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Distinctly Productive Eco-Friendly Corrosion Inhibitor for Mild Steel In Acidic Mixtureunder Different Conditions: Experimental Study

Mahima Srivastava
Associate Professor, Department of Chemistry, DBS (PG) College, Dehradun - 248001, India.

ABSTRACT
Administration of leaf extract of green inhibitor (commonly known as Borrachero or Morning Glory) on corrosion of mild steel in acid solution in paste form was investigated using traditional weight loss measurements techniques. For different solution concentrations in the form of paste, corrosion inhibition efficiency of Borrachero leaf extracts was assessed with the help of weight loss measurements.For comparison, date of rust dissolution in liquid state has also been furnished. Various physical parameters have been covered for the sake of overall inhibitor efficiency under different environmental conditions. From the results, Borrachero leaves have a good potential as environment friendly, green, corrosion inhibitor.
KEYWORDS*: mild steel, corrosion, inhibitor, dissolution, parameters, Borrachero leaf.*

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I. INTRODUCTION

Iron and mild steel are used in large quantities for structural purposes and for fabrication of machine tools. Along with rust there are other problems with iron [1][2]. Because of the slow rate of formation of the hydrogen molecule in some cases, it penetrates the crystal lattice and deforms it leading to brittleness of metal. Organic, inorganic, or a mixture of both inhibitors can inhibit corrosion by either chemisorption on the metal surface or reacting with metal ions and forming a barrier-type precipitate on its surface [3].

Due to the toxic nature and/or high cost of some chemicals currently in use as inhibitors, it is necessary to develop environmentally acceptable and inexpensive ones. Natural products can be considered as a good source for this purpose. The aqueous extracts from different parts of some plants such as Henna, *Lawsoniainermis* [4], Rosmarinousofficinalis L. [5], *Carica papaya* [6], *cordialatifolia* and curcumin [7], date palm, *phoenix dactylifera,* henna, *lawsoniainermis,* corn,*Zea mays* [8], and *NypaFruticansWurmb*[9] have been found to be good corrosion inhibitors for many metals and alloys. Leaves extracts are used as common corrosion inhibitors. The anticorrosion activity of Meethineem (*Murrayakoenigii),*Amla (*Emblicaofficianilis*), Black Myrobalan (*Terminaliachebula*), soapberry (*Sapindustrifolianus*), and Shikakai (*Accaciaconicianna*) was investigated. Corrosion inhibition has also been studied for the extracts of Beautiful swertia (*Swertiaangustifolia*). Similar results were also shown by Eucalyptus (*Eucalyptus sp.*) leaves, Jambolan (*Eugenia jambolana*), sugar-apple (*Annonasquamosa*), Babul (*Acacia Arabica*), Papaya (*Carica papaya*), Neem (*Azadirachtaindica*) and Ironweed (*Vernoniaamydalina*) were used for steel in acid media. Attap palm leaves were studied for the corrosion inhibition of mild steel in HCl media. In addition tothese, the use of herbs such as coriander, hibiscus, anis, black cumin, and garden cress as new type of green inhibitors for acidic corrosion of steel has also been seen [10 - 15].Seeds are of great concern for corrosion inhibition studies. Tobacco (*Nicotiana*), black pepper (*Piper nigrum*), *acacia* gum, and lignin can be good inhibitors for steel in acid medium. *Papaya*, *Poinciana pulcherrima*, Fedegoso (*Cassia occidentalis*), and Datura (*Daturastramonmium*) seeds are efficient corrosion inhibitors for steel [16 - 18].

In the present work our aim is to use inhibited pickling acid in the paste form so that it can be conveniently applied on large structures as well as on small tools to be pickled / cleaned. As a contribution to the current interest on environment friendly, green, corrosion inhibitors, the present study investigates the inhibiting effect of leaves of Borrachero or Morning Glory [***Iopomea carnea***], a green inhibitor. It is quite cheap and very easily available.

II. EXPERIMENTAL

Mild steel (Fe 99.30%, C 0.076%, Si 0.026%, Mn 0.192%, P 0.012%, Cr 0.050%, Ni 0.050%, Al 0.023%, and Cu 0.135%) panels of size 10 cm * 7.5 cm of pickled cold rolled closed annealed mild steel (18 SWG) cut from a single sheet were used in all experiments. For identification of specimens all were numbered and a suspension hole of about 2 mm diameter near upper edge was made. The specimens were polished to mirror finish with emery paper. They were cleaned with cotton to remove powder and traces of adhered metal, and then they were degreased with sulfur – free toluene followed by cleaning with methanol before experiments.

