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Mild Steel Corrosion Inhibition by *Euphorbia heterphylla* Extractin 0.5 M Hydrochloric Acid solution

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Abstract

Leaf extract of *Euphorbia heterophylla* was investigated for corrosion inhibition in 0.5 M HCl using, weight loss measurement, and Scanning Electron Microscopy (SEM). Experiments were performed by varying the immersion time (2, 4, 6, 8 and 10 h), inhibitor concentrations (0.5, 1.0, 1.5, 2.0 and 2.5 g/L) and temperature (298, 308, 318 and 328K). The results obtained showed that, as the concentration of inhibitor increased, the weight loss values decreased, but increased with increasing period of contact. Scanning electron microscopic studies provide confirmatory evidence on the metal surface, due to the adsorptions and with decrease of corrosion rate in the presence of inhibitor molecules.

1. Introduction

Solid waste Corrosion can be defined as the destructive attack of a material by reaction with it surrounding environment [1]. It is an important industrial problem that can cause disastrous damage to metal and alloy structures causing economic consequences in terms of repair, replacement, product losses, safety and environmental pollutions. Worldwide, a huge amount of money is wasted each year as a result of metallic corrosion. Due to this harmful effect, corrosion is an undesirable phenomenon that ought to be prevented [2]. In 2016 the annual global corrosion cost was around $2.5 Trillion, but more importantly showed that between 15 and 35 % of this cost could be save through properly applying current corrosion mitigation and technology [3]. Furthermore, in 2012 corrosion cost in US was $1trillion (us dollar) which account for about 6.2% of GDP hence, the largest single expense in the economy [4]. A corrosion inhibitor is a substance which when added in small concentration to an environment, easily, quickly and effectively reduces the corrosion rate of a metal exposed to that particular environment. Corrosion inhibitors can be divided into two broad categories namely those that enhance the formation of a protective oxide film through an oxidizing effect and those that inhibit corrosion by selectively adsorbing on the metal surface and creating a barrier that prevents access of corrosive agents to the metal surface [2]. The use of inhibitors is one of the best methods for protecting metals against corrosion in acidic medium. Inhibitors protect metals by effectively adsorbing on the surface and blocking the active sites for metal dissolution and /or hydrogen evolution, which thereby hinders the overall metal corrosion in that environment [5]. The mechanism by which inhibitors function include, causing the formation of thick corrosion products which form a passive layer, changing the characteristics of the environment either by removing or by deactivating an aggressive constituent in the environment and adsorption onto the corroding material as a thin film. Mild steel also known as low carbon steel is now the most common forms of steel because its price is relatively low and it provides material with properties that are acceptable for many applications [6]. In addition, mild steel is one of the most commonly used materials for construction in various industries due to its low cost, good ductile strength, and availability [6]. However, the challenge is that, it has low corrosion resistance especially in acidic environments and mild steel has relatively low tensile strength which suffers from yield-point run out [7].

Plants have been recognized as sources of naturally occurring compounds, some with complex molecular structures having varying physical, chemical and biological properties [8-11]. Most of the compounds extracted from plants are used in traditional applications such as pharmaceuticals and biofuels [12]. Furthermore, the uses of naturally occurring compounds are of great concern, because of their effectiveness, abundant availability and more importantly they are environmentally acceptable. Due to these advantages, extracts of some common plants and their products were used as corrosion inhibitors for metals and alloys under different environment [13-16].

Euphorbia heterophylla belongs to the family of *Euphorbiaceae.* It is commonly called Milk weed in English, Nono-Kunchiya in Hausa, Egele in Ibo and Adimeru in Yoruba, Nigeria. It grows in semi-moist places, especially on *Cassava*, *Cowpea* and *Soya bean* plantation. Phytochemical screening on *Euphorbia heterophylla* was carried out and they confirmed the presence of flavonoids, saponins, terpenoids, tannins, alkaloids, and triterpenes [17,18]. Phytochemicals are biologically active compounds that are naturally found in plant, such as vegetables, fruits, medicinal plants, flowers, leaves and roots, which act as a system of protection against many diseases, more specifically consisting of nutrients and fibres that protect the plant from diseases [19].

