ACTA TEHNICA CORVINIENSIS – Bulletin of Engineering
Tome VIII [2015] Fascicule 4 [October – December]
ISSN: 2067 – 3809

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COMPARATIVE STUDY OF WATER LILY (Nymphaeaceae) EXTRACTS ON CORROSION OF LOW AND MEDIUM CARBON STEEL IN A MILD ENVIRONMENT

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Abstract: *Fluid extract from the leave of water lily (Nymphaeaceae) was tested as corrosion inhibitor for mild steel in tetraoxosulphate (VI) acid solution. Weight loss and determination of the potential difference (Pd) of the steel samples were measured. The effect of concentration on the inhibitor performance of the extract was studied. The results obtained shown that the leave extract functioned as effective corrosion inhibitor. The fitting of the experimental data to the corrosion rate, potential difference and inhibitor efficiency equations revealed that the organic constituents of the extract were physically adsorbed on the corroding mild steel surface. The findings provide ready friendly application for the problematic fresh water weed water lily.*
Keywords: *corrosion inhibitors, potential difference, water lily plant, leave extract*

INTRODUCTION

The corrosion of metallic materials, especially ferrous alloy (low and medium) carbon steel in water saturated with H_2SO_4 is a complex phenomenon which implies a general attacks as well as localized attacks, pitting corrosion, crevice corrosion stress corrosion cracking and other forms of corrosion. The rate of corrosion depend upon many environmental factors such as; pH and presence of aggressive ions particularly oxides of sulphur and chlorides.

Low and medium carbon steel corrode in most atmospheric environment when the relative humidity exceeds 60%. Once a moisture films has formed on the metal substrate the metal is sets to corrode. It has been found that low and medium carbon steel has higher affinity for corrosion rate in mild environment. Mild steel is extensively used in industries and as a result corrodes when exposed to industrial environments and conditions.

The application of inhibitors has been said to be among the most practicable ways for protection of metals against corrosion, especially in acidic media [1, 2]. The inhibitive reactivity of inhibitors is fundamentally affected by the molecular structure of the inhibiting molecules [3, 4]. Most prominent corrosion inhibitors are organic compound containing nitrogen, sulphur, oxygen, phosphorous in their functional groups [4].

The use of natural products of plant origin as corrosion inhibitors has being widely reported by several authors [5,6]. Such interest derived from their inexpensive and friendly natures, ease availability and wide variety. Also the use of these biomass products were justified by the photochemical compound present therein with molecular and electronic structure bearing close similarity to convectional organic inhibitor.

Water lily (an aquatic herb of genus Nymphaea, family Nymphaeaceae), a precious perennial aquatic flower plant, isdivided into two ecological groups, namely Tropical and Hardywater lily [7]. Water lily is noted as one of the most important and noxious freshwater weed, ranked 8th in the list of the world ten most serious weed. Water lily is a native of tropical America. It is believed that water lily originated from Brazil and found its way into Nigeria coastal areas; water lily is known to be cheap and environmental safe as corrosion inhibitors in acidic environment [8,9].Organic heterogeneous compounds have been reported to be efficient corrosion inhibitors [10,11]. These compounds contain Nitrogen, oxygen, sulphur and aromatic ring in their molecular structure and function via adsorption of the molecules on the metal surface creating a barrier to corrosion attack.

The yields of this compound as well as the corrosion inhibitor ability vary widely depending on the part of the plant and its geographical location. Despite its long list of harmful effect on the water ways and ponds, in recent years it has been found useful in animal feeds, compost, paper energy (from biogas), biological waste water treatment and heavy metal uptake. [12].

