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Investigation of the Anti-Corrosion Activities of Aloe Vera Extract on Iron Metal Sheets

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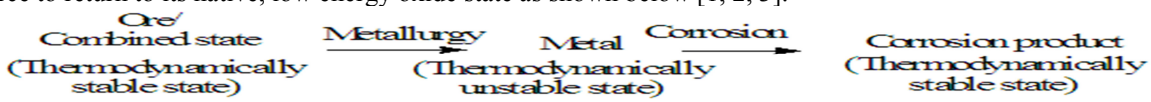
Abstract
The anti- corrosion activities of Aloe Vera extracts were investigated using weight loss method in three corrosive agents (1MHCl, fresh prepared Mango juice and Dashen Beer). The result reveals that the inhibition efficiency of Aloe Vera extract is higher at higher concentration (55.5% at 20 mg/Kg, 65.58% at 40 mg/Kg, 73.59% at 80 mg/Kg, 74.48% at 120 mg/Kg, 83.59% at 200 mg/Kg). The surface coverage area of Aloe Vera extract is also increased with concentration as (0.900 at 20 mg/Kg, 916 at 40 mg/Kg, 0.923 at 80 mg/Kg, 0.991 at 120 mg/Kg, 0.996 at 200 mg/Kg). This is due the fact that as the concentration of inhibitors increased, a larger number of inhibitors molecule is get adsorbed on the metal surface which results more coverage of the corroded metal surface. This makes the metal too difficult from further corrosion by the corrosion agents. In the other hand, the inhibition efficiency and surface coverage area of Aloe Vera are lower at higher temperature. As temperature increases from 298 to 313 K, the inhibition efficiency decreases from 83.59% to 55.5%. This is due to the fact that at an elevated temperature desorption of pre-adsorbed inhibitor molecules occur from metal surface; decomposition and rearrangement of some inhibitors may take place which increases corrosion rate at uninhibited metal surface. Adsorption of Aloe Vera extract on iron metal sheets are obeyed the Langmuir, Temkin and Frumkin adsorption isotherms. The positive value of activation energy (Ea) and the negative value of free energy of adsorption ($\Delta G^{o}ad$) support the physical adsorption of Aloe Vera extract by iron metal sheets.
Keywords: Corrosion, Anticorrosion Activities, Metal Sheet, Corrosion Agent, Adsorption and Aloe Vera Extract

1. INTRODUCTION

Corrosion is degradation and inevitably of materials and materials properties due to interactions with in their environments [1, 2]. It is mainly for metals but polymeric and ceramics also undergo degradation by corrosion agents [2]. Many recent studies have been indicated that metals are deteriorated when they contact into corrosion agents like moistures, acids and vegetables [2, 3]. As the metal contacts with corrosion agents, it oxidize from a zero metallic charge to positively charged ions, and an equivalent amount of electrons pass from the corrosion agents to the metal to neutralize the positive metal charge [1].

As a result of this uphill thermodynamic struggle, metal was corroded since it has a strong driving force to return to its native, low energy oxide state as shown below [1, 2, 3].



Corrosion process of metals.

Chemists, engineers and corrosion specialists have tried several techniques for corrosion mitigation of metals like proper selection of shape and size; organic and inorganic coatings, polymeric and nanocoating methods [3. 4]. Several workers like Alam *et al* and Kalendova *et al* also used heterocyclic compounds which possessed nitrogen, oxygen and sulphur like primary, secondary, tertiary, quaternary amine, aromatic amine and hetero cyclic aromatic amine as inhibitors in order to prevent corrosion [2, 3]. They also used rubber and nanocoatings materials like nano composite thin film coating and thermal barrier coating on surface of metal as good inhibitive effect against acidic corrosion [2, 3]. But these chemicals release harmful substances which are not suitable for environment and living organims [1-4].

To solve this problem, it is important to search natural products like Aloe Vera plant for corrosion protection of metal in acidic medium since it was found for environmental eco-friendly and available in affordable price. The Aloe Vera leaves contain several free anthraquinones and phenolic compounds that aid in absorptive processes in metal surface. The rich source of anthraquinone and other chemical composition of Aloe Vera has been resulted a wide range uses in different sectors. Therefore, this study was designed to investigate the anticorrosion activity of Aloe Vera extract on iron metal sheet in acidic medium using Weight Loss Method and UV spectroscopic method.

