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The Inhibition Characteristics of *Moringa oleifera* Leaf Extract on Mild Steel in Tetraoxosulphate (VI) Acid and Sodium Hydroxide Environments

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Abstract: The inhibiting effects of *Moringa oleifera* leaves extract on the corrosion of mild steel in 0.5 M and 1.0 M both of H_2SO_4, and NaOH solution have been investigated using weight loss techniques. A total of 72 mild steel coupons of dimensions 10 mm x 5 mm x 5 mm were suspended using nylon strings in beakers containing the media with the leaf extract, obtained by Reflux method in concentrations of 5 ml, 10 ml, 15 ml and 20 ml respectively. The setup was allowed to stand for 28 days with a coupon withdrawn from each beaker at 7 days interval for corrosion analysis. The corrosion rate profiles showed behaviors similar to those of passivating metals that begins with a steep rise in corrosion rate and progressively decreases with increasing exposure time. However, it was noticed that at an exposure time of 14 days, the coupon in the 5 ml concentration experienced a sporadic rise in corrosion rate, which we attribute to the collapse of the passive film as a result of system agitation. The inhibition efficiency of the leaf in both media was significant, suggesting that it can be used as a green and eco-friendly alternative to the synthetic and rather hazardous inhibitors in use today. In conclusion, when compared, it was established that the inhibition potentials of the leaves were better in H_2SO_4 than in NaOH.

Keywords: *Moringa Oleifera*, mild steel, metal surface. inhibition efficiency, inhibitors.

Research Paper

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INTRODUCTION

Corrosion is the unintentional attack on a metal surface in contact with its environment (Uhlig, 2004). It generally involves the degradation of materials due to chemical or electrochemical reactions with their environment which normally progresses on the surface (Callister, 2007). Various types of corrosion are distinguished (Askeland, 1985). Over the ages, efforts to preserve metals from the deleterious effects of corrosion have been intense. Among the various processes for corrosion prevention and protection includes but not limited to the use of corrosion inhibitors (Sharma, 2008; Chowdhury, 2004). In this context, to mitigate the corrosion of metal in acidic and basic media, the most suitable and effective way is by the use of chemical based inhibitors. For instance, 2-mercaptobenzimidazole derivatives proved effective in mitigating the corrosion of mild steel in hydrochloric acid solution at different temperatures (Akpanyung and Loto, 2019; Cerrato *et al.*, 2017). But synthetic inhibitors are now generating a greater environmental concern due to toxic effects of the synthetic compounds on human and animal life during their production and use (Chukwukere *et al.*, 2020; Ebenso *et al.*, 2004). Most of the commercial corrosion inhibitors employed in the industries are multicomponent inhibitors systems consisting of nitrogen and sulphur functionalities. These inhibitors are stable and effective in corrosive environment, but they are often expensive to formulate and can pose threats to public health and the environment because of their toxicity (Corrosionpedia, 2017; Corrosionpedia, 2019). Currently, the utilization of traditional corrosion inhibitors is being reduced owing to increasing concept of awareness of green technology (Hazwan *et al.*, 2016; Finsgar and Jackson, 2014). The need to make the environment clean and friendly is influencing scientists and engineers to develop inhibitors from renewable resources (Kadhim, 2017; Kumar *et al.*, 2018). Therefore, a lot of investigations have been conducted using plant extracts as corrosion inhibitors for metals in different media.

Codiaeum variegatum Brilliantissima zanzibar was used as corrosion inhibitor for mild steel in 1 mole hydrochloric (Kumar *et al.,* 2019; Lisha and Sunilaa, 2017). *Azadirachta indica* was used as corrosion inhibitor for mild steel, aluminum and tin (Okafor *et al.,* 2010). Okra mucilage, a natural grade polysaccharides, was used to inhibit the corrosion of mild steel in 0.5 M of sulfuric acid, presented as a cathodic type inhibitor for corrosion in mild steel (Manuel *et al.,* 2020; McKenzie and Vassie, 1985). From the ongoing, it is proved that efforts have been made to diversify the use of plant extracts by employing them in corrosion studies. Therefore, this study seeks to advance the frontiers of knowledge in the continuing search for suitable green corrosion inhibitors for sustainable environment.

METHODOLOGY

Materials

The materials used for the study were: mild steel rod, sieve, plastic containers, bowls, dry leaves of *Moringa oleifera*, emery paper, distilled water, filter papers, Tetraoxosulphate (VI) Acid (H_2SO_4) and Sodium Hydroxide base (NaOH) solution, cello tape, nylon thread, electronic weighing balance (Tapson's Scientific Intruments Co. Model=TAPT 3000 G), hack saw and hand file beakers, measuring cylinder, hacksaw and blades, vernier caliper and measuring tape.

