Investigation of the Inhibitive Properties of *Mangiferaindica* (Mango) Root Extract on Tin in 0.5M HCl

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Abstract:- The corrosion inhibition of ethanol extract of *Mangiferaindica* on tin (Sn) metal surfaces in 0.5M Hydrochloric acid and at ambient temperature was carried out using the gravimetric method. The results show that the percentage inhibition efficiency (% IE) of the extract increased with a relative increase in concentrations of the inhibitor throughout the test period, indicating physisorption of extract on the tin surface. The highest inhibition efficiency of 99.89% was observed at 1.0 g/L of extract concentration. The percentage inhibition efficiency at various plots did not fall below 79%.At increased concentration of extract, the corrosion rate of tin samples gradually decreased as the days progressed. This behaviour is attributed to higher adsorption level of active inhibitor molecules from the extract on the metal surface forming a thin film on the metal surface to prevent further attack from the corrosive environment thereby reducing weight loss by specimen. The least corrosion rate of 0.00006 was obtained at 1.0g/L extract concentration. The results showed that *Mangiferaindica* root extract is a good inhibitor for the corrosion of tin (Sn) in HCl media. It has a high significant effect on the reduction of the corrosion of tin at room temperature as a result of the formation of films on the substrate thereby displacing water molecules from the metal surface when compared with the uninhibited test media.

Keywords:- *Corrosion Inhibition, Mangiferaindica, Gravimetric, Physisorption, Inhibition Efficiency.*

I. INTRODUCTION

Increasing daily need and use of metallic materials for technological development has unavoidably led to major scientific problems such as corrosion phenomena, control and prevention [1]. The consequences of corrosion are many and varied and the effects of these on the safe, reliable and efficient operation of equipment or structures are often more serious than simple loss of a mass of a metal. Failure of various kinds and the need for expensive replacements may occur even though the amount of metal destroyed is quite small [2]. It has been reported after corrosion cost studies carried out in a number of countries including the United Kingdom, Sweden, Germany, and Finland that the annual cost of corrosion ranged as high as 5% of GNP [3]. This represents a huge sum of money which should have been channeled into the provision of basic social amenities in these countries. According to the Gas and Oil Pipeline Standards (GOST) of Nigeria, the standard lifetime of a pipeline is 33 years but research findings revealed that 18% of pipeline failure is caused by corrosion [4]. In practice, corrosion can never be stopped but can only be reduced significantly or delayed to a reasonable extent.

The use of corrosion inhibitors is the most economical and practical method in reducing corrosive attack on metals. To achieve reduction in the rate of corrosion, addition of small quantity of chemicals called inhibitors, which either encourage film formation or form a barrier-like layer on the metal surface, and by so doing stop or slow down the rate of metal decomposition [5]. Corrosion inhibitors are chemicals, either synthetic or natural which when added in small quantity to an environment decrease the rate of attack by the environment on metals [6]. However, most of the corrosion inhibitors used in processing industry are synthetic in nature, and hence not environmental friendly. Human health hazard like lung cancer are known to have arisen as a result of long time exposure to inorganic inhibitors such as chromates and phosphates. This has led to the use of green corrosion inhibitors which are biodegradable and contain no heavy metals or toxic compounds.

