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Corrosion Inhibition of Mild Steel in Seawater using Jatropha Stem

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The present work investigate the inhibition of Jatropha Stem Extract (JSE) in sea water using mild steel coupons of dimension 5 × 5 × 0.5 cm. The cupons were immersed in test solutions of sea water and varied concentrations of extracts of 0.1g/l to 0.9g/l was used. The functional groups of the compounds was analyzed using an FTIR. The results showed that as the concentration of the extract increases, there was a reduction in the corrosion rates. Furthermore, as the extract concentrations increased from 0.1g/l to 0.4g/l at 48hrs exposure time, the weight loss decreased by 14.3% in the medium. However, the Jatropha Stem Extract was absorbed on the substrate surface to inhibit corrosion, the morphology of phases formed from the scanning Electron Microscopy examination confirmed this trend. Hence, JSE is a good and safe inhibitor in sea water solution. The FT-IR results also indicates the presence of active corrosion inhibitor present in the Jatropha Stem.

Keywords: *Corrosion, Mild steel, Inhibitor, Jatropha, Seawater*

1. Introduction.

Corrosion is the gradual destruction of materials (usually metals) by chemical reaction with their environment. In the most common use of the word, this means electrochemical oxidation of metal in reaction with an oxidant such as oxygen. It has been an everyday challenge in all sectors of the economy and in particular, the manufacturing industry (El-Etre, 2003). Sathiyanarayanan *et al.*, (2005) concluded in their study that the use of inhibitors is one of the best methods of protecting metals against corrosion. Organic inhibitors, amongst others, adsorb directly onto the surface of the metal and can thus inhibit corrosion. Both the type of metal and the environmental conditions, particularly what gases are in contact with the metal, determine the form and rate of deterioration. Plant extracts are low-cost

and biodegradable, and so the study of plant extracts as corrosion inhibitors is an important scientific research field due to both economic and environmental benefits. It has been found that certain organic substances containing polar functions with nitrogen, sulphur and/or oxygen atoms in the conjugated system have been reported to exhibit good inhibiting properties of steel in acidic and alkaline environments (Ebenso *et al.,* 2009). The effect of corrosion on the aqueous environment of sea water, salt water and rain, can be felt when pipes corroded with toxic metals are allowed to sip into the environment thereby causing health complications to the living system as contained in the aqueous environment (Ajanaku *et al*., 2015). A lot of technological efforts have been put into developing strategies of mitigating corrosion through materials selection, changes in design philosophies and the adoption of varied prevention techniques. According to Tosun *et al*., (2006), the use of inhibitors has been well documented as an effective method of protecting metallic materials from corrosion. Although many industries have tried using inorganic processes for corrosion protection, the challenge in cost and toxicity among others are the draw back associated with these. Consequently, attention has been drawn towards the use of organic processes due to the fact that they are more eco-friendly. Organic substances (plant based) containing functional groups with oxygen, nitrogen or sulphur atoms in a conjugate system have been reported to exhibit good inhibiting properties (Raju *et al*., 2014). Depa and co-worker (2009) noted that these organic compounds present in the inhibitor can adsorb on the metal surface, block the active sites and thereby reduce the corrosion rate considerably. Most of the synthetic organic compounds showed good anti-corrosive activity, which are highly toxic to cause severe hazards to both human beings and the environment during their application.

There are concerns on the sustainability of the use of some of these green inhibitors when commercial scale processing is of interest, since some of the extracts can only be derived from specific plants which are still utilized for so many other applications; coupled with the fact that some of these plants are seasonal (Alaneme and Olusegun, 2012). Hence, the present study investigates the potentials in using Jatropha Stem Extract as a corrosion inhibitor on mild steel in sea water.

2. Materials and Method

2.1 Preparation of Specimen

Mild steel of 5mm thickness was used in this research. The mild steel was mechanically cut into coupons of the same dimensions of 50 mm x 50 mm each. The surface area treatment was done by degreasing using absolute ethanol. A hole was drilled at one end for free suspension and numbered by pinching. These coupons were degreased with acetone, washed with distilled water and then

polished with emery paper for cleaning. They were then dried. These materials were then later stored in the desiccator.

