

Inhibitor Efficiency Relative to H₂SO₄ Medium of Metals Steel Corrosion: The Integration of Plant Extracts

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Abstract: The performance evaluation of a new corrosion inhibitor was studied using mangifera indica leaf obtained in Niger Delta Area of Nigeria. The extract from the mangifera indica leaf was used to examine the efficiency in metal corrosion inhibition in acidic medium of sulphuric acid (H₂SO₄). Metals of carbon steel, mild steel and stainless steel was used in this investigation, the weight loss and corrosion rate was measured and calculated for samples immersed in the acidic medium as well as the control. The result obtained revealed that the extract obtained from mangifera indica leaf is a good corrosion inhibitor. The efficiency of the mangifera indica leaf extract was determined relative to the acidic medium used for this research work as well as results obtained revealed that stainless steel has the highest efficiency in H₂SO₄ medium followed by carbon and mild steel. Finally, the research work demonstrates the usefulness of mangifera indica leaf extract as a major corrosion inhibitor to be used in prevention of acidic medium attack on metal corrosion.

Keywords: Inhibitor, efficiency, relative, H₂SO₄ medium, metals steel corrosion, integration plant extracts

1. INTRODUCTION

Corrosion is a natural and spontaneous phenomenon that occurs when metals are exposed to reactive environment. It is the result of interaction between a metal and its environment which results in its gradual destruction [1].

A very recent study carried out suggests that at global level, corrosion causes economic loss of about 2.5 trillion US dollars which constitutes nearly 3.4% of total GDP [2-3]. However, by implementation of existing corrosion preventing technologies in a proper way, the cost of corrosion can be reduced up to 15-35% (375 -875 billion US dollars or Trillions of Nigeria Naira) [2].

Because of its association with very high economic and safety losses, corrosion is an important issue that has to be addressed by scientists and engineers working in the field of corrosion discipline and engineering throughout the world [4]. Several methods of corrosion prevention have been developed among which use of synthetic inhibitor is one of the most popular and economic method due to their ease of synthesis and application and high effectiveness at relatively low concentration. These organic compounds adsorb over the surface of metals and alloys through their heteroatoms and π electrons and form protective surface barrier thereby protect metals from corrosive degradation [5]. Generally, heteroatoms of organic inhibitors exist in polar functional groups such as -CN, -NO₂, -NH₂, -OH, -COOH, -COOC₂H₅, -OCH₃ etc. Those act as adsorption centers during adsorption of these compounds on the metallic surfaces. Additionally, these polar functional groups enhance the solubility of the compounds in the polar electrolytic media like H₂O, HCl, H₂SO₄, H₃PO₄, HNO₃ etc [6]

In another perspective, corrosion is often referred to as metallic deterioration by chemical attack or reaction of a metal with its environment [7]. It is an ever present and unceasing problem, often hard to eradicate totally. Deterrence would be more realistic and attainable rather than absolute elimination. Metallic deterioration progresses very fast after the destruction or penetration of the passive barrier which is followed by a number of reactions that alter the constituents and behaviour of both the superficial metal surface and the immediate environment. This is observed in for example oxides formation and metal ion diffusion into the coating matrix, local PH changes, and electrochemical potential. The investigation of metallic corrosion is a subject of immense conceptual and practical

concern and has thus received a substantial amount of interest. In industrial acid cleaning pickling, descaling and oil well acidizing operations, acid solutions are widely employed on metal substrates to achieve the intended purpose [8-10]. These processes however, require the use of corrosion inhibitors in order to reduce acid damage on metallic materials [11].

In the chemical, oil, gas, automobile and transportation industries, metallic degradation is one of the main factors influencing the dependability of the systems [12]. For instance in oil, gas and petrochemical concerns thousands of kilometers of pipeline, pumps, pressure, store and transport products [5]. These infrastructures are not only critical to the survival of these industries, but also indirectly to the economy of the nation. However, because a large majority of these installations with their components are made of carbon steel and Aluminum alloys they are inevitably susceptible to corrosion or degradation. In most cases these failures may result in product spillage which is invariably harmful to society as it represents a risk on safety, hazard to the environment and substantial loss of production time and money, it is also bad publicity for such concerns as compensation and litigation may be involved for these reasons a lot of attention is paid to monitoring, and inspection of these facilities [11]. However, the period or duration at which these compounds are inspected can be prolonged or eliminated by incorporating sound, corrosion protection techniques. Moreover, these techniques will reduce corrosion rate and by extension prolong inspection or monitoring time thereby reducing cost of operation [11].

