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Investigating the Inhibitive Characteristics of *Moringa Oleifera* on the Corrosion of Mild Steel

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Abstract: This work deals with the inhibitive characteristics of Moringa oleifera fruits and leaves extracts in Hydrochloric Acid solution and Sodium Hydroxide solution respectively on the corrosion of mild steel. This was carried out using weight loss and polarization techniques. The effects of immersion time, the effect of acid and alkaline concentration on the corrosion behavior of mild steel in 1.0M HCl and 1.0 NaOH with addiction of extracts were deduced. The fruits which were dried and grounded to powder of 10g and the leaves which range from 25cm^3 to 100cm^3 were used for this study. The corrosion rate was very high in the absence of inhibitors (Moringa oleifera fruits and the leaves extracts). The mild steel was cut into coupon averaging a total surface area of 4.262cm^2. The sample was weighed and immersed into a beaker containing 1.0M NaOH with different volumes of moringa leaves and 1.0M HCl with 10g dried concentrated powdered moringa fruits with coupons removed every 7 days for weight loss measurements till 4 weeks. The corrosion rates were found to be decreased by 83% in 1.0M HCl and 78% in 1.0M NaOH respectively, values of inhibition efficiency (η%) were calculated from weight loss. The results obtained showed that the Moringa oleifera fruits and leaves extracts could serve as effective inhibitors on the corrosion of mild steel in HCl and NaOH respectively.

Keywords: Moringa oleifera, Corrosion rate, Weight loss, Mild steel, Inhibitor.

I. INTRODUCTION

Corrosion is the deterioration of a metal due to its interaction with the environment. Corrosion processes are responsible for losses and failures in the industrial sector. Due to corrosion many useful properties of a metal such as malleability, ductility, electrical conductivity is lost. Synthetic organic compounds are widely used as corrosion inhibitors for the prevention of corrosion of many metals and mild steel in various aggressive environments. Because of their hazardous nature, researchers focus their attention on developing cheap, non-toxic biodegradable, and environment-friendly natural products of plants origin as corrosion inhibitors. Extracts of plants materials containing Nitrogen and the Sulphur atom has been used to control the corrosion of mild steel and other metals in different corrosion medium such as Sodium Chloride (NaCl), Hydrochloric acid (HCl), Sodium Hydroxide (NaOH), etc.

There are several reports on the use of different inhibitors to reduce corrosion of different metals, including mild steel in different media. However, there are few reports on the use of *Moringa oleifera* fruits and leaves extracts as inhibitors on the corrosion of mild steel, thus this research will contribute to knowledge in the area of corrosion of mild steel. Nonetheless, corrosion being a natural phenomenon harms metal. Mild steel is a very important metal in the manufacturing industry is highly vulnerable to corrosion which has resulted in huge economic losses. This has led to research on the discovery of diverse means of mitigating or eliminating this phenomenal occurrence. Among the various means discovered, the use of organic (green) inhibitors is popular in which *Moringa oleifera* is hereby captured or investigated.

Moringa oleifera, commonly known as drumstick or horse-radish, which is rich in vegetable oil and high in nutritional values, is used in Asia as a vegetable and medicinal plant. Moringa has a diverse range of medicinal uses as an antibacterial, antifungal, and its antinociceptive properties, as well as its wound healing ability, can prove its economic potentials.

II. MATERIALS AND METHOD

A. Materials

The materials used for this study include; 10g of dried and grounded fruits of *Moringa oleifera*, 500ml of the total surface area of 4.262cm^2 with different percentage compositions, 1M and 100ML of hydrochloric acid (HCl), electronic weighing balance, razor blade, funnel, nylon thread, paper sieve, masking tape, spring weighing balance, mortar and pestle, 0.5M and 1.0M sodium hydroxide (NaOH), hand towel, volumetric flask (250cm^3), measuring cylinder (250cm^3), filter cloth, a vernier caliper, and *Moringa oleifera* leaves.

B. Sources of Data

The *Moringa oleifera* fruits and leaves used for this research work were obtained from the Department of crop production and landscape management in the Faculty of Agriculture, Ebonyi State University, Abakaliki while the mild steel was obtained from Delta Steel Company, Aladja, Delta State.

