PRINT ISSN 1119-8362
Electronic ISSN 1119-8362

Full-text Available Online at
https://www.ajol.info/index.php/jasem
https://www.bioline.org.br/ja

J. Appl. Sci. Environ. Manage.
Vol. 26 (1) 25-29 January 2022

Inhibitive Effect of *Irvingia Gabonensis* Leaf Extract on the Corrosion of Mild Steel in 1.0M Hydrochloric Acid

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ABSTRACT: This investigation utilizes leaf extracts as corrosion inhibitors and studies the inhibitive effect of *Irvingia gabonensis* leafextracton mild steel immersed in 1.0M HCl acid at ambient conditions. The phytochemical constituents responsible for the corrosion inhibition were determined by standard phytochemical methods. The chemicals detected were alkaloids, flavonoids, saponins, and tanins. The study was carried out using eleven (11) experimental setups, which consisted of: 1.0M HCl (control 1), 10ml, 15ml, 20ml, and 25ml extracts in 1.0M HCl and distilled water (control 2). The experiment was conducted using the weight loss/corrosion rate measurement technique and the results showed that the extract concentration and exposure time had effects on the corrosion rate, whilst the 25ml extract inhibited the most in the acidic medium.The results of the experiment with the two-factor ANOVA without replication indicated that the extract concentration had a more significant effect on corrosion rate than the exposure time. Having this in mind, the inhibitive effect of *Irvingnia gabonensis* (Africa mango or ogbono) leaf extract as an organic "green" inhibitor on mild steel corrosion in an acidic medium can be said to depend on the concentration of the extract for better effectiveness and inhibition efficiency. Therefore, Irvingia gabonensis leaf extract, with an inhibition efficiency of 67.14% on mild steel in a moderate acidic environment, can be recommended for use in commercial and industrial environments where mild steel material is required in service.

DOI: https://dx.doi.org/10.4314/jasem.v26i1.4

Impact factor: http://sjifactor.com/passport.php?id=21082

Google Analytics: https://www.ajol.info/stats/bdf07303d34706088ffffbc8a92c9c1491b12470

Dates: Received: 23 August 2021; Revised: 21 December 2021; Accepted: 06 January 2022

Keywords: Inhibition, *Irvingia Gabonensis*, Phytochemical, Inhibition Efficiency

Mild steel are used in a wide variety of applications in construction, automobile and domestic appliance industries. Its high quality, endurance, good formability and relatively low cost are some of the reasons for the widespread use of these materials. However, one of the disadvantages of mild steel is that they are prone to corrosion causing aesthetic defects and deterioration of its mechanical properties. These steel materials are use in modern industries for major construction of engineering products. These equipment are exposed to high level of polluted atmosphere where corrosion is relatively severe; this can either be acidic or alkaline in nature which brings about the deterioration of the engineering structures and eventual failure if not carefully protected. (Okuma et al., 2020 and William et al., 2010). Material selection, coatings, design, alteration of environment, cathodic and anodic protection can be used to control corrosion (Leelavathii et al.,2013).But there is a growing trend to utilize plant extracts and pharmaceutical compounds as corrosion inhibitors, which are environmentally safe, readily available and of relatively low cost. Available literature has shown that naturally occurring plant leaves such as *Azadirachtaindica* leaves, *Murrayakoenigii* leaves, *Ervatamiacoronaria* leaves, *Ananascomosus* leaves, *Purpurea leaves*, *Olive* leaves have been reported to inhibit the corrosion of metals in acidic media (Oguzie, 2010). Some of these results were gotten from using electrochemical and weight loss monitoring methods and the indicate that all the extract inhibited the corrosion process by virtue of adsorption of their phytochemical constituents on the corroding steel surface and inhibition efficiency improved with concentration of the active constituents (Okuma et al., 2020).Suitable inhibitor is required to

mitigate the rate of corrosion on mild steel in order to achieve a useful service life (wikipedia.Org).