2. Materials and Methods

2.1 Description of the study Area

Kaduna state is located in the north – western part of Nigeria, on the Kaduna River. Kaduna is a trade center and a major transportation hub for the surrounding agricultural areas which has rail and road junctions. The population of Kaduna was at 4,760,084 according to 2006 Nigerian census, and this is believed to have grown to over 5.8 million as at 2013. The symbol of Kaduna state is crocodile, called Kada in the native Hausa language (Figure 1) [20].

2.2 Collection and Preparation of Coupons

Mild Steel sheets were obtained from Ahmadu Bello University (ABU) Zaria in Metallurgical Engineering Department. The metal was taken to Electrical Engineering workshop and the sheets were mechanically press-cut into different coupons (10 pieces) each was 0.40 mm thick, 3 by 2 cm (surface area 6 cm^2) in dimension. The coupons were polished with emery paper (sand paper) to get rid of any corroded surface and rinsed several times with distilled water, degreased by washing it with ethanol, dipped into acetone; air-dried and weighed using a digital weighing balance. The weights were recorded and the weighed coupons were stored in desiccators to prevent contaminations before their use for corrosion test [21]; [22].

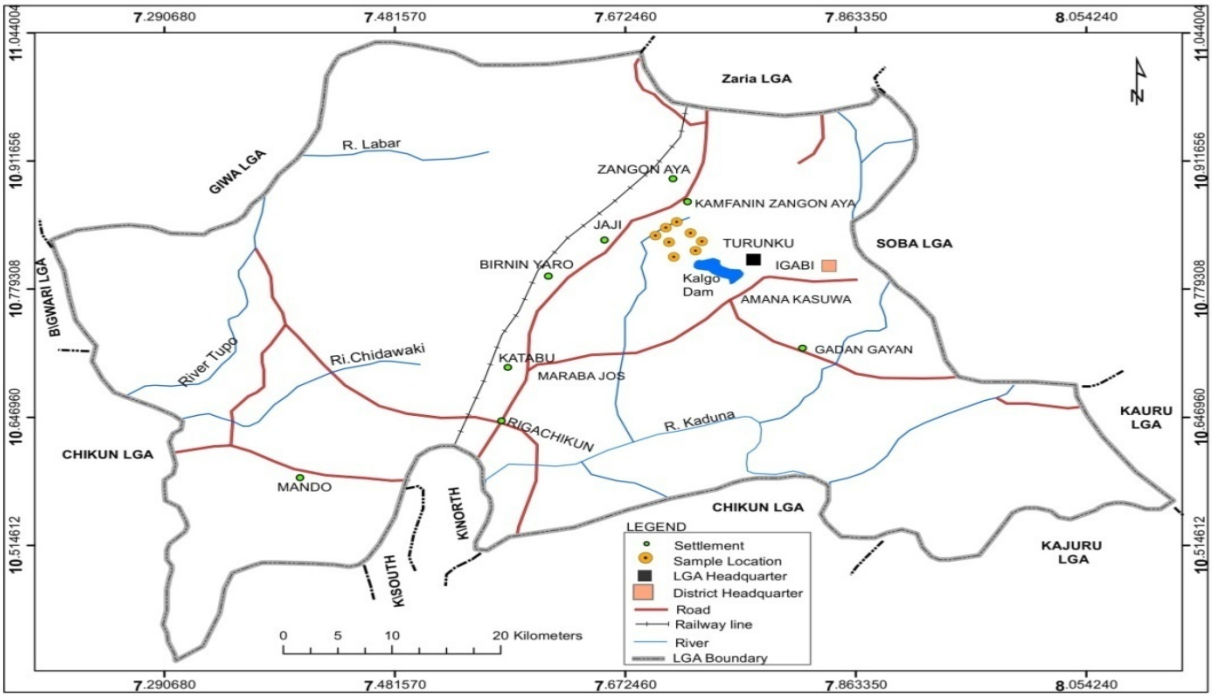

Figure 1a. Showing Map of Study Area

2.3 Collection and Preparation of Plant Extraction

Fresh leaves of *Euphorbia heterophylla* was obtained from Jaji area Kaduna State and washed twice with distilled water. The sample was authenticated at the botanical sections of the Department of Biological Science, Nigerian Defense Academy. The leaves were dried at ambient temperature (25 ^{0}C) and pulverized using pestle and mortar. One hundred gram (100 g) powdered plant (Milk Weed) were extracted for 48 hours in 500 cm^3 with ethanol using soxhlet extractor. After the solvents were recovered, the extract was heated on a water bath at 313 K until the solvents (ethanol) get evaporated. The extract obtained were used to prepared different concentrations by dissolving 0.5, 1.0, 1.5, 2.0, and 2.5 gramme of the extract in 100 cm^3 of 0.5 M HCl respectively [22].