Processing of Plant Extract, Active Ingredients and Mild Steel:

The leaves of *Moringa oleifera* were obtained from a local market in Jalingo, Taraba State. The leaves were then thoroughly washed in water to remove dust and sand particles. They were shade dried at room temperature for three days, so as to enrich the active phytochemicals in them by reducing their moisture content (Saratha *et al.,* 2009). The dried leaves were converted to powder by pounding using a mortar and pestle. The powdered samples were sieved with a sieve of 150 μm mesh size. The sieved samples of leaves of *Moringa oleifera* were stored in polythene bags until needed for corrosion studies.

Figure 1: *Moringa oleifera* leaf and seed

Extraction of active ingredients in the leaves of *Moringa oleifera* plant were done using the Reflux method (Harsimran *et al.,* 2021; Rukaiyat *et al.,* Njoku and Chidiebere, 2013; Prutton and Frey, 2016). 30 grams each of the powdered leaves of *Moringa oleifera* plant were measured using an electronic balance into four round bottom flasks. 1.0 M H_2SO_4, 0.5 M H_2SO_4, 1.0 M NaOH and 0.5 M NaOH solution was added to each of the measured samples in the four flasks. The resulting mixtures were boiled 1 hour 30 minute, on a bunsen burner. The content of each flask was allowed to cool to room temperature before being filtered using a filter paper. The filtrates were taken as the stock solution. Mild steel coupons were produced from mild steel strip. The mild steel strip was cut into seventy two test specimens each of dimensions, 10 mm x 5 mm x 5 mm. The surfaces of the test specimens were polished with abrasive paper to produce smooth surface and to remove any trace of contaminants. The test specimens were degreased in ethanol, washed thoroughly in deionized water and rinsed with acetone. The washed specimen were air dried (Ehujuiro *et al.,* 2014; Eddy *et al.,* 2011) to remove any moisture that might be present on the test specimens. The inhibitors were accurately weighed and dissolved in the prepared 0.5 M H_2SO_4, 1.0 M H_2SO_4, 0.5 M NaOH, 1.0 M NaOH solution to obtain different inhibitor(s) concentrations of 5 ml, 10 ml, 15 ml and 20 ml respectively.

Methods

The Weight Loss method of corrosion measurement was adopted for evaluating the corrosion rates of mild steel samples. The inhibitors were accurately weighed and dissolved in the prepared 0.5 M H_2SO_4, 1.0 M H_2SO_4, 0.5 M NaOH, and 1.0 M NaOH solution. The experiment was conducted in four sets and at room temperature. In each of the set of weight loss measurements, nine beakers were arranged on a table in Hydraulics Laboratory of Department of Mechanical Engineering, Taraba State University, Jalingo. 70mL of 0.5 M H_2SO_4, 1.0 M H_2SO_4, 0.5 M NaOH, and 1.0 M NaOH solution were measured and poured into each of the labeled beakers in each set. The required concentration of the extract (5 ml, 10 ml, 15 ml and 20 ml) were respectively measured from the stock solution of leaves of the *Moringa oleifera* plant. After measurement, the measured extracts (leaves of *Moringa oleifera* plant) were respectively added to each of the container containing the corrodent in each set. No inhibitor was added to the first container in each set. Four pre-weighed specimens were tired, coded and totally immersed in each of the beakers containing both the corrodent and the extracts. After every 7 days, one sample was withdrawn from each of the beakers, observed and washed with distilled water, rinsed in ethanol to remove corrosion products, air dried and re-weighed. The procedure is repeated after 14 days, 21 days and 28 days. The difference in weight of the coupon was taken as the weight loss. The inhibition efficiencies (IE %) of the inhibitors were computed using Equation 1.

$$IE\% = \left[\frac{CR_a - CR_p}{CR_a}\right]x100 \qquad (1)$$

Where, CR_p = Corrosion rate in the presence of inhibitor and CR_a = Corrosion rate in the absence of the inhibitor. The corrosion rates were computed using Equation 2.

$$CR = \frac{87.6W}{\rho At} \quad (2)$$

Where W = weight loss (mg); ρ = density of specimen (cm^3), A = area of specimen (cm^2) and t = period of immersion (hours).