C. Weight Loss Method

Weight loss measurements were performed on the mild steel sample form of size 2.5cm×2.0cm×0.025cm in 1M HCl solution with and without the addition of different concentrations of fruit extract. The sample powder of Moringa oleifera fruit extract was weighed by an electronic weighing balance and then placed in the acid solution (100ML). The duration of the immersion was 3 hours at the temperature range from 308 to 338K. After immersion, the surface of the specimen was cleaned by double distilled water followed by rinsing with acetone and the sample was weighed again to calculate inhibition efficiency (η%) and the corrosion rate (C_R).

D. Polarization Measurement Techniques

By polarization, the extrapolation of the Tafel straight line allows the calculation of the corrosion density (I_{corr}). Cathodic and anodic Tafel slopes (b_c, b_a) and inhibition efficiency (η%). The values of corrosion density (I_{corr}) were found to decrease in the presence of inhibitors. The decrease in I_{corr} can be due to the adsorption of fruit extract on the mild steel surface. Here, the inhibition efficiency (η%) is calculated using the relation

$$(\eta\%) = \frac{I_{corr(1)} - I_{corr(0)}}{I_{corr(1)}} \times 100$$

Where $I_{corr(1)}$ and $I_{corr(0)}$ are the corrosion current density values without and with inhibitor respectively. Many authors proposed the following mechanism for the corrosion of iron steel in acid solution.

$Fe + A^{n-} \rightarrow (FeA^{B})$

$(FeA^{n-}) \rightarrow (FeA^{n-}) + ne^{-}$

$(FeA^{B-}) \rightarrow (FeA^{n+}) + ne^{-}$

$(FeA^{n+}) \rightarrow (Fe^{2+}) + A^{p-}$

The cathodic hydrogen evolution

$Fe + H^{+} \rightarrow (FeH^{+})$

$(FeH^{+}) + ne^{-} \rightarrow (FeH)$

$(FeH^{+}) + H^{+} + ne^{-} \rightarrow Fe + H_2$

Table 1: Inhibition efficiency and corrosion rate in acidic medium

Inhibitor	Concentration (ppm)	Weight loss ($mgcm^2$)	(η%)	C_R (mmy^{-1})
Moringa oleifera	50	3.0	85.7	11.1
	100	2.9	86.6	10.7
	150	1.2	94.0	4.4
	200	0.8	96.1	2.9
	250	0.7	96.6	2.5
	300	0.4	98.2	1.4

III. RESULTS

A. Effects of HCl and NaOH Concentration

The effects of increasing the concentration of acid (HCl) and alkaline (NaOH) from 0.5M to 0.2M depicts the variation of inhibition efficiency (η%) as shown in table 2. From Figures 6 and 7, it can be seen that the inhibition efficiency of fruit extract decreases with an increase in HCl acid concentration from 0.5M to 2.0M. This decrease in inhibition efficiency can be attributed to increases aggressiveness of solutions with an increase in acid concentration while inhibition efficiency of leaves extracts increases with an increase in sodium hydroxide (NaOH) concentration from 0.5M to 2.0M. This behavior may be attributed to the uniform adsorption of the formed oxide layer on the metal surface.

Table 2: Effect of HCl and NaOH Concentration

Inhibitor	Concentration (ppm)	Weight loss ($mgcm^2$)	(η%)	C_R (mmy^{-1})
Moringa oleifera	0.5	89.4	2.8	2.1
	1.0	97.0	2.0	1.0
	1.5	96.0	1.5	0.5
	2.0	98.2	1.2	0.4
	0.5	98.0	0.2	0.5
	1.0	96.4	2.6	0.8