2.4 Weight Loss Measurement

The weight loss of mild steel was evaluated in gramme by immersing the respective weighted coupons in 100 cm^3 beakers containing concentrations of inhibitor (0.5, 1.0, 1.5, 2.0 and 2.5 g / L) for the test solutions and another 100 cm^3 of the uninhibitor sample in 0.5 M HCl solution at 25 ^{0}C for 2, 4, 6, 8 and 10 h respectively. The coupons were retrieved and then washed several times, scrubbed with brittle brush under fast-flowing water, rinsed in ethanol to remove corrosion products, dried with acetone and re-weighted [21-24]. The experiment was repeated with the introduction of five different concentrations of 0.5, 1.0, 1.5, 2.0and 2.5 g/L for 35, 45 and 55 ^{0}C respectively. The initial and final weights of the coupons were calculated using equation 1:

$$\Delta W = W_1 - W_2 \qquad (1)$$

Where W_1 and W_2 are the weights in grams before and after immersion respectively, from weight loss data the corrosion rates (CR) were calculated using equation 2:

$$CR\ (gcm^{-2}h^{-1}) = \frac{\Delta w - \Delta w}{At} \qquad 2$$

Where ΔW' and ΔW are the weight loss in the absence and presence of inhibitor respectively, A is the total area of mild steel in cm^2 and t is the time of immersion.

2.4 Surface Morphological Study

A surface morphological study was performed using scanning electron microscope. The coupons were immersed in 2.5 g/L of the test solution that was prepared from 0.5 M HCl solution and another 0.5 M HCl solution (control) sample for 7 days at room temperature.

3. Results and Discussion

3.1 Weight loss at various concentrations, time and temperature

From the results showed in Table 1, it revealed that, weight loss values in the present of inhibitor were found to decrease with increasing concentration in the inhibitor but increased as the period of contact is increased.

Table 1. Mild steel weight loss at specific concentrations and time in 0.5 M HCl at 298, 308, 318 and 328K respectively

		Weight loss (mg)				
Temp (K)	**Conc (g/L)**	**2 h**	**4 h**	**6 h**	**8 h**	**10 h**
298	Blank	0.030	0.035	0.040	0.050	0.052
	0.5	0.016	0.020	0.024	0.030	0.033
	1.0	0.012	0.016	0.020	0.026	0.028
	1.5	0.009	0.013	0.016	0.022	0.023
	2.0	0.007	0.010	0.013	0.019	0.022
	2.5	0.004	0.008	0.010	0.016	0.020
308	Blank	0.026	0.032	0.042	0.054	0.070
	0.5	0.014	0.019	0.026	0.033	0.045
	1.0	0.012	0.015	0.023	0.029	0.042
	1.5	0.009	0.013	0.020	0.027	0.040
	2.0	0.008	0.010	0.017	0.024	0.035
	2.5	0.006	0.008	0.015	0.021	0.030
318	Blank	0.022	0.036	0.045	0.058	0.070
	0.5	0.012	0.022	0.029	0.038	0.048
	1.0	0.011	0.020	0.028	0.037	0.047
	1.5	0.010	0.019	0.026	0.035	0.045
	2.0	0.009	0.018	0.025	0.033	0.043
	2.5	0.008	0.016	0.023	0.031	0.040
328	Blank	0.044	0.066	0.094	0.108	0.128
	0.5	0.028	0.044	0.068	0.084	0.102
	1.0	0.025	0.042	0.063	0.081	0.098
	1.5	0.023	0.039	0.059	0.078	0.095
	2.0	O.020	0.037	0.056	0.075	0.090
	2.5	0.018	0.034	0.052	0.068	0.085

These values were lowered than values obtained for blank sample (control sample). Indicating effective and efficient inhibition of this extract that corroborate with other finding by (El – Sabbah *et al*., [25] and could be attributed to the presence of some phytochemical in the extract such as Tannins, Flavonoid and Alkaloid which tend to reduce the metal dissolutions by blocking the active sites and adsorbing on the metal surface.

