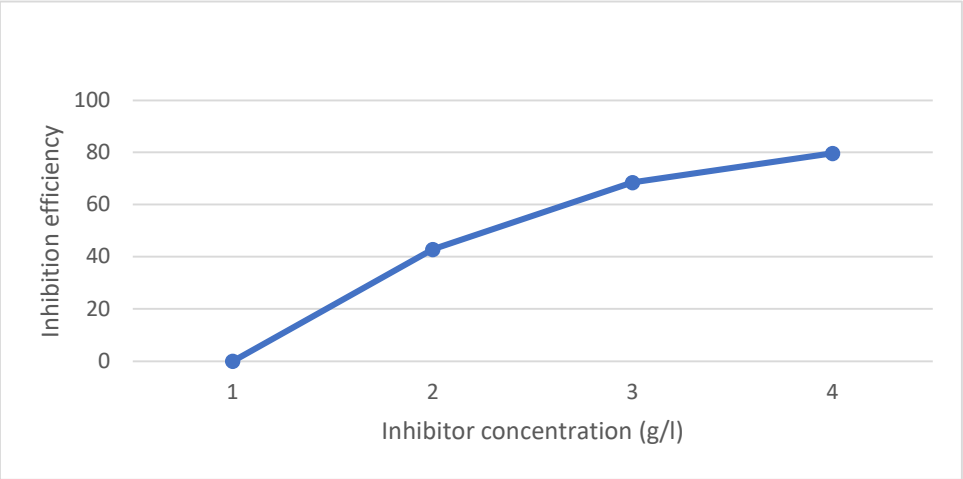

Figure 3.3. Variation of inhibition efficiency with extract concentration for mild steel coupon in 0.5M H_2SO_4 solutions containing S. *alata extract at* 30^0C.

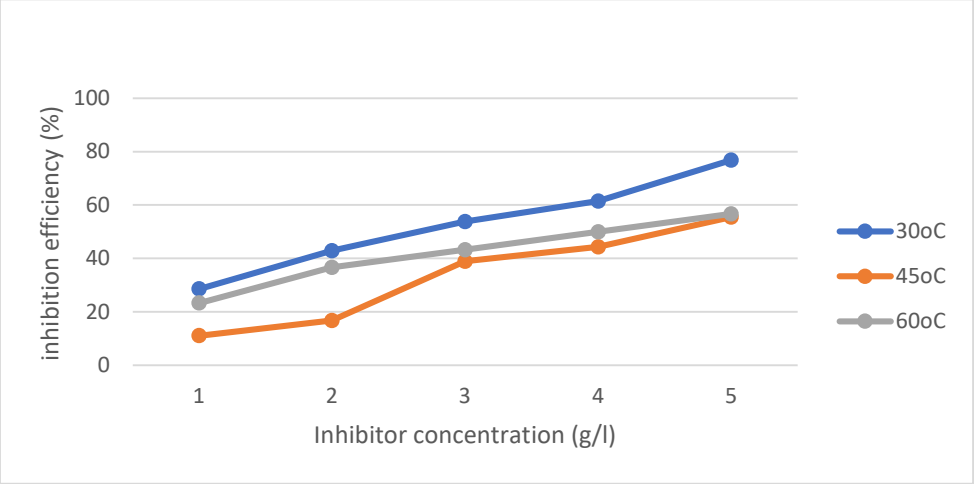

Figure 3.4. Variation of inhibition efficiency with extract concentration for mild steel coupon in 0.5M H_2SO_4 solutions containing S. *alata extract at* 30^0C, 45^0C and 60^0C.

3.4. Effects of Inhibitor Concentration on Corrosion Rate

The corrosion rates for hydrogen evolution were obtained from the slope of the plot of volume of hydrogen gas evolved against inhibitor concentration for gasometric analysis, as shown in Fig 3.5. For the gravimetric analysis, the corrosion rate was obtained from the slope of weight loss per surface area against time. It was observed that the corrosion rate decreases as inhibitor concentration increases at 30°C, 45°C and 60°C for gasometric and weight loss method. This indicates that the plant extract mitigates the corrosion of mild steel in 0.5M H_2SO_4 solution and that the extent of corrosion inhibition depends on the amount of the extract present.