All the acid and chemicals used in the experiment were of AR grade quality. Distilled water was used for the preparation of solution. In the study, 4N solutions of acid were prepared.

Clay – soil was collected, washed, dried, powdered and sieved. 100 gm sieved soil was taken in a plastic glass with a hole at the bottom. This glass was put over uninhibited and inhibited acids. Soil-soaked acid uniformly and thus pickling paste was prepared. 100 gm soil soaked 31.3 cc acid.

Polished and weighed panels were suspended by a V-shaped hook made of capillary over 100 % humidity for 6 months at room temperature. In 6 months, heavy rust appeared on the panels. Panels were re-weighed to get the amount of rust.

Pickling paste was applied over weighed rusted panels under different conditions. After the experiment, paste was removed by washing with saturated sodium bicarbonate solution. The panels were again washed with water and dried with hot air. The panels were finally weighed to get the amount of rust dissolved. Experiments were conducted in triplicate and mean value is reported in the Table.

The Borrachero leaves were dried, crushed, and powdered. This powder thus obtained was used as inhibitor. 1 mg of it was added to 100 cc of acid and kept for 24 hours. This acid was used for the preparation of inhibited pickling paste.

The inhibitor efficiency was calculated from the following equation:

$$\%IE = \frac{W_{uninhibited} - W_{iinhibited}}{W_{uninhibited}} * 100$$

Where,

%IE = Inhibitor efficiency
$W_{uninhibited}$ = Wt. loss without inhibitor
$W_{inhibited}$ = Wt. loss with inhibitor

Variables Studied:

A. Rate of dissolution in Uninhibited System
1. Effect of Change of Concentration of acids
2. Effect of Time of Application
B. Rate of dissolution in Inhibited System
1. Effect of Concentration of inhibitor in acid mixture
2. Effect of Change of Concentration of acids
3. Effect of Time of Application

III. RESULT AND DISCUSSION

A. Dissolution Rate in Uninhibited System

1. Effect of Change of Concentration of HCl and H_2SO_4

4N HCl and H_2SO_4mixed in different proportions from 0-100 to 100-0 and then they were made to paste. Rate of dissolution of rust due to paste and attack of mild steel due to paste given in Table 1 and figure 1[a, b and c]. For comparison, the attack due to mixture of acid in liquid state is also given. As per the results, on increasing the quantity of HCl from 0 to 40 parts in the mixture, rust dissolution increased from 0.24 gm/dm^2 to 0.9 gm/dm^{2}in 10 min. with further increase in the proportion of HCl upto 100 parts, rust dissolution decreased. Attack due to paste having different proportions of HCl and H_2SO_4did not show much variation in weight loss however, the weight loss was minimum in HCl:H_2SO_4:: 40 : 60.

Table 1: Effect of change of ratio of HCl(4N) and H_2SO_4(4N) in paste state on the dissolution of rust and on the rate of attack of mild steel [RT; 1hr., 3.0 gm paste/dm^2= coating thickness] [for comparison dissolution rate of mild steel in liquid state also determined]

Volume of Acid (C.C.)	Rate of Dissolution of Rust (gm/dm^2/10 min)	Weight Loss (mg/dm^2/hr)	
		Paste State	Liquid State
0+100	0.24	27.9	524
10+90	0.41	26.1	452
20+80	0.57	24.3	347
30+70	0.69	21.8	224
40+60	0.9	20.5	188
60+40	0.73	22.9	193
80+20	0.51	23.1	205
90+10	0.48	24.2	215
100+0	0.35	24.8	220

Fig 1a: **Effect of change of ratio of HCl(4N) and H_2SO_4(4N) in paste on the rate of dissolution of rust [RT; 1hr., 3.0 gm paste/dm^2 = coating thickness]**