Therefore, this research is concerned with the inhibitive effect of *Irvingia gabonensis* leaf extract on the corrosion of mild steel in 1M HCl acidic environments. *Irvingia gabonensis* is indigenous to the humid forest zone from the northern tip of Angola, including Congo, DR Congo, Nigeria, Côte d'Ivoire and south-western Uganda. It is planted in parts of this area, *e.g.* in south-western Nigeria and southern Cameroon, and also in Côte d'Ivoire, Ghana, Togo and Benin. Irvingia gabonensis grows straight, up to a height of 40 metres (130 ft) and 1 metre (3 ft 3 in) in diameter. It has buttresses to a height of 3 metres (9.8 ft). The outer bark is smooth to scaly with grey to yellow-grey color. The crown is evergreen, spherical and dense. Leaves are elliptic; one margin is often a little rounder than the other, acuminate, dark green and glossy on the upside. Flowers are yellow to greenish-white in small panicles.

The flowers are bisexual. The fruit is nearly spherical, green when ripe with a bright orange pulp (Olesegun et al., 2004). Determining the inhibitive of *Irvingia gabonensis* leaves extract as a corrosion inhibitor of mild steel in acidic and alkaline media will ensure the following: Reduce cost in controlling mild steel since *Irvingia Gabonensis* leaves extract is readily available and cheap, Since the extract is a green inhibitor, which is non-toxic, it will promote the successful use of mild steel in various environments and can be easily discharged without causing harm to the environment, requiring no further treatment and also the media used for the experimental study and the evaluation of the phytochemical constituent of the extract will ensure its wider application in the industry as well as for domestic purposes. Olusegun *et al* (2004) carried out a research on inhibitive effect of *citrus paradisi* (Grape fruit) on the corrosion of mild steel in HCL using weight loss technique in the temperature range of 30^0c to 50^0c,the inhibitive efficiency increased with increase in inhibitive concentration but decrease with an increase in temperature.(Singh et al., 2010) evaluated the inhibition of the corrosion of mild steel in hydrochloric acid solution by the extract of Kalmegh (Andrographis paniculata) leaves extracts. Inhibition was found to increase with increasing concentration of the extract. The inhibition was assumed to occur via adsorption of the inhibitor molecules on the metal surface which obeyed Langmuir adsorption isotherm. Therefore, this investigation utilizes leaf extracts as corrosion inhibitors and studies the inhibitive effect of *Irvingia gabonensis* leaf extracton mild steel immersed in 1.0M HCl acid at ambient conditions.

MATERIALS AND METHODS

Preparation of Test Material and Media: Corrosion test samples used for the study were cut and prepare from a commercially bought mild steel coupon, with nominal chemical composition(C=0.0080, Cu=0.027, Fe=99.6, Mn =0.271, P=0.003, Si=0.0001, S=0.0092, Ni=0.026, Cr=0.011) %.Other items such as analytical grade 1.0M HCL acid,1.0M NaOH solution,96% analytical grade n-Hexane and distilled water were purchased from a chemical store at Owerri Open Market, Imo State, Nigeria. *Irvingia gabonensis* leave were bought from Oguta1,Imo State, Nigeria, the leave were washed, sundried in open air at about 30^0c to $–40^0$c for ten days to ensure proper removal of moisture and subsequently grounded using a 20kg grinding mill to near powder particles, the juice is then extracted and tied with a cloth material, soaked in a bottle of analytical grade n-Hexane solvent for about two days.250ml of the resulting solution was then poured into a flask and heated to reflux at about 70^0c for 3hrs as shown in Figure.1**.**

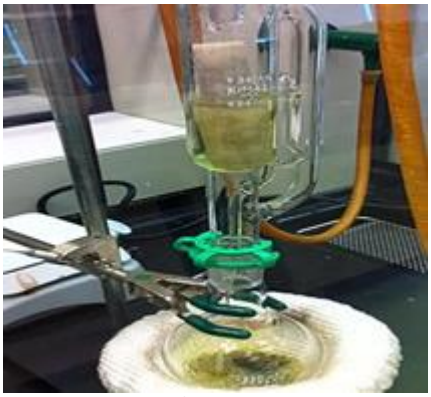

Fig 1: An Assembly of a laboratory soxhlet extractor

Fig 2: Immersion of Sample test Medium

Quantitative Phytochemical Analysis: The quantitative tests were carried out using standard methods of analysis of alkaloids, flavonoids, tannins, saponins and resins as described (Olawale. 2007).