From time, human beings have used plants for their basic needs such as shelters, production of food stuff, fertilizers, flavors and fragrance, clothing, medicines etc. Plants have also been used as corrosion inhibitors [7]. The entire parts of a plant which consists of leaves, stem, bark, root and fruits/seeds have some trace of chemical constituents in different quantities. Most researchers are now exploring all the parts of the plant in order to ascertain their corrosion inhibition capacities and efficiencies on different metals as no parts of the plant should be treated as a waste as long as it has trace of some chemical constituents. [8], made a suitability assessment of neem, mahagony, cashew, locust bean husk, and *Acacia nolitica* pod extracts as corrosion inhibitors. The results showed the ability of the inhibitors to reduce stress corrosion cracking of carbon steel in acidic media. In the same light, [9], studied the inhibitive action of leaves, seeds and a combination of leaves and seeds extracts of *Phyllanthusamarus* on mild steel corrosion in 0.5 MHCl and H_2SO_4 solutions using weight loss and gasometric techniques. The results indicated that the extracts functioned as good inhibitors in both environments, and inhibition efficiency increased with extracts concentration. The temperature studies revealed an increase in inhibition efficiency with rise in temperature. [10], investigated corrosion inhibition effect of *Justiciagendarussa* extract (JGPE) on mild steel in 1 M HCl medium by weight loss and electrochemical techniques. They achieved inhibition efficiency of 93% with 150 ppm JGPE at 25°C. [5], investigated the inhibitive and adsorption properties of ethanol extract of *Terminaliacatappa* for the corrosion of mild steel in 0.5 M and 1 M H_2SO_4solution using weight loss, hydrogen evolution, and infrared methods of monitoring corrosion. The results showed an increase in inhibition potential of ethanol extract of *T. catappa* which they attributed to the presence of saponin, tannin, phlobatin, anthraquinone, cardiac glycosides, flavanoid, terpene, and alkaloid in the extract. [11], investigated the inhibition of low-carbon-steel corrosion in 1M HCl and 0.5 M H_2SO_4 by extracts of *Dacryodisedulis* (DE) using gravimetric and electrochemical techniques. They found that the extract inhibited the uniform and localized corrosion of carbon steel in the acidic media, affecting both the cathodic and anodic partial reactions. [12], modeled *Azadirachtaindica* (Neem) seed extract-inhibited corrosion of mild steel and copper in H_2SO_4medium. They found that copper had a generally lower corrosion rate due to its higher electrochemical potential of +0.02V. More so, at varied concentration of the acidic medium, corrosion for both metals occurred at the highest acid concentration (1.5M H_2SO_4). Therefore, corrosion efficiency was highest when the concentration of acid was lowest (0.5M H_2SO_4).

This study, seeks to carry out an investigation of corrosion inhibition capabilities of ethanol extract of mango (*Mangiferaindica*) root in 0.5M HCl on tin (Sn).

II. EXPERIMENTATION

Materials Preparation

Tin coupon: The low tin sheet coupon used for this research work was obtained from the CIS/ Metallurgy Laboratory of the Federal University of Technology, Owerri (FUTO), Imo State, Nigeria. The dimensions of the tin sheets were 30mm x 30mm x 2mm, with a perforated hole of 2mm diameter. The specimens were polished with 120 – 150 mesh abrasive for a smoother surface, cleaned with acetone, dried in the air and kept in a desiccator.

Acid: 0.5M of HCl was prepared by dissolving 41.5ml of concentrated HCl (which itself had a percentage purity of 37%, molar mass of 36.5g/mol and density of 1.18g/cm^3) in 1000cm^3 of distilled water, in a standard flask to obtain the required concentration.

Extraction of Plant Extracts: The roots of the *Mangiferaindica* were dug up from one of the many trees in the university (FUTO) campus. They were cut to bits, washed, sun-dried for ten days, and then ground to powder using a mechanical grinder. The powdery mass was oven-dried until a constant mass was reached. The extraction process was carried out with the use of a small-scale reflux extractor which is available in the Chemical Engineering Transport Phenomena Laboratory, Federal University of Technology, Owerri. The reflux extractor consists of a reflux condenser and an electric heating mantle.

The solid material (prepared powder roots of mango) was poured into a Pyrex glass round bottom flask containing the extraction solvent (ethanol). The reflux suspended on the retort stand was placed on a round bottom flask containing the extraction solvent. The extraction solvent in the flask was heated over an extended period of time, and its vapours condensed in the reflux condenser. The condensed extract was transferred back into the flask. The process was continued until a maximum extraction had occurred at a given time of two hours.