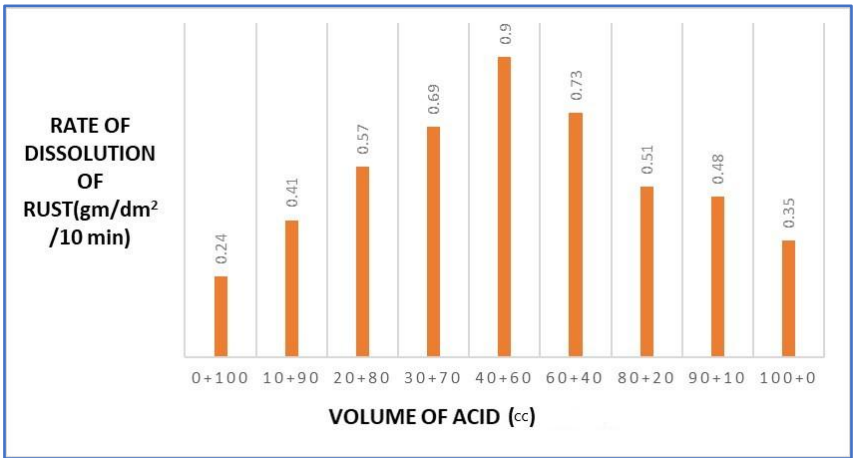


Fig 1b: Effect of change of ratio of HCl(4N) and H_2SO_4(4N)in paste on the rate of attack of mild steel [RT; 1hr., 3.0 gm paste/dm^2 = coating thickness]

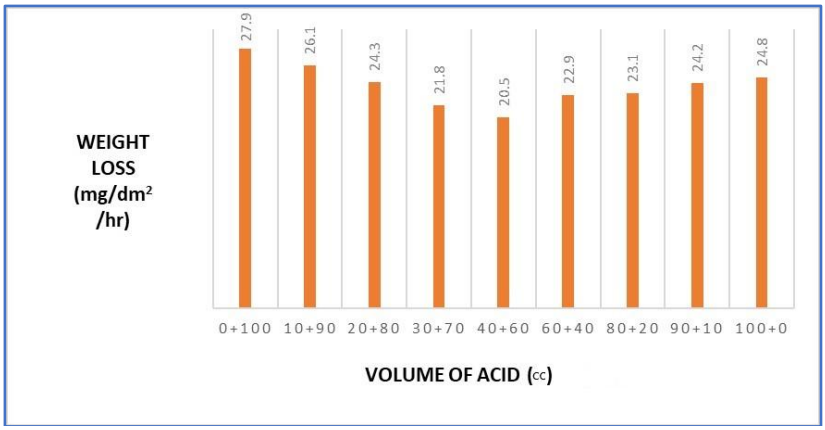
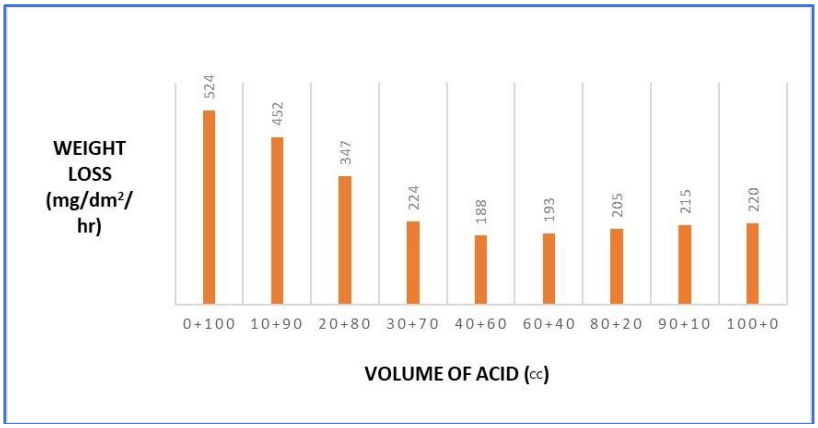


Fig 1c: **Effect of change of ratio of HCl(4N) and H_2SO_4(4N) in liquid state on the rate of attack of mild steel [RT; 1hr.]**



2. Effect of Time of Application

Table 2 and figure 2[a, b and c] shows effect of period of exposure on dissolution of rust and on corrosion of mild steel due to 40 parts HCl(4N) and 60 parts H_2SO_4(4N) in liquid and paste state. Results show that rate of dissolution of rust varied from 1.0 gm/dm2 in 10 min. to 2.5 gm/dm2 in 180 min. In paste state, the attack in 10 min. was 20 mg/dm2 which increased to 41.2 mg/dm2 in 180 min. In liquid state, the rate of attack was 187 mg/dm2 which increased to 229 mg/dm2 in 180 min. In this case also the attack due to liquid was much higher than that due to paste.

