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Corrosion Inhibition of Mild Steel in 1m HCL Using Unripe Plantain Peel Extracts

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Abstract:
Musa Paradisiacapeels extract was used as a corrosion inhibitor on mild steel in hydrochloric acid 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 0.4 g/l extract in 1M HCl which is encouraging. It was concluded that Musa Paradisiaca peels extract can be used as corrosion inhibitor as this will reduced the importation cost, increase the gross domestic product (GDP) of the nation and make the environment free of toxic chemical inhibitor. The use of the peels extract as corrosion inhibitor is recommended for use in the process industries.

Keywords: *Musa Paradisiaca peels, corrosion inhibitor, Mild steel, Hydrochloric acid (HCl) Langmuir, Adsorption.*

1. Introduction

The degradation of a material by electrochemical reaction with its environment is termed corrosion. Corrosion is a naturally occurring phenomenon commonly defined as deterioration of metal surfaces caused by the reaction with the surrounding environmental conditions. In most common use of the word, this means electrochemical oxidation of metals in reaction with an oxidant such as oxygen. Rusting, the formation of iron oxides is a well-known example of electrochemical corrosion. This type of damage typically produces oxides or salts of the original metal. Corrosion can also occur in materials other than metals, such as ceramics or polymers, although in this context, the term degradation is more common. Corrosion degrades the useful properties of materials and structures, including strength, appearance and permeability to liquids and gases.

Corrosion of mild steel is an electrochemical reaction that requires the presence of water (H_2O), oxygen (O_2) and ions such as chloride ions (Cl^-), all of which exist in the atmosphere. Atmospheric chloride ions are in greatest abundance anywhere near the coastline. This electrochemical reaction starts when atmospheric oxygen oxidizes iron in the presence of water. In addition, the atmosphere also carries emissions from human activity, such as carbon dioxide (CO_2), carbon monoxide (CO), sulphur dioxide (SO_2), nitrous oxide (NO_2) and many other chemicals.

Also, if any two dissimilar metals are in contact with each other, the more reactive metal will corrode in preference to the less reactive metal.

A corrosion inhibitor is a substance which, when added to an environment, reduces the rate of attack by the environment. The use of corrosion inhibitors is one of the best methods of combating corrosion. In order that they can be used effectively, three factors must be considered, namely:

i. Identification of the corrosion problems,
ii. The economics of the inhibition process.
iii. The compatibility of the inhibitor with the process being used.

. Corrosion inhibitors can be divided into two broad categories, namely those that enhance the formation of a protective oxide film through an oxidizing effect and those that inhibit corrosion by selectively adsorbing on the metal surface and creating a barrier that prevents access of corrosive agents to the metal surface.

Preventing the corrosion of mild steel has played an important role in various industries, especially in the chemical and petrochemical processing industries that employ the use of mild steel. A number of studies have been conducted to investigate effective methods for preventing corrosion. (yuhazri.,2011).

The development of new corrosion inhibitors of non-toxic type, which do not contain heavy metals and inorganic phosphates, is of considerable importance (Fengling *et al*., 2009).

Inorganic substances such as phosphates, chromates, dichromate and arsenates are often used in process industry applications as inhibitors to decrease the corrosion of various types of alloys, mostly mild steels. However, they suffer a major disadvantage because of their high toxicity, and as such their use has come under severe criticism.(K.O. Orubite and N.C. Oforka ,2004) These toxicity effects have resulted in renewed interest in organic substances as anticorrosion agents.

James and Akaranta (2009) studied the inhibiting action of acetone extract of red onion skin on the corrosion of zinc in hydrochloric acid solution using weight loss method. The results of the study revealed that different concentrations of extract inhibit zinc corrosion. Inhibition efficiency is found to vary with concentration and temperature. The inhibition efficiency, greater than 90% was attained at concentration of 0.08 g/L of red onion skin extract.

Due to the toxic nature of inorganic-based compounds and their associated high costs, efforts have been focused on the use of these plant extracts as potential agents to reduce corrosion in various typical industrial solutions. Plants have been recognized as sources of naturally occurring compounds, some with rather complex molecular structures and having varying of physical, chemical and biological properties (Farooqi*et al*. 1997)

The above attributes have made plants become an important source of a wide range of eco-friendly (green) corrosion inhibitors. This paper seeks to study corrosion inhibition of mild steel using unripe plantain peel extracts.