2. MATERIAL AND METHODOLOGY

2.1. Equipment and Instrument

Thermostat was used to maintain temperature. Soxhlet" apparatus *(*model: 774419, England*)* were used for "extraction purpose. UV-Vis (*model: sp65, UK*) was also used for absorbance measurement. The equipment's analytical balance, test tube, beaker, desiccators, shaker and oven were used during entire laboratory works.

2.2. Chemicals and Reagent

The reagent 37% HCl (Merk, Munich, Germany), acetone, Dashen Beer, Iron metal sheets and fresh Mongo juice were used during this work.

2.3. Samples Collection

Plant Samples: Mature healthy and fresh leaves of Aloe Vera were collected around *Arba Minch* town.
Iron metal sheets: All Iron metal sheets were purchased from Arba Minch building store. Dashen Beer and fresh Mongo juice were obtained from *Arba Minch* campus at "*ommo* lounge".
Procedures: The same surface area of 3 cm x 3 cm iron sheets were thoroughly washed with soap, running water, distilled water and finally was degreased with acetone. The samples were dried and stored in desiccators. They were weighted and results were recorded before immersing in the test solution. The tested iron metal sheets were dipped into 40 mL solution of Dashen Beer, Fresh Mango juice and 1M HCl acid in 100 mL beakers. Various concentration of turbid Aloe Vera extracts (20, 40, 80, 120 and 200 mg/Kg) were added and left for 20 hours at different temperatures (298k, 308k, and 313k) in *thermostat*. The specimens were removed from the electrolyte, washed thoroughly with distilled water, dried and weighed. The inhibition efficiencies were evaluated using the formula [1]:

$IE\% = \frac{W - Wi}{W} \times 100\%$. Where, W is weight loss in absence of inhibitor and WI is weight loss in presence of inhibitor.

2.4. Statistical Analysis and Models

After the data were obtained and recorded, we use data analysis packages such as Microsoft Excel 2007 and originlab 8.1. Math type program was used to write formula and equation. All measurements were done in triplicate and the results were reported as average values ± SD. Besides these, in order to acquire a better understanding for adsorption mode of the inhibitor on the surface of the iron sheets, the data was tested with several adsorption isotherms, including Langmuir, Frumkin and Temkin. To calculate thermodynamic parameters of the corrosion process, Arrhenius and transition state equations were also used.

3. RESULT AND DISCUSSION

In many industries such as sugar, beverage, tanning, cement and other chemical industries metals are corroded and deteriorated [3, 4]. This is due to electrochemical reaction that occurs on the metal surface when they come in contact with different corrosion agents (*vegetable juices, acids, moisture etc*.). This corrosion causes a great loss of economy such as it reduces the thickness, the mechanical strength, the conductivity, the malleability and the ductility of metals [4, 5]. It also reduces the cost and efficiency of the machine; it blocks and damages pumps, pipes, boilers and buildings [5]. Inlight of these, this study is developed environmental eco-friendly corrosion protection agents using Aloe Vera extract as natural product by subjecting different corrosion agents (*Dashen Beer, HCl acid and Mongo juice*).

There are a variety of organic and inorganic compounds such as antimony trichloride ($SbCl_3$), zinc chromate ($ZnCrO_4$), phosphate to form surface layer of ferric phosphate $FePO_4$ [5]. *Aza* and oxygen, sulphur containing heterocyclic compounds also have been used as corrosion inhibitors for the protection of steel in acid medium [4, 5]. However, these inhibitors suffer from drawbacks, they are effective only at high concentration and they are harmful to the environment due to their toxicity. Therefore, this study is insighted into a new nontoxic and co-effective natural corrosion inhibitor. It is eco-friendly, available in affordable price and it has no any side effect. Due to these characteristics, Aloe Vera extract used as inhibitor in corrosive solution for protection of iron metal sheets by forming a thin layer or film on the surface of the metal thereby protecting them. The surface coverage area (Θ) and corrosion rate K (mmpy) were calculated the following formula and the values are represented in table1 below.

$$\theta = \frac{k_o - k}{k_o} \; and \; k = \frac{13.56 \, \Delta W}{DAt}$$

Where, k_o=corrosion rate without Aloe Vera extract, k= corrosion rate with Aloe Vera extract, W = weight loss of test coupon expressed in kg, A = Area of test iron metal sheets in M^2, D = Density of the material in kg/ M^3

Table 1. *Inhibition efficiency, surface coverage area and corrosion rate of Aloe Vera extract at different concentration with1M HCl as corrosion agent.*

Concentration(mg/Kg)	K(mmpy)	IE%	θ
0.0	42.0000	-	0.000
20.0	0. 3600	55.5	0.900
40.0	0.3500	65.58	0.916
80.0	0.0320	73.59	0.923
120.0	0.0230	74.48	0.991
200.0	0.0014	83.59	0.996

Where, K(mmpy)= corrosion rate in millimeter penetration per year, IE%= inhibition efficiency, θ= surface area coverage.

