Corrosion Inhibition of Mild Steel by Anogeissus Leiocarpa Root Extract Using Hexane in Acidic Medium

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Abstract: **The menace caused by corrosion on mild steel and on the economy of any nation cannot be overlooked. If not checked will result in damning consequence. As a result there has been several researches tailored in this regard, controlling corrosion by using inorganic inhibitors. However, these inorganic inhibitors are not environmentally friendly. Organic inhibitors (of plant origin) appears to be good alternative due to the presence of phytochemicals and it's readily available. One of such plants is the hexane root extract of Anogeiossus Leiocarpus (Africa birch). The method used is weight loss at 303k, 313k, 323k and 333k. The concentration of root extract used on mild steel are 0.7, 0.8, 0.9 and 1.0 grams. The results show the highest inhibition efficiency of 81 % for 1.0 g/l and 21 % for 0.7 g/l in 1M H_2SO_4 at 303k. This result implies that with increase of inhibitor, both surface coverage and inhibition efficiency increases but with decrease in corrosion rate. It was also observed that increase in temperature, there is reduction in inhibition efficiency. At 333k, IE % for 0.1 g/l is 51 % and 0.7 g/l is 13 %. For each temperature, it was also observed that with time increase, there is progressive decrease in weight loss and corrosion rate but increase in both surface coverage and IE %. The data derived from this research confirmed the fact that corrosion inhibition mechanism was affected by the root extracts.**

***Key words*: inhibitor, mild steel, Anogeissus leiocarpa, inhibition efficiency, corrosion rate, surface coverage.**

I. INTRODUCTION

Mild steel is a type of carbon steel that contains a low level of carbon. Its carbon composition is between 0.05% - 0.25% by weight. Mild steel possesses the following characteristics; magnetic properties, ductility, malleability, affordability, and low carbon which makes it suitable for a wide range of applications. Mild steel is the most common alloy used in aircraft manufacture because of its durability, lightweight and ability to withstand severe pressure at high altitudes. Other uses of mild steel include structural steel, signs, cars, furniture and decorations, wire, fencing and Nails (Ayuba and Mustapha, 2013). Despite its wide range of technological applications, its poor resistance to corrosion in acidic medium limits its applicability. However, mild steel is observed to be degraded in mineral acid environments such as HCl, H_2SO_4, and HNO_3.

Acids such as hydrochloric acid are used mostly in industrial processes such as cleaning, pickling, acid de-scaling and oil well-acidifying processes. During these processes, the aggressiveness of acid solutions, mild steel corrodes severely which results in a terrible waste of both resources and money (Muralisankar, 2017). However, the use of corrosion inhibitors is one of the bail out in the protection of mild steel against corrosion in acidic environments.

Corrosion is a natural process that converts a refined metal into a more chemically stable form such as oxide, hydroxide, carbonate or sulfide. It is the gradual destruction of materials by chemical and/or electrochemical reaction with their environment. Umeozokwere *et.al* (2016) defines corrosion as a natural process that reduces the binding energy in metals with the end result involving a metal being oxidized as the bulk metal losses one or more electrons. The lost electrons are conducted through the bulk metal to another site where they are reduced. In corrosion, the site where the metal atom losses electron is called the anode and the reducing species is called the cathode. Also, corrosion can be said to be the degradation of metallic materials properties due to interactions with its environments.

Compounds that slow down or stop corrosion of mild steel when present in aggressive acidic medium are prospective corrosion inhibitors, and there are two types of corrosion inhibitors; inorganic and organic. Protective action of inorganic inhibitors is related with the formation of oxide film or insoluble salt on the metal surface. On the other hand, protective action of organic inhibitors comes from the adsorption on the oxide films. Organic corrosion inhibitors have the advantages of being inexpensive, non-toxic, and eco-friendly. These advantages have provoked numerous and intensive searches on the use of naturally occurring substances or their extracts for the inhibition of the corrosion of metals (Eddy, Odoemelam, and Ama, 2010).

Phytochemical screening of *Anogeissus leiocarpus* by Mann, Yahaya, Banso and Ajayi (2008) revealed the presence of alkaloids, glycosides, steroids, phenol, tannins, anthraquinones, saponins and flavonoids in the root extracts of the plant. Thus, the root of *Anogeissus leiocarpus is used by* *rural dwellers in the treatment of diseases caused by fungi, bacteria and virus. In addition,* Studies has shown that organic compounds, mainly those with N, S, and O, display significant inhibition efficiency (Bothi Raja, P. et al., 2008). In view of this property, this study aims at investigating the inhibition of corrosion of mild steel in acidic medium. Though plants have proven to be good organic inhibitor (green inhibitor) and are found to be readily available, cheap and environmental friendly (Anuradha, et al., 2008).