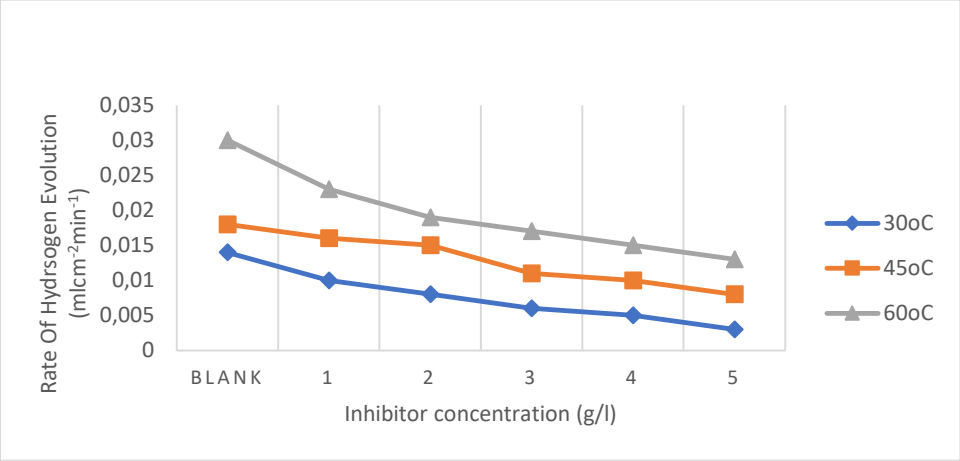

Figure 3.5. Variation of hydrogen evolution with concentration for mild steel coupon in 0.5M H_2SO_4 solutions containing S. *alata extract at* 30^0C, 45^0C and 60^0C.

3.5. Effects of Temperature on Inhibition Efficiency

Inhibition efficiency decreased with increase in temperature from 30°C to 45°C and increased from 45°C to 60°C as shown in Fig 3.6 and also indicated in Table 3.2. The decrease in efficiency is attributed to the decrease in the protective nature of the inhibitive film formed on the metal surface at higher temperature due to desorption of the inhibitor molecules. While the increase in efficiency from 45°C to 60°C is as a result of chemisorption of inhibitor molecules on the metal surface.

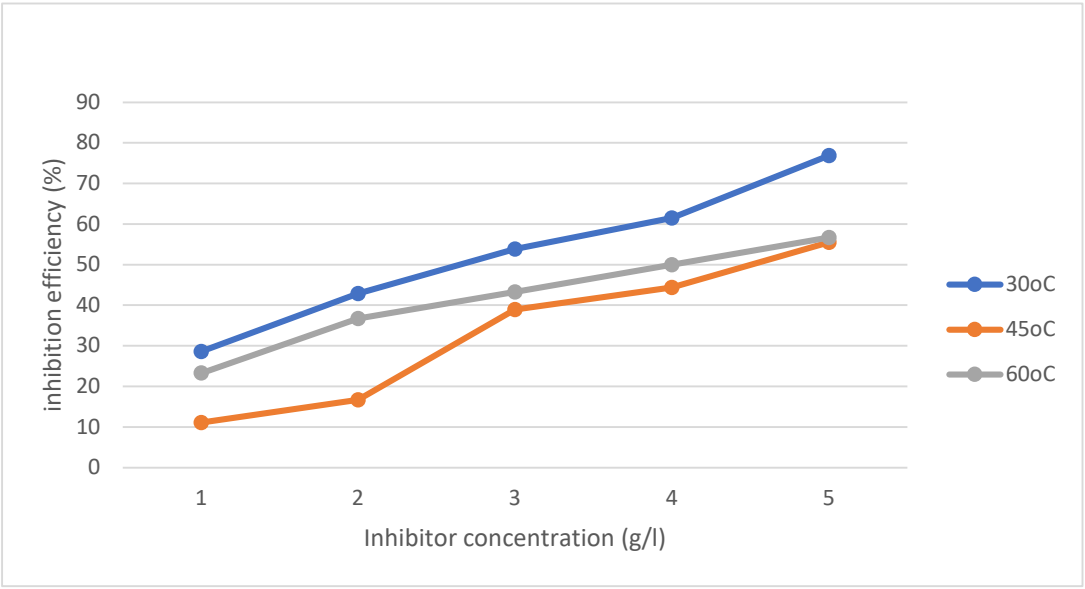

Figure 3.6. Variation of inhibition efficiency with extract concentration for mild steel coupon in 0.5M H_2SO_4 solutions containing S. *alata extract at* 30^0C, 45^0C and 60^0C.

3.6. Application of Adsorption Isotherm Model

An inhibitor acts by means of a specific adsorption mechanism that depends on the composition of the corrodent, inhibitor structure and concentration as well as temperature. A decreased in inhibition efficiency with rise in temperature suggests that the inhibitor molecules were physically adsorbed on the metal surface, while a reverse behavior suggests chemisorption. Generally, an inhibitor may either be physically or chemically adsorbed on the metal surface. The possible trend in inhibition efficiency with increase in temperature from Fig. 3.7, Fig. 3.8 and Table 3.2 infers physisorption at room temperature (30°C), desorption of a fraction of the inhibition molecules at 45°C and chemisorption at 60°C.