As shown in (Fig.1 and Fig.2, and Table 1), the rate of corrosion is decreased with increasing of inhibitor concentration, but the inhibition efficiency and surface coverage area are increased with increasing inhibitor concentration. This is due the fact that increasing the concentration of inhibitors, a larger number of inhibitors molecule are get adsorbed on the metal surface resulting more coverage of the corroded metal surface [6]. This makes the metal difficult from further corrosion by the corrosion agents.

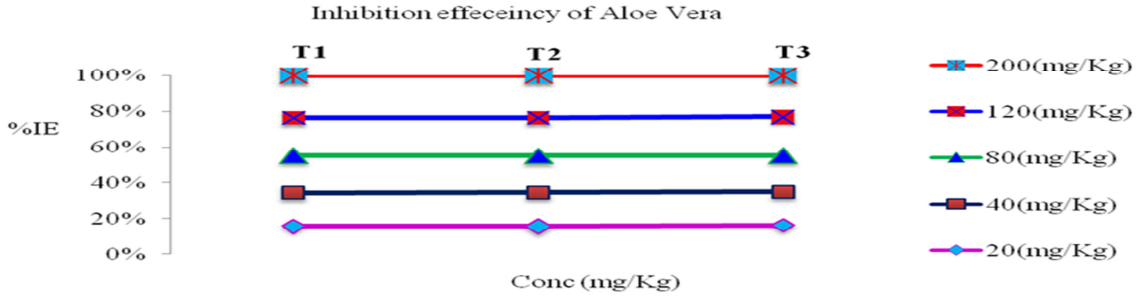


Fig. 1. *Plots of IE% Vs Concentration (mg/Kg) for iron metal sheets at different concentration (at20, 40, 80,120 and 200mg/Kg), Where, T_1= 298k, T_2=308k, T_3=313k.*

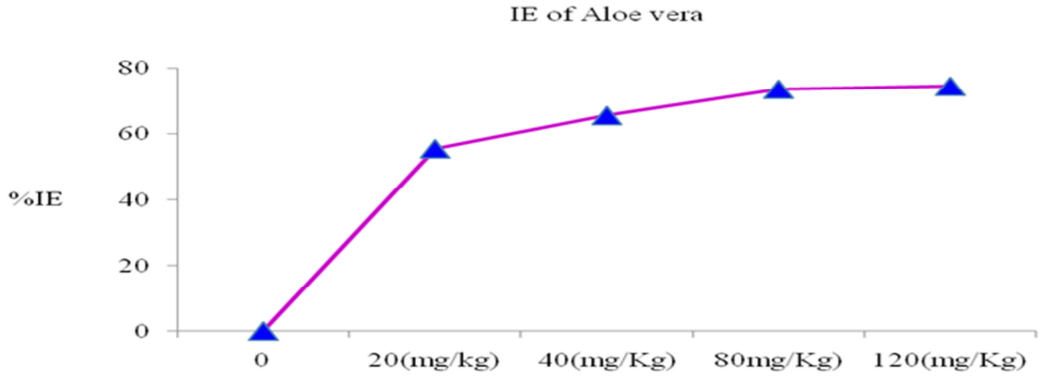


Fig. 2. *Direct relation of IE% with the concentration at 298k.*

As it has been seen in (Fig.1 and Fig.2), the inhibition efficiency of Aloe Vera extract is concentration dependent [4, 5]. Its inhibition efficiency of Aloe Vera extract against 1MHCl acid as corrosion agent lies between 55.5 to 85.9% at different concentration. As shown Fig.2 the inhibition efficiency of Aloe Vera extract is assembled with its concentration as 55.5% at 20 mg/Kg, 65.58% at 40 mg/Kg, 73.59% at 80 mg/Kg, 74.48% at 120 mg/Kg and 83.59% at 200 mg/Kg. This reveals that the inhibition activity of Aloe Vera extract initially increase with concentration linearly. But gradually it form constant; further increasing of the inhibition concentration doesn't has a significance increment. This is due to the fact that the surface area of the metal already covered by initial inhibitor concentration.