II. MATERIALS AND METHODS

2.1 Material Collection

Anogiessus leiocarpa roots was collected in 2019 from Langtan L.G.A. of Plateau state, Nigeria. The plant was authenticated at the Federal College of Forestry¸ Bauchi Road, Jos-North, Plateau State. The roots were air dried in the lab for a period of one week and was pounded into powder form using mortar and pestle for surface area increase. The root was further sieved to remove chaffs. This was followed by weighing 1000 grams of the powder root for n-hexane cold extraction in an extraction glass tank. It was allowed to stay for 72 hours. The soxhlet was used for recovery process. The root extract gotten was stored in in the chemistry lab at ambient temperature of 25 – 30 ^{0}C.

2.2 Mild steel Preparation

The mild steel was collected from Jos building material market with 0.4 mm specification (thickness). It was further cut into various pieces with 2 cm x 2 cm. The coupons were abraded with series of emery paper of different grades. It was abraded in order to remove every trace of corrosion on the surface of the mild steel. A tiny hole was drilled at the Centre of diameter 2.5 mm of each specimen for the purpose of suspension in the cormorant. The coupons were de-greased by washing with ethanol and dipped in acetone and preserved in a desiccator. The mild steel was taken to NMDC in Jos Plateau state for metal analysis. The result shows the following compositions: Co. 226 %, Si 0.115 %, Mn 0.297%, P 0.032%, S 0.032 %, S 0.010 %, C 0.034 %, Ni 0.023 %, Mo 0.002 %, Al 0.0054 %, Cv 0.0096 %, Co 0.0035 %, Ti< 0.0010 %, N60.0098 %, V0.0036 %, W<0.010 %, Pb 0.0031 %, B<0.0005 % Sn 0.0056 %, Zn< 0.0020 %, As 0.015 %, B:< 0.0020 % Ca 0.0048 %. Ce 0.0064 %, Zr 0.0049 %, la 0.0022 % and Fe 99.2 %.

2.3 Gravimetric Method

In this method, a previously weighed coupon was completely immersed in six differed beakers containing 40 ml of 1M H_2SO_4. Five of the beakers in addition to coupon and solution, also contained different quantity of leave extract ranging from 0.7 to 1.0 g. The sixth beaker served as the control. These samples were inserted into a water bath at 303 k. After 3 hours, the corrosion product was removed and rinsed in acetone and allowed to dry before reweighing. The process was repeated at temperatures; 303 K, 313 K, 323 K and 333 K. The average weight loss (mean of triplicate samples) was calculated. From this, the inhibition efficiency (% IE), the degree of surface coverage (Ɵ) and the corrosion rate of mild steel were calculated using Equations 1 – 3 (Ameh *et al.*, 2012*).*

$$\% IE = \left[\frac{1 - W1}{W2}\right] x\ 100 \qquad (1)$$

$$\theta = \left[\frac{1 - W1}{W2}\right] \qquad (2)$$

$$CR = \frac{\Delta W}{At} \qquad (3)$$

Where CR is the corrosion rate of mild steel in g/cm^2/h

W_1 and W_2 are the weight losses (g) for mild steel in the presence and absence of the inhibitor.

Ɵ is the degree of surface coverage of the inhibitor.

A is the area of the mild steel coupon (in cm^2).

t is the period of immersion (in hours) and

ΔW is the weight loss of mild steel after time, t.