2.2. Preparation of Plant Extracts

About 2kg of Jatropha was obtained from Omu-Aran town, the Jatropha stem was sun dried and then grinded with an industrial grinder into a powdered form, it was then filtered. The fine powder obtained was completely soaked in ethanol solution for 24hrs with intermittent stirring to have a homogeneous solution and the extract collected through filtering in the form of a paste-like sample. The filtrate was then subjected to evaporation process to remove the excess of alcohol in it. The filtrate obtained was the inhibitor in pure form, so the pure extract was later collected and stored. The stock solution of the extract was prepared by using different weights of the extract that dissolved in 10 liters of seawater. The chemical compositions of the Jatropha stem were determined. Acetone was then used to dry and preserve the extract in a desiccator to prevent it from reacting with the environment.

2.3. Weight loss measurement

The simplicity and reliability of the measurement offered by the weight loss method is such that the techniques form the baseline method of measurement in many corrosion monitoring programmes. The coupons were weighed using digital weighing scales using electronic weighing balance (HX 302T with 0.01g accuracy) for initial and final weight before and after the immersion test. Before weighing the final weight, the plates were cleaned by immersion into ethanol to clean up the corroded and extraction layer on the plates and then dried at room temperature. Weight loss measurements were conducted under total immersion using 250 ml capacity beakers containing 0 – 0.9 g/l test solution at 30 oC maintained in the laboratory, the mild steel coupons were weighed and suspended in the beaker.

2.4. Procedure

The mild steel specimens were immersed into 10 liters of seawater containing various concentrations of the inhibitor (0%, 0.10g/l, 0.20 g/l, 0.30 g/l, 0.40 g/l, 0.50 g/l, 0.60 g/l, 0. 70 g/l, 0.80 g/l and 0.90 g/l) in the presence and absence of corrosion inhibitor for about 336 hours. Then, various percentages of the inhibitor were added to the other beakers containing the various test samples. The specimens were totally immersed in all 10 test solutions and then left for 336 hours during which readings were carried out at intervals of 48 hours. A total of 8 readings were taken down and the results also were penned down accordingly. The weights of the specimens before and after immersion were determined after

every 48 hours using the weighing balance. The corrosion products were cleansed with distilled water, dried and then re-weighed to determine its weight.

The inhibition efficiency (IE) was calculated using the following equation:

$$IE(\%) = \frac{C_{r1} - C_{r2}}{C_{r1}} x\ 100 \quad (1)$$

Where Cr_1 is the corrosion rate in the absence of inhibitor and Cr_2 is the corrosion rate in the presence of inhibitor.

The corrosion rate (Cr) was calculated using the weight loss measurement obtained from the investigation with the formula below:

$$C_r = \frac{\Delta m}{A.t} \quad (2)$$

Where;

Δm = mean weight loss (g), A = area of specimen (m^2) and t = time (hrs).

2.5. Surface Examination

For morphological study, surface features (50 mm × 50 mm × 5 mm) were examined before and after exposure to seawater solution for 336 hours with (maximum inhibitor) and without inhibitor. Scanning electron microscope (SEM) was used for this investigation. The compounds present in the extract was confirmed by Fourier Transform Infrared (FT-IR) analysis. Physicochemical analysis was also used to determine the parameters of the sea water.

3. Results and Discussions

3.1. Physicochemical Properties of Seawater

The physicochemical properties of the seawater were determined and the results obtained are as shown in Table 1. It was confirmed that the seawater has high amount of oxygen which aids corrosion.

Table 1. Physicochemical properties of seawater

S/N	Parameters	Results
1	Temperature	28.3 ^oC
2	Ph	7.88
3	Iron	0.10mg/L
4	Chlorine	0.07mg/L

5	Sulphate	10mg/L
6	Potassium	1.1mg/L
7	Nickel	0.2mg/L
8	Zinc	1.4mg/L
9	BOD	0.04mg/L
10	COD	0.062mg/L
11	E.C	41ms/cm
12	TDS	20500mg/L
13	D.O	0.10mg/L
14	Magnesium	<<
15	Calcium	<<

NB: << means that the quantities of these parameters were too small and were negligible.

Table 1 above shows the phytochemical constituents of the sea water (SW), the presence of minerals and bio-living species in sea water has been reported by (Riggs, 1973). Similarly, the effect of polar groups has been reported by (Riggs, 1973; Negm *et al*., 2009). Authors observed that these polar groups have the ability to form continuous layer on the metal surface. Hence, forming a complex metal ions at the metal surface.

