Study of *Moringa oleifera* and *Vitex doniana* Sweet Leaf Extracts for use as Eco-friendly Corrosion Inhibitors in NaOH

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ABSTRACT

This study reports on the effects of *Moringa oleifera* and Vitex doniana leaves extract on mild steel in different environments (0.5 M and NaOH, 1.0 M. The mild steel samples were pre-weighed and immersed in NaOH, and containing the leaves extract, with the control samples immersed in solutions of the media without the leaf extracts. The set-ups were allowed to stand for 672 hours, with a set of samples from each of the environment withdrawn at intervals of 168 hours for corrosion characterization. The samples were then analyzed by the weight loss method to determine the corrosion penetration rates. The results obtained from the different environments indicate that the corrosion inhibition increased as concentrations of *Moringa oleifera* and *Vitex doniana* increased. The findings also confirmed that the extract functioned as effective and excellent inhibitors in the media and their inhibitive actions are attributed to their phytochemical constituents which aided more film build up on the metal surface. The results also showed a non-uniform decrease in the corrosion rate which decreased exponentially as the concentration of the inhibitor was increased. The results show good potentials for application in biostructural, metallurgical, nanomaterials, and in manufacturing industries.

(Keywords: mild steel, corrosion penetration rate, corrosion inhibition, weight loss method, inhibitors)

INTRODUCTION

Most well-known acid inhibitors are organic compounds containing nitrogen, sulphate, and oxygen. There is increasing concern about the toxicity of corrosion inhibitors used in industry today. The toxic effects not only impact living organisms but can also poison the Earth. The safety and environmental issue of corrosion inhibitors arose in industries has always been a global concern. Hence, many alternative corrosion inhibitors are being developed, ranging from rare earth elements to organic compounds (Verma, Quraishi and Ebenso, 2013; Victoria, Prasad and Manivannam, 2015; Callister, 2007).

Green corrosion inhibitors are biodegradable and do not contain heavy metals or toxic compound (Khanna, 2015). The successful use of natural substances to inhibit the corrosion of metals in acidic and alkaline environments has been reported by some research groups (Ede, Okorie, and Agbo, 2013; Abida and Harikashna, 2014; Kowsari, Payami, Amini, Ramezanzadeh and Javanbakht, 2014).

Corrosion is a destructive phenomenon, chemical or electrochemical in nature, which can attack any metal or alloy through reaction by the surrounding environment and in extreme cases may cause structural failure. Corrosion can be also defined as the deterioration of material by reaction to its environment (Idenyi, Nwofe, and Idu, 2015; Idu, Idenyi, and Nwofe, 2015). The corrosion occurs because of the natural tendency for most metals to return to their natural state (e.g., iron in the presence of moist air will revert to its natural state, iron oxide). The use of inhibitors is one of the best options of protecting metals against corrosion. Several inhibitors in use today are either synthesized from cheap raw materials or chosen from compounds having hetero atoms in their aromatic or long chain carbon system (Idu, Nwofe, Kalu, and Idenyi 2016; Torres, *et al.,* 2014; Bobina, *et al.,* 2013).

Acid and alkaline solutions are widely used in industry, where the most important fields of application are acid pickling, industrial acid cleaning, and oil well acidification. Because of the general aggressive action of acid and alkaline solutions, the practice of inhibition is commonly used to reduce the corrosive attack on metallic materials (Raja, *et al.,* 2013).

Moreover, since the whole idea of metal protection is anchored on economic gain and environmental sustainability, the substance to be used as metal corrosion inhibitor must be cheap, readily available, and environmentally friendly. Hence, our interests this study are geared towards finding alternative materials that can replace inorganic metal corrosion inhibitors.

Leaves of plants are some of the sources of cheap, readily available, and non-toxic green metal corrosion inhibitors (Elmsellem, et al., 2016; Nnanna, et al., 2016). Products of leaves are organic in nature and contain certain phytochemical substances such as: tannins, flavonoids, saponins, organic and amino acids; alkaloids, and pigments which could be extracted by simple less expensive procedures.

The research interest has been necessitated by the fact that the present corrosion inhibitors in the market for the protection of mild steel in the alkaline and acidic exposures are hazardous to the environment and thus compromise safety and sustainability drives (Daoud, *et al.,* 2014; Hussin , *et al.,* 2016; Arthur, 2013; Andi, *et al.,* 2013). Therefore, there is an urgent need to develop inhibitors that are eco-friendly and sustainable.