III. RESULTS AND DISCUSSION

3.1 Results

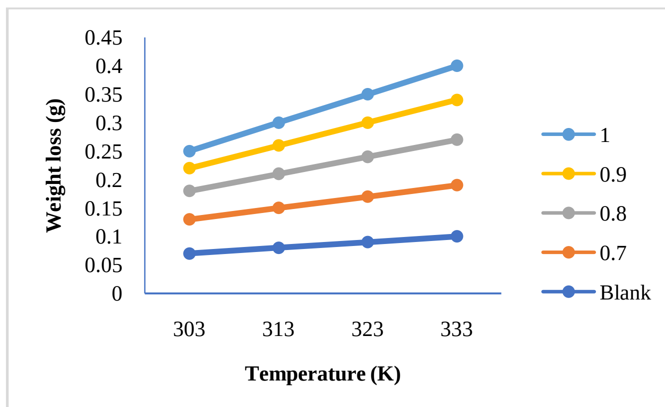

Figure 1A: Effect of Solution temperature on Mild Steel Weight Loss in Blank and Acid Solution containing Hexane root extract for 1h

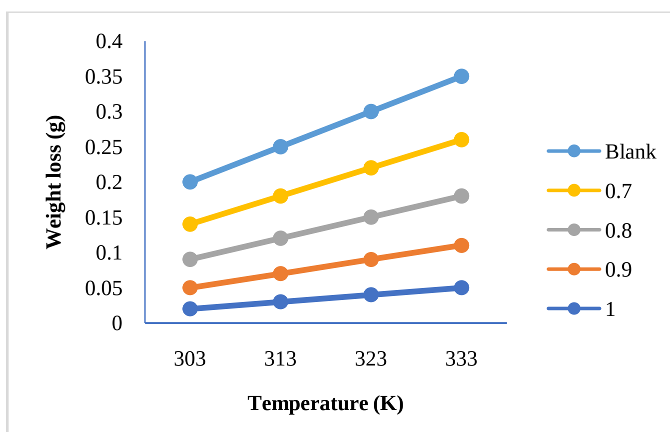

Figure 1B: Effect of Solution temperature on Mild Steel Weight Loss in Blank and Acid Solution containing Hexane root extract for 2h.

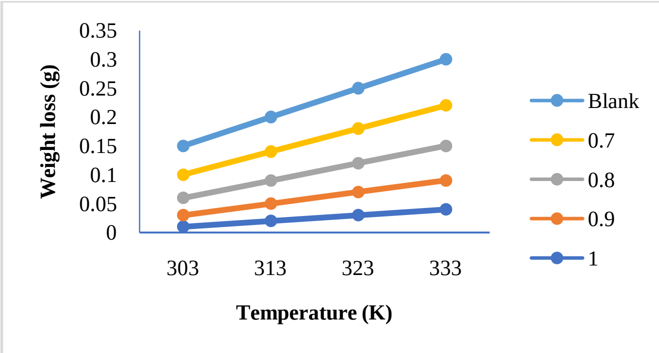

Figure 1C: Effect of Solution temperature on Mild Steel Weight Loss in Blank and Acid Solution containing Hexane root extract for 3h

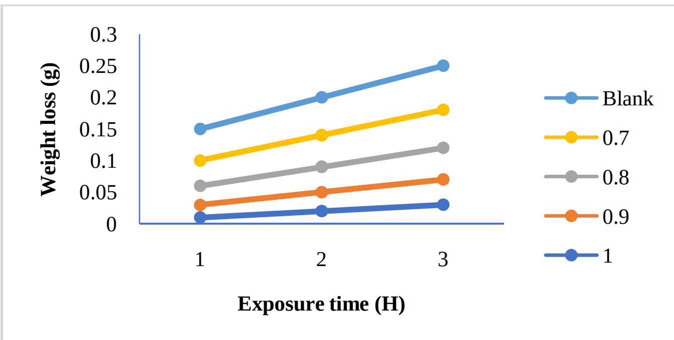

Figure 2A: Weight loss vs contact time for blank and acid solutions containing Hexane root extract at 303K

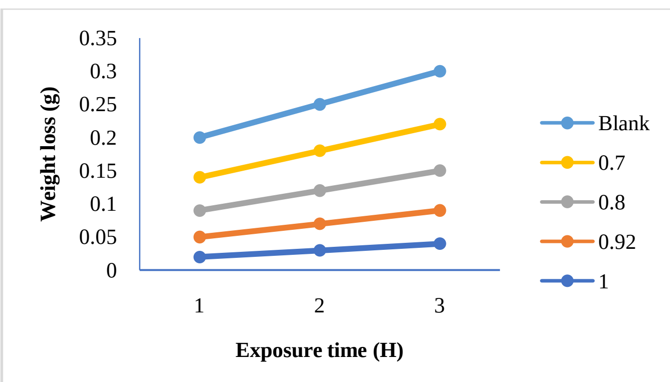

Figure 2B: Weight loss vs contact time for blank and acid solutions containing Hexane root extract at 313K