The obtained data for *Senna alata* extract have been applied to adsorption isotherm equations, and the Langmuir adsorption isotherm fitted best (R^2= 0.9675 at 30°C, R^2= 0.9804 at 45°C and R^2= 0.9968 at 60°C), which results were gotten from gasometric measurements only. This suggests a monolayer adsorption of the molecules of the phytochemical constituents of the *Senna alata* extracts on the surface of the metal as shown in Fig 3.8.

The Langmuir adsorption isotherm equation is given as

$$\frac{c}{\theta} = c + \frac{1}{k}$$

Where, 0 is the surface coverage, C is the inhibition concentration, and K is the equilibrium constant for the adsorption reaction.

The activation energy values calculated in Table 4.2 was done using the equation.

$$Log\ \frac{R_{H2}}{R_{H1}} = \frac{Ea}{2.303R}\left[\frac{1}{T_2} - \frac{1}{T_1}\right]$$

Where;

R_{H1} and R_{H2} = the corrosion rates at temperatures T_1 and T_2, respectively

k = Equilibrium constant for the adsorption reaction (Ikpi *et al.,* 2012).

The Gibbs free energy, ΔG were calculated from the equilibrium values as shown in Table 3.3, using the formula;

ΔG_{ads} = - 2.303 RT Log (55.5 K)

Table 3.3. Adsorption equilibrium constant (Keq), adsorption free energy (ΔG_{ads}) and correlation coefficient (R^2), for mild steel coupons in 0.5 H_2SO_4 solution containing *S. alata* extract at 30^0C, 45^0C and 60^0C.

Temperature (^{0}C)	Equilibrium Constant (k)	Slope	R2	Δ G_{ads} (Kjmol-1)
30	0.332	0.779	0.9675	-7.342
45	0.211	0.981	0.9804	-6.506
60	0.315	1.183	0.9968	-7.923

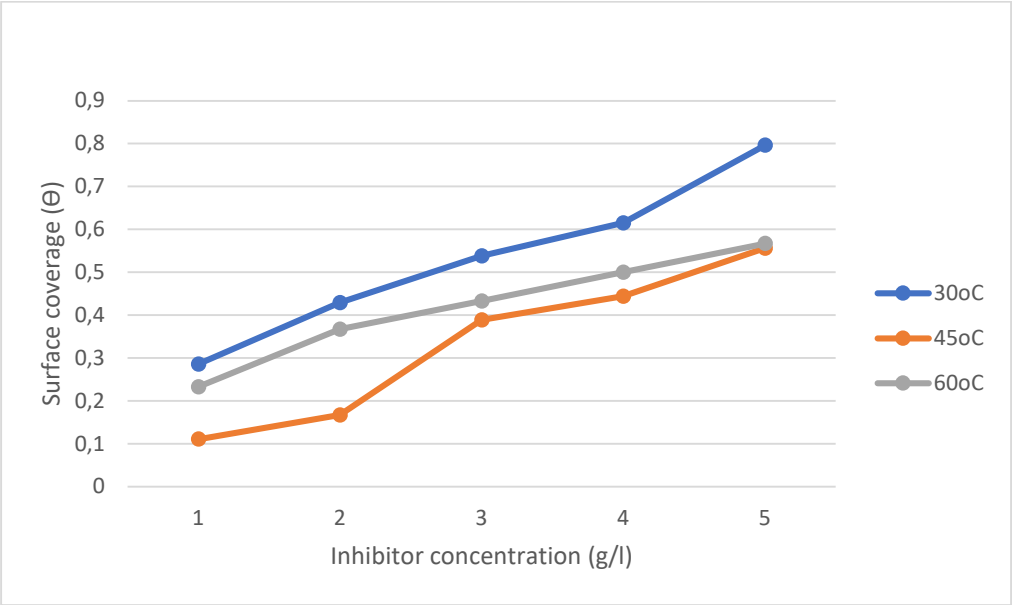

Figure 3.7. Variation of inhibition efficiency with extract concentration for mild steel coupon in 0.5M H_2SO_4 solutions containing S. *alata extract at* 30^0C, 45^0C and 60^0C.