Extract concentrations: 0.2M concentrate of *Mangiferaindica* root extract was prepared by refluxing 50g of powdered root material in 250ml of ethanol solvent. Hence, a volume of 20ml, 30ml, 40ml and 50ml gave the different concentrations of 0.4g/l, 0.6g/l, 0.8g/l and 1.0g/l of extracts, respectively.

III. GRAVIMETRIC METHOD

The gravimetric process was carried out for tin metal samples of dimension 30mm x 30mm x 2mm. The initial weights of metal coupons were taken, two metals for each test media at different concentrations of inhibitor in acidic media. An uninhibited control was set up. The experiment was carried out at total immersion. In each experiment, 10 cleaned coupons were weighed and immersed completely in the inhibited acid solutions. The same was done for 2 coupons but this time immersed in the control. At ambient temperature of 30^o C, the coupons were retrieved at intervals of 2 days progressively for 21 days; this was to allow for the specimen to react in the solution.

Finally, the samples were washed with running water to remove any corroded product(s), dipped in acetone, dried and re-weighed. The weight loss (ΔW) was taken as the difference between the weight at a given time and the initial weight of the test coupon. The resulting weight losses obtained were used to calculate the corrosion rate (CR) of the tin metal and inhibition efficiency of the extract (IE) as given in equations (1) and (2).

A Corrosion Rate

The expression for measurement of corrosion rate (CR) in millimeters penetration per year (mm/yr) was used to measure corrosion rate (CR) for the specimens, which is expressed as follows:

$$\boldsymbol{C.R.} = \frac{\Delta W}{a \times t} \quad (1)$$

whereΔW is weight loss of tin (g), a is the total surface area of the specimen in (cm^2), t is the exposure time in hours (h), The total surface area of metal sample was derived by:

$$a = 2(xy + xz + yz) \quad (2)$$

where a, x, y and z are the total surface area of specimens, length (30mm),breadth(30mm) and thickness (2mm) of the coupon sample. The density of tin (Sn) is 7.31g/ml.

B Inhibitor Efficiency

The percentage inhibitor efficiency (IE) was calculated using the relation in the equation:

$$IE\% = \frac{CR_0 - CR_I}{CR_0} \times 100\% \quad (3)$$

where CR_I and CR_0 are the corrosion rates in (mm/yr) with and without different concentrations of the extracts, respectively [13].

IV. RESULTS AND DISCUSSION

The following results were obtained during the gravimetric experimentation carried out to ascertain the corrosion inhibition of tin (Sn) metal sheets in 0.5M HCl media at various concentrations of *Mangiferaindica* root extract.

A Weight loss

The results from weight losses for tin specimens immersed in 0.5M HCl for 21 days at 2 days intervals for each of the six media as displayed in Table 1 and Figure 1, show that the weight losses for all the different concentrations were less compared to the control medium. As days increased from 2 to 20 days for the different concentration of extracts from 0.2g/L – 1.0g/L, it was observed that the highest weight loss was about 0.34g compared to 1.68g for the control medium . This showed that the inhibitor was effective in reducing corrosion. The weight loss after 20 days for 0.1g/L concentration of extract was highest while for 1.0g/L was least. This showed that the best corrosion inhibition was obtained at 1g/L. Thus, at increased concentration, the weight loss of the metal samples reduced. Considering equal time intervals, it was observed that weight loss decreased as extract concentration increased from 0.2 to 1.0 g/L.

Table 1: Values of average weight loss obtained after experimentation.

Concentration of Inhibitor extract (g/L)	0	2 days	4 days	6 days	8 days	10 days	12 days	14 days	16 days	18 days	20 days
0.2	-	0.0315	0.0720	0.0840	0.065	0.182	0.034	0.162	0.1715	0.199	0.3405
0.4	-	0.0315	0.052	0.0895	0.1235	0.146	0.033	0.181	0.1635	0.2065	0.3235
0.6	-	0.015	0.0265	0.080	0.111	0.001	0.009	0.157	0.1465	-0.34	0.211
0.8	-	0.0445	0.0345	0.1015	0.1365	0.141	0.055	0.2005	0.1825	0.193	0.232
1.0	-	0.023	0.001	0.0485	0.0735	0.055	0.033	0.116	0.068	0.1535	0.160
Control	-	0.5495	0.8985	1.168	1.3155	1.328	1.3915	1.5975	1.6135	1.634	1.6805