Table 2: Effect of time of application of paste on the dissolution of rust and on the rate of attack of mild steel [60 H_2SO_4(4N) +40 HCl(4N); RT; 3.0 gm paste/dm^2 = coating thickness] [for comparison dissolution rate of mild steel in liquid state also determined]

Time of Application (min.)	Rate of Dissolution of Rust (gm/dm^2)	Weight Loss (mg/dm^2)	
		Paste State	Liquid State
10	1.0	20.0	187
30	1.8	26.1	194
60	1.2	34.3	203
120	2.1	39.5	216
180	2.5	41.2	229

Fig 2a:Effect of time of application of paste on the dissolution of rust and on the rate of attack of mild steel [60 H_2SO_4(4N) +40 HCl(4N); RT; 3.0 gm paste/dm^2 = coating thickness]

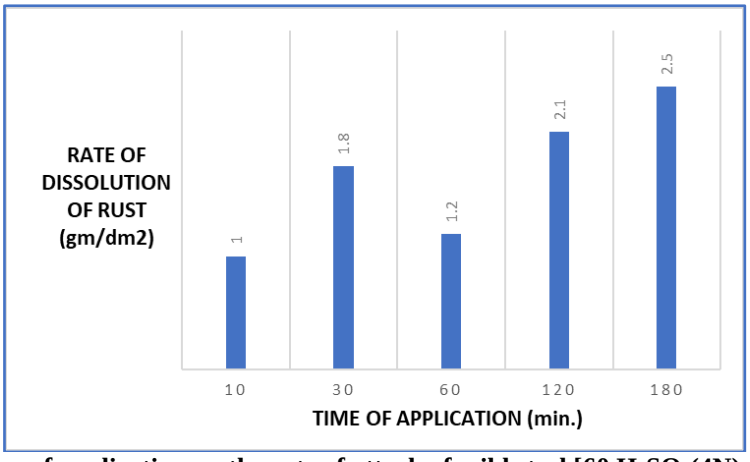


Fig 2b:Effect of time of application on the rate of attack of mild steel [60 H_2SO_4(4N) +40 HCl(4N); RT; 3.0 gm paste/dm^2 = coating thickness]

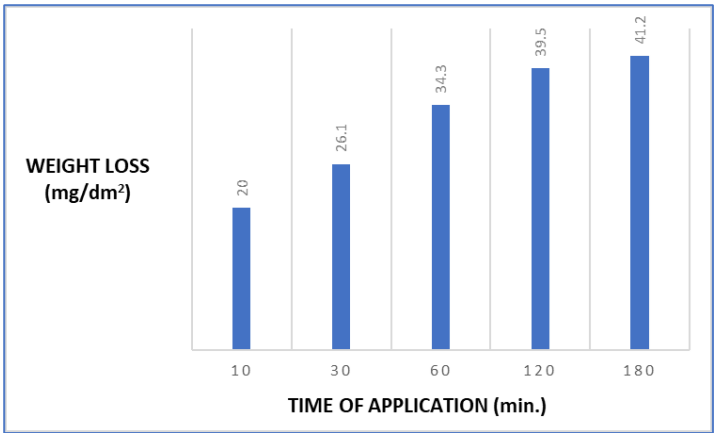
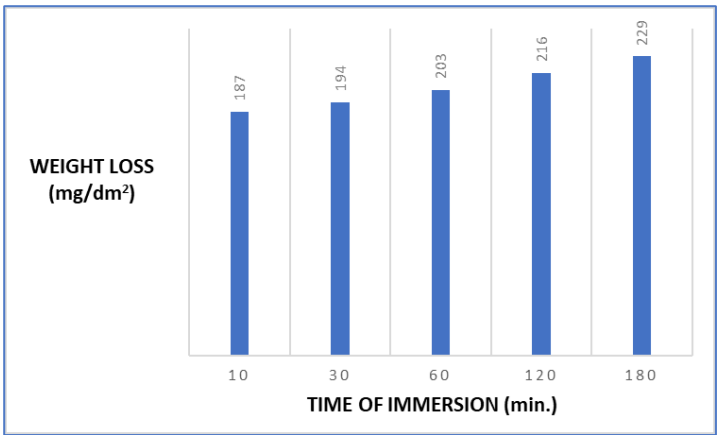


Fig 2c:Effect of time of application on the dissolution of mild steel [60 H_2SO_4(4N) +40 HCl(4N); RT]



B. Dissolution Rate in Inhibited System

1. Effect of Concentration of inhibitor in acid mixture

The effect of concentration of leaf extract 0.01% to 5% in paste containing 40 parts HCl(4N) and 60 parts H_2SO_4(4N) on its inhibitive efficiency for mild steel at room temperature is shown in Table 3 and figure 3[a, b and c]. Results show that when0.01% Ipomoea was added to paste, weight loss reduced from 20.4 mg/dm2/hr to 10.2 mg/dm2/hr, as the concentration of Ipomoea was further increased, weight loss continuously decreased. Inhibitor Efficiency also increased continuously with increase in concentration of inhibitor.