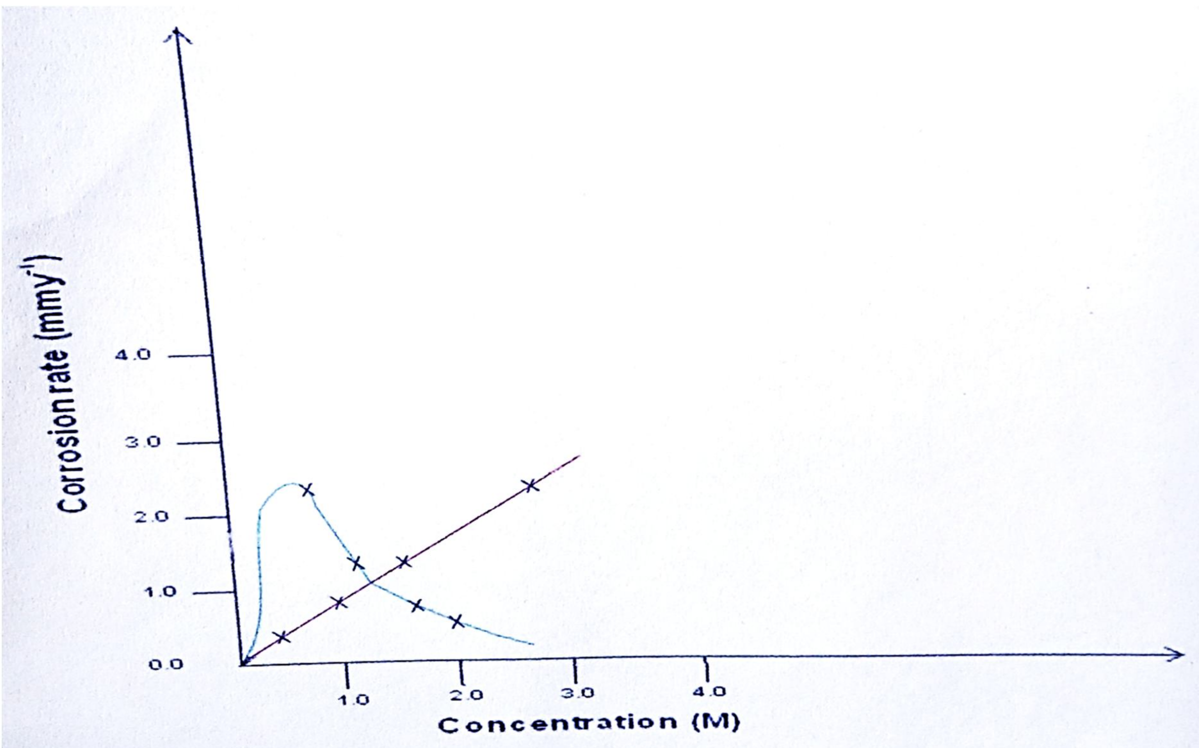

Figure 1: Plots of corrosion rate against concentration of HCl and NaOH

B. Effect of Inhibitor Concentration

Figure 7 clearly shows the effects of fruits concentration on the inhibition efficiency (η%) in 1M HCl. From the figure, the inhibition efficiency increases (η%) and on the other hand, corrosion rate decreases (C_R) with an increase in the *Moringa oleifera* fruit's concentration up to their optimum level after which a further increase in the inhibitor concentration did not cause any significant in inhibition efficiency and corrosion rate. At an optimum concentration of 300ppm, the Moringa oleifera fruits extract showed maximum inhibition efficiency (η%) of 97.3% in HCl.

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Figure 8 shows the effect of leaves concentration on inhibition efficiency (η%) in 1M NaOH. The inhibition efficiency was found to increase with an increase in the volume(s) of the leaves between 25cm^3 to 25cm^3 while the corrosion rate decreases. However, a further increase in the leaves' volume did not yield more increase in η% and C_R.