This also showed that there was increase in corrosion inhibition with increase in extract concentration. Obviously, there were slight deviations from the trend which can be as a result of non-uniform immersion of test coupons. The tin samples in the control medium relatively corroded more than the inhibited media. This can be explained from the uninterrupted displacement of hydrogen ions that led to the oxidative formation of the chloride of tin.

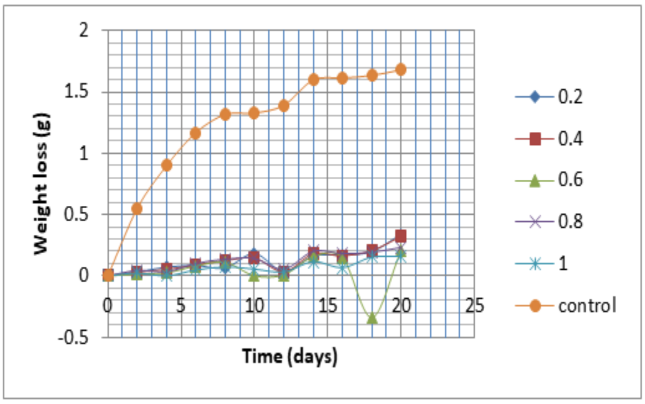

Fig 1: Variation of Weight loss with Time

B Corrosion rate

Corrosion is an oxidative reaction and redox reaction at best. Hence, from the wide variance of the control medium and the inhibited media, it can be deduced that the phytochemicals present in the *Mangiferaindica* root extract are antioxidative, hence, a reduced corrosion rate was observed in the inhibited media. At increased concentration of extract, the corrosion rate of tin samples gradually decreased as the days progressed. This behaviour is attributed to higher adsorption level of active inhibitor molecules from the extract on the metal surface forming a thin film on the metal surface to prevent further attack from the corrosive environment thereby reducing weight loss by specimen, which is in agreement with the findings of [8], [9] and [14].

Table 2: Corrosion Rate (g/cm²/day)

Concentration of Inhibitor extract (g/L)	0	2 days	4 days	6 days	8 days	10 days	12 days	14 days	16 days	18 days	20 days
0.2	-	0.00071	0.00088	0.00069	0.00040	0.00089	0.00014	0.00110	0.00053	0.00054	0.00083
0.4	-	0.00078	0.00064	0.00074	0.00076	0.00072	0.00013	0.00063	0.00050	0.00056	0.00079
0.6	-	0.00037	0.00033	0.00065	0.00068	0.00058	0.00004	0.00055	0.00045	0.00044	0.00052
0.8	-	0.00110	0.00043	0.00083	0.00084	0.00069	0.00022	0.00070	0.00056	0.00053	0.00057
1.0	-	0.00056	0.00006	0.00040	0.00045	0.00029	0.00013	0.00041	0.00021	0.00042	0.00039
Control	-	0.01300	0.01100	0.0095	0.00810	0.00650	0.00570	0.00560	0.00490	0.00440	0.00410