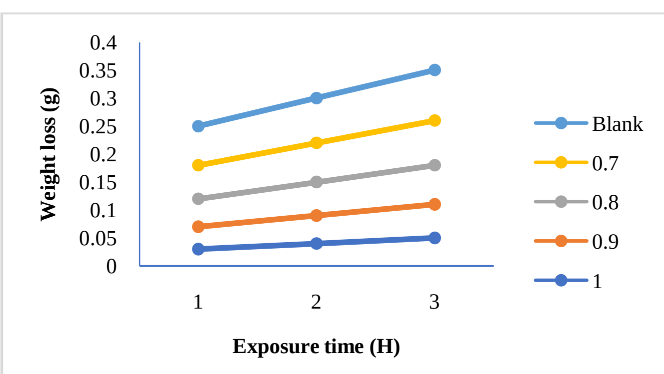

Figure 2C: Weight loss vs contact time for blank and acid solutions containing Hexane root extract at 323K

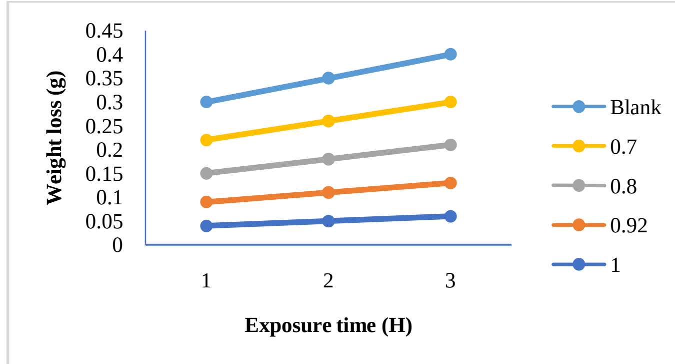

Figure 2D: Weight loss vs contact time for blank and acid solutions containing Hexane root extract at 333K

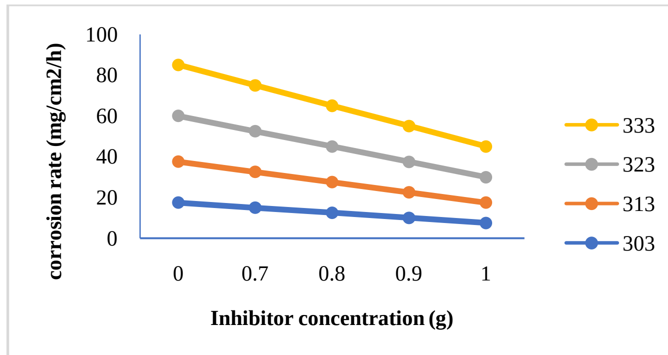

Figure 3A: Variation of corrosion rate with inhibitor (Hexane root extract) concentration at different temperatures for 1h

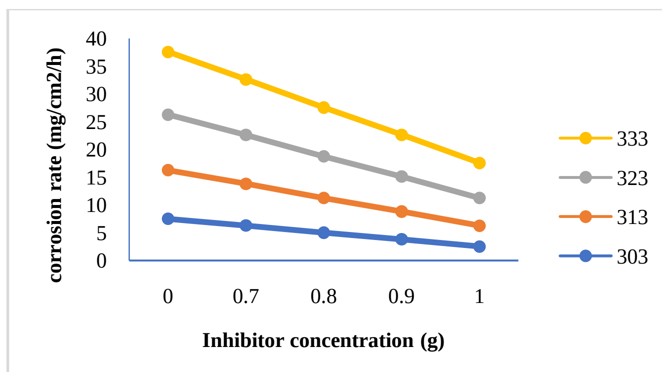

Figure 3B: Variation of corrosion rate with inhibitor (Hexane root extract) concentration at different temperatures for 2h

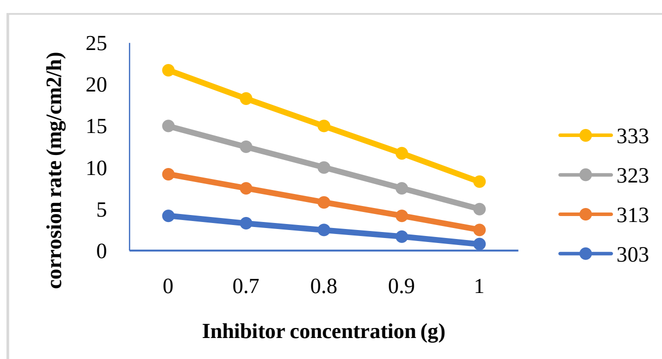

Figure 3C: Variation of corrosion rate with inhibitor (Hexane root extract) concentration at different temperatures for 3h