3.2 Corrosion rate at various Concentrations, Time and Temperature

From the results obtained in Table 2, corrosion rates were observed to decrease with increased in the concentrations of inhibitor but decreased with increasing period of contact of the inhibitor. And this indicates the rate at which corrosion for mild steel in HCl decreases on addition of more extract of *Euphorbia heterophylla* which are in line with previous results by Adejo *et al*., [26] and Ocheni *et al*., [27]. This process blocks the active sites and hence decreases the rate of corrosion attack when the inhibitor concentration increases. In this present study, it was found that the extract of *Euphorbia heterophylla* is adsorbed on the metal surface and decreases the area available for corrosion to take place. These could be attributed to more Inhibitor molecules adsorption onto the steel surfaces when inhibitor concentration was increased.

Table 2. Corrosion rate for mild steel at different concentrations, time and temperature in 0.5 M HCl

		Corrosion rate (mg cm^{-2} h^{-1})				
Temp (K)	**Conc(g/L)**	**2 h**	**4 h**	**6 h**	**8 h**	**10 h**
298	Blank	0.00250	0.00146	0.00111	0.00104	0.00087
	0.5	0.00133	0.00083	0.00067	0.00063	0.00055
	1.0	0.00100	0.00067	0.00056	0.00054	0.00047
	1.5	0.00075	0.00054	0.00044	0.00046	0.00042
	2.0	0.00058	0.00042	0.00036	0.00040	0.00037
	2.5	0.00033	0.00033	0.00028	0.00033	0.00033
308	Blank	0.00217	0.00133	0.00117	0.00113	0.00117
	0.5	0.00117	0.00079	0.00072	0.00069	0.00075
	1.0	0.00100	0.00063	0.00064	0.00060	0.00070
	1.5	0.00075	0.00054	0.00056	0.00056	0.00067
	2.0	0.00067	0.00042	0.00047	0.00050	0.00058
	2.5	0.00050	0.00033	0.00042	0.00044	0.00050
318	Blank	0.00183	0.00150	0.00125	0.00121	0.00117
	0.5	0.00100	0.00092	0.00081	0.00079	0.00080
	1.0	0.00092	0.00083	0.00078	0.00077	0.00078
	1.5	0.00083	0.00079	0.00072	0.00073	0.00075
	2.0	0.00075	0.00075	0.00069	0.00069	0.00072
	2.5	0.00067	0.00067	0.00064	0.00065	0.00067
328	Blank	0.00421	0.00316	0.00300	0.00274	0.00260
	0.5	0.00268	0.00211	0.00217	0.00213	0.00207
	1.0	0.00239	0.00196	0.00201	0.00213	0.00199
	1.5	0.00220	0.00187	0.00188	0.00205	0.00193
	2.0	0.00192	0.00177	0.00179	0.00198	0.00183
	2.5	0.00172	0.00163	0.00166	0.00172	0.00172

3.3 Effect of Weight loss on time

Figures 2a – 2d showed the effect of weight loss on time for mild steel in 0.5 M HCl containing various concentrations of the extract. It is evident from the plots that weight loss of mild steel decreased with increase in period of contact and the increase was observed throughout this research.

