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# Comparative Studies Of Corrosion Inhibition Of Methanol Extract Of *Senna Occidentalis* On Mild Steel In Sulphuric And Hydrochloric Acids

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## ABSTRACT

The study of corrosion inhibition of *senna occidentalis* methanol extract on mild steel in 0.5M, 1M and 1.5M HCl and $H_2SO_4$ was carried out by adsorption isotherm studies using gravimetric method. The corrosion rate of mild steel coupon in the plant extract was found to decrease with immersion time (2-6 hours) and with increase in concentration of inhibitor (400ppm-800ppm). The result further showed an increase in inhibition efficiency of the inhibitor up to 313k indicating an adsorption of extracts on the mild steel surface. The adsorption on mild steel was found to obey the Langmuir adsorption isotherm.

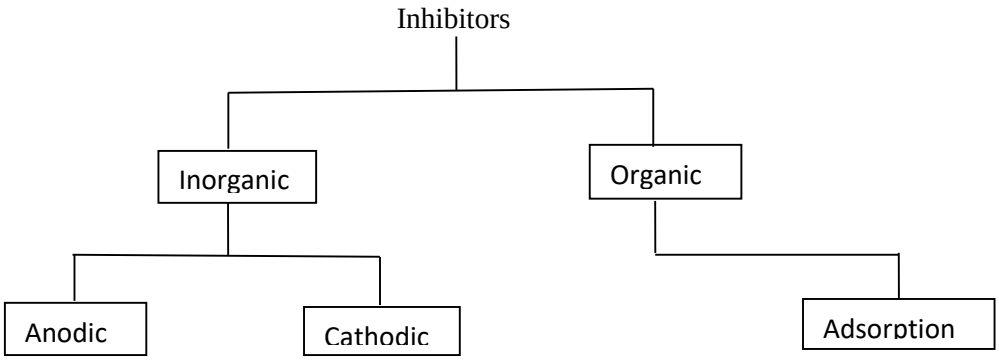
Keywords: *Methanol extract, corrosion inhibition, senna occidentalis, mild steel*

## INTRODUCTION

Corrosion of metal is a serious environmental problem that has been given adequate attention in the oil and gas industries, because during industrial processes such as acid cleaning and etching, metal surfaces are often made to come into contact with the acid medium and this metals corrode due to the attack of the acid on the metal. Corrosion is an inevitable phenomenon and the only way to avoid corrosion totally is to operate in a vacuum but conditions make it impossible [3]. Acid solutions are extensively used in industry, the most important of which are acid pickling, industrial acid cleaning, acid decaling and oil well acidizing.

The commonly used acids are hydrochloric acid, sulphuric acid and nitric acid. Since acids are aggressive, inhibitors are usually used to minimize the corrosive attack on metallic materials. Inhibitors are widely used in the corrosion protection of

metals in several environments [1]. The use of inorganic inhibitor such as chromate, mercride and arsenate are found to be very toxic to both human and other living organisms and hence no longer encouraged to be used [5].




The organic acid inhibitor that contains oxygen, nitrogen and/or sulfur is adsorbed on the metallic surface blocking the active corrosion sites. Although the most effective and efficient organic inhibitors are compounds that have $\pi$-bonds, it present biological toxicity and environmental harmful characteristics [6]. The concentrations of the inhibitor in the medium is critical due to the metal surface covered is proportional to the inhibitor concentration [7]. Some examples are amines, urea, Mercaptobenzothiazole (MBT), benzotriazole etoliotriazol, aldehydes, heterocyclic nitrogen compounds, sulfur containing compounds, accetylenic compounds and also ascorbic acid, succinic acid, tryptamine, caffeine and extracts of natural substances. There are still some inhibitors that act in vapor phase (volatile corrosion inhibitor) such as dicyclohexylammonium benzoate, diisopropylammonium nitrite or benzoate, ethanolamine benzoate or carbonate and also the combination of urea and sodium nitrite [9].

Nevertheless, the known hazardous effects of most synthetic organic inhibitors and the needs to develop cheap, non-toxic and environmentally benign processes have now made researcher to focus on the use of natural products. These natural organic compounds are either synthesized or extracted from aromatic herbs, spices and medicinal plants [6].