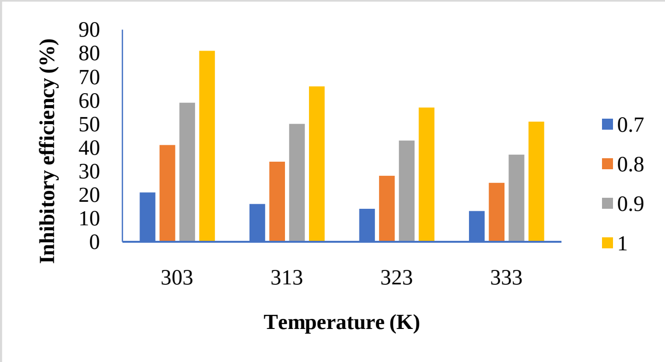

Figure 4A: Variation of IE with temperature at different concentrations of inhibitor (Hexane root extract) for 1h.

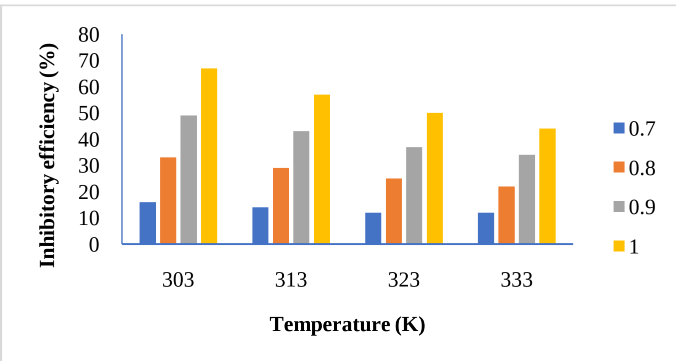

Figure 4B: Variation of IE with temperature at different concentrations of inhibitor (Hexane root extract) for 2h.

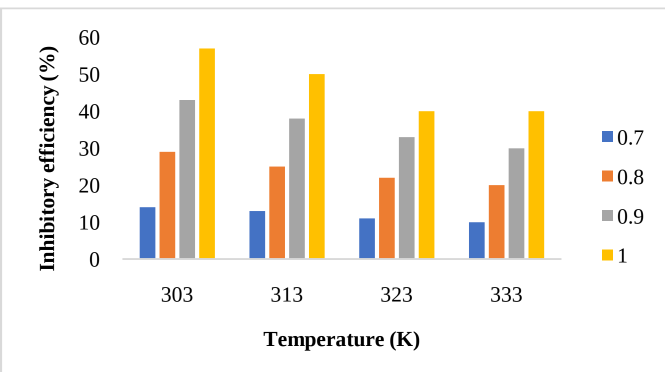

Figure 4C: Variation of IE with temperature at different concentrations of inhibitor (Hexane root extract) for 3h.

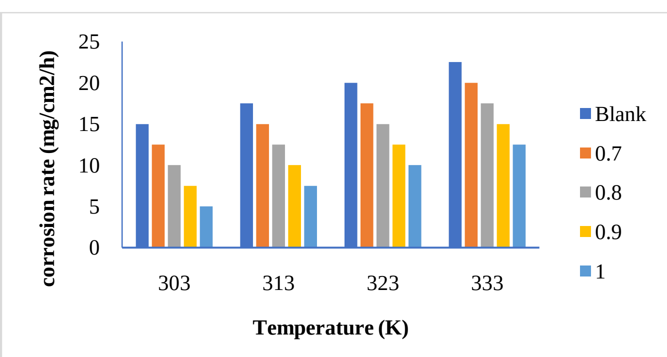

Figure 5: Variation of corrosion rate for different concentrations of inhibitor (Hexane root extract) at different temperatures for 3h.