In recent time, studies have been carried out to identify more useful application of this abundant noxious weed and certain active compound with antioxidant activates such as carotenoids, phenols, alkaloids, and terpenoids have been successfully obtained from water lily and Crassipes extract [10]. The antioxidant showed corrosion inhibition efficiency on magnesium alloy in saline environmentand it may be due to the presence of a great number to double bonds, amine and hydroxyl groups [10]. However, the water lily extract has not be been studies for corrosion inhibitor ability on low and medium carbon steel. The present study *investigate the inhibitive effect of leave and root extract of water lily on mild steel and medium carbon steel in H_2SO_4 solution using weight lost and potential difference methods.*

MATERIALS AND METHOD

Materials

The materials used in this study are low and medium carbon steel gotten from Pulpit Steel Company Ikorodu, Lagos, Nigeria.The elemental composition of each material in weight percent (wt%) wasobtained by the use of optical emission spectrographic (Model: Maxx LMF04, Part No: 76004134). Water lily plant was collected from Ipoti- Ekiti in Ekiti-State, Nigeria. The results for the elemental composition of the materials used are in Tables 1- 3.

***Table 1**. Elemental composition of medium carbon steel*

Element	C	Si	Mn	F
Wt %	0.382	0.243	0.654	0.0176
Element	S	Cr	Mo	Ni
Wt %	0.0409	0.0105	0.0212	0.0788
Element	Al	Co	Cu	Nb
Wt %	0.0016	0.0112	0.192	<0.0010
Element	Ti	V	W	Pb
Wt %	0.00037	0.0047	<0.0050	<0.0010
Element	Sn	As	Zr	Bi
Wt %	0.0226	0.0091	0.0016	0.0037
Element	Ca	Ce	Sb	Te
Wt %	0.0018	0.0030	<0.0010	0.0016
Element	Se	Ta	B	Zn
Wt %	<0.0020	<0.0070	0.0026	0.0049
Element	La	N	Fe	
Wt %	<0.00030	0.0118	98.17	

***Table 2**. Elemental compositions (wt%) of the procured mild steel pipe.*

Elements / Wt %					
C	Si	Mn	P	S	
0.133	0.307	0.82	0.0061	0.0081	
Cr	Ni	Mo	Al	Sn	
0.080	0.102	0.038	0.0036	0.0063	
Cu	Co	Ti	Nb	V	
0.178	0.0085	0.0003	0.0054	0.0016	
W	Pb	B	Zr	La	
<0.0001	<0.0001	0.0007	0.0006	<0.0001	
Zn	As	Bi	Ca	Ce	Fe
0.0042	0.0005	0.0010	0.0010	0.0023	98.30

***Table 3**. Mineral analysis of elemental composition of water lily*

Sample Code	Fe (ppm)	Mg (ppm)	Ca (ppm)	Cu (ppm)	K (ppm)
WL	32.80	7.00	61.50	0.09	233.00
Sample Code	Mn (ppm)	Na (ppm)	P (ppm)	Nitrogen %	
WL	0.66	69.90	4215.00	2.60	

EXPERIMENTAL PROCEDURE

Samples Preparation

The low and medium carbon steels were cut into rectangular pieces numbering thirty six, eighteen from each sample, and all with length of 20 mm by 20 mm breath. The surfaces of each sample were polished to remove rust using emery papers of different grit sizes (ranging from P60 up toP2200) in a single-deck polishing machine-DC motor (Motor capacity: ½ HP DC) and the samples were kept inside desiccators to prevent corrosion before immersion. The total surface area and weight of each sample were taken using LCD digital vernier (Range: 0-150 mm, Resolution: 0.01mm/0.0005 in) and analytical weighing balance (ranging from 0.001 mg up to 100 tones) and kept in a desiccators, ready for immersion for corrosion investigation.