Table 3: Effect of inhibitor concentration on the rate of attack of mild steel by paste [60 H_2SO_4(4N) +40 HCl(4N); RT; 1 hr.; 3.0 gm paste/dm^2 = coating thickness

Concentration of Inhibitor (%)	Log C	Weight Loss (mg/dm^2)	Log θ	Inhibitor Efficiency (%)
NIL	-	20.4	-	-
0.01	2	10.2	1.699	50
0.1	1	9.1	1.7404	55
0.5	1.699	8.7	1.7559	57
1	0	8.1	1.7782	60
2	0.301	7.2	1.8129	65
5	0.699	6.9	1.8195	66

Fig 3a:Effect of concentration of inhibitor on the rate of attack of mild steel by paste [60 H_2SO_4(4N) +40 HCl(4N); RT; 1 hr.; 3.0 gm paste/dm^2 = coating thickness]

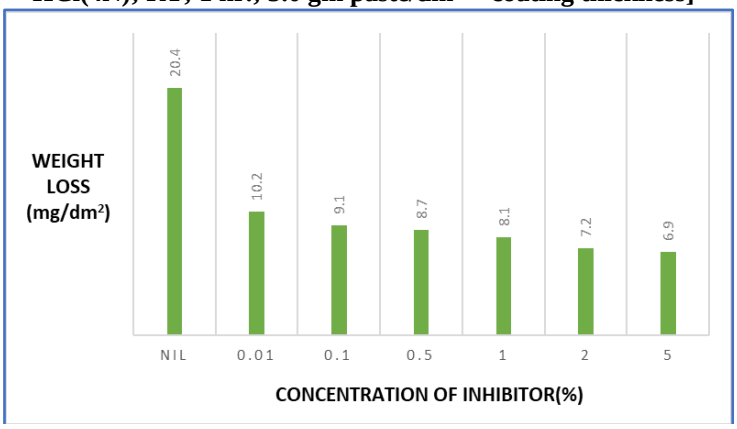
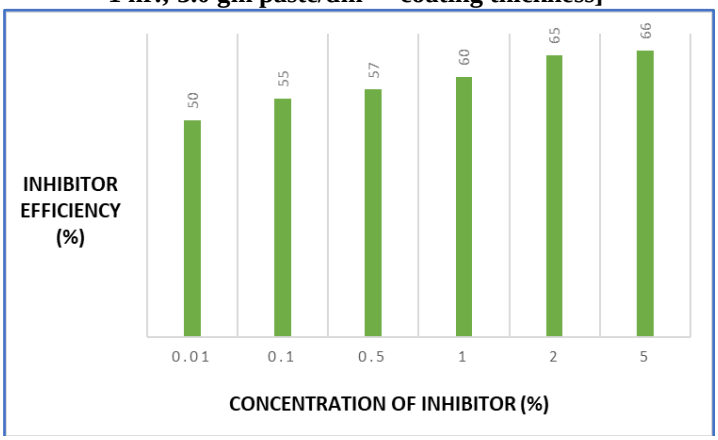


Fig 3b:Effect of concentration of inhibitor on its inhibitive performance [60 H_2SO_4(4N) +40 HCl(4N); RT; 1 hr.; 3.0 gm paste/dm^2 = coating thickness]



2. Effect of Change of Concentration of acids

4N HCl and 4N H_2SO_4 were mixed in different proportions from 0-100 to 100-0, converted to paste and 1% inhibitor was added to it. Rate of dissolution of rust and attack of mild steel due to inhibited paste is given in Table 4 and figure 4[a, b and c]. Results show that attack due to inhibited paste having different proportions of HCl and H_2SO_4 did not show much variation in weight loss, however, the weight loss was minimum in HCl:H_2SO_4::40:60. The inhibitor efficiency varied from 61% to 68%.