Due to its economic and ecological implications and low level awareness, the problems of metallic degradation continue to reoccur worldwide. The world corrosion organization in April 24, 2009 started a campaign of creating awareness for corrosion and the problems associated with it. It was tagged international corrosion control for socio economic welfare of society preservation of resources and protection of the environment. The aim of this research is to examine the effectiveness of the plant extract from *mangifera indica* leaf as an agent of inhibition on metal corrosion in H₂SO₄ acidic medium.

2. MATERIALS AND METHODS

2.1. Materials

The materials used in this research include: H₂SO₄, *mangifera indica* leaf (mango leaf), phenols, ethanol, acetone, electrochemical impedance spectroscopy (EIS), desiccator, silicon carbide paper, mild steel, stainless steel and carbon steel

2.2. Experimental Apparatus for the Research

The following apparatus were used on this investigation: Distilled water, detergent, thermometer, nose mask, hand glove, container with lid, test tube, measuring cylinder, thread and iron brush

2.3. Sample Collection

The sample (Raw materials) was be obtained from Khana Local Government Area of Rivers State, Nigeria and transported to chemical /petrochemical Engineering laboratory, Rivers State University Port Harcourt. All samples were cleaned with tap water and detergent to eliminate rust and scale and washed with distilled water then oven dried at 40°C for 56 days (8Weeks) until complete dryness. The samples were then stored in a plastic bags at room temperature (25°C).

2.4. Preparation of Leaf Extract

Before the extraction, the samples were grinded using grinder with a sieve of 2.5mm. A 20g of each sample was extracted three times with a solvent (methanol/water: 70/30: V/V) for 2 hours in a water bath at 60°C. The refluxed solution of each sample was filtered, and the filter liquor

Was evaporated to 100ml of dark brown residue, and then degreased with hexane and extracted separatory funnel. The extract was filtered and the collected solid was used to prepare the desired concentration by dilution. A stock solution was prepared by weight, from the collected solid and used to prepare the desired concentration by dilution. The solid residue was obtained for complete dryness and preserved in desiccators. Concentrations of the stock solution were determined by drying sample and measuring the weight of the residue relative to the volume of the sample taken. Using dilution, stocks with different extract concentration were prepared.

2.5. Experimental Procedure

The following metal specimens, carbon steel, mild steel, stainless steel which were cut into dimension 2.0cm x 0.4cm in a lathe machine in mechanical workshop Rivers State University.

Holes of 2.5mm in diameter will be bored at one end of each of the carbon steel, mild steel, stainless steel coupons which were fastened to long copper wire. All the sample was weighed with electronic balance, and then placed in the acid solution (100ml), the duration of the immersion was be for 56 days at the temperature range from 25°C to 30°C, the surface of the specimen was well labeled, cleaned with distilled water followed by rinsing with Acetone and the sample was weighed again from the initial weight in order to calculate the inhibition efficiency (η %) and corrosion rate (C_R).

3. RESULTS AND DISCUSSION

3.1. Weight Loss Results

The weight loss of carbon, mild and stainless steels coupon at the end of the experiment with and without inhibition are presented in Figures.

3.2. Corrosion Rate Results

Corrosion rate of each of the steel coupon was calculated in mils per year (mpy) which is given by the relationship below.

$$C_R \text{ (mpy)} = \frac{\text{weight loss of steel coupon (g)} \times 100 \text{ (mils/in}^2) \times 365 \text{ (days/yr)}}{\text{Density of coupon (g/cm}^3) \times 16.4 \text{ (cm}^3/\text{in}^2) \times \text{Area (in}^2) \times \text{Time (days)}} \quad (1)$$

Simplifying the above equation (1) leads to :

$$C_R \text{ (mpy)} = \frac{22300 \times \text{weight loss of steel coupon (g)}}{\text{Density of Coupon (g/cm}^3) \times \text{Area (in}^2) \times \text{Time (days)}} \quad (2)$$

3.3. Inhibitor Efficiency Results

The efficiency of the inhibitor can be found by the relationship given below:

$$\eta = \frac{W_0 - W_i}{W_0} \times 100\% \quad (3)$$

Where η = inhibitor efficacy

W_0 = weight loss without inhibition.