Preparation of Inhibitor from Water lily Extract

The leaves of the water lily plant were plucked and placed inside an oven for drying at atemperature of 70°C for 5 hours. The dried leaves were then pulverized to very fine particles using a mechanical grinding machine. The water lily leaves were pulverized (dried and ground to powder) to give room for large surface area for extraction of higher concentration of active ingredients responsible for corrosion inhibition [13]. The 20g, 40g, and 60g each of the pulverized leaves (Nymphaeaceae) were measured and poured into different beaker containing 1000 ml of distilled water. The resultant solution was kept for 24 hours to allow it to soak properly thereafter, filtered and stored. From the stock solution, 20g/L, 40g/L and 60g/L were concentrated to 100ml filtratein water bath (DKZ Series, shaking water bath) at a temperature of 100°C for 5 hours. Finally, from each stock solution 5ml, 10ml. 15ml, 20ml, 25ml, and 30ml of solution were prepared as inhibitors for each sample. Total samples of eighteen were prepared for low and medium carbon steel.

Experimental Method

A sample each from low and medium carbon steel respectively was immersed in a plasticcontainercontaining 0.5M $H_2SO_4$with no inhibitor added to it to serve as the control sample. Another sample from each material was also immersed in a plastic container containing 0.5MH_2SO_4 in a closed environment with no inhibitors added to it, which also served as second control experiment.

The prepared concentration of extract from 20g of the water lily leave extract were poured at avolume of 5 ml, 10 ml, 15 ml, 20 ml, 25 ml and 30ml into plastic containers containing 0.5MH_2SO_4 as the corrosive medium and each of the steel sample was immersed in the mixture of the container. The procedure was carried out for the prepared 20g, 40g and 60g of inhibitor respectively.

Measurement of Electrode Potentials and Corrosion Rates from Weight loss

The electrode potential between the samples and dilute 0.5MH_2SO_4 environment were taken at aninterval of three times daily for 30 days. The electrode potential was measured using DT8300D digital multi-meter with zinc rod as reference electrode. The reference electrode was immersed in the medium when readings were to be taken and removed after each measurement. The electrode potential values were converted into standard calomel electrode using the relation below:

$$Electrode\ potential\ mV\ (SCE) = Ezn - 1030mV\ [12, 13] \qquad (1)$$

where E_{zn} is Electrode potential reading obtained using the zinc rod. SCE is standard calomel electrode. E_{zn}

The weight loss measurements were taken by removing each of the samples from the corrosive medium at intervals of three days (72 hrs) for thirty days, clean and dry beforeweighing using analytical digital weighing balance. The pH values of the solution were also recorded. The weight losses were recorded and the cumulative weight loss was calculated. The corrosion rate was determined using the relation below:

$$R = W/DA(T/365) \quad (2)$$

where: R = corrosion rate (mg/mm^2/year), W= weight loss, A= surface area of specimens (mm^2), D = density of the specimen and T/365 = exposure time in days extrapolated to year.