Researchers have so far investigated the application of plant extracts, as well as other organic inhibitors against corrosion of steel

in acidic fluids. The application of the extract of *Mangifera indica* (mango) leaves and bark for corrosion of mild steel in diluted sulphuric acid ($H_2SO_4$) medium had also been reported [4]. The weight loss measurements and electrochemical impedance spectroscopic studies were used to determine the inhibition efficiency of the inhibitors. Though the extract of leaves and bark showed a significant effect on the corrosion rate separately, the combination of these two extracts exhibited rather higher efficiency [8].

In this research work, an attempt was made to find out a naturally occurring cheap and environmentally safe substance that may be used as corrosion inhibitor for corrosion of mild steel in acidic medium, a *Senna occidentalis* was used.

## Materials and Methods

### Sample Collection

The leaves of *Senna occidentalis* were collected from ABU Dam, Ahmadu Bello University, Zaria, Kaduna State Nigeria.

### Preliminary treatment of plant leaves (*Senna occidentalis*)

The leaves of *S. occidentalis*were air dried in the Chemistry laboratory and were grounded and sieved in 0.2mm mesh.

### Preparation of mild steel

The mild steel strips used in the study was gotten from locally metal dealers and it was mechanically pressed – cut into coupons, each of a particular dimension and thickness with the following composition, 0.14%C, 0.35%Mn, 0.17%Si, 0.03%P and the rest of Fe. Each coupon was degreased by washing with zinc dust, methanol and cleaned with acetone and it was allowed to dry in the air before in a moisture of free desiccators [2].

### Preparation of leaves extracts

The powdered sample, (50g) was soaked in 200ml methanol for leached extraction between 24 – 48 hours. The refluxed solution was carefully filtered; 50ml of the filtrate volume was poured into a petri dish over water bath and evaporated to dryness. The residues will be further dried in an oven at 100$^{\circ}$C for one hour and was transferred to the desiccators to cool for two hours and concentrated stock sample was expressed in terms of percentage (m/m). It was from this stock sample of *Senna occidentalis* leaves extracts, the different concentration of the extract in 0.5M, 1M and 1.5M sulphuric acid and also 0.5M, 1M and 1.5M hydrochloric acid was prepared. Similar kind of preparation has been reported in similar study using aqueous plants extracts in the recent year [2].

### Gravimetric method

The coupons of mild steel was weighed using a digital balance, labeled and

completely immersed in the conical flasks containing the test solution (0.5M, 1M and 1.5M $H_2SO_4$ and HCl) with and without inhibitor for a long as two hours and covered with aluminum foil at the temperature of 313K and at room temperature of 298K. After every two hours, the coupons were removed by washing each with distilled water and rinsed in acetone and dry air before reweighing. The experiment was repeated continuously for a period of 10 hours. The weight loss of the metal in the corrosive solution, the inhibitor efficiency was expressed as (1%) of the inhibitor, the degree surface coverage ($\theta$) and the corrosion rate of the mild steel (CR) will be calculated using equation 1, 2, 3 and 4 respectively below.

$W = W_1 - W_2$ …… 1

$1\% = (1-W_1/W_2) \times 100$ …… 2

$\theta = W_1 / W_2$ …… 3

$C.R = kW / pAT$ …… 4

Where $W_1$ and $W_2$ are the weight of the metal before and after exposure t

$\theta$= Degree of surface coverage

$\triangle W$ = weight loss of the mild steel in gram after time (T)

**Adsorption Isotherms**

- Langmuir isotherm equation relates the degree of surface coverage ($\theta$) with the concentration of the inhibitor in the bulk electrolyte as given below:

  $K_{ads} = \theta / C (1- \theta)$

  Where; $K_{ads}$ = Equilibrium constant of adsorption

  C= Concentration of inhibitor

  $\theta$ =Degree of surface coverage

- Free energy of adsorption. The free energy absorption of inhibitors will be calculated according to equation below [11].