Extracts of vegetable leaves are at the top of the list of non-toxic organic materials that have been used as corrosion inhibitors to replace environmentally hazardous synthetics. They are non-toxic, environmentally friendly, and readily available. As a result of the important of corrosion control, the need for carrying out this study on the inhibition characteristics of vegetable leaf extracts on the corrosion susceptibility of mild steel in selected media, is a source of concern to the corrosion engineer.

MATERIALS AND METHODS

Material Preparation

Mild steel rod was used for this study. The mild steel rods were sourced from Ebonyi State Building Material Market metal stock-lists. The chemicals and reagents that were used in this study were of analytical grade. Cylindrical mild steel samples of diameter 10mm and height of 20mm were machined using a lathe machine and hacksaw. Each coupon was degreased by washing in ethanol, dried in acetone, and kept in a desiccator and then the weight of each coupon was weighed before inserting it into beaker to obtain the weight difference.

Preparation of the Leaf Extracts

The leaves were collected from Nkalaha town in Ebonyi State and were identified by laboratory technologist in the Department of Applied Biology, Ebonyi State University, Abakaliki, Ebonyi State, Nigeria. 50 g of leaves of each vegetable extract; *Moringa oleifera* and *Vitex doniana leaves* were placed in 500 cm^3 of distilled water and boiled for about 2 hours and under 80°C of temperature before being carefully filtered. From the weight of extracted mass as above, different concentrations of 25, 50, 75 and 100 cm^3, respectively of the vegetable extracts were separately put into four beakers. The first beaker was kept plain, without any extract addition (control experiment) while the concentrations of the NaOH was 0.5 M and 1.0 M, respectively. A total of thirty-four (34) beakers were rinsed with distilled water and dried in air before the experiment was set up, so as to avoid additional water.

The coupons were immersed in the different media by means of a nylon thread hung on a retort stand and tied to the coupons. Samples of the coupon were inserted into the beakers and allowed to stand for 28 days (672 hours) with a set withdrawn after every 7 days (168 hours).

Weight Loss Method

The sample of mild steel was first weighed using a digital weighing balance, METTLER TOLEDO model ME204E with a least count of 0.0001g, labelled and immersed in the test solutions of NaOH without and with inhibitor, respectively. The weight loss of each of the sample coupons was determined and recorded. The determination of weight loss and recording was repeated consistently every 68 hours (7 days) for a period of 672 hours (28 days). Prior to measurement, each coupon was washed in absolute ethanol, rinsed in distilled water, dried in acetone and then weighed. The same experiment was repeated in the absence and presence of inhibitor. From the weight loss measurements, the corrosion rate, were deduced using relevant equations from the literature (Idenyi, *et al.,* 2015; Benali, *et al.,* 2013) hence:

$$\text{Corrosion Rate} = \frac{\Delta W}{AT} \quad \textbf{(1)}$$

Where CR is corrosion rate in $gcm^{-2}h^{-1}$,

ΔW is weight loss in g,

T is exposure time in hours,

A is exposed area of coupon in cm^2.

RESULTS AND DISCUSSION

Corrosion Penetration Rate Analysis

Figure 1 shows the variation of corrosion rate with duration time for the corrosion of mild steel in 0.5 M NaOH containing various concentrations of *Moringa oleifera* leaf extract (25 - 100 cm^3). From the figure, it can be seen that the normal corrosion profile for passivating metals was noticed. This involves a sharp rise in corrosion rate followed by a gentle decrease as duration time increased. The rate of decrease of corrosion rate was very high in the first seven days of the experiments and then slowed down subsequently. This behavior is an indication that there must have been an agitation of the system that led to the collapse of the passive film, exposing the metal surface to a rather accelerated corrosion attack; a phenomenon that is supported by theoretical assertions (Idenyi, *et al*, 2016).

The results obtained for the variation of corrosion rate with exposure time for the mild steel specimens immersed in 1.0M NaOH without and with varied concentrations of added *Moringa oleifera* leaf extract are presented in Figure 2.