RESULTS AND DISCUSSIONS

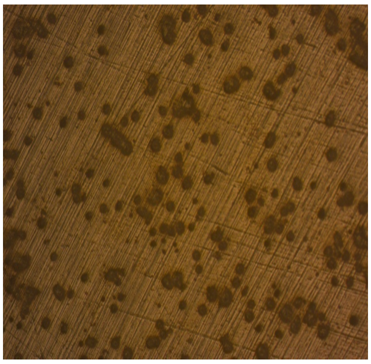

***Figure1a**: micrograph of medium carbon steelafter corrosion*

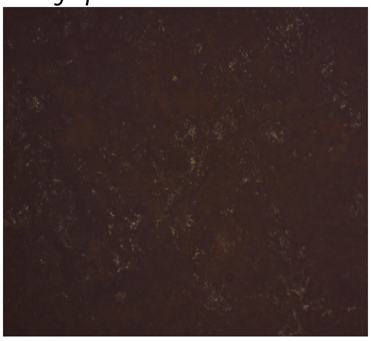

***Figure1b**: micrograph of medium before corrosion*

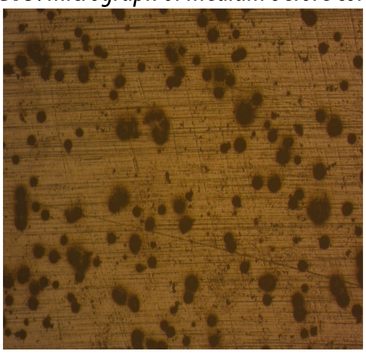

***Figure 1c**: micrograph of low carbon steel after corrosion*

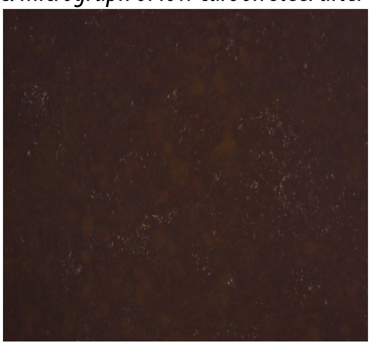

***Figure 1d**: micrograph of low carbon steel before corrosion*

Elemental composition of Inhibitor

Table 4 shows the elemental composition of the inhibitor, which contains metals and non-metals. The main constituents of water lily leaves extract which are also metal constituents are iron, copper, manganese, sodium, potassium, phosphorus, calcium and magnesium which formed high proportion of the total amount at 99.99% and the non-metal is nitrogen which formed very minor proportion of the total amount at 0.0000001%. The inhibitive action of water lilly (Nymphaeaceae) leaves extract towards the corrosion of low and medium carbon steel can be attributed to the neutralization of nitrogen by the metals by a direct chemical reaction of the metals and non-metals to form hygroscopic salt which likely prevents corrosion of the sample in the mild corrosion environment [14].

***Table 4**. Mineral analysis of elemental composition of water lily*

Elements	Fe	Mg	Ca	Cu	K
ppm	32.80	7.00	61.50	0.09	233.00
Elements	Mn	Na	P	N	
ppm	0.66	69.90	4215.00	2.60	

Corrosion rate of low and medium carbon steel exposed to mild environment with various concentration of water lily leave extracts

The corrosion rate of low and medium carbon steel was found to reduce progressively as the amount of the extract increases from 20g to 60g in a mild environment. In Figure 2 to 7, corrosion rate decreases, it was probably due to the formation of the protective film on surface of the corrosive samples as a result of increase in adsorption of the compound of water lily extract on the carbon steel surface [5]. More so, the corrosion rate was also found to decrease as the exposure day increases to 42thdays. In the Figure 2 to 4, the corrosion rate of medium carbon steel in a mild environment without an inhibitor was merged with the corrosion rate of medium carbon steel with different concentration of inhibitor in a mild environment, and this was as a result of ability of the steels to develop protective films as mention above against corrosion despite the fact that the percentage by weight in Table 1 of chromium (0.0105) and nickel (0.0788) of medium carbon steel was low to function as corrosion resistance. Meanwhile in Figure 5 to 7, the corrosion rate of low carbon steel was diverge since the chemical composition of low carbon steel used in Table 2 contains very low value of chromium (0.080) and nickel (0.102) in chemical composition of steel which may catered for corrosion resistance[14]. Generally it can be said that, the main factors in the corrosion experiment in a mild environment and in an open condition with different concentration of water lily leave extract are the protectiveness of corrosion by films produced and decrease the rate of oxygen diffusion. The degree of film protection is largely determine by the pH of the solution directly adjacent to the corroding sample, but this film requires considerable time to develop its full protectiveness, and is not readily destroy when the alkalinity of the solution is within pH 7.1 – 8.7 under the same condition of the experiment above, the steels showed corrosion inhibition by developing protective film [15]. Therefore the corrosion rate of each of the sample in inhibited media was merged in a good proportion as compared to sample *in water lily extract inhibition which shown that the water lily leaves extract can function better as corrosion inhibition.*