W_i = weight loss with inhibitor

Alternatively inhibitor efficiency can also be found as:

$$\eta = \frac{C_{R_0} - C_{R_i}}{C_{R_0}} \times 100\% \quad (4)$$

Where C_{R_0} = corrosion rate without inhibition.

C_{R_i} = Corrosion rate with inhibition

The efficiency of the inhibition of the plant extract was acid medium used in the experiment which is H₂SO₄.

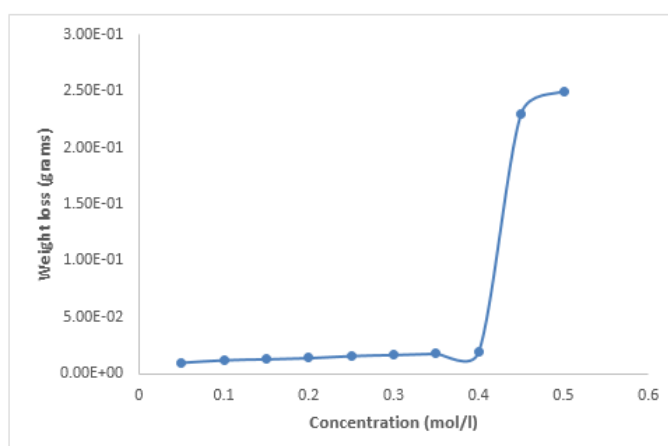


Figure1. Profile Plot of Weight Loss versus Concentration for Carbon Steel without Plant Extract in H₂SO₄ Media

In Figure 1 the weight loss carbon steel coupon increases continuously as the concentration of the H₂SO₄ medium increases from 0 to 0.5mol/litre, hence the increase in weight loss is as a result of absence of inhibition. The variation in Weight loss can be attributed to the variation in the concentration and period of exposure.

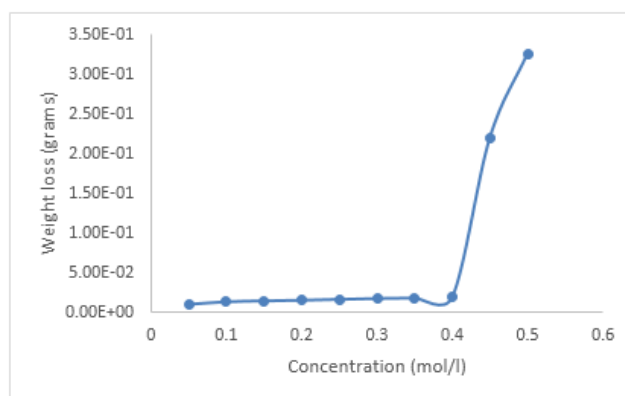


Figure2. Profile Plot of Weight Loss versus Concentration for Mild Steel without Plant Extract in H₂SO₄ Media

In Figure 2 the weight loss mild steel coupon increases continuously as the concentration of the H₂SO₄ medium increases from 0 to 0.5mol/litre, hence the increase in weight loss is as a result of absence of inhibition. The variation in Weight loss can be attributed to the variation in the concentration and period of exposure.

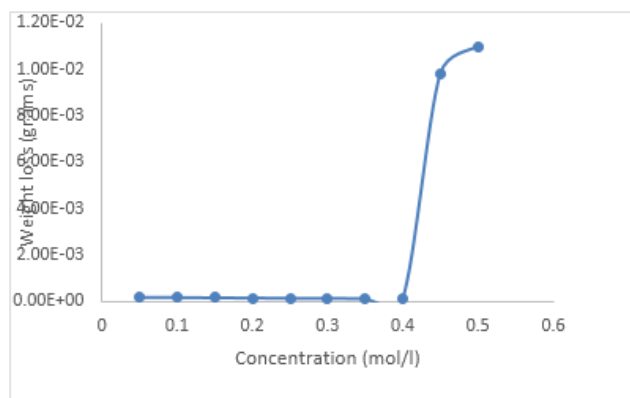


Figure3. Profile Plot of Weight Loss versus Concentration for Stainless Steel without Plant Extract in H₂SO₄ Media

In Figure 3 the weight loss stainless steel coupon increases continuously as the concentration of the H₂SO₄ medium increases from 0 to 0.5mol/litre, hence the increase in weight loss is as a result of absence of inhibition. The variation in Weight loss can be attributed to the variation in the concentration and period of exposure.