Table 3: Effect of inhibitor concentration on fruits extract

Inhibitor	Concentration (ppm)	Weight loss (mgcm^2)	(η%)	C_R (mmy^{-1})
Moringa oleifera fruits	150	1.2	94.0	4.4
	200	0.8	96.1	2.9
	250	0.7	96.6	2.5
	300	0.5	97.3	1.5
	150	1.2	94.0	4.4
	200	0.8	96.1	2.9

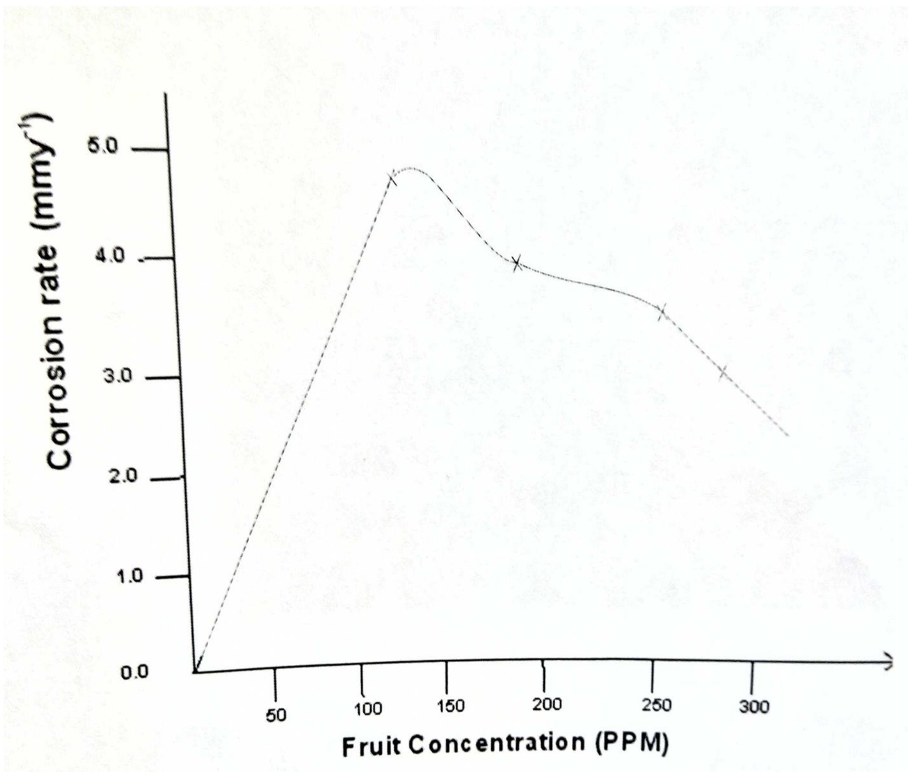

Figure 2: Plot of corrosion rate against fruit concentration at 1M HCl

Table 4: Effect of inhibitor concentration on leaves extract

Inhibitor	Concentration (ppm)	Weight loss (mgcm^2)	(η%)	C_R (mmy^{-1})
Moringa oleifera leaves	25	1.4	93.5	4.2
	50	0.9	95.4	2.8
	75	0.6	96.2	2.4
	100	0.4	97.0	1.4
	25	1.4	93.5	4.2
	50	0.9	95.4	2.8