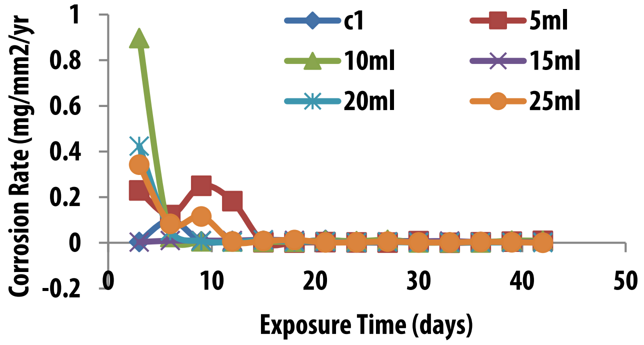

***Figure 2**: Corrosion Rate for 20g inhibitor for Medium Carbon Steel immersed in 0.5M H_2SO_4 at differentconcentrations of inhibitor*

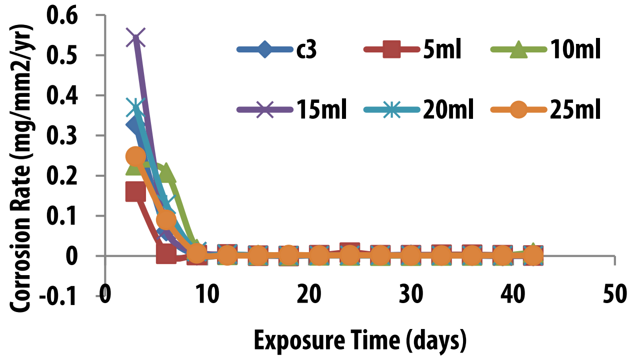

***Figure 3**: Corrosion Rate for 40g inhibitor forMedium Carbon Steel immersed in 0.5M H_2SO_4 at different concentrations of inhibitor*

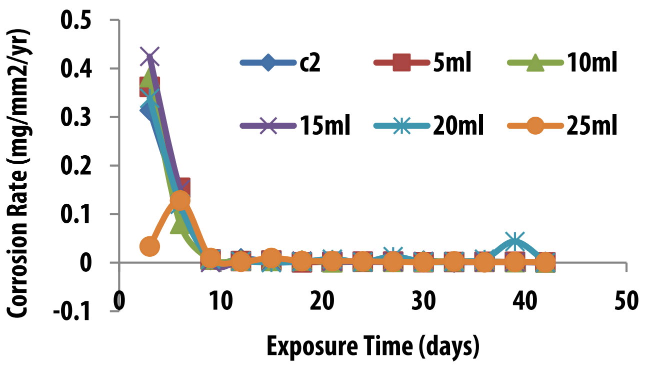

***Figure 4**: corrosion rate of 60g inhibitors forMedium Carbon Steel immersed in 0.5M H_2SO_4 at different concentration*

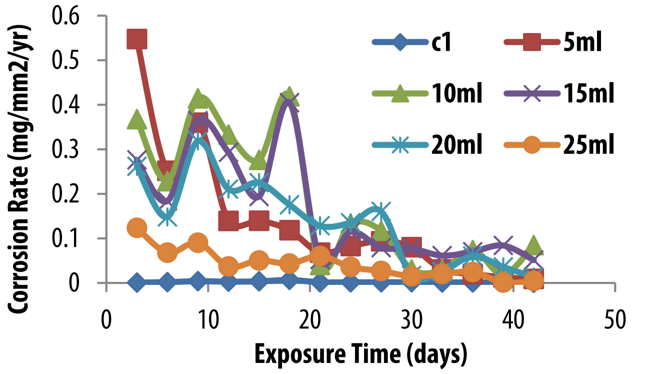

***Figure 5**: Corrosion Rate for 20g inhibitor for Low Carbon Steel immersed in 0.5M H_2SO_4 at different concentrations of inhibitor*