  $\triangle G_{ads} = -2.30RT \log (55.5K_{ads})$

**Results and Discussions**

The result of the corrosion rate and percentage inhibition efficiency (%) of *Senna occidentalis*in (0.5M, 1M &1.5M) $H_2SO_4$and HCl acidic mediums at 298k and 313k obtained from weight loss measurement after two hours and six hours, respectively, are presented in the Tables 1 to 11.

Table 1 revealed the inhibition efficiency (IE), degree of surface coverage (θ), corrosion ro the corrosive solution, respectivelyate (CR) and weight loss (WL), at various concentrations and temperature using 0.5M Sulphuric acid. The IE, θ, CR and WL at 298K for two hours were: 0%, 1.1934, 0.7061 and 1.2148g, respectively. Similarly, the IE, θ, CR and WL at 400ppm and 298K for two hours in 0.5M sulphuric

acid were: 10.04%, 1.371, 0.5229 and 0.8996g, respectively. Furthermore, when the concentration of the inhibitor was increased to 600ppm at 298K, the IE, θ, CR and WL recorded were: 10.14%, 1.1321, 0.2196 and 0.8979g, respectively. On increasing the concentration of the inhibitor to 800ppm at the same temperature of 298K for two hours, the IE, θ, CR and WL recorded were: 10.38%, 1.1268, 0.5209 and 0.8962g, respectively as reflected in table 1.

Upon increasing the temperature and exposure time to 313K and 6 hours, the IE, θ, CR and WL recorded were: 0%, 1.1995, 0.2415 and1.2467g respectively in 0.5M $H_2SO_4$ at zero concentration of the inhibitor. However, when the concentration of the inhibitor was 400ppm and the temperature and the time of exposure were 313K and 6 hours, the IE, θ, CR and WL were 11.7%, 1.134, 0.1709 and 0.8821g, respectively. On increasing the concentration to 600ppm and 800ppm at temperature 313K for six hours in 0.5M sulphuric acid, the IE, θ, CR and WL were:13.07%, 14.38%, 1.1237, 1.204, 0.168, 0.1659 and 0.8693g, 0.8529g, respectively.

Table 2 revealed the IE, θ, CR and WL at various concentrations and temperature using 1M Sulphuric acid as could be observed from the Table. The IE, θ, CR and WL at 298K for two hours were: 0%, 1.2049, 0.7409 and 1.2746g, respectively. Similarly, the IE, θ, CR and WL at 400ppm and 298K for two hours in 1M sulphuric acid were: 13.76%, 1.1307, 0.5012 and 0.8624g, respectively. Furthermore, when the concentration of the inhibitor was increased to 600ppm at 298K, the IE, θ, CR and WL recorded were: 15.99%, 1.1225, 0.4882 and 0.8401g, respectively. On increasing the concentration of the inhibitor to 800ppm at the same temperature of 298K for two hours, the IE, θ, CR and WL recorded were 17.64%, 1.1153, 0.4787 and 0.8236g, respectively.

When the temperature and the exposure time were increased to 313K and 6 hours, the IE, θ, CR and WL recorded were 0%, 1.2092, 0.2513 and 1.2969g respectively when the concentration of the inhibitor was zero in 1M sulphuric acid. However, when the concentration of the inhibitor was 400ppm and the temperature and the time of exposure were 313K and 6 hours, the IE, θ, CR and WL were 21.05%, 1.183, 0.1529 and 0.7895g respectively. Also, when the concentration was increased to 600ppm and 800ppm at temperature 313K for six hours in 1M sulphuric acid, the IE, θ, CR and WL were:

Table 3 revealed the IE, θ, CR and WL at various concentrations and temperature using 1.5M Sulphuric acid as could be observed from the Table. The IE, θ, CR and WL at 298K for two hours were 0%, 1.2162, 0.7743 and 1.3323g, respectively. Similarly, the IE, θ, CR and WL at 400ppm and 298K for two hours in 1.5M sulphuric acid were 24.59%, 1.1124, 0.4383 and 0.7541g respectively. Furthermore, when the concentration of the inhibitor was increased to 600ppm at 298K, the IE, θ, CR and WL recorded were 26.18%, 1.1061, 0.429 and 0.7382g respectively. On increasing the concentration of the inhibitor to 800ppm at the same temperature of 298K for two hours, the IE, θ, CR and WL recorded were 27.46%, 1.1002, 0.4216 and 0.7254g respectively.