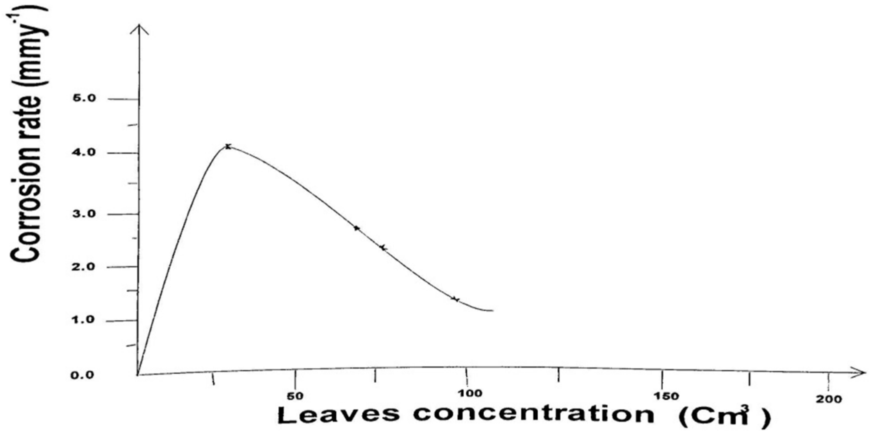

Figure 3: Plot of corrosion rate against leaves concentration at 1M NaOH

C. *Effect of Immersion Time*

To assess the stability of inhibition efficiency of Moringa oleifera fruits and leaves extracts on a time scale, weight loss measurements were performed in 1M HCl and 1M NaOH in the absence and presence of fruits and leaves extracts for 2 to 8 hours and 170 to 680 hours respectively at a temperature of 308K. The inhibition efficiency was plotted against immersion time as seen from figure 7 and 8, the inhibition efficiency increases with an increase in immersion time. The value of (η%) increased from 82.0% to 98.2% for fruits extract in 1M HCl for 2 to 8 hours and from 89.2% to 99.2% for leaves extract in 1M NaOH for 170 to 680 hours. However, a plot of corrosion against immersion time also revealed that corrosion rate decreases with an increase in immersion time in both acid and alkaline medium though there are no significant variations as can be seen from figures 9 and 10. These results suggested that studied Moringa oleifera fruits and leaves extracts are effective corrosion inhibitors for mild steel.

Table 5: Effect of immersion time on leaves extract

Inhibitor	Weight loss (mgcm^2)	Immersion time (hrs)	(η%)	C_R (mmy^{-1})
Leaves	0.70	170	89.1	0.08
	0.50	340	92.0	0.07
	0.25	510	94.0	0.04
	0.20	680	99.0	0.02
	0.70	170	89.1	0.08
	0.50	340	92.0	0.07

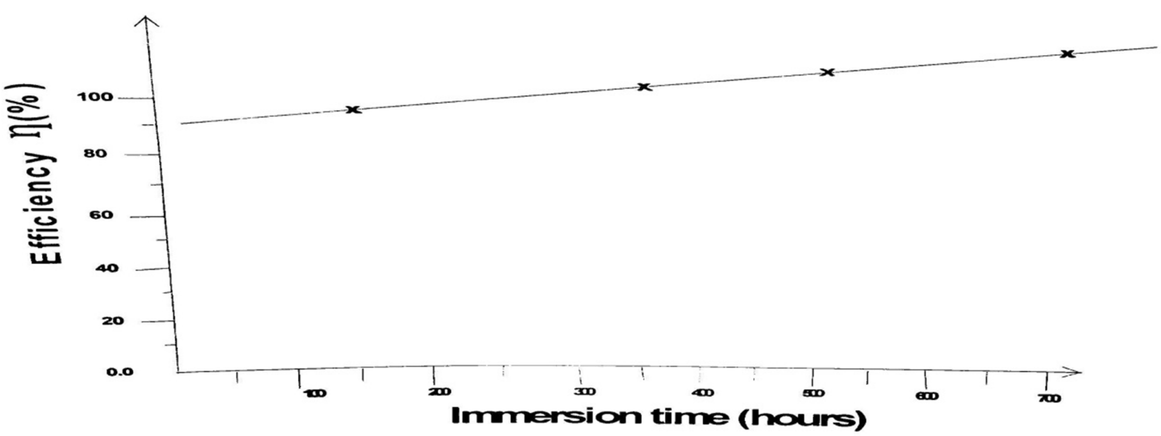

Figure 4: Plot of efficiency against immersion time in the *Moringa Oleifera* leaves extract in 1M NaOH for 170 to 680 hours.

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Table 6: Effect of immersion time on fruits extract

Inhibitor	Weight loss (mgcm^2)	Immersion time (hrs)	(η%)	C_R (mmy^{-1})
Fruits	0.5	2	82.0	2.2
	0.4	4	89.0	1.6
	0.3	6	92.0	1.0
	0.2	8	98.2	0.6