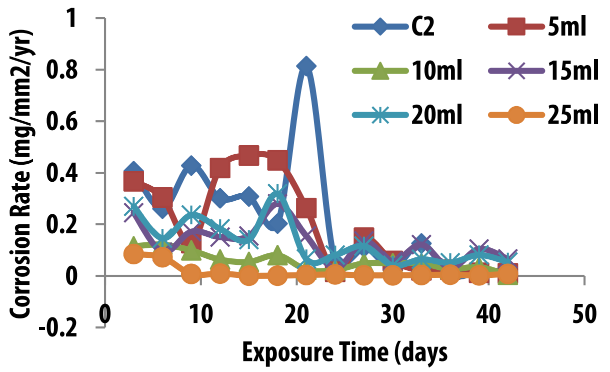

***Figure 6**: Corrosion Rate for 40g inhibitor for Low Carbon Steel immersed in 0.5M H_2SO_4 at different concentrations of inhibitor*

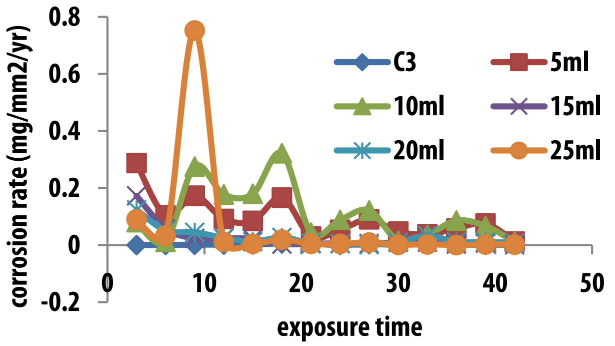

***Figure 7**: Corrosion Rate for 60g inhibitor forLow Carbon Steel immersed in 0.5M H_2SO_4 at different concentrations of inhibitor*

Effect of Inhibitor Concentration on Inhibitor efficiency

The effect of inhibitor concentration on inhibition efficiency of water lily leaves extract on low and medium carbon steel were represented in Figure 8 to 13. For low carbon steel, the extract showed maximum inhibition efficiency of 100% at concentration of 5ml of 20g of water lily per 100ml distilled water at 39th day exposure period in Figure 8 as compared to the inhibition efficiency of extract on medium carbon steel with the maximum inhibition efficiency of 95.0 % at concentration of 10ml of 20g of water lily per 100ml distilled water at 12days exposure period, and further increase in extract to 15ml, 20ml, and 25ml and 60 ml of water lily per 100 ml distilled water does not cause any significant change in the performance of the extract in Figure 11.

In low carbon steel, the extract showed maximum inhibition efficiency of 99.71% at concentration of 25ml of 40g of water lily per 100 ml distilled water at 6th day of exposure period in Figure 8 and compared to the inhibitors efficiency of extract on medium carbon steel with the maximum inhibition efficiency of 95.1% at concentration of 10ml at 18th day of exposure period, further increase or decrease in extract concentration of water lily per 100ml distilled water does not also cause any significant change in performance of the extract Figure 12.

The extract showed maximum inhibition efficiency of 98.85% for low carbon steel at concentration of 20ml of 60g of water lily per 100ml of distilled water at 24th day of exposure period in Figure 10 as also compared to inhibition efficiency of extract on medium carbon steel with the maximum inhibitor of 93.02% at concentration of 10ml at 24th day of exposure period; and further increase in extract concentration from

25ml per 60g of water lily per 100 ml distilled water does not cause any significant change in performance of the extract in Figure 13.

It was therefore observed that inhibition efficiency was consistent with the extract concentration and exposure time in Figure 8 to 13and more so the water lily leaves extract can function better for the corrosion inhibition for low carbon and medium carbon steel, but function more efficiently in low carbon steel[16].

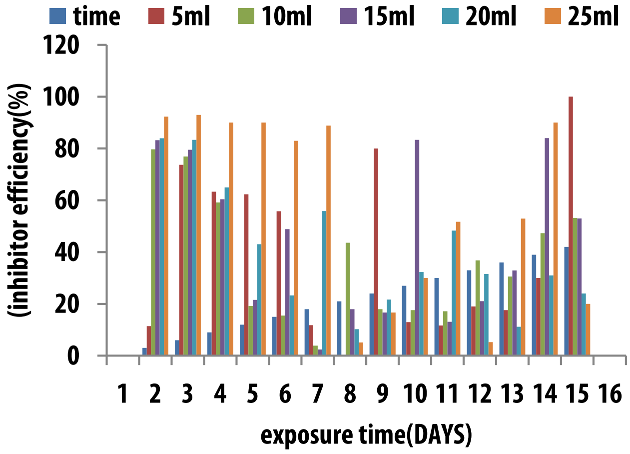

***Figure 8**: The plot of inhibitor efficiency against time for Low Carbon Steel at 20g inhibitor in 0.5M H_2SO_4concentration*