Table 2. The Pytochemicals of Jatropha Curcas leave extract [12]

S/N	constituent	presence
1	Tannis	+++
2	Terpenes	+++
3	Anthra-quinone	+++
4	Alkaloids	+++
5	flavonids	+++
6	Deoxy sugar	++
7	Cardiac glycoside	++
8	Saponins	+

+++ = highly present, ++ = moderately present, + = present in trace amount

From table 2 above, chemical compounds in Jatropha Leaves were captured, other constituents such as alpha-D-glucoside, apigenin, sterols

stigmasterol and vitexin were reported by (Rani and Selvaraj, 2014). The above differences in constituent might be due to differences in geographical locations. The effect of these constituents and the structural construction of molecules has been reported to greatly influence the inhibiting efficiency (Negm *et al.*,2010) of the inhibitor molecules.

3.2. Weight Loss Measurement

Figure 1 below shows the trend in the weight loss with respect to exposure time. It can be deduced that there is a significant reduction in the weight loss of test specimens immersed in varying concentrations of the extract in comparison to the blank solution. It was observed that as the concentration of the extract increases, the weight loss reduces signifying corrosion inhibition. The reduction in the weight loss could be attributed to the phytochemical constituents. Oguzie (2007) noted that the adsorption of these constituents on the substrate creates a barrier to the dissolution of metal in corrosive medium which is known as passivation. The 0.1g/l recorded a weight loss of 0.08g after 48 hrs exposure time, for 0.2g/l recorded 0.09g, 0.3g/l recorded 0.07g, 0.4g/l recorded 0.07g, for 0.5g/l recorded 0.07g, while 0.6g/l, 0.7g/l, 0.8g/l, 0.9g/l had 0.08g,0.05g, 0.07g, 0.05g respectively.

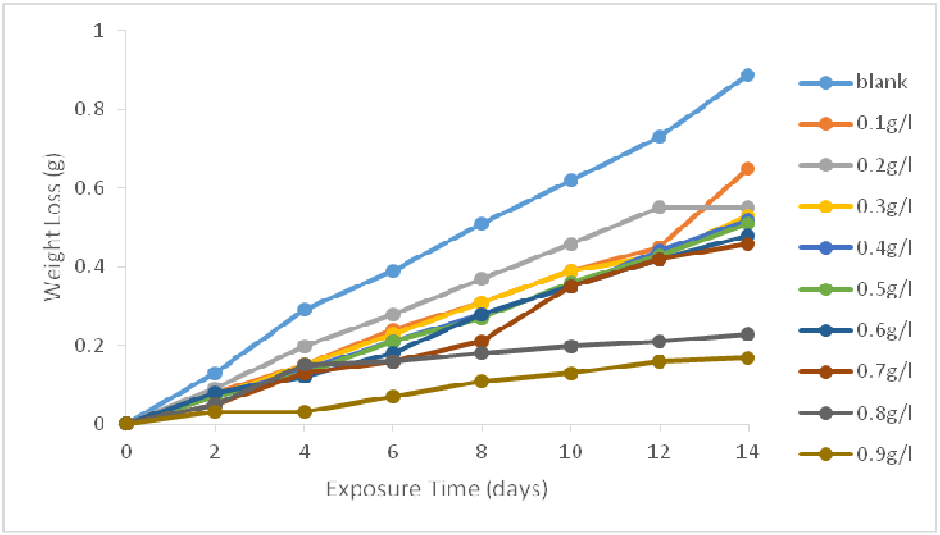

Figure 1: graph showing weight loss (g) against exposure time (days)