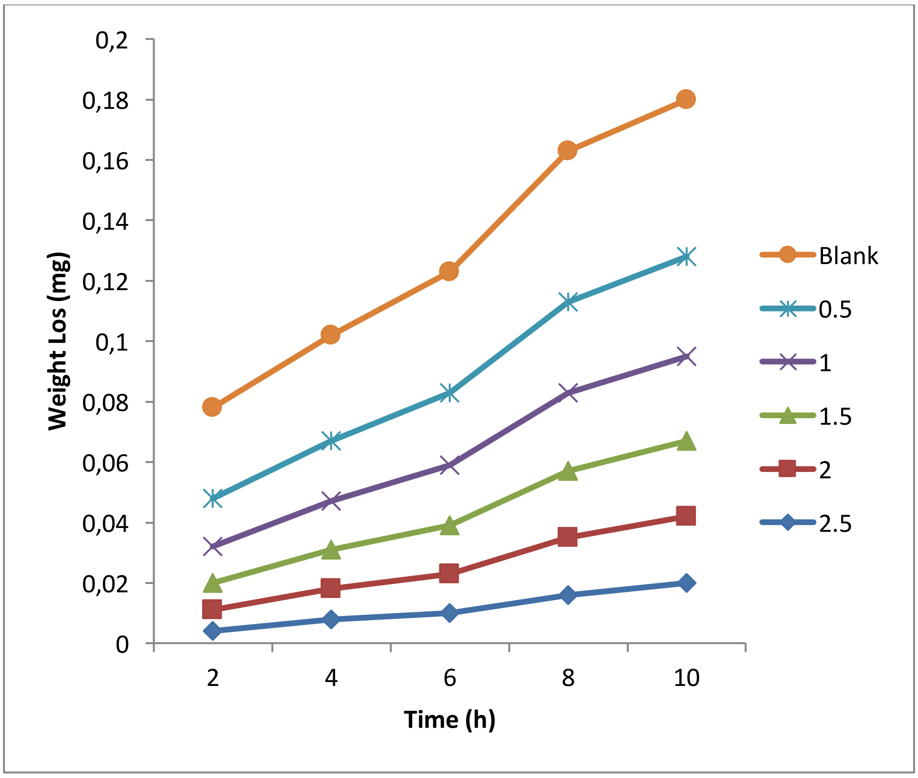

Figure 2a. Effect of Weight loss on Time in Various Concentrations of *Euphorbia heterophylla* for corrosion inhibition of Mild steel in 0.5 M HCl at 298K.

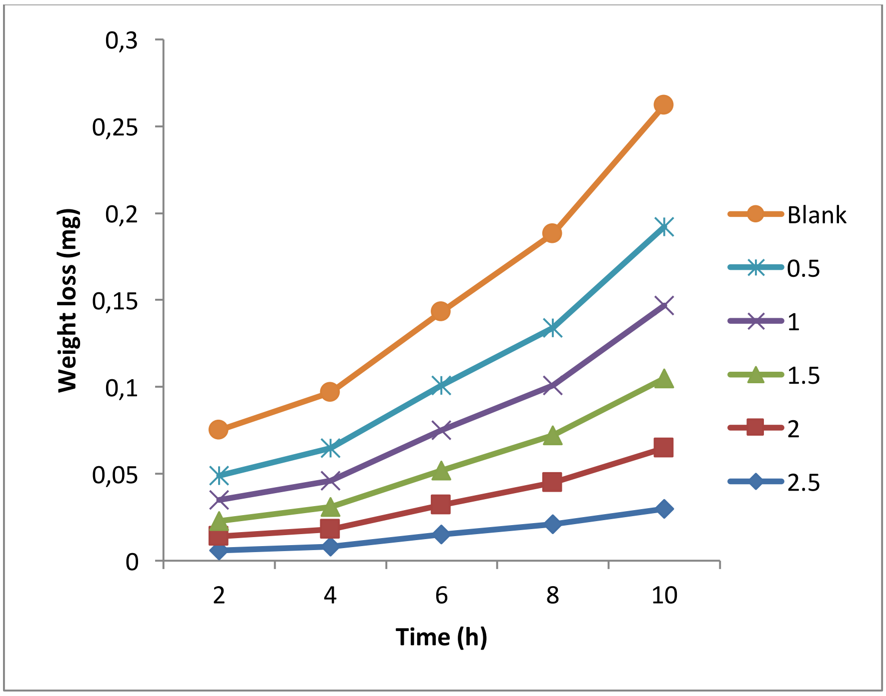

Figure 2b. Effect of Weight loss on Time in Various Concentrations of *Euphorbia heterophylla* for corrosion inhibition of Mild steel in 0.5 M HCl at 308K.