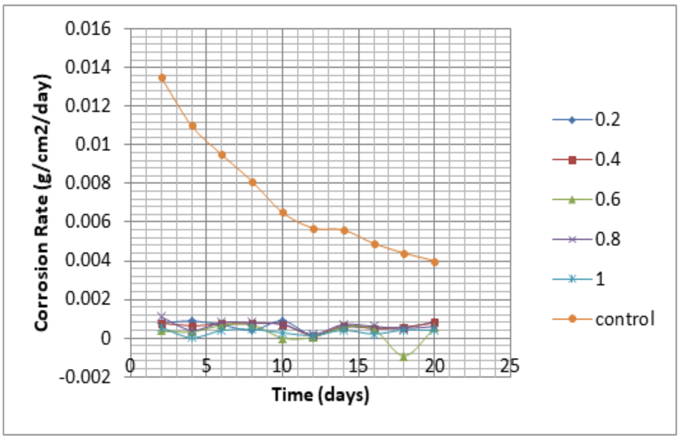

Fig 2: Corrosion rate against time

C Inhibition efficiency

From the results obtained as presented in Table 3 and Figure 3, percentage inhibition efficiency increased with concentration of extract. At 1.0g/L *Mangiferaindica*extract in 0.5M of HCl, the inhibition efficiency experienced was highest at 99.89% relative to other concentrations of extract except at 0.6g/L which was 120%. This value (120%) is not achievable; it actually came about as a result of obvious deviation from the trend probably due tonon-uniform immersion of test coupons during the conduct of the experiment.The percentage inhibition efficiency at various plots did not fall below 79%.

More so, it was noticed that inhibition efficiency generally decreased with time. This could be due to the fact that the extract gradually lost its inhibitive effect on the test coupons as the days went on.

Table 3: Inhibition Efficiency in percentage (%)

Concentration of Inhibitor extract (g/L)	0	2 days	4 days	6 days	8 days	10 days	12 days	14 days	16 days	18 days	20 days
0.2	-	94.27	91.99	92.81	95.06	86.3	97.56	89.86	89.37	87.82	79.74
0.4	-	94.27	94.21	92.34	90.57	89.01	97.63	88.67	89.87	87.36	80.75
0.6	-	97.27	97.05	93.15	91.56	99.92	99.35	90.17	90.92	120.81	87.44
0.8	-	91.90	96.16	91.31	89.62	89.38	96.05	87.45	88.69	88.19	86.19
1.0	-	95.81	99.89	95.85	94.41	95.86	97.63	92.74	95.79	90.61	90.48
Control	-	-	-	-	-	-	-	-	-	-	-

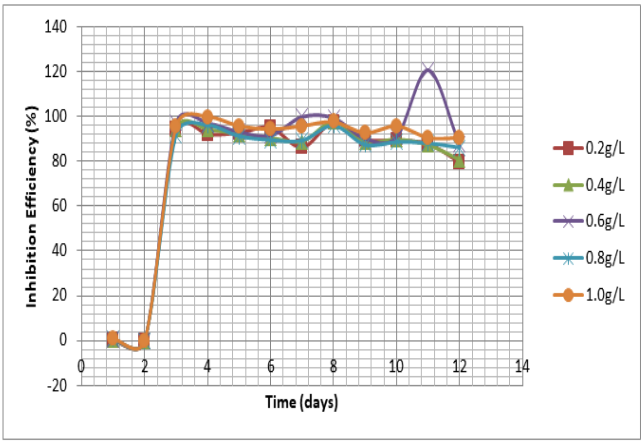

Fig 3: Variation of Inhibition efficiency with Time

V CONCLUSION

Mangiferaindica extract is a good inhibitor for the corrosion of tin (Sn) in HCl media. It has a high significant effect on the reduction of the corrosion of tin at room temperature as a result of the formation of films on the substrate thereby displacing water molecules from the metal surface when compared with the uninhibited test media.

The efficiency of the inhibitors increased with increased concentration (physisorption). The inhibition efficiency of the extracts at room temperature at gravimetric conditions was 99.89% at 1.0g/L of extract concentration.

REFERENCES

[1]. Loto C.A., LotoT.R. and PopoolaI.P.A. (2011), *"Corrosion and Plant Extracts Inhibition of Mild Steel in HCl",*.International Journal of The Physical Sciences, 6(15), pp3616-3623.

[2]. Umoren A.S. (2009) *"Polymers as Corrosion Inhibitors for Metals in different Media : AReview"*,The Open Corrosion Journal, 2, pp.175-188.

[3]. Corrosion Control Solutions (n.d.).Retrieved March 12, 2013,fromhttp://www.correx.com/library_corrosion_control_solutions.php.