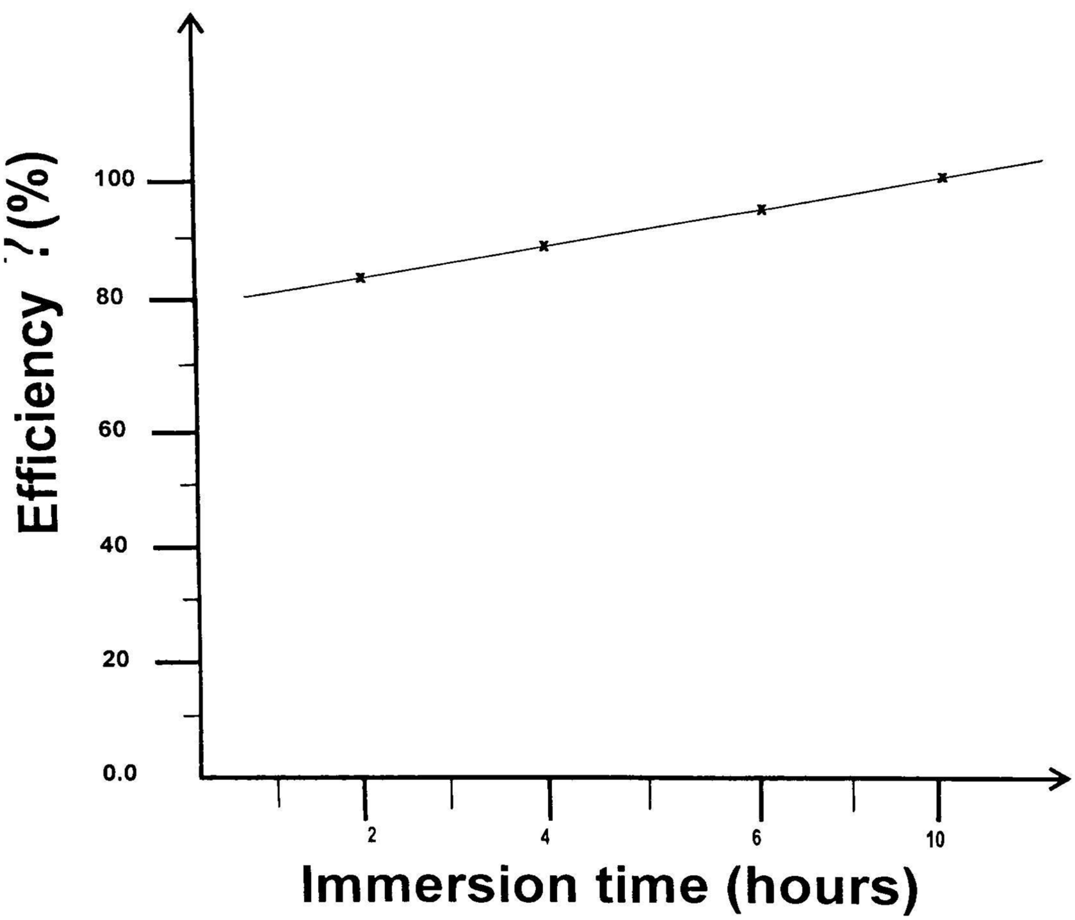

Figure 5: Plot of efficiency against immersion time in the Moringa oleifera fruits extract in 1M HCl for 2 to 8 hours.

Table 7: Effect of immersion time in the absence and presence of *Moringa oleifera* fruits extract

Inhibitor	Weight loss (mgcm^2)	Immersion time (hrs)	(η%)	C_R (mmy^{-1})
Moringa oleifera fruit absence	2.9	2	79.1	10.5
	1.2	4	89.0	4.4
	0.8	6	90.0	2.9
	0.7	8	92.0	2.2
Moringa oleifera fruit presence	0.6	2	96.0	2.2
	0.5	4	97.0	1.6
	0.4	6	98.0	1.0
	0.3	8	98.2	0.6