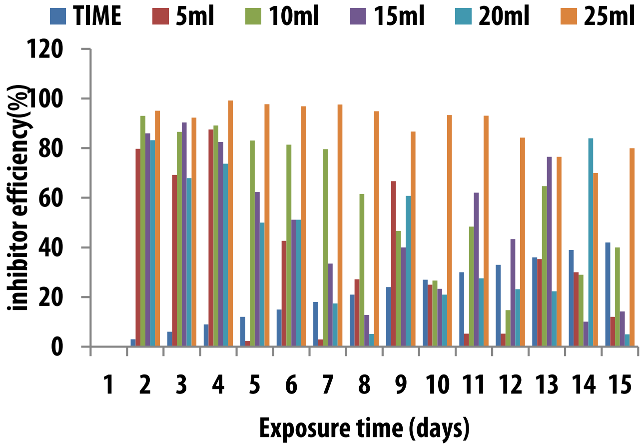

***Figure 9**: The plot of inhibitor efficiency against time for Low Carbon Steel at 40g inhibitor in 0.5M H_2SO_4 concentration*

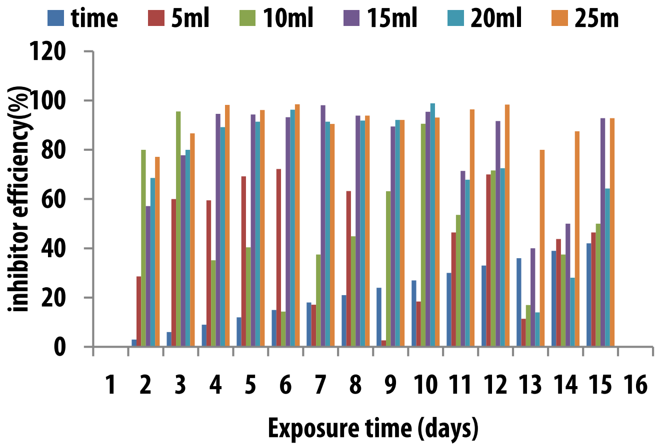

***Figure 10**: The plot of inhibitor efficiency against time Low Carbon Steel for at 60g of inhibitor in 0.5M H_2SO_4concentration.*

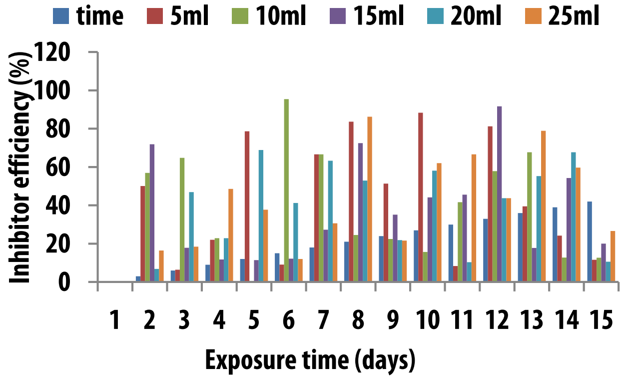

***Figure 11**: The plot of inhibitor efficiency against time for Medium Carbon Steel at 20g inhibitor in 0.5M H_2SO_4 concentration*