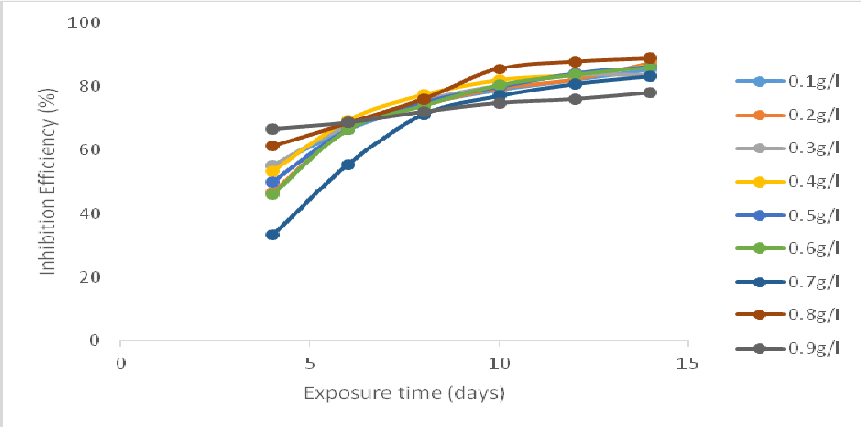

Figure 2: Inhibition efficiency against exposure time (days)

A representative graph showing the inhibition efficiency against time was captured in figure 2 above. The Inhibition efficiency of the extract was observed to increaser with Jatropha Stem Extract (JSE) concentrations and attained 75.3 and 81.7% at concentrations of 0.8g/l and 0.9g/l respectively. By this attainment, JSE is more active at the surface of the substrate. The presence of surface active constituents whose activity increases with the increase in concentration of the extract hence enhancing the film formation over the substrate thereby, mitigating corrosion.

3.3. Surface Analysis

3.3.1. Fourier Transform Infra-red (FT-IR) Analysis

The concentration with the highest inhibition efficiency was found out and then the samples were sent to the laboratory for analysis. Fourier Transform Infrared (FT-IR) was used to evaluate the nature of the film formed on the surface of the metal.

Figures 3 and 4 showed the IR spectra of the metal with 0 g/l inhibition concentration (blank) and 0.90 g/l inhibition concentration respectively. At 3142.1 cm^{-1}, there was a strong and broad band which was associated with O-H stretching of the carboxylic acid present in the Jatropha stem. Also, the strong band at 1640 cm^{-1} was assigned to conjugated C=O stretching vibration. The bands between 1000 and 1350 cm^{-1} can be attributed to very strong C-F stretch of the alkyl halide group present. The result confirms that Jatropha stem contained some compounds which acted as corrosion inhibitor.

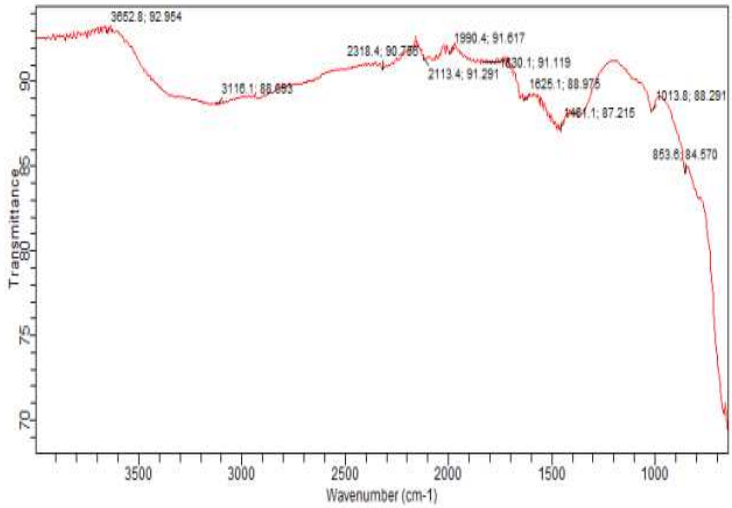

Figure 3. FT-IR spectra of product with 0 g/l (blank) inhibition concentration in seawater