Table 4: Effect of change of ratio of HCl(4N) and H_2SO_4(4N) in inhibited paste on the dissolution of rust and on the rate of attack of mild steel [inhibitor = 1%; RT; 1 hr.; 3.0 gm paste/dm^2 = coating thickness]

Volume of Acid (C.C.)	Rate of Dissolution of Rust (gm/dm^2/30 min)	Weight Loss (mg/dm^2)		Inhibitor Efficiency (%)
		Paste State	Liquid State	
0+100	0.56	27.9	8.9	68
10+90	0.81	26.1	8.6	67
20+80	0.97	24.3	8.2	66
40+60	1.5	20.5	7.1	65
60+40	1.4	22.9	8.3	64
80+20	1.2	23.1	8.5	63
90+10	1	24.2	9.1	62
100+0	0.7	24.8	9.6	61

Fig 4a: Effect of change of ratio of HCl(4N) and H_2SO_4(4N) in inhibited paste on the dissolution of rust [inhibitor = 1%; RT; 1 hr.; 3.0 gm paste/dm^2 = coating thickness]

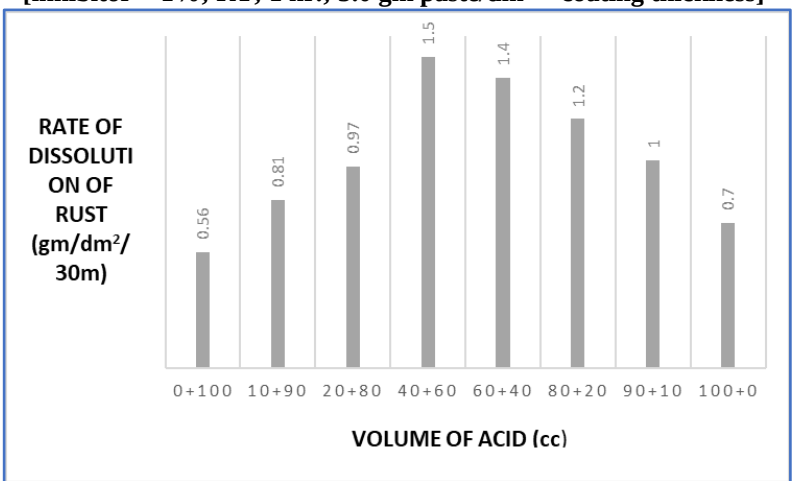


Fig 4b: Effect of change of ratio of HCl(4N) and H_2SO_4(4N) in inhibited paste on the rate of attack of mild steel [inhibitor = 1%; RT; 1 hr.; 3.0 gm paste/dm^2 = coating thickness]

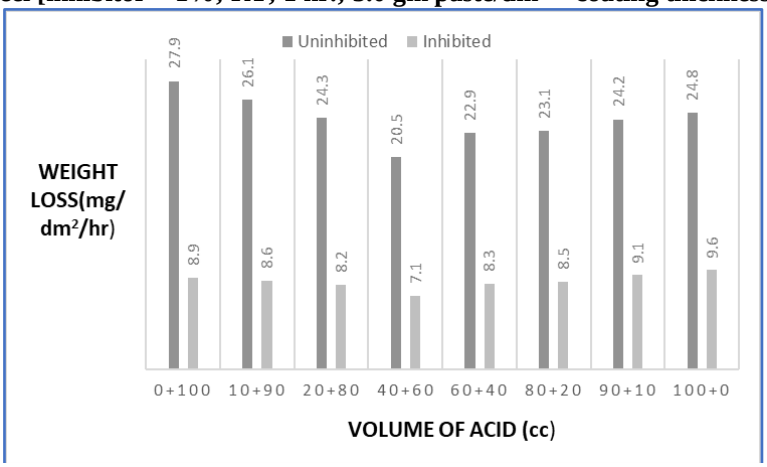
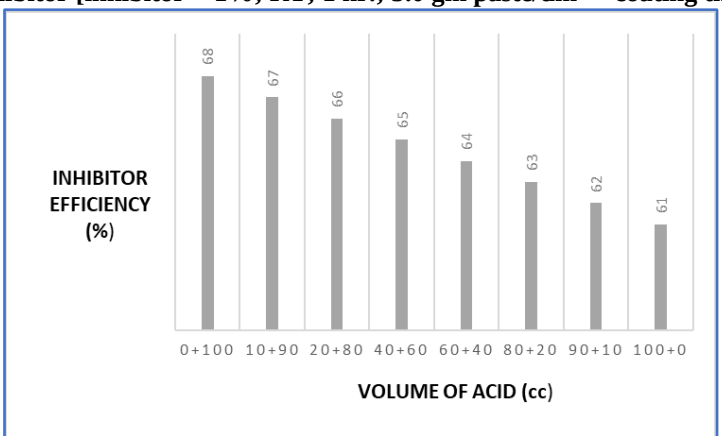


Fig 4c: Effect of change of ratio of HCl(4N) and H_2SO_4(4N) in inhibited paste on the inhibitor efficiency of the inhibitor [inhibitor = 1%; RT; 1 hr.; 3.0 gm paste/dm^2 = coating thickness]