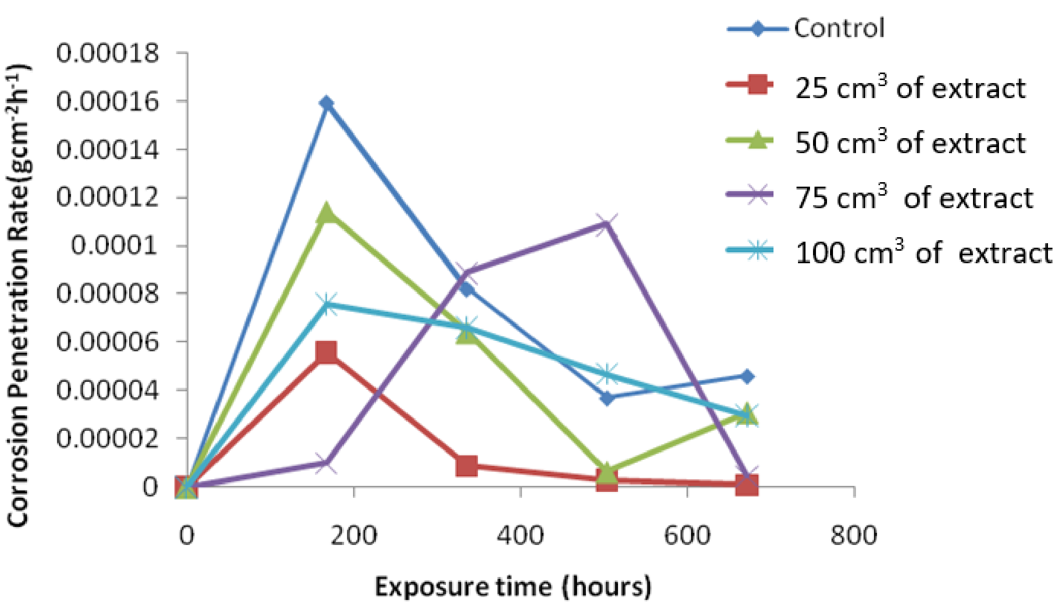

Figure 1: Variation of Corrosion Rate with Exposure Time for the Corrosion of Mild Steel in 0.5M NaOH Solution Containing various Volumes of *Moringa oleifera* Leaf Extract.

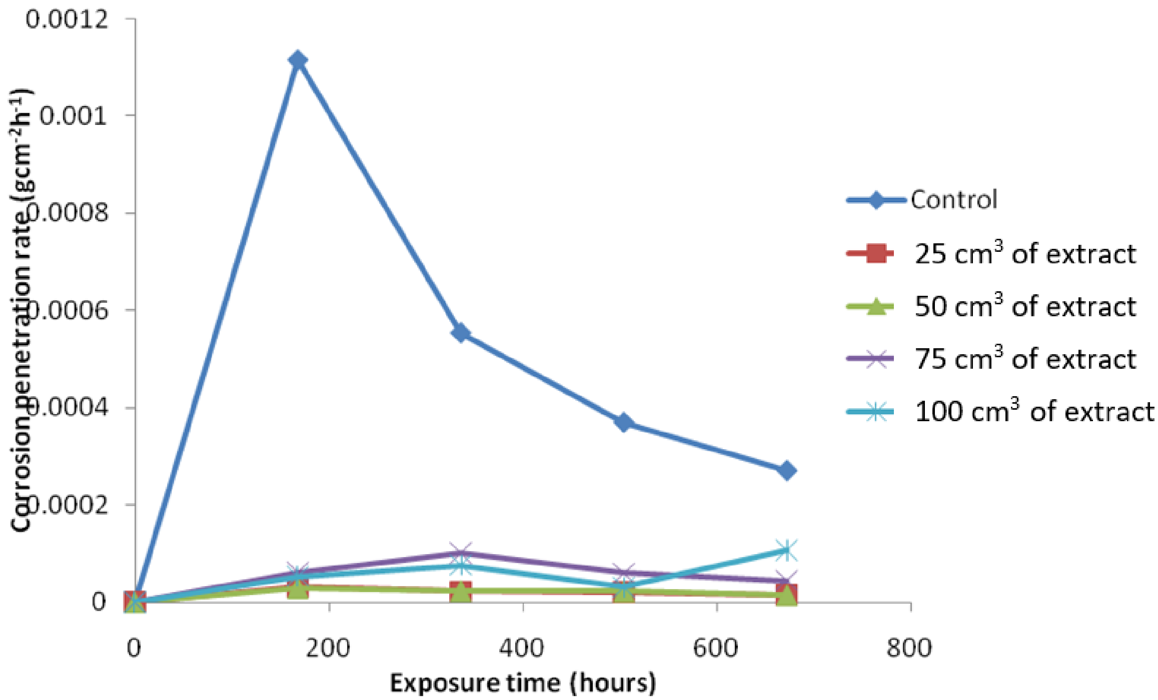

Figure 2: Variation of Corrosion Rate with Exposure Time for the Corrosion of Mild Steel in 1.0 M NaOH Solution Containing various Volumes of *Moringa oleifera* Leaf Extract.