RESULTS AND DISCUSSION

Results

The results obtained are shown in Figures 1 – 12. While Figures 1 – 4 represent the variation of corrosion rate with exposure time for the corrosion media under consideration, Figures 5 – 8 represent the inhibition efficiency of the *Moringa oleifera* leaf extract as a function of the concentration of the extract in the corrosion media and Figures 9 – 12 represent the Langmuir plots obtained for the leaf extract in the corrosion media.

Discussion

Corrosion Rate Analysis

A careful examination of the Figures 1 – 4 shows that the general trend for the corrosion behavior of passivating metals was followed. There was an initial steep rise in corrosion rates particularly in the first 7 days followed by a progressive decrease in the corrosion rates as the exposure time increased up to the 28th day. This behavior is explained by the fact that the metal surface became progressively enveloped by the resultant corrosion product leading to a passive film adsorbing to the metal surface; thereby shielding the surface from direct contact with the corrosion media, a phenomenon known as passivation (Stewart *et al.*, 2012; Uwah *et al.*, 2010). The effectiveness of the adsorption layer in preventing further corrosion is amply supported by Langmuir relationship that tries to examine layer thickness and uniformity on the nature and concentration of the corrosion media, a phenomenon largely influenced by system temperature, atomic vibrations and molecular diffusional movements (Loto *et al.*, 2011; Vaninkova and Kabanov, 1948; Yuli *et al.*, 2018). Curiously, however, we notice a clear departure of the corrosion trend for the coupon in 5 ml of the extract in the 1.0 M NaOH on the 14th day. There was an unusual sporadic increase in corrosion rate showing that the passive layer had collapsed, thereby subjecting the metal to a more aggravated corrosion attack (Ali *et al.*, 2008; Caroline *et al.*, 2015). The probable cause of this breakdown of the passive layer could be an unintended system agitation by an interloper considering that the experiment was set up in a laboratory that is open to all manner of personnel and students alike. A mere dashing of the feet against the table by a passerby is enough to cause this breakdown of the fragile passive film.

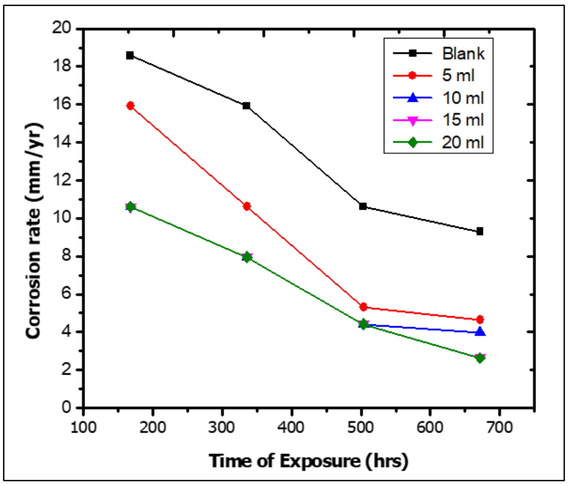

Figure 1: Corrosion rate of mild steel against exposure time for *Moringa oleifera* leaf extract in 0.5M H_2SO_4

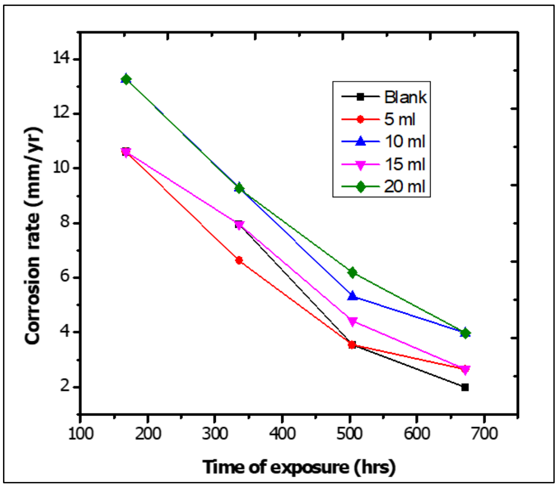

Figure 2: Corrosion rate of mild steel against exposure time for *Moringa oleifera* seed extract in 1.0 M H_2SO_4