2. Materials and Methods

Mild steel coupons of initial weight 6.0- 6.5g cut into rectangular shapes of 3cm by 4cm with thickness 2mm was degreased with acetone to remove grease, oil and dust, washed with distilled water and dried. The coupons were then mechanically polished with 400 and 600 grade emery papers, cleaned and dried. The 25 coupons were then attached to 5 pieces of stick in a set of 5 with the aid of thread passed through a drilled hole on the coupons. The prepared mild steel specimens were then weighed in a weigh balance and immersed in 5 different beakers containing 500 ml of 1M HCl for five days with various concentration of the extract.

2.1. Musa Paradisiacaextract Preparation

Samples of Musa Musaparadisiaca peels were collected from Alakahia market in Obio-akpo area of Rivers State and were washed carefully with distilled water to remove any form of dirt from the peels. The peels were dried under the sun until a constant weight was obtained . This was to ensure complete removal of water from the peels. The dried Musa paradisiaca peels were grounded using an industrial scale grinder to powdered form. The powdered Musa paradisiaca peels was then run through the wire mesh sifter to obtain very fine powdered samples and to separate the shaft of the peels. The fine powdered were completely soaked in 100ml of ethanol solution for 96 hours, after which the mixture was stirred properly in order to have homogenous solution and then filtered. The filtrate was subjected to the evaporation process to remove the ethanol in the filtrate. The inhibitor was obtained in its pure form at the end of the evaporation process. The stock solution of the extract obtained were used in preparing different concentrations of the extract by dissolving 0.1g/l, 0.2g/l, 0.3g/l and 0.4g/l of the extract in 1M of HCL respectively.

2.2. Weight Loss Measurement

Weight loss measurements were carried out by weighing the specimens before and after immersion in the 500ml of 1M HCl acid solution in the absence and presence of inhibitors at various extract concentrations of 0.1g/l, 0.2g/l, 0.3g/l and 0.4g/l. Mild steel specimens were immersed in 500ml of 1M HCL with the various extract concentration for five days at room temperature. One coupon from each of the solution were taken out after 24,48,72,96 and 120hrs respectively, washed, dried and reweighed accurately.The acid solution under investigation represents various real industrial environments including pickling acids, stimulation fluids, and/or cleaning solutions for inorganic carbonate scales.

From the weight loss results, the inhibition efficiency (%I) of the inhibitor, degree of surface coverage and corrosion rates (CR) were calculated using equations 1,2 and 3 respectively.

$$\mathrm{I}E\% = \left(\frac{w0-wi}{CR0}\right) * 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

$$\mathrm{K}= \frac{\theta}{1-\theta} c \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2$$

$$CR = \frac{87.6W}{\rho At} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3$$

where W_i and W_0 are the weight losses (g) for mild steel in the presence and absence of the inhibitor in HCl solution, θ is the degree of surface coverage of the inhibitor, ρ is the density of coupons, A is the area of the mild steel coupon (in cm^2), t is the period of immersion (in hours) and W is the weight loss of mild steel after time, t.

3. Results and Discussion

EXTRACT CONC G/L	WEIGHT OF COUPONS IN GRAMS AT				
	24HRS	48HRS	72HRS	96HRS	120HRS
0	6.32	6.29	6.25	6.2	6.16
0.1	6.49	6.34	6.32	6.28	6.25
0.2	6.41	6.37	6.35	6.32	6.30
0.3	6.42	6.4	6.39	6.38	6.36
0.4	6.44	6.43	6.42	6.41	6.40

Table 1: Weight of steel bar in different concentration of Musa paradisiacaextract in 1M HCL at different time interval.

EXTRACT CON G/L	WEIGHT LOSS OF COUPONS				
	24HRS	48HRS	72HRS	96HRS	120HRS
0	0.18	0.25	0.21	0.30	0.34
0.1	0.11	0.18	0.16	0.22	0.25
0.2	0.09	0.15	0.13	0.18	0.20
0.3	0.08	0.11	0.10	0.12	0.14
0.4	0.06	0.08	0.07	0.09	0.10

Table 2: Weight loss of steel bar in different concentration of Musa paradiscara extract in 1M HCL

CONCENTRATION OF UNRIPE PLANTAIN PEEL EXTRACT (g/l)	INHIBITION EFFICIENCY OF COUPONS AT				
	24HRS	48HRS	72HRS	96HRS	120HRS
0	0	0	0	0	0
0.1	38.89	23.81	28	26.67	26.47
0.2	50	38.1	40.0	40.3	41.18
0.3	55.56	56.38	58.4	59.9	60.82
0.4	66.67	67.9	69.3	70	70.59