Fig3: pH Measurement of Test Media using HI 221O pH Meter

*Test for alkaloids:*1 cm³ of 1% HCl was added to 3cl of each extracted in a test tube. Each extract was treated with few drops of Meyer's reagent. A creamy white precipitate was observed indicating the presence of alkaloids.

Test for flavonoids: 2cm³ of extract was heated with 10cm3 of ethyl acetate in a water bath and cooled. The layers where allowed to separated and the colour NH3 layer was (red coloured) formed.

Test for tannins: Two drops of 5% $FeCl_3$ was added to 1cm³ of extract. A dirty – green precipitate was in the extract.

Test for saponins: Frothing Test: 2 cm³ of Irvingia gabonensis extract in a test tube was vigorously shaken for 2mins, frothing indicating the presence of saponin

Test for resins: 5 cm³ of copper was added to 5cm³ of Irvingia gabonensis extract, the resulting solution was shaken vigorously and allowed to separate. A green coloured precipitate indicating the presence of resin.

Experimental Analysis: This study was based on the inhibition efficiency of *Irvingia gabonensis* leaf extract as a corrosion inhibitor for mild steel. The result of the corrosion rate and corroded surface area can be calculated by the formula given below.

$$Corrosion\ rate\ (mm/yr) = \frac{KW}{\rho At} \ldots\ldots (1)$$

Where: W = weight loss (mg); ρ = density of specimen (g/cm³); A = area (cm²) = 13.6701cm²; t = exposure time (hr.); K = 87.60

Surface Area (cm²) = 2 $(LB + LT + BT)$ – 2 $(\frac{\pi D^2}{4})$ – (πDT) …. (2)

Where: L = length of the coupon; B = width of the coupon; T = thickness of the coupon; D = diameter of the coupon

For the coupons used;

Surface Area (cm²) = 2 $(3*2 + 3*0.2 + 2*0.2)$ – 2 $(\frac{3.14*0.3^2}{4})$ – $(3.14 * 0.3 * 0.2)$ = 13.6701cm²

RESULTS AND DISCUSSION

Weight Loss and Corrosion rate: The data obtained from the experiment is presented in figure 4 for inhibitor extract in 1.0M HCl solution. The mild steel coupons immersed in 1.0M HCl solution without any inhibitor (control 1) had the most weight loss for the duration of 576hrs with the total weight loss of 1610mg.For the inhibited setups the weight loss decreased with increased concentration of the inhibitor in each of the 1.0M HCl solutions. This could have been due to a larger concentration of the inhibiting species contained in the solution with 25ml extract having the greatest inhibiting effect with a total weight loss of 510mg.The corrosion rates of the mild steel coupons are as shown in Table 1 and presented in Figure 4 for 1.0M HCl solution. From the plots, the specimen without inhibitor in 1.0M HCl solution had the highest corrosion rate throughout the experiment and the samples with inhibitor all had low corrosion rates, with the specimen in 25ml inhibitor having the least corrosion rate of approximately 0.7464mm/yron the 576hrs. This high corrosion rate as observed in the 1.0M HCl solutions can be further attributed to the presence of Cl^- ions while the distilled water (control 2) medium which contains OH^- recorded a relatively low corrosion rate of 0.08548mm/yr.