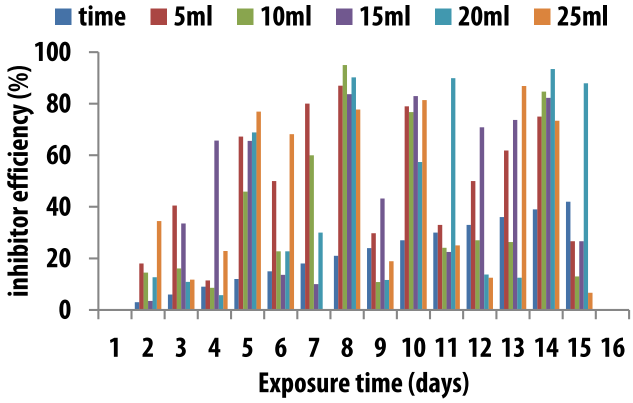

***Figure 12**: The plot of inhibitor efficiency against time forMedium Carbon Steel at 40g of inhibitor in 0.5M H_2SO_4 concentration.*

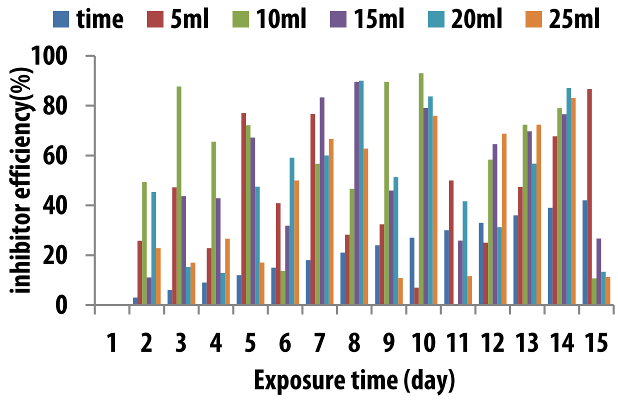

***Figure 13**: The plot of inhibitor efficiency against time for Medium Carbon Steel at 60g of inhibitor in 0.5M H_2SO_4 concentration.*

Potential Difference

The observation made in the variation of electrode potential with exposure time for the low and medium carbon steel in a mild environment with various concentration of inhibitor in Figure 13 to 18 showed different behaviours in corrosion media. In low carbon steel, the corrosion potentials were within -720mV SCE to -523 mV SCE throughout the exposure period and most especially the sample without inhibitor had the corrosion potential within the range of -770 mV SCE to -591 mV SCE which indicate more susceptibility to corrosion as the electrode potential value moved towards positive (-591 mV SCE) and this was as a result of ability of low carbon steel to form protective films to prevent corrosion in Figure 13 to 15. The corrosion potentials in medium carbon *steel range from -876 mV SCE to -232 mV SCE throughout the exposure period and that of low steel was within the range of -776 mV SCE to -350 mV SCE, but in the absence of inhibitor, the potential difference rage from -826mV SCE to -601Mv SCE which indicate less susceptibility to corrosion. But at 20 ml of 60 g water lily per 100 ml distilled water, the extract inhibitor helped in reducing susceptibility to corrosion rate as electrode potential moved toward positive (-523 mV SCE) the same behaviour was observed in medium steel at 5ml of 20g water lily per 100 ml distilled water which also helped reducing susceptibility to corrosion rate as electrode potential move towards positive (-232mV SCE) as shown in Figure 16 to 18 [17].*

CONCLUSIONS

This work had gone through series of examination and analysis to investigate the efficiency of water lily leaves extract as inhibitor on low and medium carbon steel, and to compare the inhibitor efficiency on the steels samples in a mild environment respectively, and the following conclusion were drawn:

- *The inhibitive action of water lily leaves extract towards the corrosion of the samples can be attributed to the neutralization of nitrogen by metals by a direct chemical reaction of the samples in a mild environment.*
- *Finally, the inhibition efficiency of water lily leaves extract as compared as an inhibitor for low and medium carbon steel in a mild environment is very effective and function better in low carbon steel than medium carbon.*

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ACTA Technica CORVINIENSIS
BULLETIN OF ENGINEERING
ISSN:2067-3809