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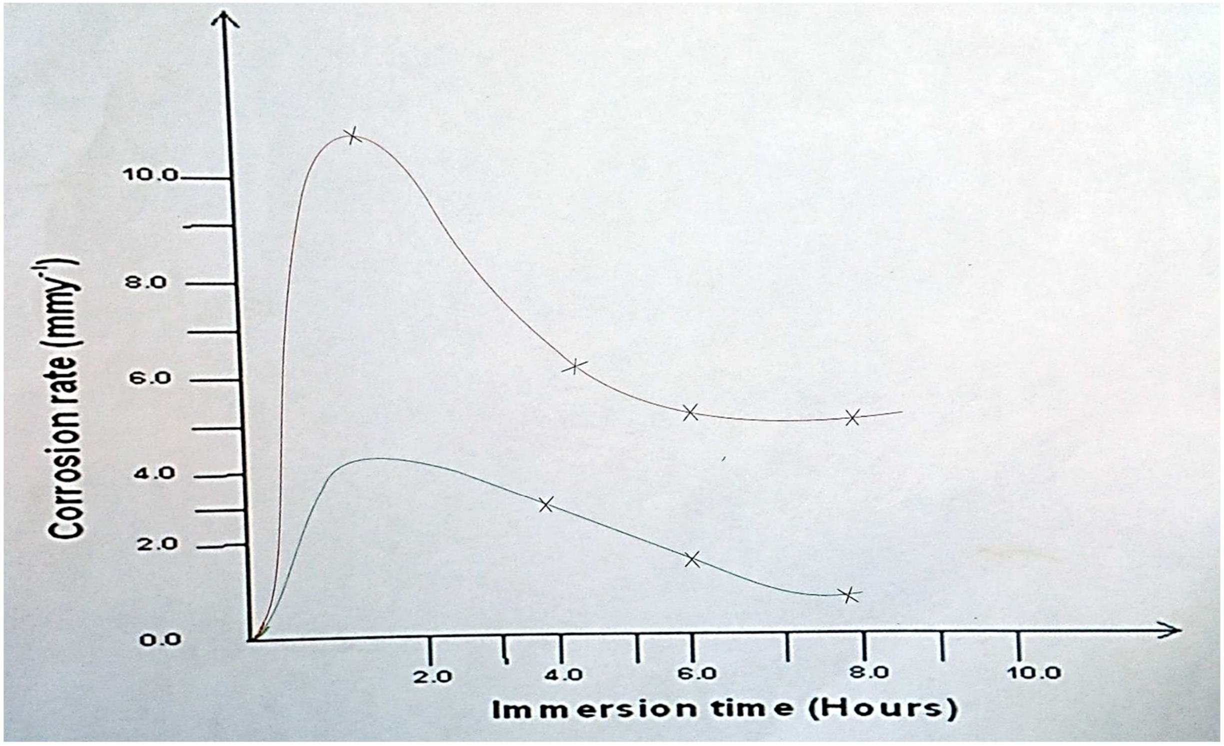

Figure 6: Plots of corrosion rate against immersion time in the absence and presence of Moringa oleifera fruits extract

Table 8: Effect of immersion time in the presence of the Moringa oleifera leaves extract for 170 to 680 hours.

Inhibitor	Weight loss (mgcm^2)	Immersion time (hrs)	(η%)	C_R (mmy^{-1})
Leaves	0.70	170	87.0	0.08
	0.50	340	98.0	0.07
	0.35	510	98.4	0.04
	0.22	680	99.6	0.01