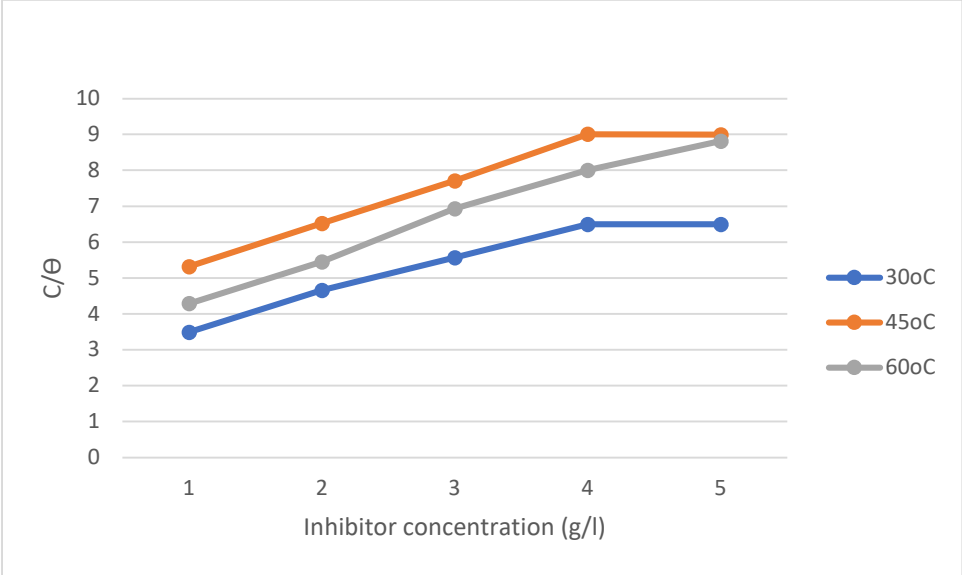

Figure 3.8. Langmuir adsorption isotherm for mild steel in 0.5M H_2SO_4 solutions containing S. *alata extract at* 30^0C, 45^0C and 60^0C.

3.7. Kinetic Consideration

The kinetics of corrosion of mild steel in acidic media in the presence and absence of *Senna alata* extract is explained by plotting the logarithm of the weights of the metal after retrieval from the different concentration against time, t. linear plots, as shown in Fig. 4.8 which reveals first order kinetics with the mathematical expression given as

$$Log\ W_f = \log W_0 - \frac{k}{2.303}\ t$$

Where;

W_f and W_0 - are the final weights after retrieval of coupons and initial weights of coupons, respectively. K is the corrosion rate constant and t is time (Ebenso *et al* 2008).

The rate constant (K) values are shown in Table 3.1. It was observed that the rate constant increased as the inhibitor concentration increases, with the highest value occurring at 5.0g/l. The half-life values obtained from Table 3.1 were observed to increase with increase in inhibitor concentration.

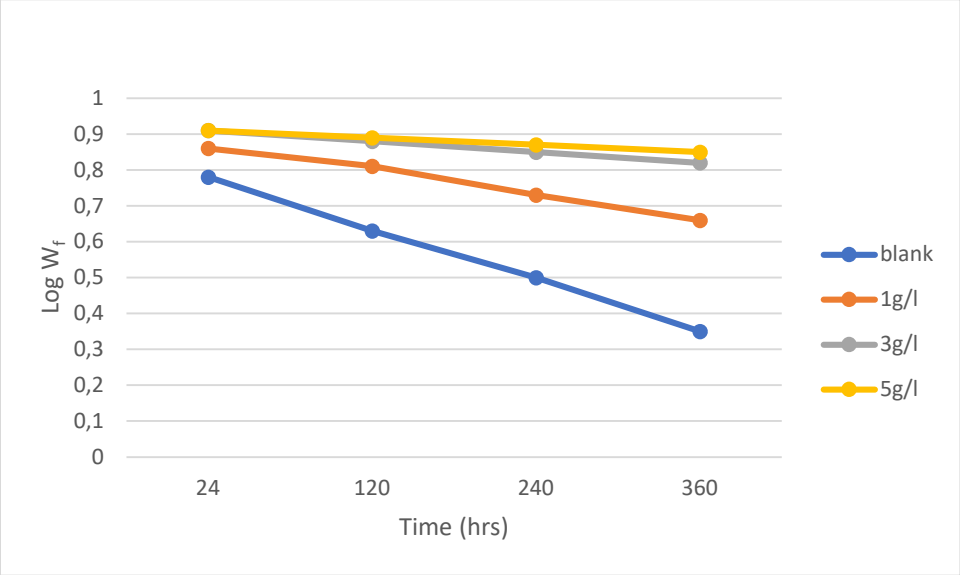

Figure 3.9. Plot for log a against time for mild steel in 0.5M H_2SO_4 solutions in the absence and presence of S. *alata extract at* 30^0C.

4. CONCLUSION

Senna alata extracts acts as an inhibitor for mild steel corrosion in H_2S0_4 solution. The inhibition efficiency of *its* extract increases with increase in extract concentration. Physical adsorption is proposed for the increase in inhibitor efficiency at room temperature, while at elevated temperature it indicates chemisorption. The adsorption of *S.alata* extract on mild steel surface obeys the Langmuir adsorption isotherm. The inhibitive effect of other members of *Senna alata* should also be studied. The stems and roots of *Senna alata* extract should be studied in the corrosion of mild steel in acidic, alkaline, and neutral media. Due to the wide applications of metals, the inhibitive property of *Senna alata* extract should be studied in the corrosion of other metals other than mild steel.

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