On increasing the temperature and the exposure time were increased to 313K and 6 hours, the IE, θ, CR and WL recorded were 0%, 1.2226, 0.2644 and 1.3648g, respectively when the concentration of the inhibitor was zero in 1.5M sulphuric acid. However, when the concentration of the inhibitor was 400ppm and the temperature and the time of exposure were 313K and 6 hours, the IE, θ, CR and WL were 33.28%, 1.0982, 0.1293 and 0.6672g respectively. Also, when the concentration was increased to 600ppm and 800ppm at temperature 313K for six hours in 1.5M sulphuric acid, the IE, θ, CR and WL for these concentrations were: 34.17%, 36.75%, 1.0934, 1.0863, 0.1274, 0.1225 and 0.6583g, 0.6325g, respectively.

Table 4 revealed IE, θ, CR and WL at various concentrations and temperature using 0.5M Hydrochloric acid as could be observed from the table. The IE, θ, CR and WL at 298K for two hours were 0%, 1.1956, 0.7126 and 1.2226g respectively. Similarly, the IE, θ, CR and WL at 400ppm and 298K for two hours in 0.5M hydrochloric acid were 11.8%, 1.134, 0.5059 and 0.882g, respectively. Furthermore, when the concentration of the inhibitor was increased to 600ppm at 298K, the IE, θ, CR and WL recorded were 13.06%, 1.1273, 0.4987 and 0.8694g respectively. On increasing the concentration of the inhibitor to 800ppm at the same temperature of 298K for two hours, the IE, θ, CR and WL recorded were 14.31%, 1.1205, 0.4915 and 0.8569g, respectively.

When the temperature and the exposure time were increased to 313K and 6 hours, the IE, θ, CR and WL recorded were 0%, 1.2033, 0.2454 and 1.2665g, respectively when the concentration of the inhibitor was zero in 0.5M hydrochloric acid. However, when the

concentration of the inhibitor was 400ppm and the temperature and the time of exposure were 313K and 6 hours, the IE, θ, CR and WL were 21.02%, 1.1183, 0.153 and 0.7898g, respectively. Also, when the concentration was increased to 600ppm and 800ppm at temperature 313K for six hours in 0.5M hydrochloric acid, the IE, θ, CR and WL for these concentrations were: 23.16%, 25.04%, 1.1108, 1.1039, 0.1325, 0.1452 and 0.684g, 0.7496g, respectively.

Table 5 revealed IE, θ, CR and WL at various concentrations and temperature using 1M Hydrochloric acid as could be observed from the table. The IE, θ, CR and WL at 298K for two hours were 0%, 1.2078, 0.7494 and 1.2894g, respectively. Similarly, the IE, θ, CR and WL at 400ppm and 298K for two hours in 1M hydrochloric acid were 30.02%, 1.1035, 0.4014 and 0.6998g, respectively. Furthermore, when the concentration of the inhibitor was increased to 600ppm at 298K, the IE, θ, CR and WL recorded were 31.59%, 1.0975, 0.3924 and 0.6841g, respectively. On increasing the concentration of the inhibitor to 800ppm at the same temperature of 298K for two hours, the IE, θ, CR and WL recorded were 34.16%, 1.0901, 0.3778 and 0.6586g, respectively.

When the temperature and the exposure time were increased to 313K and 6 hours, the IE, θ, CR and WL recorded were 0%, 1.2188, 0.2606 and 1.3453g respectively when the concentration of the inhibitor was zero in 1M hydrochloric acid. However, when the concentration of the inhibitor was 400ppm and the temperature and the time of exposure were 313K and 6 hours, the IE, θ, CR and WL were 51.08%, 1.0701, 0.0947 and 0.4892g, respectively. Also, when the concentration was increased to 600ppm and 800ppm at temperature 313K for six hours in 1M hydrochloric acid, the IE, θ, CR and WL for these concentrations were: 53.72%, 55.04%, 1.0639, 1.0598, 0.0899, 0.0871 and 0.4628g, 0.4496g, respectively.