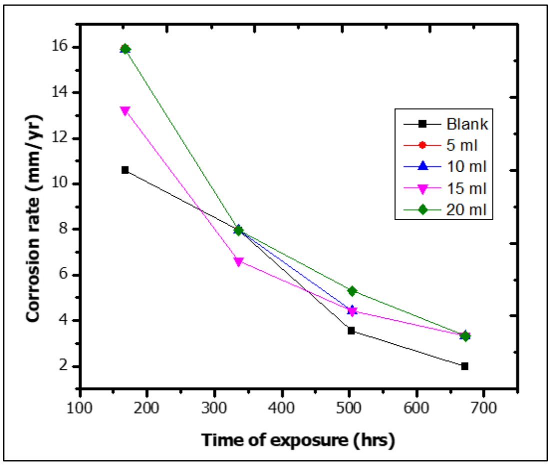

Figure 3: Corrosion rate of mild steel against exposure time for *Moringa oleifera* leaf extract in 0.5 M NaOH

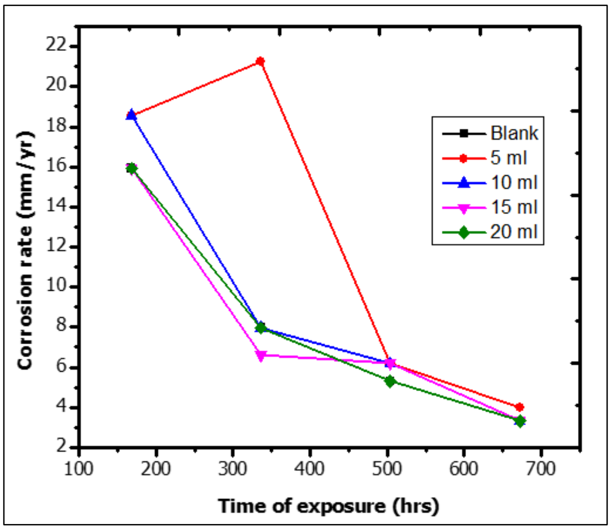

Figure 4: Corrosion rate of mild steel against exposure time for *Moringa oleifera* leaf extract in 1.0 M NaOH

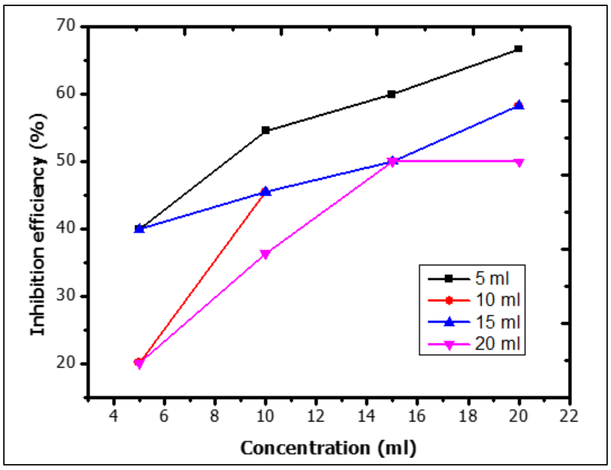

Figure 5: Inhibition efficiency against concentration of *Moringa oleifera* leaf extract on the mild steel in 0.5 M H_2SO_4

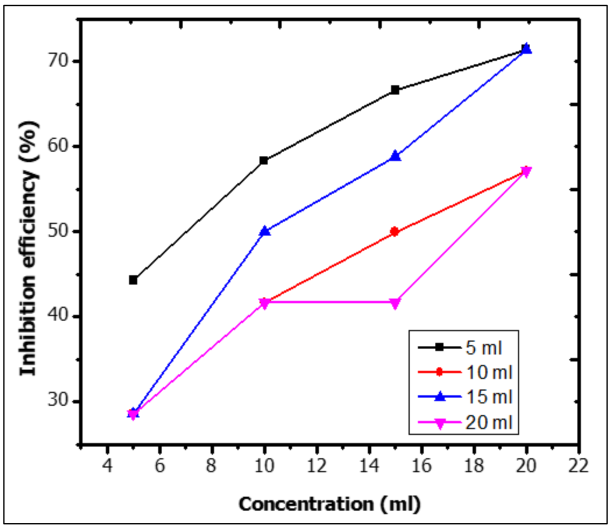

Figure 6: Inhibition efficiency against concentration of *Moringa oleifera* leaf extract on the mild steel in 1.0 M H_2SO_4