The results obtained show a high value of corrosion rate for the test media without *Moringa oleifera* leaf extract. The addition of *Moringa oleifera* leaf extract to the test media resulted in reduction of corrosion rate. The difference in corrosion rate for the test media with *Moringa oleifera* leaf extract was not much from 168 to 672 hours intervals.

In comparison, the extract concentration at 25 cm^3 and 50 cm^3 showed a better corrosion inhibition performance than that of the 75 cm^3 and 100 cm^3. At the concentration of 25 cm^3, it gave the best corrosion inhibition performance among the other extract concentrations used. It could be described in this experiment to be the optimum value for the extract inhibition performance in the tested environment. Eddy *et al,* (2008), observed that as the concentration of *Hydrophyllum capitatum* extract in 1.0 M NaOH increased, the corrosion rate of mild steel decreased. This is in agreement with the findings in the current study.

Figure 3 depicts the corrosion behavior of the mild steel in 0.5 M NaOH at various concentrations of *Vitex doniana* Sweet (Black plum, 'Uchakuru') leaf extracts for 672 hours study duration. At the end of 168 hours, the corrosion rate was 0.002 gcm^{-2}h^{-1}. This further decreased 0.008 mm/yr at the end of 336 hours and thereafter reduced from 0.003 to 0.002 gcm^{-2}h^{-1} at the end of 504 and 672 hours, respectively. Between 504 and 672 hours, the coupon experienced insignificant corrosion deterioration rates. The formation of a passive film is responsible for these insignificant corrosion rates. The corrosion rate once again resumed at the first seven day because of breakage in the earlier form passivating layer. This trend, however, continued till the end of experimental period.

The results obtained for the variation of corrosion rates with experimental period for the mild steel immersed in 1.0 M NaOH with varied concentrations of added *Vitex doniana* leaf extract and without *Vitex doniana* leaf extracts are presented in Figure 4. The results obtained show a great value of corrosion rate for the test media without *Vitex doniana* leaf extract. The addition of *Vitex doniana* leaf extract to the test media resulted in reduction of corrosion rates.

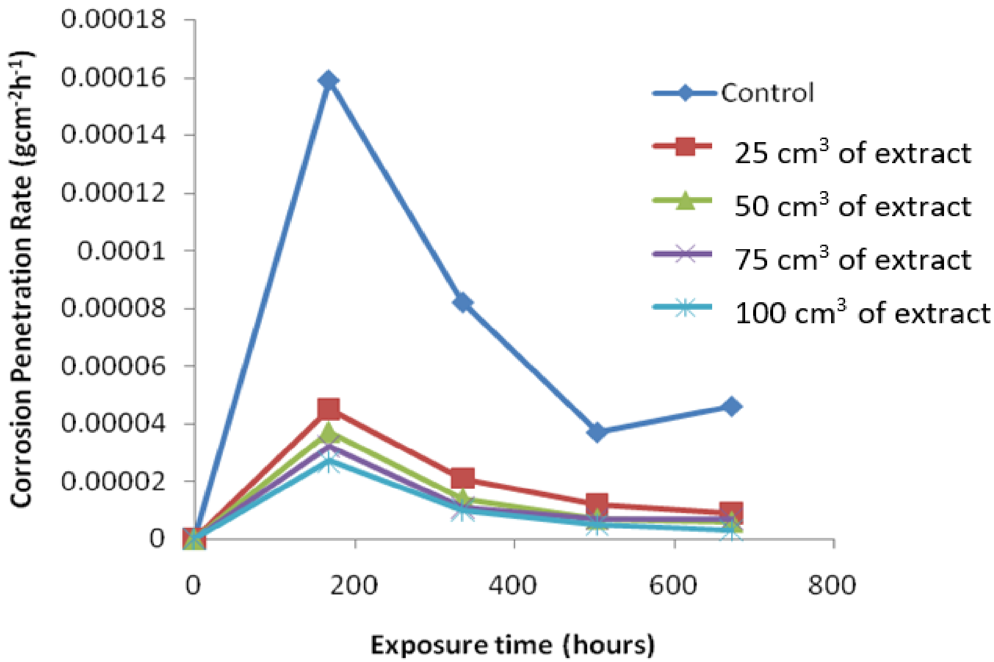

Figure 3: Variation of Corrosion Rate with Exposure Time for the Corrosion of Mild Steel in 0.5M NaOH Solution Containing various Volumes of *Vitex doniana* Leaf Extract.