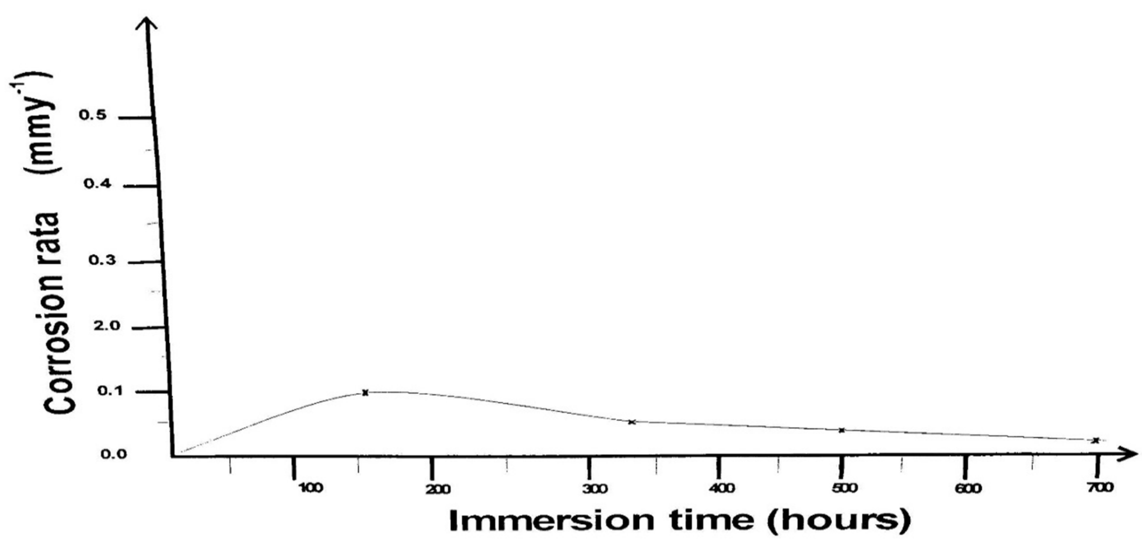

Figure 7: Plot of corrosion rate against immersion time in the presence of the Moringa oleifera leaves extract for 170 to 680 hours.

IV. DISCUSSION

A corrosion inhibitor is a chemical substance which when added in small concentration to an environment, effectively decreases the corrosion rate typically a metal or an alloy (Grafen et al., 2002). In other words, corrosion inhibitors are substances or mixtures that in low concentration and aggressive environments inhibit, prevent or minimize the corrosion (Obot et al., 2006). An efficient inhibitor is compatible with the environment, economical for application, and produces the desired effect when present in small concentrations.

A corrosion inhibitor can be added to a fluid such as fuel or lubricant. In this case, the corrosion inhibitor travels with the fluid, protecting the systems through which the fluid moves. Commonly, it forms a thin film that prevents reactions between compounds in the fluid and systems such as pipes. This type of corrosion inhibitor may be blended into the fluid continuously or added periodically to maintain a protective film. Corrosion inhibitors can also be sprayed or painted on to create a thin layer that will protect from corrosion. Many people do this regularly when they oil locks and hinges to prevent them from rusting and to keep them moving smoothly. The thin layer of oil acts as a corrosion inhibitor to prevent oxidation, so that rusting cannot occur. To work effectively, the surface needs to be clean when the chemical is applied, as otherwise corrosive reactions can take place underneath the corrosion inhibitor (McMahon and Wallace, 2014).

Once corrosion has already started, a corrosion inhibitor may be used to slow the rate of damage, depending on the corrosives involved and the situation. Some corrosion inhibitors will also remove surface layers of corrosion to help restore the material to its original finish before depositing a layer of protection. It is a good idea to regularly inspect systems treated with corrosion inhibitors to confirm that the system is still protected and to check for signs of corrosion and system failure (McMahon and Wallace, 2014). The inhibitor reacts with a potential corrosive component present in aqueous media and the product is complex (Umoren and Ekanem, 2010; Hong et al., 2008).

V. CONCLUSION

"*Moringa oleifera*" or "green inhibitor" refers to the substances that are biocompatible in nature, environmentally acceptable, readily available, and renewable sources. Due to biodegradability, eco-friendliness, low cost, and easy availability, the extract of Moringa oleifera and its by-products have been used as an inhibitor for mild steel under different environments (Ebenso et al, 2004). The molecular structure of this organic green inhibitor is the main factor determining its characteristics. The presence of heteroatom (S, N, O) with free electron pairs, aromatic rings with decolonized π-electrons, alkyl chains, substituent group, in general, improves inhibition efficiency. In general, organic compounds show higher inhibition efficiency as compared to inorganic (Acharya et al., 2013).

From the results obtained, it is clearly shown that *Moringa oleifera* extracts could serve as an effective inhibitor of corrosion of mild steel in HCl acid solution, and thus offers good protection against corrosion of mild steel. It is also shown that *Moringa oleifera* extracts can exhibit high inhibition efficiencies in both acidic and alkaline mediums, and the inhibition efficiency of the extract of *Moringa Oleifera* is dependent on the concentration of the extract, and it increased with increasing concentration of the extract in the acidic medium.

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