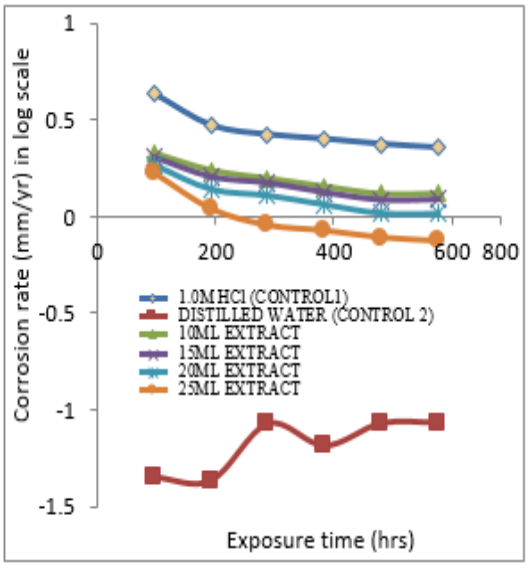

Fig 4: Plots of Corrosion rate (mm/yr) against exposure time (hrs)

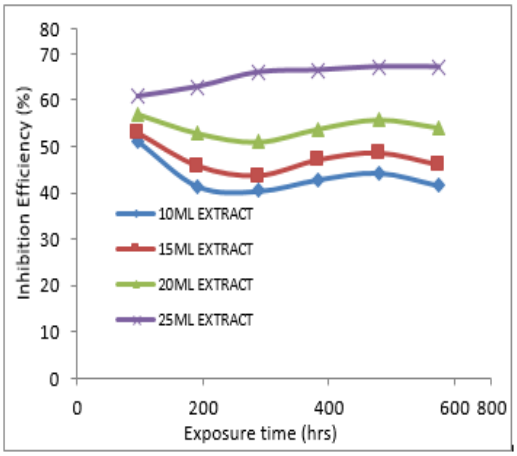

Fig 5: Plots of Inhibition Efficiency (I.E %) Against Exposure time

The results of the inhibition efficiency obtained by calculations is presented in Figure 5 for the 1.0M HCl. There was increasing inhibition efficiency gradually as the exposure time increased with the highest inhibition efficiency of 67.14% on the 25ml concentration for the 480hrs duration. This phenomenon is caused by the extract adsorbing on the surface of metal and depresses further metal dissolution and reduction reactions.

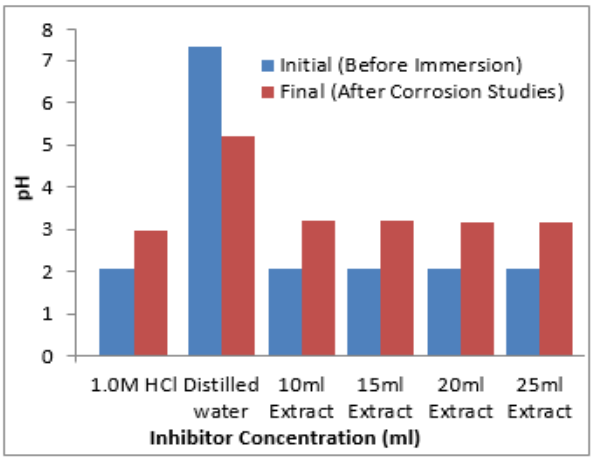

Fig 6: plots of pH against Inhibitor Concentration

The pH measurement result, as shown in Figure 6, illustrates the pH of the various solutions before and after corrosion studies. The results show a significant increase in the pH values of all solutions evaluated.

Statistical Analysis: Two –factor single level experiment ANOVA test (F-test) was used to evaluate the separate and combined effects of concentration of *Irvingnia gabonensis* extracts and exposure time on the weight loss of mild steel in 1.0M HCl solution using Microsoft Excel Spread sheet. The F-test was used to examine the amount of variation within each of the samples relative to the amount of variation between samples. The sum of samples among columns (exposure time) was obtained with equation provided in the Microsoft Excel Spread Sheet.

On the basis of the results shown in Table 4 and presented in Figure 7 below, it can be concluded with 95% confidence that the exposure time and concentration of *Irvingia gabonensis* leaf extract partially affects the corrosion rate of mild steel in 1.0M HCl environment. It can be seen from the correlation of the graphical chart Plots of F-values showing the influence of exposure time and concentration of *Irvingia gabonensis* leaf extract on weight loss measurements in 1.0M HCl. It was further observed that the concentration of *Irvingia gabonensis* leaf extract had greater significant effect on the corrosion rate with F value of 20.34583; while the exposure time has a lesser effect on the weight loss with F value of 1.231856.