[4]. Achebe, C.H.,Nenke, U.C., and Anisiji, O.E.(2012),"*Analysis of Oil Pipeline Failure in the Oiland Gas,"*Retrieved March13, 2013 from http://www.iaeng.org/publication/IMECS2012/IMECS2012 pp1274-1279.

[5]. Obot I.B. and Obi-Egbedi N.O. (2010), *"An Interesting and Efficient Green Corrosion Inhibitor for Aluminium from Extracts of Chlomolaenaodorata L. in Acidic Solution"*, Journal of Applied Electrochemistry, 40(11), pp.1977–1983.

[6]. Lebrini M., Robert F., LecaniteA. and RoosC. (2011),*"Corrosion inhibition of C38 steel in 1M hydrochloric acid medium by alkaloids extract from Oxandraasbecki plant"*,*Corrosion Science*, 53(2), pp. 687-695.

[7]. Benali, O, Benmehdi, H., Hasnaoui, O., Selles, C. and Salghi, R. (2013). Green Corrosion Inhibitor: Inhibitive action of tannin extract of *Chamaeropshumilis* plant for the corrosion of mild steel in 0.5M H_2SO_4. *J. Mater. Environ. Sci*., 4(1) pp. 127 – 138.

[8]. Yawas D.S. (2005),*"Suitability Assessment of some Plant Extracts and Fatty acid Vegetable oils as Corrosion Inhibitors"*, Ph.D. Dessertation in the Department of Mechanical Engineering, Ahmadu Bello University (A.B.U.), Zaria, Nigeria.

[9]. Okafor C.P., Ikpi E.M.,Uwah I.E., EbensoE.E., Ekpe and Umoren, .A.S. (2008),*"Inhibitory Action of Phyllanthusamarus Extracts on the Corrosion of Mild Steel in Acidic Media"*, Corrosion Science, 50(8), pp.2310-2317.

[10]. Satapathy, K.A, Gunasekaran,G, Sahoo, C.S, Amit, .K, and Rodrigues,V.P, (2009). *"Corrosion Inhibition by Justiciagendarussa Plant Extract in Hydrochloric acid Solution"*,Corrosion Science, 51(12),pp.2848-2856.

[11]. OguzieE.E., Enenebeaku C.K., Akalezi O.C. Okoro C.S.AyukA.A. and Ejike E.N. (2010),*"Adsorption and Corrosion-inhibiting Effect of Dacryodisedulis Extract on Low-carbon-steel Corrosion in Acidic Media"*,*Journal of Colloid and Interface Science*, 349(1), pp.283-292.

[12]. Ekeke I.C., Osoka E.C., Etim C.E., Ojiaku C.E., Eluagu P.U. andIgwemoh H.E. (2019),*"ModellingAzadirachtaindica (Neem) seed extract-inhibited corrosion of Mild Steel and Copper in H_2SO_4 Medium"*, Department of Chemical Engineering, Federal University of Technology, Owerri, Imo State, Nigeria.

[13]. Khaled, K.F, (2008),*"New Synthesized guanidine derivative as a green corrosion for mild steel in acidic solutions"*, International Journal of Plant, Animal and Enviroment, (3), pp. 462-475.

[14]. Kairi I.N. and Kassim J. (2013), *"The Effect of Temperature on the Corrosion Inhibitionof Mild Steel in 1 M HCl Solution by Curcuma Longa Extract"*,International Journal ofElectrochemical Science, (8), pp. 7138–7155.

[15]. Callister Jr. W.D. and Rethwisch D.G. (2010),*Material Science and Engineering: AnIntroduction* (8^{th} edition),New York: John Wiley & Sons Inc., USA, pp. 674 – 718.

[16]. Nwabanne J.T. and Okafor V.N. (2011),*"Inhibition of the Corrosion of Mild Steel in Acidic Medium by Vernoniaamygdalina": Adsorption and Thermodynamics Study*,Journal of Emerging Trends in Engineering and Applied Sciences, 2(4): pp.619-625.