Table 3: Inhibitor efficiency for various concentration of Musa paradiascasra extract in 1M HCL

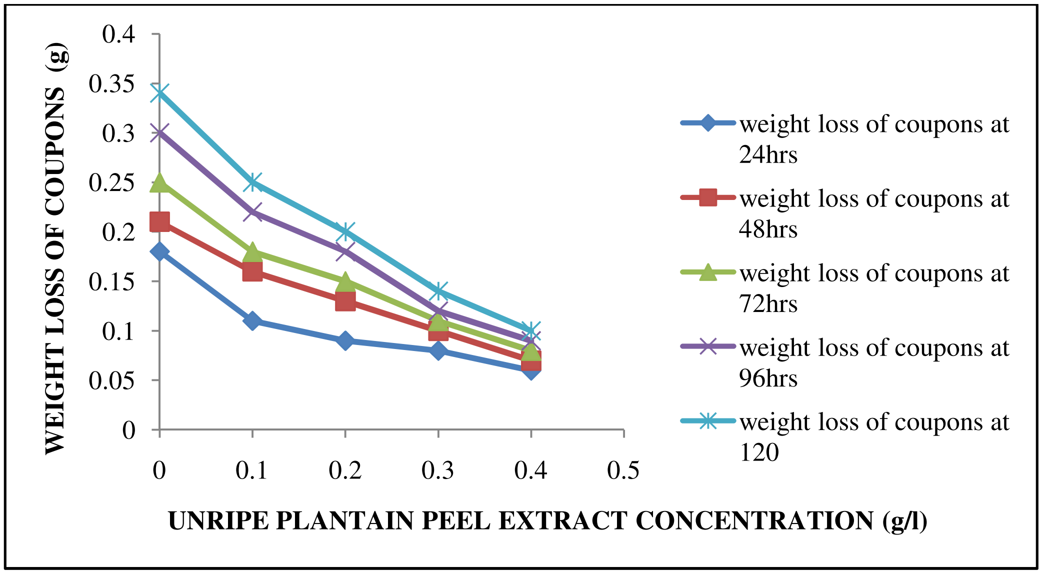

Figure 1: A graph of weight loss in mild steel bar against concentration of Musa paradisiaca in 1M HCL at different time

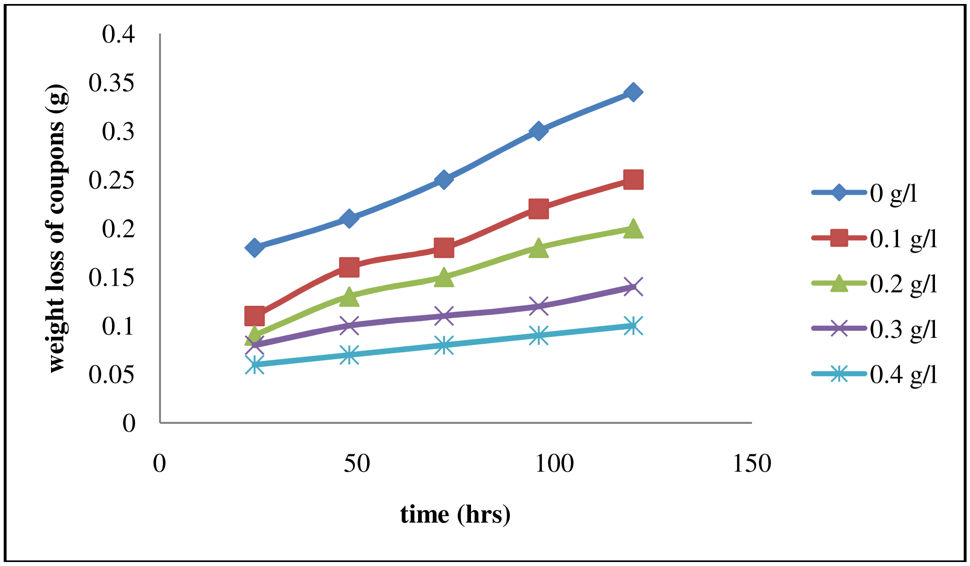

Figure 2: A graph of weight loss in mild steel bar against time.