3. Effect of Time of Application

Table 5 and figure 5[a, b and c] shows the dissolution of rust and weight loss of mild steel specimens for different periods (10 min – 180 min) due to paste containing 4N HCl (40 parts) + 4N H_2SO_4 (60 parts) with and without 1% inhibitor at room temperature. Results show that rate of dissolution of rust increased from 1.2 gm/dm^2 in 10 min. to 2.4 gm/dm^2 in 180 min. Weight loss of mild steel in uninhibited paste varied from 20.0 mg/dm^2 to 41.2 mg/dm^2 and in inhibited paste from 7.8 mg/dm^2 to 12.3 mg/dm^2 for same time range.

Table 5: Effect of time of application of inhibited paste on the rate of dissolution of rust and on the rate of attack of mild steel [60 H_2SO_4(4N) +40 HCl(4N); inhibitor = 1%; RT; 3.0 gm paste/dm^2 = coating thickness]

Time of Application (min.)	Rate of Dissolution of Rust (gm/dm^2)	Weight Loss (mg/dm^2)		Inhibitor Efficiency (%)
		Un.	In.	
10	1.2	20.0	7.8	61
30	1.6	26.1	9.3	64
60	1.6	34.3	11.6	66
120	1.8	39.5	12.2	69
180	2.4	41.2	12.3	70

Fig 5a: Effect of time of application of inhibited paste on the rate of dissolution of rust [60 H_2SO_4(4N) +40 HCl(4N); inhibitor = 1%; RT; 3.0 gm paste/dm^2 = coating thickness]

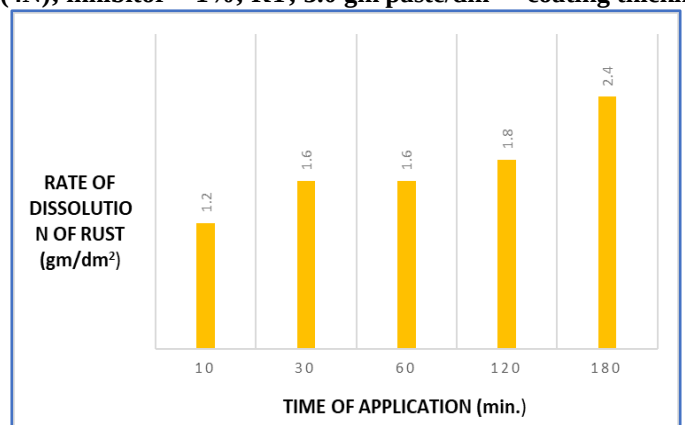


Fig 5b: Effect of time of application of inhibited paste on the rate of attack of mild steel [60 H_2SO_4(4N) +40 HCl(4N); inhibitor = 1%; RT; 3.0 gm paste/dm^2 = coating thickness]

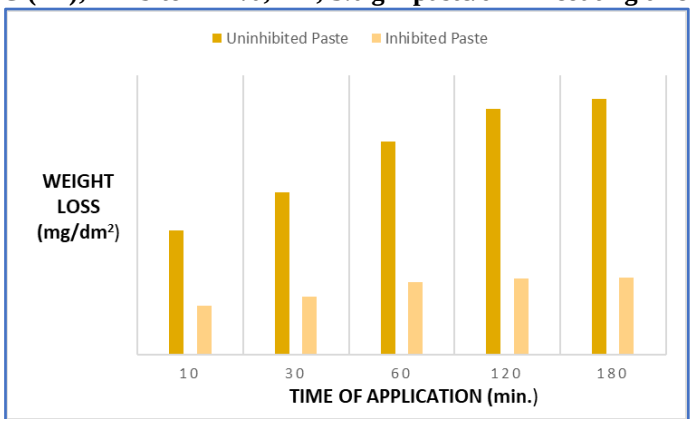
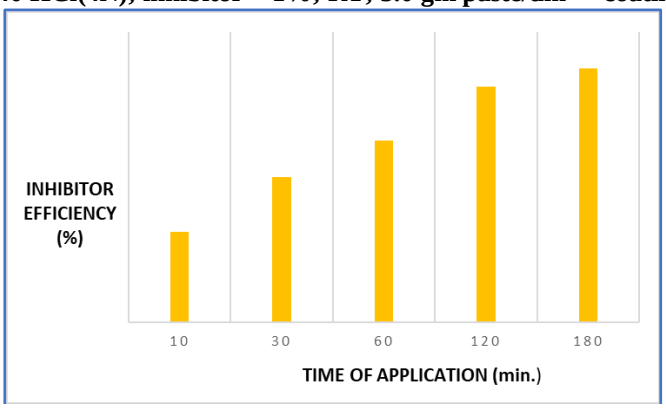