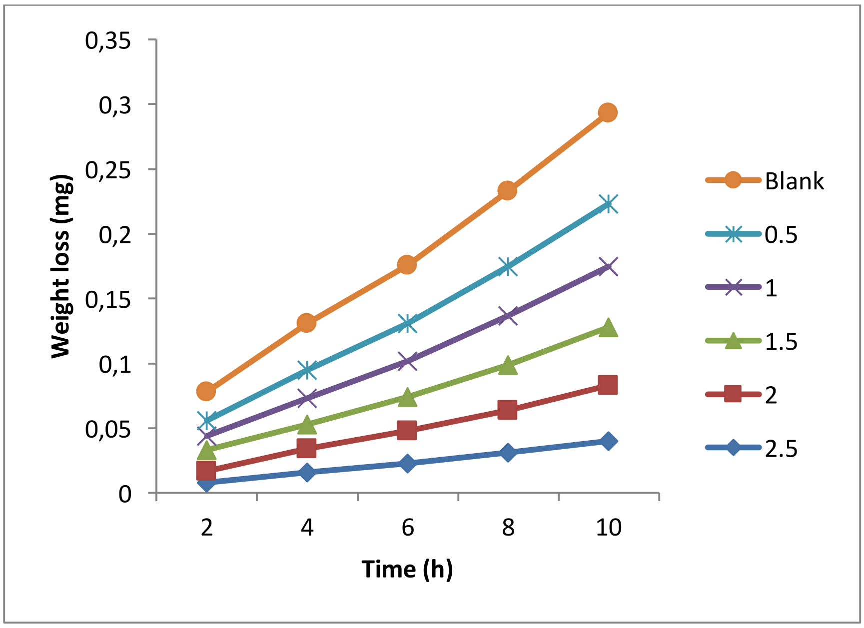

Figure 2c. Effect of Weight loss on Time in Various Concentrations of *Euphorbia heterophylla* for corrosion inhibition of Mild steel in 0.5 M HCl at 308K.

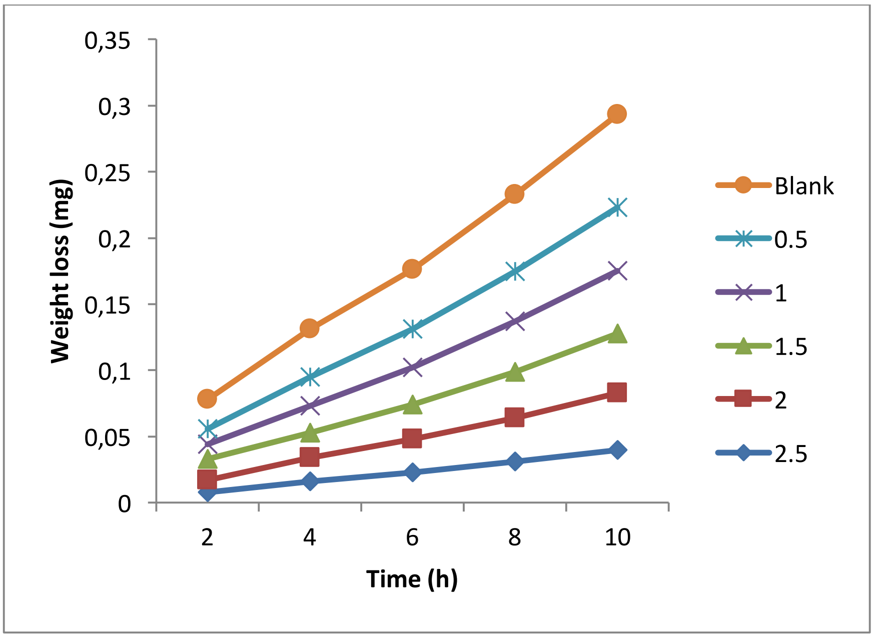

Figure 2d. Effect of Weight loss on Time in Various Concentrations of *Euphorbia heterophylla* for corrosion inhibition of Mild steel in 0.5 M HCl at 318K.

3.5 Effect of Weight loss on Temperature

As showed from **figure 2f** the effects of weight loss on temperature of mild steel in 0.5 M Hydrochloric acid solutions. The weight loss value was found to increase with increasing in temperature from 298, 308, 318 and 328 K respectively. The data obtained suggest that extract from *Euphorbia heterophylla* was discovered to be adsorbed on the metal surface at different temperature of this research in 0.5 M Hydrochloric solution and the recorded increase in weight loss was required to increasing the strength of adsorption which corroborate with other finding by Orie and Christiana [28]. This could be characterized due to the presence of phytochemicals presence in the extract.