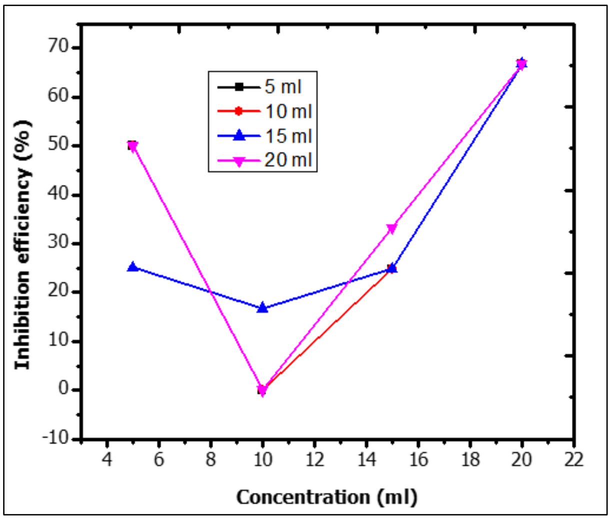

Figure 7: Inhibition efficiency against concentration of *Moringa oleifera* leaf extract on the mild steel in 0.5 M NaOH

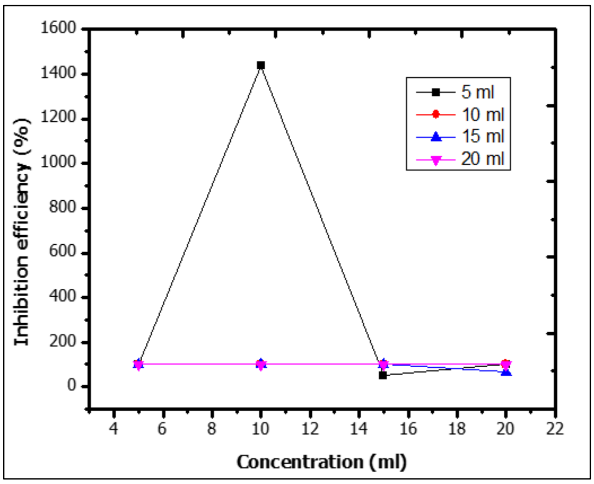

Figure 8: Inhibition efficiency against concentration of *Moringa oleifera* leaf extract on the mild steel in 1.0 M NaOH