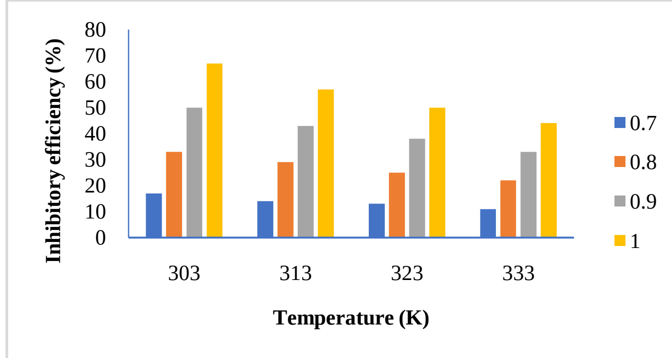

Figure 6: Variation of IE for different concentrations of inhibitor (Hexane root extract) at different temperatures for 3h.

3.2 Discussion

The mild steel corrosion behavior in 0.1M H_2SO_4 was investigated in the absence and presence of *Anogeissus Leiocarpus* root extracts using weight loss methods. Visual observation of the two categories of coupons, (i.e. with and without inhibitor) after exposure reveals changes in colors of coupons from bright shining surface to dull surface. The changes in colors were more intense in coupons exposed to solution without the extract (the control). Variation of weight loss with temperature 303k, 313k, 323k and 333k for mild steel specimen in 0.1M H_2SO_4 solution containing different concentration of *Anogeissus Leiocarpus* are shown in the figures

1A – 1C. The graphs shows that as time increases, the weight loss of mild steel for all solution including blank solution also increases. Also figure 2A – 2D shows that as the inhibitor concentration increases at constant time and temperature the weight loss of mild steel decreased as a result of the inhibitor molecule molecules which covers more of the metal surface as the concentration of the inhibitor increases. This result is in agreement with that of Ahmad et al (2014) who studied the inhibition of aluminum alloy in HCl by date palm leaf extract.

From figures 3A-3C, the graphs shows that corrosion rate is concentration dependent. In the presence of inhibitor, corrosion rate is reduced when compared with the blank. Thus, with the increase in extract (which increases molecules) into 0.1M H_2SO_4 solution, retards corrosion of mild steel and the extend of retardation is depended on both temperature and concentration. According to Niamien et al (2011), that both

corrosion rate and inhibition efficiency of inhibitor, depends on several parameters such as the number of absorption sites (N, S, O, P), charge density, molecular size, heat of adsorption, heat of hydrogenation, and mode of interaction on the metal surface. In figures 4A-4C, the graphs indicates that the inhibition efficiency for mild steel in 0.1M H_2SO_4 medium at different concentration of inhibitor increases with increase in concentration of extract. This is as a result of strong interaction between the inhibitor molecule and the mild steel surface which results in adsorption (Aouniti et al., 2015). In addition, the inhibition efficiency is observed to decrease with increase in temperature from 303 through 333 K. This is because of the desorption of inhibitor molecules on the metal surface at high temperature (Shah et al., 2011). At concentration of 1.0 g/l for temperatures 303 -333 K for 1 h gave the maximum inhibition efficiency of 81, 66, 57 and 51 % respectively. This implies that the longer the exposure time in the acidic medium, the weight loss increases which is as a result of increase in corrosion rate. The reason for this is because considerable amount of the molecules of the inhibitor has been used up by the mild steel (Nazeer et al., 2012)

Figures 5 and 6 gives a summary of the relationship between corrosion rate, inhibition efficiency, concentration of inhibitor, exposure time and temperature. Corrosion rate is dependent on temperature and concentration of inhibitor (figure 5) and same factors affect inhibition efficiency in figure 6.

IV. CONCLUSION AND RECOMMENDATION

The result revealed that, the plant extract of *Anogeisus Leiocarpus* root extract is a good corrosion inhibitor in acidic media and can be applied by the metallurgical industries as corrosion inhibitors. The researchers recommend that further work should be investigated on thermodynamic property and adsorption functions of the hexane root extract of *Anogeisus Leiocarpus.* In addition, other solvents base on polarity such as ethyl acetate, methanol and water is suggested.

REFERENCES

[1] Abdel Rehim, S. S.,El deeb, M., M., Sayyah, S. M. (2009). Corrosion of tin in citric acid solution and the effect of some inorganic anions. Mat. Chem. and Phy., 80(3), 696 – 703.

[2] Ahmad, M. A., Nabeel, A. J., Nuhu, D. M. and Rihan, O. (2014). Thermodynamics and Kinetics of inhibition of Aluminum in Hydrochloric Acid by Date Palm Leaf Extract. Journal of Applied Science and Environmental Management., 18(3), 543-551.