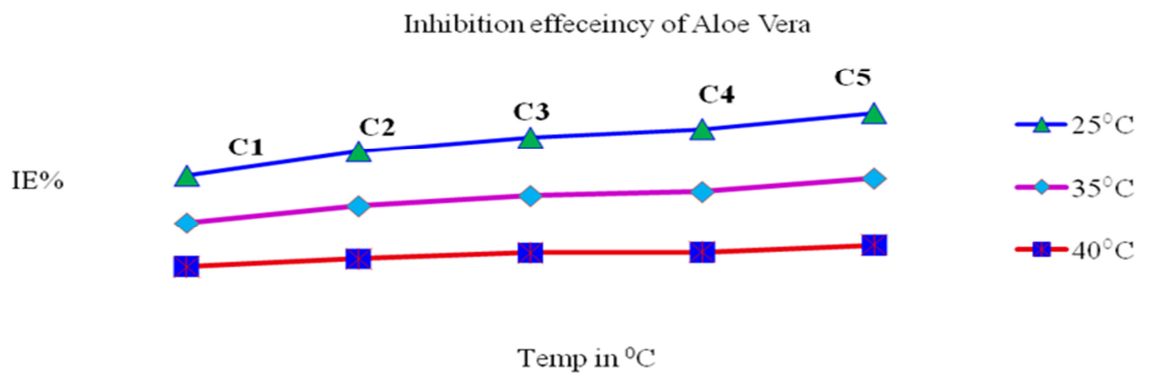


Fig. 3. *The plot of IE% Vs T (^{0}C) for iron metal sheets at different temperature (298k, 308k and 313k). Where, C_1=20 mg/Kg, C_2=40 mg/Kg, C_3=80 mg/Kg, C_4=120 mg/Kg and C_5=200 mg/Kg.*

The result observed in Fig.3 indicates that inhibitors are active, produces good inhibition efficiency and surface coverage area at lower temperature. On increasing temperature from 298 to 313 K inhibition efficiency decreases from 83.59% to 55.5%. At an elevated temperature desorption of pre-adsorbed inhibitor molecules occur from metal surface; decomposition and rearrangement of some inhibitors may take place; heterogeneous reaction rate increases at uninhibited metal surface and corrosion rate linearly increases with the increase of temperature [4]. This observation is attributable to an increased rate of dissolution process of iron metal sheets and partial desorption of the inhibitor from the metal surface with increasing temperature.

Aloe Vera extract forms a thin protective film on metal surface by adsorptive bond/Lewis acid-base type of reaction where inhibitor acts as electron donor and the metal as acceptor [6]. But the anticorrosion efficiency of Aloe Vera extract varies with the nature, the concentration and the type of corrosion agents. In order to address the corrosion activities of different corrosive agent against iron metal sheets, three corrosive solutions were also taken (Mango, Dashen Beer, HCl) and the results were shown in Fig.4.