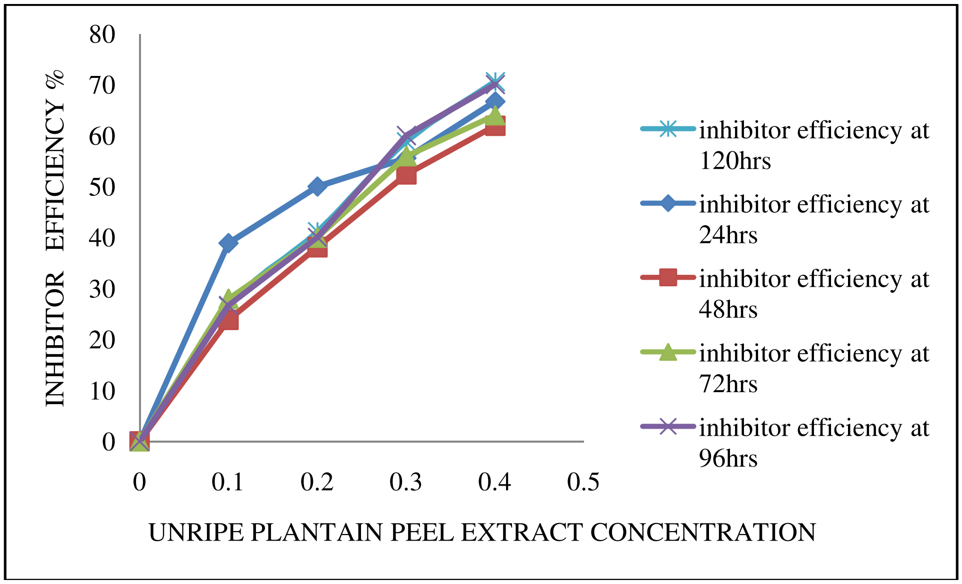

Figure 3: A graph of percentage inhibitor efficiency against inhibitor concentration for various time.

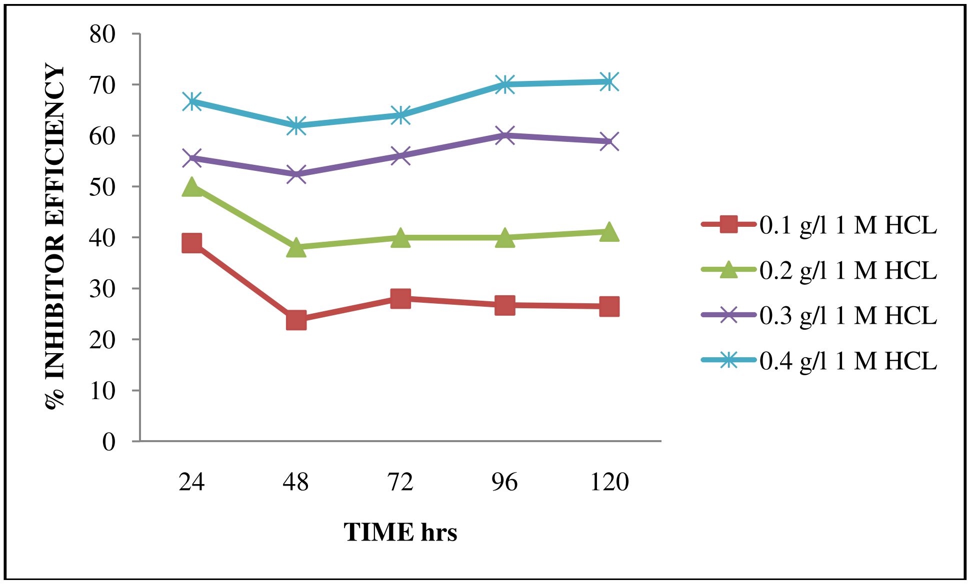

Figure 4: A graph of percentage inhibitor efficiency against time for different inhibitor concentration.

Corrosion rate of mild steel in mils per year (MPY)					
Concentration(g/l)	**24HRS**	**48HRS**	**72HRS**	**96 HRS**	**120HRS**
0	0.164	0.096	0.076	0.068	0.062
0.1	0.100	0.073	0.055	0.050	0.042
0.2	0.082	0.059	0.046	0.041	0.037
0.3	0.073	0.046	0.033	0.027	0.026
0.4	0.055	0.0320	0.024	0.021	0.018

Table 4: Corrosion Rates of Mild Steel at Various Concentrations of Unripe Plantain Peel Extract at Their Various Time Intervals.