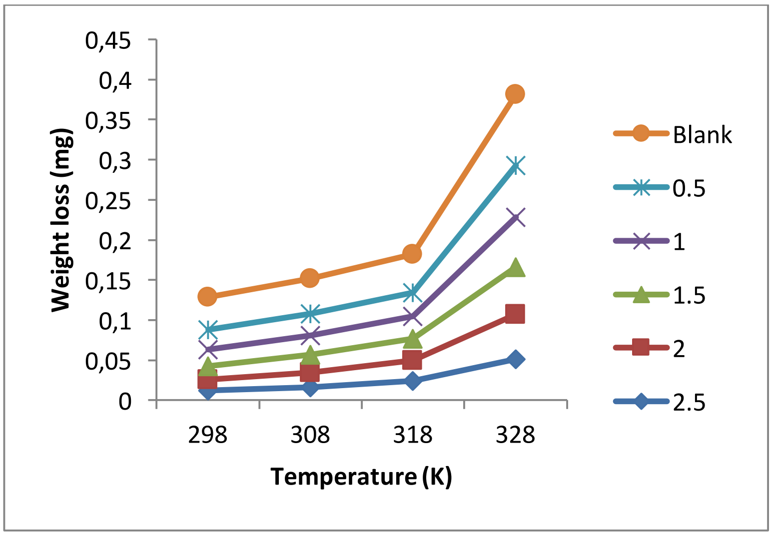

Figure 2f. Effect of weight loss on Temperature in Various concentration of *Euphorbia heterophylla* for corrosion inhibition of Mild-steel in 0.5 M HCl

3.5Scanning Electron Microscopy

Surface analysis of metal by Scanning Electron Microscopy was carried out on Phenom Pro X MVE 0987612. The surface morphology of unprotected and protected mild steel were analyzed at magnification of 1.0KX and operated at a voltage of 15KV. Scanning electron microscopy revealed that extract of *Euphorbia heterophylla* adsorbed on the surface of mild steel and increased its smoothness thereby decreasing the rate for corrosion attack (Figure 3a and 3b). Scanning electron microscope picture of unprotected mild steel in Hydrochloric acid is shown in figure 7 and was enormously damaged due to corrosion, in the absence of the extract.

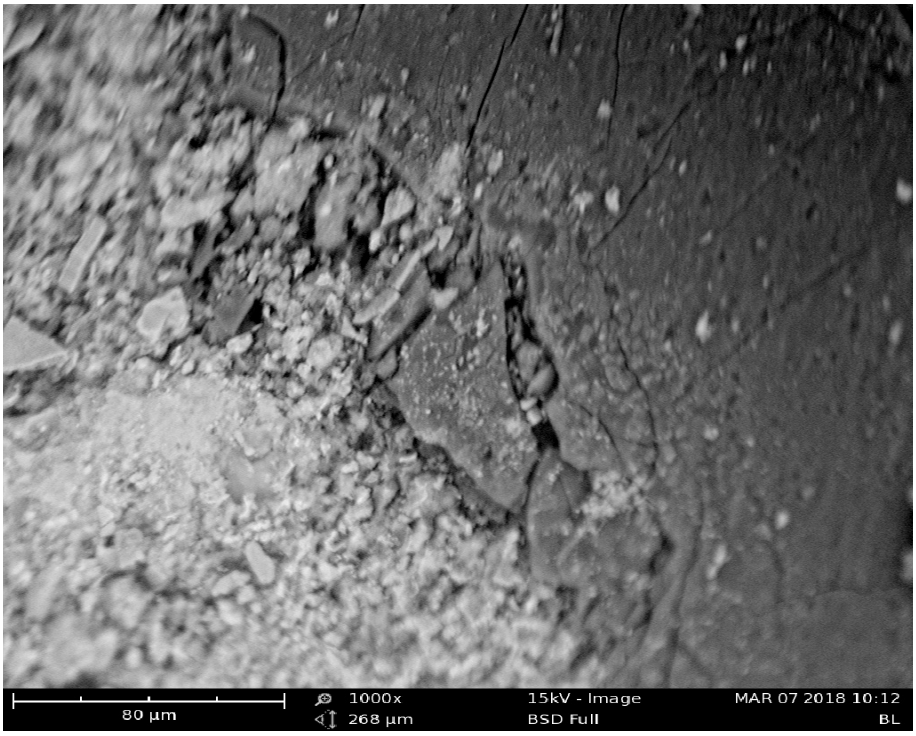

Figure 3a. Scanning Electron Microscopy of Mild steel with Hydrochloric acid

Figure 3b Scanning Electron Microscopy of Mild steel with 0.5 M Hydrochloric acid with *Euphorbia heterophylla*

Conclusion

From the results above, the efficacy demonstrated by extract of *Euphorbia heterophylla* as corrosion inhibitor is excellent. It was revealed that as the concentration of the inhibitor increases, weight loss is decreasing but increased with the period of contact. Surface morphological studies revealed that the extract of *Euphorbia heterophylla* adsorbed on the surface and increased the smoothness of mild steel which decreases the tendency for metal surface to corrode.

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