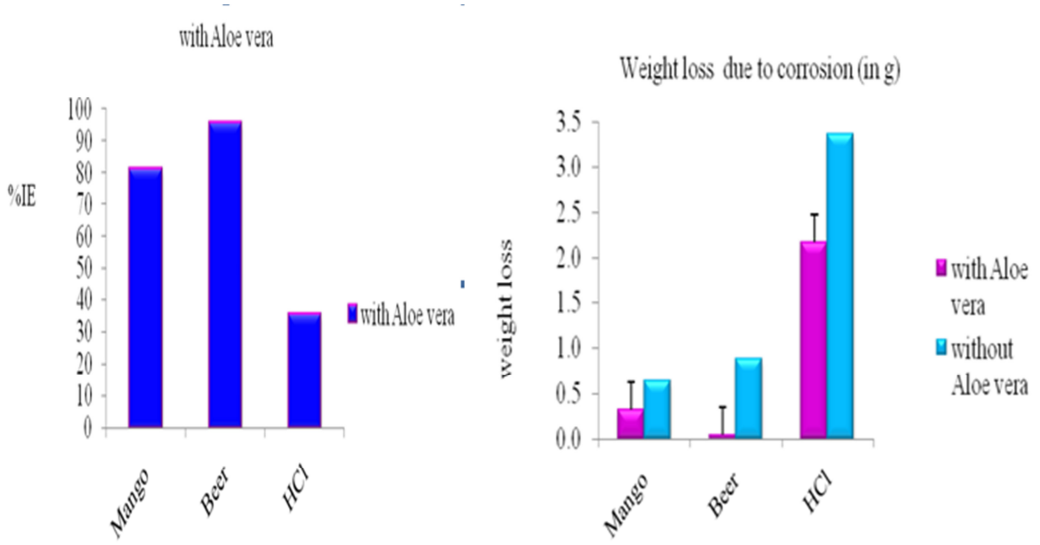


Fig. 4. *The anticorrosion activities of Aloe Vera against different corrosive agent (Mango, Dashen Beer, HCl).*

As indicated in Fig.4 the anticorrosion activities of Aloe Vera extract was investigated in three corrosive agents' Mango, Dashen Beer and HCl. The inhibition efficiency of Aloe Vera extract is higher in Mango and in Dashen Beer than HCl (i.e. 95.5% in Dashen Beer, 80.95% in Mango, 35.5% in HCl). This is due to the fact that inhibitors mainly dependent on the type of corrosion agent, its concentration, temperature, velocity, presence of dissolved solids and the type of metallic materials involved.

3.1. Thermodynamic Studies and Adsorption Isotherms

Adsorption isotherms: Adsorption isotherms are too useful in order to understand the adsorption mechanism of inhibitors on the metal surface during corrosion reaction of metals and alloys [7, 8]. The most frequently used adsorption isotherms are Frumkin, Temkin and Langmuir isotherms [8-9].

3.2. Langmuir Isotherm

Langmuir can relate the concentration of the adsorbate (Aloe Vera extract) to the degree of surface coverage (Θ) according to equation given below [8-10]:

$$\frac{C}{\theta} = \frac{1}{K} + C$$ Where, K is the equilibrium constant of adsorption.

By plotting C/Θ against C, straight line graphs were obtained (Fig. 5.), which confirms that Langmuir adsorption isotherm is obeyed [8]. As it seen in (Table 2), both the value of coefficient of determination (R^2) and slope of the Langmuir adsorption isotherm are best pronounced at 298 K than at 313 K. This indicates that the adsorption performance of the inhibitor by metal surface is strongly influenced by temperature. The lower value of slope at 313K also indicates that the strength of the attractive manner of the inhibitor on metal surface is decreased with temperature [8-10].

Table 2. *Adsorption parameters for iron metal sheets in 1 M HCl solutions containing Aloe Vera extract at various temperatures.*

Temperature	Slope	R^2
298 K	1.125	0.999
308K	1.104	0.997
313K	1.103	0.996

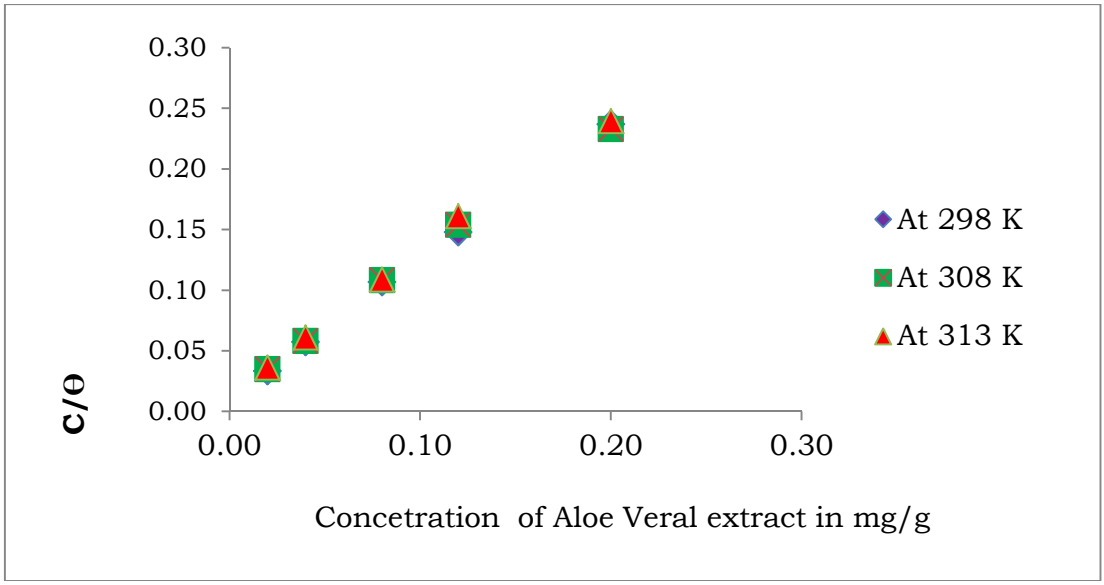


Fig. 5 *Lumgumuir adsorption isotherms for Aloe Vera extract at different temperature.*