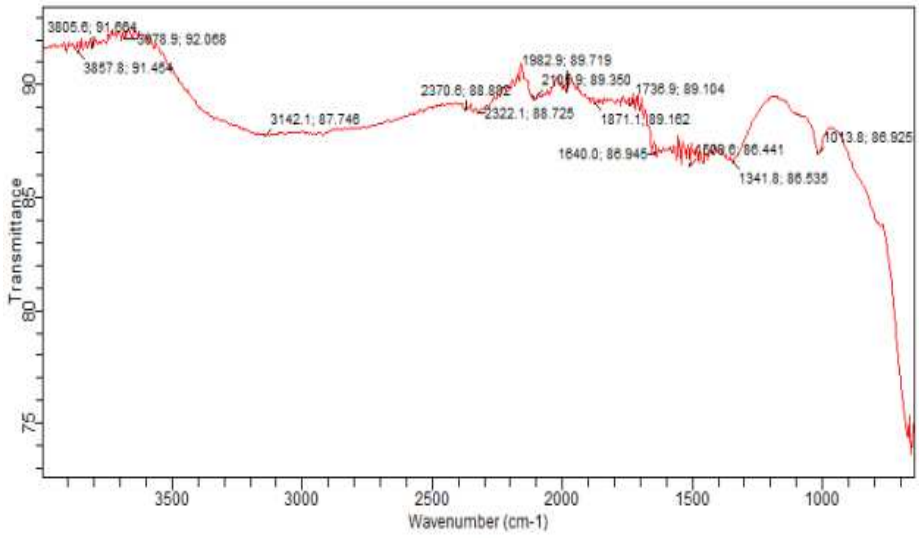

Figure 4. FT-IR spectra of product with 0.9g/l inhibition concentration in seawater solution.

3.3.2. Scanning Electron Microscope (SEM) Analysis

Scanning Electron Microscope (SEM) was also used for the surface analysis of the coupons at 0 g/l (blank) and 0.9g/l respectively. Figure 5 (a) and (b) show the SEM micrographs of the mild steel surface after immersion in seawater with 0 g/l (blank) and 0.9g/l inhibitor respectively.

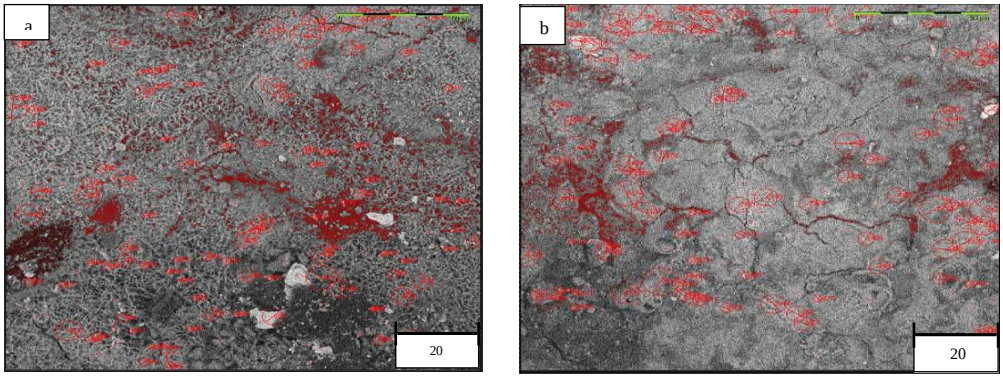

Figure 5. Representative SEM micrograph of blank (0 g/l) and 0.9g/l of inhibitor

Figure 5. a) and b) are both representative SEM micrographs for 0.9g/l and 0g/l (blank) respectively. The morphology of phases in figure 5 b) above shows that there are no adsorption layer on the substrate. However, this trend changes as the substrate was exposed to incremental concentrations. Noticeably, at 0.9g/l represented by fig 5 a) above, incremental film formation was observed to be densely populated around the substrate.

Initially, the corrosion rate was high at the onset of the reaction, however, as the exposure time increases, the corrosion rate decreases drastically. High corrosion rates was observed at the initial stages of the exposure time because active sites have not been covered on the substrate as a result of inhibitor molecules. Negm and Zaki (2009) reported that as the inhibitor increases, the active sites on the substrates decreases hence, the dissolution reaction decreases.

4. Conclusion

The study showed that Jatropha stem is a very good eco-friendly corrosion inhibitor for mild steel in seawater. The SEM analysis showed that the coupons immersed into medium without inhibitor corroded more than the metals that were immersed into medium with inhibitor. The FT-IR spectra showed active corrosion inhibitors present in the Jatropha extracts. It was also observed that the maximum amount of inhibition efficiency at 0.90g/l inhibition concentration was 81.7%, while

the amount of inhibition efficiency at 0.10 g/l concentration was 66.67 %. The inhibition efficiency was observed to have a linear relationship with the inhibition concentration i.e. the inhibition efficiency increase as the inhibition concentration increased.

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