Table 6 revealed the IE, θ, CR and WL at various concentrations and temperature using 1.5M Hydrochloric acid as could be observed from the table. The IE, θ, CR and WL at 298K for two hours were 0%, 1.2269, 0.8056 and 1.3861g respectively. Similarly, the IE, θ, CR and WL at 400ppm and 298K for two hours in 1.5M hydrochloric acid were 60.56%, 1.0558, 0.2262 and 0.3944g respectively. Furthermore, when the concentration of the inhibitor was increased to 600ppm at 298K, the IE, θ, CR and WL recorded were 61.06%, 1.0533, 0.2234 and 0.3894g respectively. On increasing the

concentration of the inhibitor to 800ppm at the same temperature of 298K for two hours, the IE, θ, CR and WL recorded were 63.32%, 1.0483, 0.2104 and 0.3668g respectively.

When the temperature and the exposure time were increased to 313K and 6 hours, the IE, θ, CR and WL recorded were 0%, 1.2424, 0.2833 and 1.4624g, respectively. When the concentration of the inhibitor was zero in 1.5M hydrochloric acid. However, when the concentration of the inhibitor was 400ppm and the temperature and the time of exposure were 313K and 6 hours, the IE, θ, CR and WL were 71.19%, 1.0402, 0.0558 and 0.2881g, respectively. Also, when the concentration was increased to 600ppm and 800ppm at temperature 313K for six hours in 1.5M hydrochloric acid, the IE, θ, CR and WL for these concentrations were: 73.91%, 75.9%, 1.0351, 1.0312, 0.0505, 0.0467 and 0.2609g, 0.241g, respectively.

Table 7 revealed the Langmuir Adsorption Isotherms ($K_{ads}$) at various concentrations and temperature using 0.5M sulphuric acid. The $K_{ads}$ at 400ppm at 298K and 313K were: 0.3897 and 0.3799, respectively. When the concentration was increased to 600ppm at 298K and 313K, the $K_{ads}$ were: 0.2492 and 0.2392 respectively. On increasing the concentration of the inhibitor to 800ppm at 298K and 313K, the $K_{ads}$ were: 0.1786 and 0.2248, respectively.

Table 8 revealed the Langmuir Adsorption Isotherms ($K_{ads}$) at various concentrations and temperature using 1M sulphuric acid. The $K_{ads}$ at 400ppm at 298K and 313K were: 0.3694 and 0.5412 respectively. When the concentration was increased to 600ppm at 298K and 313K, the $K_{ads}$ were: 0.2292 and 0.2078 respectively. On increasing the concentration of the inhibitor to 800ppm at 298K and 313K, the $K_{ads}$ were: 0.1607 and 0.1455 respectively.

Table 9 revealed the Langmuir Adsorption Isotherms ($K_{ads}$) at various concentrations and temperature using 1.5M sulphuric acid. The $K_{ads}$ at 400ppm at 298K and 313K were: 0.3126 and 0.2696 respectively. When the concentration was increased to 600ppm at 298K and 313K, the $K_{ads}$ were: 0.1956 and 0.1789 respectively. On increasing the concentration of the inhibitor to 800ppm at 298K and 313K, the $K_{ads}$ were: 0.1378 and 0.1172 respectively.

Table 10 revealed the Langmuir Adsorption Isotherms ($K_{ads}$) at various concentrations and temperature using 0.5M hydrochloric acid. The $K_{ads}$ at 400ppm at 298K and 313K were: 0.3799 and 0.3307 respectively. When the concentration was increased to 600ppm at 298K and 313K, the $K_{ads}$ were: 0.2392

and 0.2051 respectively. On increasing the concentration of the inhibitor to 800ppm at 298K and 313K, the $K_{ads}$ were: 0.1688 and 0.1434 respectively.