	CORROSION RATE	
	Ipy	**Mm/y**
Completely satisfactory	<0.01	0.25
Use with caution	<0.03	0.75
Use only for short exposures	<0.06	1.5
Completely unsatisfactory	>0.06	1.5

Table 5: Acceptable corrosion rates

Degree of surface coverage (θ)					
EXTRACT (g/l)	**24HRS**	**48HRS**	**72HRS**	**96HRS**	**120HRS**
	–	–	–	–	–
0	0.3889	0.2381	0.28	0.2667	0.2647
0.1	0.5	0.381	0.4	0.4	0.4118
0.2	0.5556	0.5238	0.56	0.6	0.5882
0.3	0.6667	0.619	0.64	0.7	0.7059
0.4					

Table 6: Degree of Surface Coverage (θ)

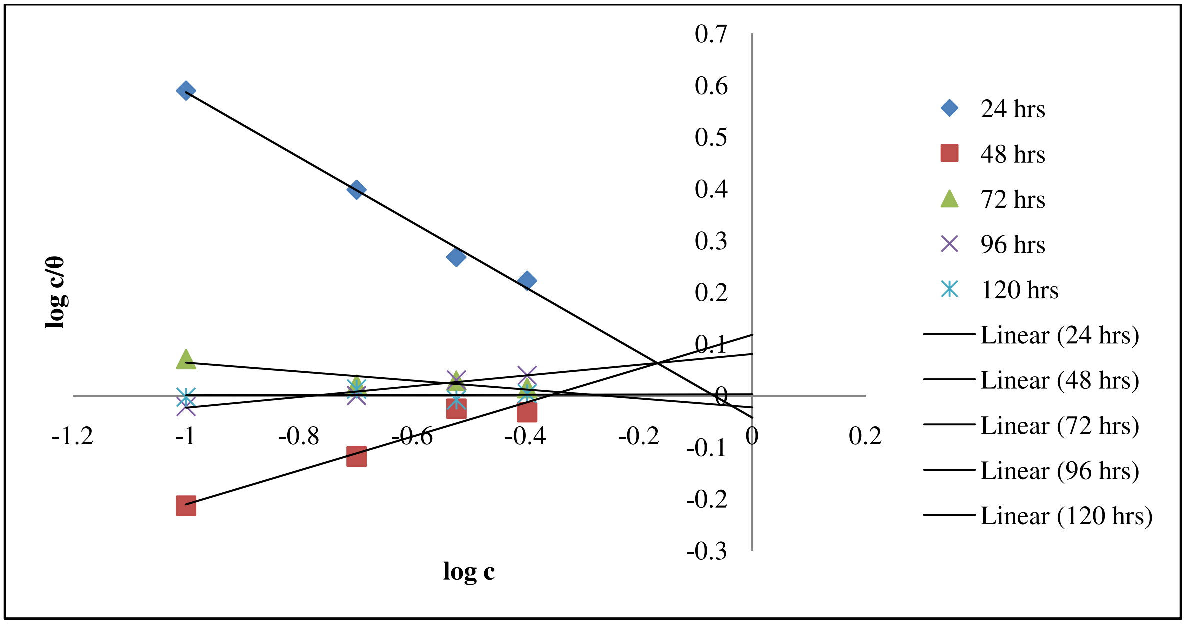

Figure 5: Langmuir Curve Fittings for Adsorption of Unripe Plantain Peel Extracts on Mild Steel Electrode in 1m HCl.

ΔGads (kj/mol) of mild steel using unripe plantain peel extracts as inhibitor					
Concentration(g/l)	**24HRS**	**48HRS**	**72HRS**	**96HRS**	**120HRS**
0.1	-20244.414	-18482.11	-19023.95	-18858.01	-18832.60
0.2	-21364.34	-20161.75	-20359.600	-20359.60	-20480.84
0.3	-21917.75	-21600.43	-21961.95	-22369.09	-22247.82
0.4	-23081.97	-22566.93	-28495.94	-22247.82	-23533.97

Table 7: Values of free energy changes for the corrosion of mild steel in 1 M HCl in the presence of different concentrations of unripe plantain peels extract at different time intervals