[3] Ameh, P. O., Eddy,N.O., Gambia, C. E. (2012). Physiochemical & rheological studies on some natural polymers & their potentials as corrosion inhibitors. Lambert Academic Publishing, UK, pp. 28 -34.

[4] Anuradha, K.,Vimala,R. Narayanasamy, B., Arokia selvi, J., Rajendran, S. (2008). Corrosion inhibition of Carbon steel in low chloride media by an Aqueous extract of Hibiscus Rose – Sinensis. Linn. Chem. Eng. Comm., 195: 352 – 366.

[5] Aouniti, A., Elmsellem, H., Tighadouini, S., Elazzouzi, M. and Radi, S. (2015). Schiff's Base Derived from 2-acetyl thiophene as Corrosion Inhibitor of Mild Steel in Acidic Medium. Journal of Taibah University for Science, 10, 774-775.

[6] Ayuba, A., & Mustapha, A, (2013). Inhibitive and Synergistic Properties of Ethanolic Extract of Anogeissus Leiocarpus Leaves on the corrosion of Aluminum in HCl solution. Chem.Search Journal, 4, 55-56.

[7] Bothi Raja, P., Sethuraman, M.G.(2008). Natural products as corrosion inhibitor for metals in corrosive media – A Review. Mater Lett., 62: 113 – 116.

[8] Ebana, R. U.B., Madunagu, B. E. Etok, C.A. (1993). Anti-microbial effect of strophantus hipides Secamone afzeli on some pathogenic bacteria and their drug Research strain. Nigeria Journal of Botany, 6,27-31.

[9] Eddy, N. O., Odoemelam, S. A., Ama, I, N. (2010). Ethanol Extract of Ocimum Gratissimum as a corrosion inhibitor for the corrosion of mild steel in H_2SO_4. Green Chemistry letters and Reviews. 1-8.

[10] Eddy, N. O.,Paul, O.,A., Odey, D., Anduang, O. (2014). Adsorption and chemical studies on the inhibition of the corrosion Aluminium in hydrochloric acid by Commiphora africana gum. International journal of chemical, material & Environmental Research, 1(1): 16 -28.

[11] Eddy, N.O., Odoemelam, S. A., Ibiam E. (2009). Adsorption and inhibitive properties of ethanol extract of costus on the inhibition of the corrosion of aluminum in H_2SO_4. Journal of surface Sci. and Technol., 25(3 – 4),1-14.

[12] Frank, K., and Goswarmi, D. Y. (2004).The Hand book of mechanical Engineering: 2nd edition. CRC Press.

[13] Loto, C. A., Loto, R. T., Popoola, A. P. I. (2011). Effect of neem leaf (Azadirachita indica) extract on the corrosion inhibition of mild steel in dilute acids. International Journal of the Physical sciences , vol. 6(9), pp.2249 – 2257.

[14] Mann, A. A. (2008). An antifungal property of crude plant extract from Anogeissus leiocarpus and Terminalia avicennioides. Tanzania Journal of Health Research, Vol. 10,No. 1, pp. 34-38.

[15] Nazeer, A. A. and Fouda, A. S. (2012). Adsorption and Corrosion Inhibition Behavior of Carbon Steel by Cefoperazone as Eco-friendly Inhibitor in HCl. Journal of Materials Engineering and Performance, 2314-2322.

[16] Niamien, P., Essy, F., Trokourey, A., Sissouma, D. and Diabate, D. (2011). Inhibition effects of 2-Mercaptobenzimidazole (MBI) and 2-Thiobenzylbenzimidazole (TBBI) on copper Corrosion in 1M Nitric Acid Solution. Arican Journal of Environmental Science and Technology, 5, 641-652.

[17] Okafor, P. C., Osabor, V.I., Ebenso, E. E. (2007). Eco-friendly corrosion inhibitors: Inhibitive action of ethanol extracts of Garcinia kola for the corrosion of mild steel in H_2SO_4 solutions. Pigment and Resin Technol., 36: 299 – 305.

[18] Selvarant, F. R., Santhamadharasai, S., Sahayaraji, W. J., Amalraj, J. A., Rajendran, S.(20004). Synergistic effect of succinic acid and Zn^{2+} in controlling Corrosion of Carbon steel. Bull. Electrochem., 20, 561 – 565.