Table 11 revealed the Langmuir Adsorption Isotherms ($K_{ads}$) at various concentrations and temperature using 1M hydrochloric acid. The $K_{ads}$ at 400ppm at 298K and 313K were: 0.2855 and 0.1875 respectively. When the concentration was increased to 600ppm at 298K and 313K, the $K_{ads}$ were: 0.1783 and 0.1133 respectively. On increasing the concentration of the inhibitor to 800ppm at 298K and 313K, the $K_{ads}$ were: 0.1228 and 0.0792 respectively.

Table 12 revealed the Langmuir Adsorption Isotherms ($K_{ads}$) at various concentrations and temperature using 1.5M hydrochloric acid. The $K_{ads}$ at 400ppm at 298K and 313K were: 0.1478 and 0.1045 respectively. When the concentration was increased to 600ppm at 298K and 313K, the $K_{ads}$ were: 0.0936 and 0.0606, respectively. On increasing the concentration of the inhibitor to 800ppm at 298K and 313K, the $K_{ads}$ were: 0.0633 and 0.0402, respectively.

The results of weight loss study show that inhibition efficiency of the extract on corrosion of mild steel increase with increase in its concentration. The corrosion rate calculated shows that the concentration of the inhibitor (400ppm – 800ppm) increases (2 – 6Hours) at 298K in both acids media respectively. The Degree of surface coverage also decreases as the inhibition efficiency increases. The inhibition efficiency calculated indicates an increase in inhibitor efficiency at lower concentration and also indicated a physisorption of extracts on the mild steel surface. This clearly indicates that the protective films of the inhibitor formed on the surface of the specimen are stable at higher temperature [3].

The adsorption isotherm (Langmuir adsorption isotherm) also decreases with increase in concentration of the inhibitor (400ppm – 800ppm) at 298K and 313K in both acids media. Many researchers have explained the Langmuir adsorption isotherm with an interaction of adsorbed species on the metallic surfaces [12].

In general, the corrosion inhibitor retards the corrosion by controlling the reactions of the inhibitor and the mild steel with the process of adsorption of inhibitor on the solid surface of metal. It is very essential to know the nature of adsorption of the inhibitor so as to ascertain the mode of inhibition and the adsorption isotherm that fits the experimental results [12].

The gravimetric analysis shows that the Sample *Senna Occidentalis* is a good inhibitor on the surface of the mild steel [10].

By implication, *Senna occisentalis* as corrosion inhibitor would perform preferentially for mild steel area of application in acidic environment.

**Table 1:** Corrosion rate and percentage inhibition efficiency of *Senna occidentalis* using 0.5M $H_2SO_4$

| Time (hours) | Temp (K) | Conc. (ppm) | WL (g) | CR | Θ | IE (%) |
|---|---|---|---|---|---|---|
| **2** | 298 | Blank | 1.2148 | 0.7061 | 1.1934 | 0 |
| **2** | 298 | 400 | 0.8996 | 0.5229 | 1.1371 | 10.04 |
| **2** | 298 | 600 | 0.8979 | 0.2196 | 1.1321 | 10.14 |
| **2** | 298 | 800 | 0.8962 | 0.5209 | 1.1268 | 10.38 |
| **6** | 313 | Blank | 1.2467 | 0.2415 | 1.1995 | 0 |
| **6** | 313 | 400 | 0.8821 | 0.1709 | 1.134 | 11.79 |
| **6** | 313 | 600 | 0.8693 | 0.1684 | 1.1273 | 13.07 |
| **6** | 313 | 800 | 0.8562 | 0.1659 | 1.1204 | 14.38 |

**Table 2:** Corrosion rate and percentage inhibition efficiency of *Senna occidentalis* using 1M $H_2SO_4$

| Time (hours) | Temp (K) | Conc. (ppm) | WL (g) | CR | Θ | IE (%) |
|---|---|---|---|---|---|---|
| **2** | 298 | Blank | 1.2746 | 0.7409 | 1.2049 | 0 |
| **2** | 298 | 400 | 0.8624 | 0.5012 | 1.1307 | 13.76 |
| **2** | 298 | 600 | 0.8401 | 0.4882 | 1.1225 | 15.99 |
| **2** | 298 | 800 | 0.8236 | 0.4787 | 1.1153 | 17.64 |
| **6** | 313 | Blank | 1.2969 | 0.2513 | 1.2092 | 0 |
| **6** | 313 | 400 | 0.7895 | 0.1529 | 1.183 | 21.05 |
| **6** | 313 | 600 | 0.7762 | 0.1504 | 1.1121 | 22.38 |
| **6** | 313 | 800 | 0.7586 | 0.1469 | 1.1053 | 24.14 |