3.3. Temkin Adsorption Isotherm

A straight line was obtained when the surface coverage (Θ) was plotted against log C for the inhibitor at different temperature by maintaining in thermostat. The linear line of Aloe Vera extract at various temperatures (298k, 308k and 313k) shows that the adsorption obeys a Temkin adsorption isotherm (Fig. 6).

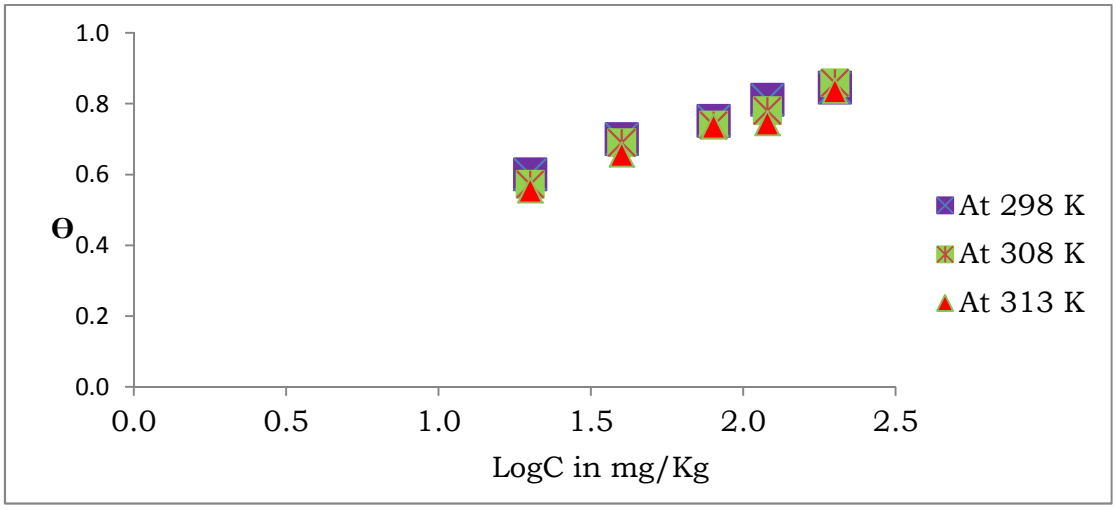


Fig. 6. *Temkin adsorption isotherms for Aloe Vera extract at different temperature.*

3.4. Frumkin Adsorption Isotherm

The plot of %IE against Log C (Fig.7) shows a linear line which makes obvious the adsorption of the inhibitor on iron metal sheets obeys the Frumkin isotherm [8-9].

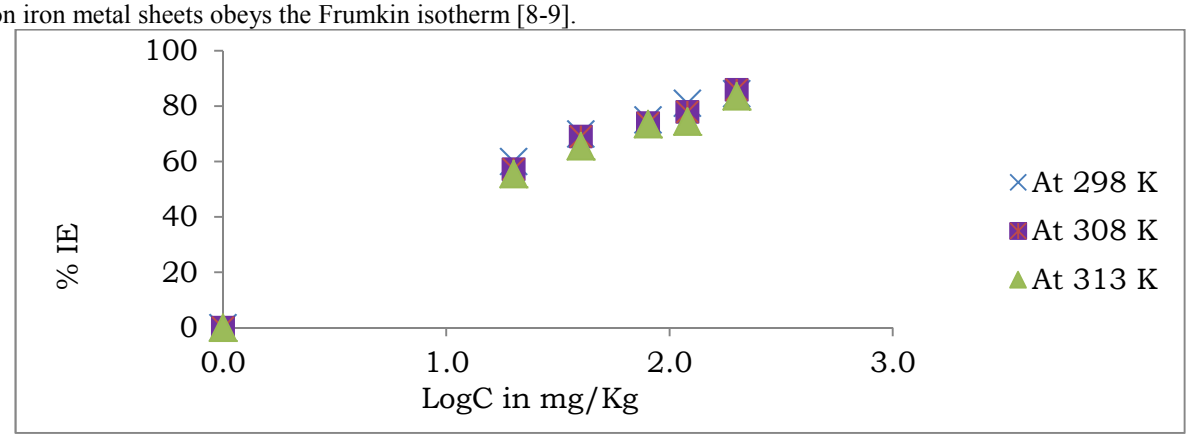


Fig. 7. *Frumkin adsorption isotherms for Aloe Vera extract at different temperature.*