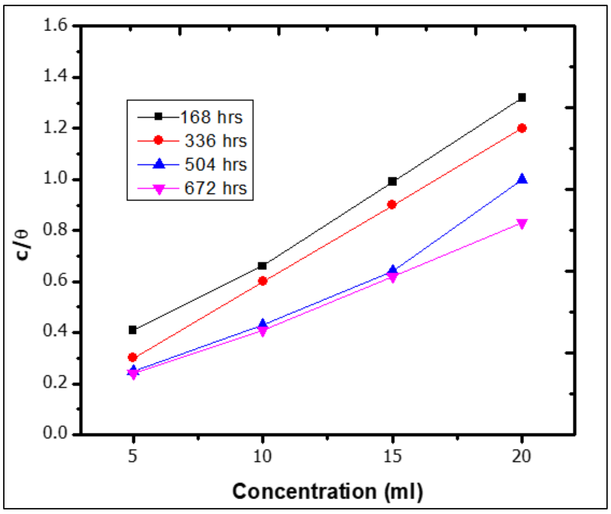

Figure 9: Langmuir for *Moringa oleifera* leaf extract in 0.5 M H_2SO_4

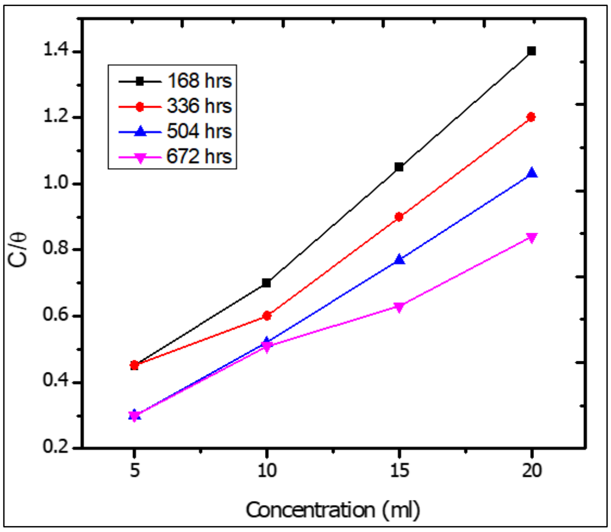

Figure 10: Langmuir for *Moringa oleifera* leaf extract in 1.0 M H_2SO_4

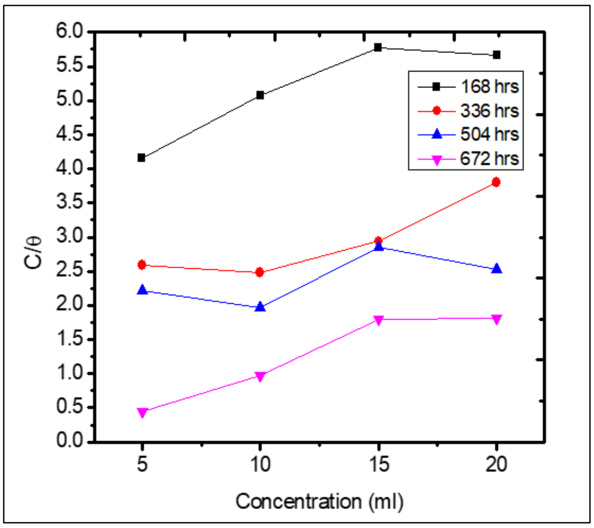

Figure 11: Langmuir for *Moringa oleifera* leaf extract in 0.5 M NaOH

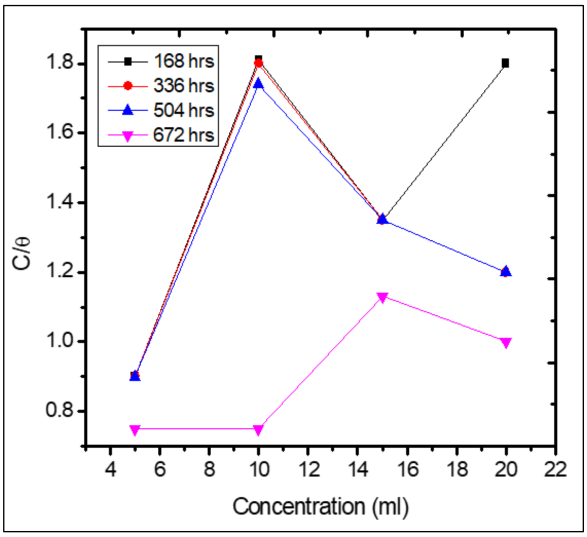

Figure 12: Langmuir for *Moringa oleifera* leaf extract in 1.0 M NaOH

Inhibition Efficiency

A cursory look at Figures 5 – 8 reveals expectedly that inhibition efficiency of the leaf extract increased as media concentration of the leaf extract increased. It is noticed that there is an indirect relationship between corrosion rate data and inhibition efficiency, such that in a given corrosion-inhibitor medium, the higher the corrosion rate values the lower the efficiency (Omotosho, 2016; Hou *et al.*, 2017). However, for the NaOH media as can be seen from Figures 7 – 8, the linear relationship between inhibitor efficiency and concentration was not followed, particularly in the 1.0 M NaOH where the deviation by the 5 ml is so apparent. This again goes to support the fact that there is was an unintended system agitation that affected the chemical kinetics of the system under consideration. The deleterious effects of NaOH as a highly corrosive substance is well-known (Vaniukova *et al.*, 1948). Apparently, the attack of the mild steel in the NaOH media did not occur uniformly over its surface thereby leading to the observed deviations in the corrosion behavior. Closely associated with inhibition efficiency is the Langmuir adsorption isotherm. Figures 9 – 12 represent an adaptation of the Langmuir plots for this study. A simplistic assumption adopted here is that the surface coverage of the adsorbed layer (ϴ) is related to inhibition efficiency as follows:

$$\theta = \left[\frac{CR_a - CR_p}{CR_a}\right] \quad (3)$$

Where, CR_p = Corrosion rate in the presence of inhibitor, CR_a = Corrosion rate in the absence of the inhibitor and θ = coverage of the adsorbate on the metal surface.

Following from this assumption, it can be seen that the adsorption of the corrosion product on the metal surface, leading to passivation was fairly in agreement with established findings, except for the 1.0 M NaOH media were the already discussed system agitation ultimately affected the adsorption process. In effect, if proper modulations and other critical factors relevant to the Langmuir adsorption isotherm principles were carried out a perfect correlation could have been established.

Conclusion

Based on the foregoing discussions, we conclude that the progression of the corrosion rate of mild steel in H_2SO_4 and NaOH was appreciably impeded by the presence of the leaf extracts of *Moringa oleifera* in a manner that depicts a direct relationship between inhibition efficiency and extract concentration. However, in comparative terms, the leaf extract showed a better inhibition in H_2SO_4 than in NaOH. In all, the study establishes the inhibition potentials of the leaves of *Moringa oleifera* as a veritable green inhibitor to serve as alternatives to the rather deleterious synthetic and inorganic inhibitors in use today.

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