**Table 3:** Corrosion rate and percentage inhibition efficiency of *Senna occidentalis* using 1.5M $H_2SO_4$

| Time (hours) | Temp (K) | Conc. (ppm) | WL (g) | CR | Θ | IE (%) |
|---|---|---|---|---|---|---|
| **2** | 298 | Blank | 1.3323 | 0.7743 | 1.2162 | 0 |
| **2** | 298 | 400 | 0.7541 | 0.4383 | 1.1124 | 24.59 |
| **2** | 298 | 600 | 0.7382 | 0.429 | 1.1061 | 26.18 |
| **2** | 298 | 800 | 0.7254 | 0.4216 | 1.1002 | 27.46 |
| **6** | 313 | Blank | 1.3648 | 0.2644 | 1.2226 | 0 |
| **6** | 313 | 400 | 0.6672 | 0.1293 | 1.0982 | 33.28 |
| **6** | 313 | 600 | 0.6583 | 0.1274 | 1.0934 | 34.17 |
| **6** | 313 | 800 | 0.6325 | 0.1225 | 1.0863 | 36.75 |

**Table 4:** Corrosion rate and percentage inhibition efficiency of *Senna occidentalis* using 0.5M HCl

| Time (hours) | Temp (K) | Conc. (ppm) | WL (g) | CR | Θ | IE (%) |
|---|---|---|---|---|---|---|
| **2** | 298 | Blank | 1.2226 | 0.7126 | 1.1956 | 0 |
| **2** | 298 | 400 | 0.882 | 0.5059 | 1.134 | 11.8 |
| **2** | 298 | 600 | 0.8694 | 0.4987 | 1.1273 | 13.06 |
| **2** | 298 | 800 | 0.8569 | 0.4915 | 1.1205 | 14.31 |
| **6** | 313 | Blank | 1.2665 | 0.2454 | 1.2033 | 0 |
| **6** | 313 | 400 | 0.7898 | 0.153 | 1.1183 | 21.02 |
| **6** | 313 | 600 | 0.684 | 0.1325 | 1.1108 | 23.16 |
| **6** | 313 | 800 | 0.7496 | 0.1452 | 1.1039 | 25.04 |

**Table 5:** Corrosion rate and percentage inhibition efficiency of *Senna occidentalis* using 1M HCl

| Time (hours) | Temp (K) | Conc. (ppm) | WL (g) | CR | Θ | IE (%) |
|---|---|---|---|---|---|---|
| **2** | 298 | Blank | 1.2894 | 0.7494 | 1.2078 | 0 |
| **2** | 298 | 400 | 0.6998 | 0.4014 | 1.1035 | 30.02 |
| **2** | 298 | 600 | 0.6841 | 0.3924 | 1.0975 | 31.59 |
| **2** | 298 | 800 | 0.6586 | 0.3778 | 1.0901 | 34.16 |
| **6** | 313 | Blank | 1.3453 | 0.2606 | 1.2188 | 0 |
| **6** | 313 | 400 | 0.4892 | 0.0947 | 1.0701 | 51.08 |
| **6** | 313 | 600 | 0.4628 | 0.0899 | 1.0639 | 53.72 |
| **6** | 313 | 800 | 0.4496 | 0.0871 | 1.0598 | 55.04 |