The linearity of different adsorption models (Lamgumuir, Temkin, Frumkin) isotherms, reveal the adsorption of Aloe Vera extract on iron metal sheets is monolayer.

3.5. Thermodynamic Studies

Thermodynamic parameters; heat of Enthalpy (ΔH), Ea and Heat of adsorption Qads of *Aloe Vera extract* on iron metal surface were calculated using different Equations [8-9]. The Value of heat of adsorption of *Aloe Vera extract* on iron metal surface was calculated using equation given below [8-9]:

$$Q_{ads} = 2.305R\left[\log\left\{\frac{\theta_2}{1-\theta_2}\right\} - \log\left\{\frac{\theta_1}{1-\theta_1}\right\}\right] x \left\{\frac{T_1T_2}{T_2-T_1}\right\} KJ/mol$$

Where Qads is the heat of adsorption, R is the universal gas constant, Θ_1 and Θ_2 are the degrees of surface coverage of the inhibitors at temperatures T_1 and T_2, respectively. The Value of heat of adsorption of *Aloe Vera extract* on iron metal sheets of between 298k and 308 K, and 308k and 313 K are -355.580kJ/mol, -123.085kJ/mol, respectively. The negative values of heat of adsorption indicate that adsorption of Aloe Vera extract is spontaneous and occurs via physical Adsorption mechanism.

The activation energy for the corrosion of iron metal sheets in 1M HCl solution was evaluated using the Arrhenius equation given below [9]:

$$\log\frac{CR_2}{CR_1} = \frac{E_a}{2.303R}\left\{\frac{T_2-T_1}{T_1T_2}\right\}$$

Where, Ea is the activation energy of the reaction, R is the gas constant, T is the temperature and, considering a change in temperature from 303 K (T_1) to 313 K (T_2), the corresponding values of the corrosion rates at these temperatures are CR_1 and CR_2, respectively. The Values of Activation energy between 298k and 308 K, and

308k and 313 K are 72015.16J/mol, 55879.33 J/mol, respectively. The values obtained at lower temperature is 72015.16J/mol which is greater than the value (55879.33 J/mol) that obtained at higher temperature, indicating that the inhibition efficiency of Aloe Vera extract decreased as the temperature increased. This is due to the fact that Activation energy is the energy that required oxidizing metal; it implies that more energy needed to the system for the corrosion to take place.

In general Aloe Vera extract protect the surface of metals either by reacting with the impurities in the environment that cause corrosion or by dispersing onto metals from a solution, it then forms a thin layer or film on the metal surface [1, 5]. Thus, Aloe Vera extract serves as good anticorrosion activities in different corrosive environment especially in acidic media such as sugar, beverage and other chemical industries. The anticorrosion activities of Aloe Vera extract also intended to reduce material losses resulting from the corrosion of piping, tanks, metal components of machines, ships, bridges, machine, etc; and to use safety and eco-friendly corrosion inhibitor.

4. CONCLUSION

Aloe Vera is a natural product and eco-friendly with human being which applied for corrosion protection in many industries, garages, for farmers' material and others. The anticorrosion activity of Aloe Vera extract was investigated using weight loss method. On the basis of the result, the anticorrosion activities Aloe Vera extract is more effective at higher concentration and lower temperature. The inhibition efficiency lies between 55.5 to 83.59% at different concentration (20-200 mg/Kg). The inhibition efficiencies and surface coverage area of Aloe Vera extract increases as function of its concentration. The straight line of Lumgumuir, Temkin and Frumkin adsorption isotherms indicate the adsorption of Aloe Vera extract on iron metal sheets is mono-adsorption. The negative value of heat of adsorption also reveals the adsorption process is exothermic. This is the reason why the inhibition efficiency of Aloe Vera extract decreased as the temperature increased.

The anticorrosion activities of Aloe Vera extracts have ample significance in this world since it is available at low price, highly efficient and eco-friendly.

Acknowledgement

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