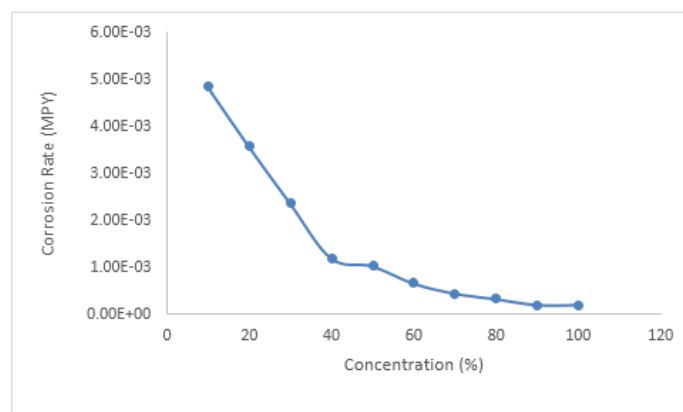


Figure4. Profile Plot of Corrosion Rate versus Concentration for Carbon Steel with Plant Extract

In Figure 4 corrosion rate of the carbon steel coupon decreases from as the concentration of the plant extract increase up to the maximum amount (100% concentration). Further observation shows that the corrosion is constant, hence the plant extract forms complete inhibition with carbon steel at 90% concentration, therefore there can be no further corrosion taking place in the carbon steel coupon above this concentration. The variation in corrosion rate can be attributed to the variation in the concentration and period of exposure.

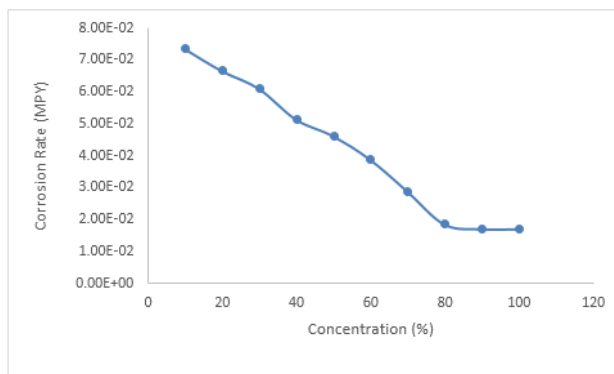


Figure5. Profile Plot of Corrosion Rate versus Concentration for Mild Steel with Plant Extract

In Figure 5 corrosion rate of the mild steel coupon decreases from as the concentration of the plant extract increase up to the maximum amount (100% concentration). Further observation shows that the corrosion is constant, hence the plant extract forms complete inhibition with carbon steel at 80% concentration, therefore there can be no further corrosion taking place in the carbon steel coupon above this concentration. The variation in corrosion rate can be attributed to the variation in the concentration and period of exposure.

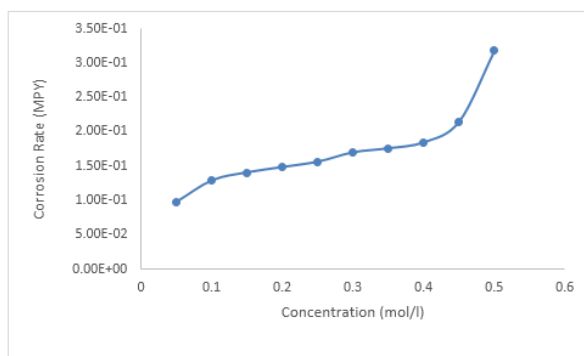


Figure6. Profile Plot of Corrosion Rate Versus Concentration for Stainless Steel without Plant Extract in H₂SO₄ Media

In Figure 6 the corrosion rate of carbon Steel Coupon increases continuously as the concentration of the H₂SO₄ medium increases from 0 to 0.5mol/litre, hence the increase in corrosion rate is as a result of absence of inhibition. The variation in corrosion rate can be attributed to the variation in the concentration and period of exposure.