Phytochemical Analysis: The summary of the results from the quantitative phytochemical analysis of *Irvingia gabonensis*leaf extract, the biochemical species detected were alkaloids, flavonoids, saponins, tanins and resins. Among which tanins was identified to be the most active biochemical inhibitor. It is sold under the brand name Nox Primer, used for the production of anti-corrosive primer for the treatment of rusted steel surfaces prior to painting, and as a rust converter to transform oxidized steel into a smooth sealed surface and rust inhibitor (William et al 2010).

Surface Morphological Analysis: The scanning electron microscope micrographs revealed that in the absence of inhibitor, the surface was heavily corroded with formation of pits, however in the presence of inhibitor, there was significantly less damage on the surface, as shown in Figures 8 (a), (b), and (c) .The attack could be caused by the presence of chloride ion in acidic media. Because of the reactions of these substances, the layer thickness of the coating varies, resulting in localized corrosion characterized by pits formation. However, when the leaf extract inhibitor is added, the process is slowed; this was attributed to the mild steel surface forming an excellent protective coating.

Conclusion: From the corrosion studies, Irvingia gabonensis (African mango) leaf extract significantly reduced mild steel corrosion; the inhibitor demonstrated an inhibition efficiency of around 67.14% in a 25-ml concentration of 400 ml of 1.0M HCl solution. Because the inhibitor is easily obtained

and environmentally friendly, it is therefore recommended that Irvingia gabonensis (African mango) leaf extract be used as a green inhibitor for moderate acidic environments in commercial and industrial settings where mild steel is required in services

Table 4: Summary of ANOVA analysis for weight loss measurements in 1.0M HCl

Source of Variation	SS	df	MS	F	P-value	F crit
Exposure time(hrs)	89259	5	17851.75	1.231856	0.412294843	5.050329058
Concentration of ***Irvingiagabonensis***	294847	1	294846.8	20.34583	0.006337193	6.607890974
Residual	72459	5	14491.75			
Total	456564	11				

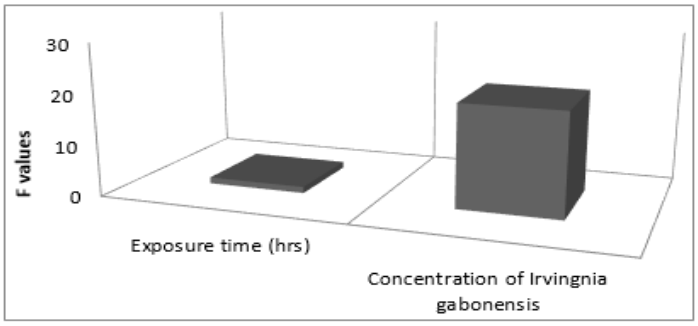

Fig 7: plots of F values showing the influence of exposure time and concentration of *Irvingia*gabonensis on Weight loss measurements in HCl

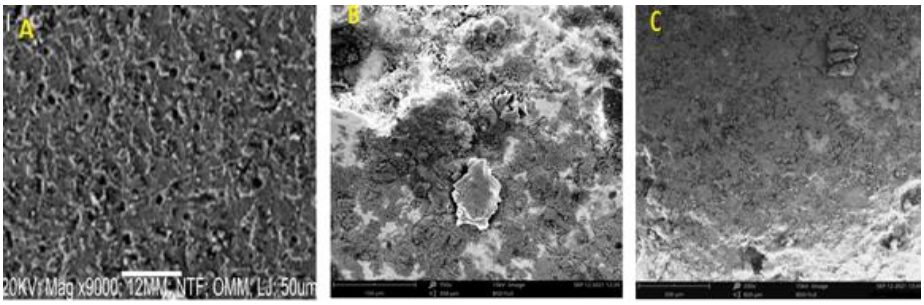

Fig 8: SEM micrographs of mild steels after corrosion in 1 M HCl containing Irvingia Gabonensis extract at 40^{o} C (a) without inhibitor & (b) 10ml inhibitor extract (c) 25ml inhibitor extract

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