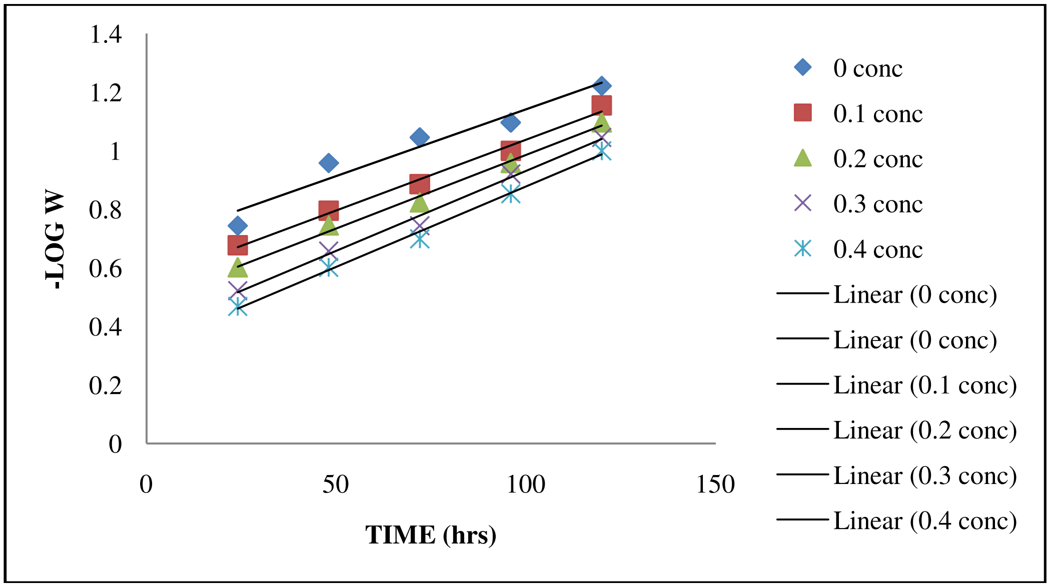

Figure 6: relationship between –logw and time (hrs) at various concentrations of unripe plantain peel extracts.

Conc (g/l)	K_1 (hrs^{-1})	$t^{1/2}$ (hrs)	R^2
0	0.0106	54.696	0.942
0.1	0.0111	54.696	0.991
0.2	0.0115	60.156	0.993
0.3	0.0127	62.715	0.992
0.4	0.0127	65.38	0.995

Table 8: Half-life of mild steel bars in 1M HCl.

Table -1 and-2 revealed that as the concentration of inhibitor increases, the weight loss of mild steel bar decreases. This means that the inhibitor concentration is inversely proportional to weight loss of materials. It also showed that corrosion is a function of time. That is as time increases, the rate of corrosion also increases at a specified condition. This supports the findings of Eddy and Ebenso, (2008).

Tables 3and 4 shows the inhibitor efficiency and the corrosion rate for various concentration of Musa paradisiacaextract in 1M HCL at different time interval. It shows that as the inhibitor concentration increases, percentage of inhibitor efficiency also increases and the corrosion rate decreases which means inhibitor efficiency is directly proportional to inhibitor concentration at a particular time. and suggests that the inhibitor molecules act by adsorption on the metal surface. Consequently the increase of the inhibitor efficiency was ascribed to the increase in surface coverage, see table-.6;It also revealed that at a specified concentration, percentage inhibitor efficiency is inversely proportional to time. The optimum inhibitor efficiency was approximately 71 %, which corresponds to 0.4 g/l *Musa paradisiaca*extract in 1M HCL at 120 hours. when converted to ipy gives 0.0000018 which is less than 0.01ipy, proved to be completely satisfactory see table -5.

4. Conclusion

- The inhibitor molecules show high inhibitive efficiency for corrosion of mild steel in 1M HCl.
- The percentage inhibitive efficiency of the inhibitor increases with its concentration and its increase in exposure time.
- The degree of surface coverage exerted by the inhibitor molecules on the mild steel surface increases with the inhibitor concentration
- The inhibitor molecules are adsorbed on the mild steel surface blocking the reaction sites. The surface area available for the attack of the corrosive species decreases with increasing inhibitor concentration
- The inhibition of mild steel by unripe plantain peels extract approximates a first order reaction.
- The adsorption of unripe plantain peels extract on mild steel fits into the Langmuir mode.
- An increase in the concentration of unripe plantain peels extract in the corrosive medium, brings about an increase in the half-life of mild steel in the medium.

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