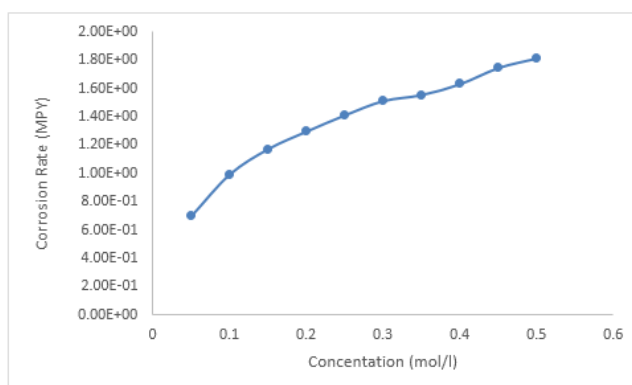


Figure7. Profile Plot of Corrosion Rate Versus Concentration for Mild Steel without Plant Extract in H₂SO₄ Media

In Figure 7 the corrosion rate of carbon Steel Coupon increases continuously as the concentration of the H₂SO₄ medium increases from 0 to 0.5mol/litre, hence the increase in corrosion rate is as a result of absence of inhibition. The variation in corrosion rate can be attributed to the variation in the concentration and period of exposure.

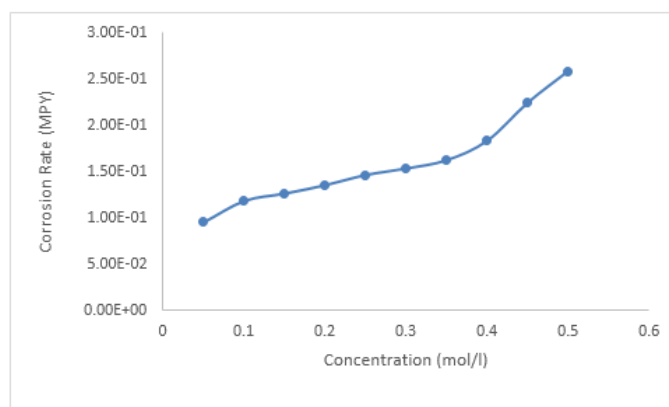


Figure8. Profile Plot of Corrosion Rate Versus Concentration for Stainless Steel without Plant Extract in H₂SO₄ Media

In Figure 8 the corrosion rate of carbon Steel Coupon increases continuously as the concentration of the H₂SO₄ medium increases from 0 to 0.5mol/litre, hence the increase in corrosion rate is as a result of absence of inhibition. The variation in corrosion rate can be attributed to the variation in the concentration and period of exposure.

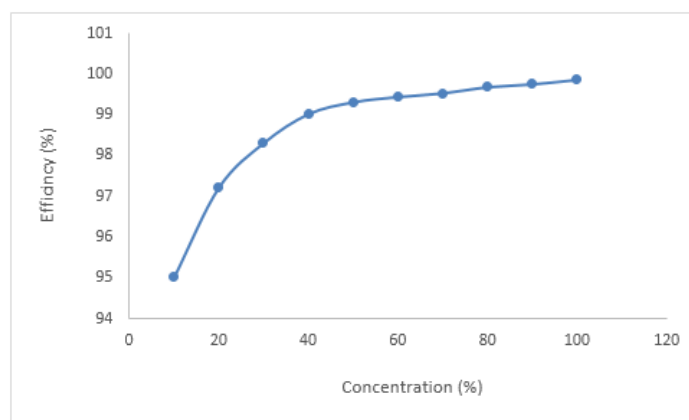


Figure9. Profile Plot of Efficiency versus Concentration Relative to H₂SO₄ Medium for Carbon Steel

In Figure 9 the efficiency of the plant extract increases as its concentration is increasing in the H₂SO₄ medium. The maximum efficiency of the plant extract reaches up to 98.86%. The variation in inhibitor efficiency can be attributed to the variation in the concentration and period of exposure.

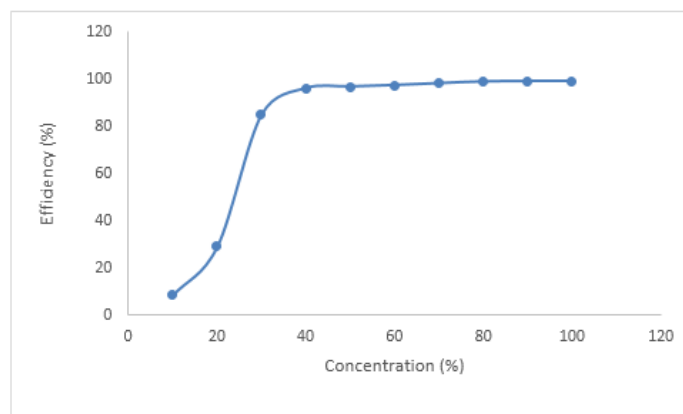


Figure10. Profile Plot of Efficiency versus Concentration Relative to H₂SO₄ Media for Mild Steel

In Figure 10 the efficiency of the plant extract increases as its concentration is increasing in the H₂SO₄ medium. The maximum efficiency of the plant extract reaches up to 98.06%. The variation in inhibitor efficiency can be attributed to the variation in the concentration and period of exposure.