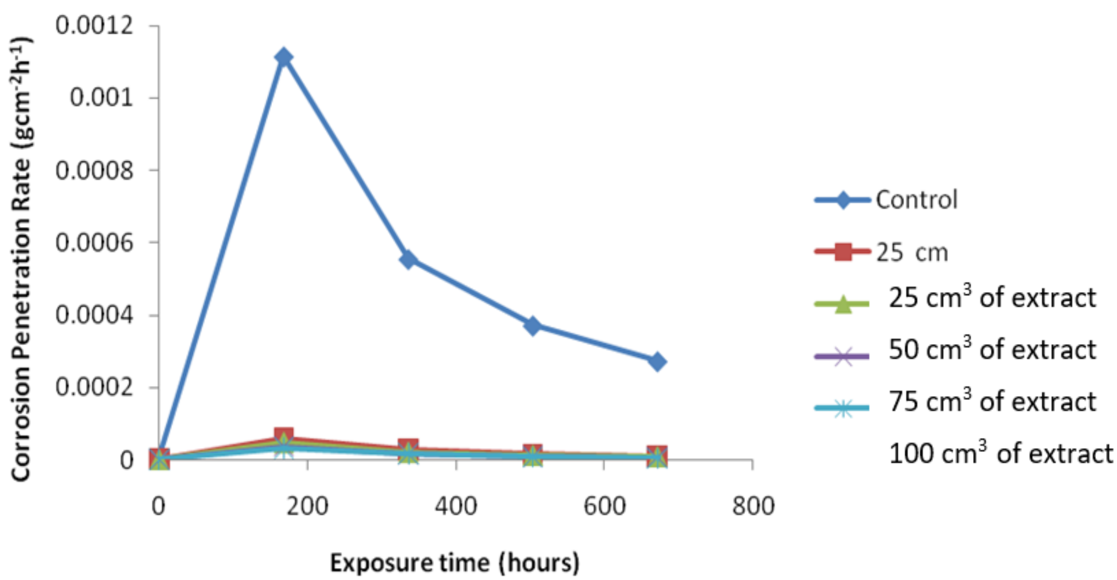

Figure 4: Variation of Corrosion Rate with Exposure Time for the Corrosion of Mild Steel in 1.0M NaOH Solution Containing various Volumes of *Vitex doniana* Leaf Extract.

The differences in corrosion for the test media with and without *Vitex doniana* leaf extracts was much for 168 hours, but from 336 hours to 672 hours there was an increased in corrosion rate for the media without *Vitex doniana* extract (Control experiment) and a decrease in corrosion rate for the media with leaf extracts. The *Vitex doniana* leaf extract shows good inhibition characteristics on the corrosion rate of coupons in 1.0M NaOH solution medium. These results are consistent with those reported by (Odewunmi *et al.,* 2015).

CONCLUSION

In this study, weight loss corrosion penetration rates were used to study the ability of *Moringa oleifera* and *Vitex doniana* leaf extracts to retard the corrosion of mild steel in different concentrations of alkaline media. The major findings of the study are:

1. Experimental data showed that in the presence of different concentrations (25-100cm^3) of *Moringa oleifera* and *Vitex doniana* leaf extracts inhibited the corrosion of mild steel in alkaline environments.

2. The results indicated that the corrosion rates of mild steel decreased with increasing concentration of leaves extract; at the lowest concentration of *Moringa oleifera* leaf extract in 0.5 M NaOH at 25cm^3, the inhibition efficiency is increased markedly and reached 97%.

3. The results of the weight loss were all in very good agreement to support the conclusions, and the inhibitor possessed all the characteristics which the industries require for potential inhibitor.

4. *Moringa oleifera* and *Vitex doniana* leaf extracts have proved to be a promising natural source material as an alternative non-toxic, low cost, and eco-friendly inhibitors that can replace the synthetic chemicals which are currently used in various biomedical, biostructural, metallurgical, nanomaterials, and in manufacturing industries.

5. In comparative terms, *Moringa oleifera* leaf extract is seen to have best inhibition characteristics at lowest concentration in alkaline environments, while *Vitex doniana* leaf extract was found to have good inhibitory properties at higher concentrations among the two extracts investigated.

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