**Table 6:** Corrosion rate and percentage inhibition efficiency of *Senna occidentalis* using 1.5M HCl

| Time (hours) | Temp (K) | Conc. (ppm) | WL (g) | CR | Θ | IE (%) |
|---|---|---|---|---|---|---|
| **2** | 298 | Blank | 1.3861 | 0.8056 | 1.2269 | 0 |
| **2** | 298 | 400 | 0.3944 | 0.2262 | 1.0558 | 60.56 |
| **2** | 298 | 600 | 0.3894 | 0.2234 | 1.0533 | 61.06 |
| **2** | 298 | 800 | 0.3668 | 0.2104 | 1.0483 | 63.32 |
| **6** | 313 | Blank | 1.4624 | 0.2833 | 1.2424 | 0 |
| **6** | 313 | 400 | 0.2881 | 0.0558 | 1.0402 | 71.19 |
| **6** | 313 | 600 | 0.2609 | 0.0505 | 1.0351 | 73.91 |
| **6** | 313 | 800 | 0.241 | 0.0467 | 1.0312 | 75.9 |

**LANGMUIR ADSORPTION ISOTHERMS RESULT ALSO TABULATED AND PLOTTED AS FOLLOWS;**

**Table 7:** Value of activation parameters (Langmuir adsorption isotherms) for 0.5M $H_2SO_4$

| Conc ppm | $K_{ads}$ at 298k | $K_{ads}$ at 313k |
|---|---|---|
| **400** | 0.3897 | 0.3799 |
| **600** | 0.2492 | 0.2392 |
| **800** | 0.1786 | 0.2248 |

**Table 8:** Value of activation parameters (Langmuir adsorption isotherms) for 1M $H_2SO_4$

| Conc ppm | $K_{ads}$ at 298k | $K_{ads}$ at 313k |
|---|---|---|
| **400** | 0.3694 | 0.5412 |
| **600** | 0.2292 | 0.2078 |
| **800** | 0.1607 | 0.1455 |

**Table 9:** Value of activation parameters (Langmuir adsorption isotherms) for 1.5M $H_2SO_4$

| **Conc ppm** | **$K_{ads}$ at 298k** | **$K_{ads}$ at 313k** |
|---|---|---|
| **400** | 0.3126 | 0.2696 |
| **600** | 0.1956 | 0.1789 |
| **800** | 0.1378 | 0.1172 |

**Table 10:** Value of activation parameters (Langmuir adsorption isotherms) for 0.5M HCl

| **Conc ppm** | **$K_{ads}$ at 298k** | **$K_{ads}$ at 313k** |
|---|---|---|
| **400** | 0.3799 | 0.3307 |
| **600** | 0.2392 | 0.2051 |
| **800** | 0.1688 | 0.1434 |

**Table 11:** Value of activation parameters (Langmuir adsorption isotherms) for 1M HCl

| **Conc ppm** | **$K_{ads}$ at 298k** | **$K_{ads}$ at 313k** |
|---|---|---|
| **400** | 0.2855 | 0.1875 |
| **600** | 0.1783 | 0.1133 |
| **800** | 0.1228 | 0.0792 |

**Table 12:** Value of activation parameters (Langmuir adsorption isotherms) for 1.5M HCl

| **Conc ppm** | **$K_{ads}$ at 298k** | **$K_{ads}$ at 313k** |
|---|---|---|
| **400** | 0.1478 | 0.1045 |
| **600** | 0.0936 | 0.0606 |
| **800** | 0.0633 | 0.0402 |

## CONCLUSION

*Senna occidentalis* appreciably inhibits the corrosion rate more in the HCl than in the $H_2SO_4$ acidic media. The highest inhibition efficiency in the HCl was 75.9% while in the $H_2SO_4$ was 36.75%. However higher %IE were obtained in the HCl medium than at $H_2SO_4$ medium which clearly shows that mild steel has more protection in HCl than in $H_2SO_4$ environment using *S. occidentalis*

as corrosion inhibitor. The Langmuir isotherms also recorded a progressive trend with increase in temperature in HCl and $H_2SO_4$ media which indicates that more adsorption of the inhibitor was obtained in HCl than in $H_2SO_4$ media. Furthermore, the protective films of this extract are seen to increase with increase inhibitor concentrator as a result of the displacement of water molecule from the surface of the metal. Also, the increase in temperature result to the stability of the film found on the metal surface [3] and [12].

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