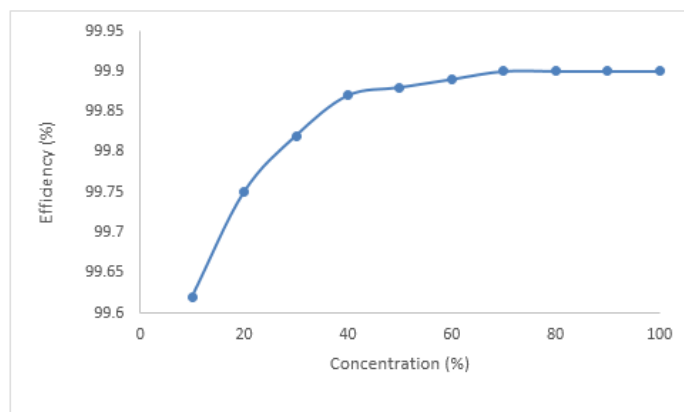


Figure11. Profile Plot of Efficiency Versus Concentration Relative to H₂SO₄ Medium for Stainless Steel

In Figure 11 the efficiency of the plant extract increases as its concentration is increasing in the H₂SO₄ medium. The maximum efficiency of the plant extract reaches up to 98.99%. The variation in inhibitor efficiency can be attributed to the variation in the concentration and period of exposure.

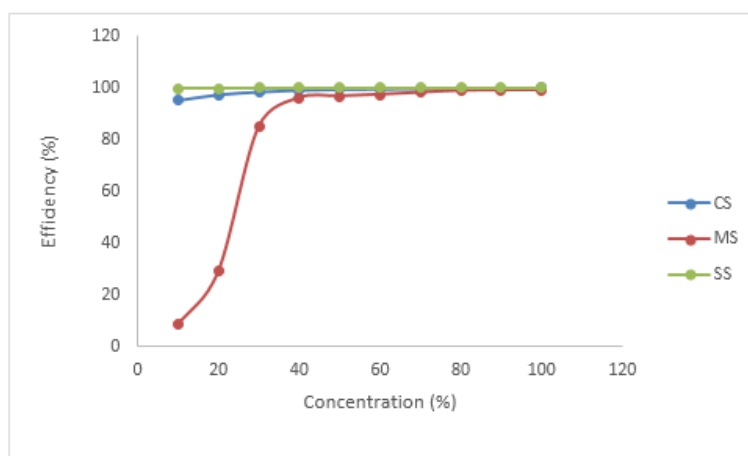


Figure12. Profile Plot of Efficiency Versus Concentration for all Three Steel Coupon in H₂SO₄ medium

In Figure 12 the efficiency of stainless steel is the highest in the H₂SO₄ medium followed by carbon steel and mild steel. The reason for stainless steel having the highest efficiency is because of its excellent corrosion resistant ability and to quickly form inhibition with the plant extract. The variation in inhibitor efficiency can be attributed to the variation in the concentration and period of exposure.

4. CONCLUSION

The weight loss as a result of placing three steel coupon: carbon steel, mid steel, and stainless steel in acidic medium of H₂SO₄ reveals that after a period of 8 weeks (56 days), mild steel showed the highest weight loss of 8.53×10^{-3} g and 3.26×10^{-2} g for H₂SO₄ medium, followed by carbon steel with 1.99×10^{-2} g and 2.31×10^{-2} g for the acidic medium then lastly stainless steel gave 2.03×10^{-2} g and 1.9×10^{-2} g for the acidic medium.

Corrosion rate of the three steel coupon was estimated on the basis of mils per year (mpy) for H₂SO₄ medium with and without plant extract, the trend showed that mild steel, carbon steel and stainless steel all formed inhibition with the plant extract at different concentration of 80%, 90% and 100% respectively.

The efficiency of the plant extract relative to H₂SO₄ medium was compared for the three steel coupon and it was observed that the efficiency of plant extract. Stainless steel had this highest inhibition efficiency in the two acidic medium followed by carbon steel and mild steel.

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