Fig 5c: Effect of time of application of inhibited paste on the inhibitive performance of inhibitor [60 H_2SO_4(4N) +40 HCl(4N); inhibitor = 1%; RT; 3.0 gm paste/dm^2 = coating thickness]



IV. CONCLUSION

In lieu of the results, paste having HCl: H_2SO_4:: 40 : 60 composition of mixed acid gave the best output.The adsorption of Borrachero leaf extract is of Freundlich type i.e., there is unimolecular adsorption of inhibitor molecule on the metal surface which is uniform over the surface. This unimolecular layer forms at an incredibly low concentration.

DECLARATION OF CONFLICTING INTERESTS

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Orcid Id of Author - https://orcid.org/0000-0002-2275-0270

REFERENCES

[1]. I. N. Putilova,S. A. Balezin and V. P. Barannik,"Metallic Corrosion Inhibitor",PergamonPress,New York,pp.104-110,1960.
[2]. K. Srivastava and B. Sanyal,Labdev Journal of Science and Technology(India),8-A(4),pp.104,1970.
[3]. K. Srivastava and P.Srivastava,British Corrosion Journal,16(4),pp.221,1981.
[4]. H. Al-Sehaibani, "Evaluation of extracts of Henna leaves as environmentally friendly corrosion inhibitors for metals," *Materialwissenschaft und Werkstofftechnik*, vol. 31, no. 12, pp. 1060–1063, 2000.
[5]. M. Kliškić, J. Radošević, S. Gudić, and V. Katalinić, "Aqueous extract of Rosmarinusofficinalis L. as inhibitor of Al-Mg alloy corrosion in chloride solution," *Journal of Applied Electrochemistry*, vol. 30, no. 7, pp. 823–830, 2010.
[6]. Bochuan Tan, Bin Xiang, Shengtao Zhang, Yujie Qiang, Lihui Xu, Shijin Chen, Jiahong He,""Papaya leaves extract as a novel eco-friendly corrosion inhibitor for Cu in H2SO4 medium",*Journal of Colloid and Interface Science*,Vol. 582, Part B,pp 918-931,2021.
[7]. I. H. Farooqi, A. Hussain, M. A. Quraishi, and P. A. Saini, "Study of low-cost eco-friendly compounds as corrosion inhibitors for cooling systems," *Anti-Corrosion Methods and Materials*, vol. 46, no. 5, pp. 328–331, 1999.
[8]. H. H. Rehan, "Corrosion control by water-soluble extracts from leaves of economic plants," *Materialwissenschaft und Werkstofftechnik*, vol. 34, no. 2, pp. 232–237, 2003.
[9]. K. O. Orubite and N. C. Oforka, "Inhibition of the corrosion of mild steel in hydrochloric acid solutions by the extracts of leaves of NypafruticansWurmb," *Materials Letters*, vol. 58, no. 11, pp. 1768–1772, 2014.
[10]. E. A. Noor, "Comparative study on the corrosion inhibition of mild steel by aqueous extract of Fenugreek seeds and leaves in acidic solution," *Journal of Engineering and Applied Sciences*, vol. 3, no. 1, pp. 23–30, 2008.
[11]. J. Buchweishaija and G. S. Mhinzi, "Natural products as a source of environmentally friendly corrosion inhibitors: the case of gum exudate from Acacia seyal var. seyal," *PortugaliaeElectrochimicaActa*, vol. 26, no. 3, pp. 257–265, 2008.
[12]. E. E. Oguzie, "Evaluation of the inhibitive effect of some plant extracts on the acid corrosion of mild steel," *Corrosion Science*, vol. 50, no. 11, pp. 2993–2998, 2018.
[13]. P. C. Okafor, M. E. Ikpi, I. E. Uwah, E. E. Ebenso, U. J. Ekpe, and S. A. Umoren, "Inhibitory action of Phyllanthusamarus extracts on the corrosion of mild steel in acidic media," *Corrosion Science*, vol. 50, no. 8, pp. 2310–2317, 2008.
[14]. M. A. Quraishi, A. Singh, V. K. Singh, D. K. Yadav, and A. K. Singh, "Green approach to corrosion inhibition of mild steel in hydrochloric acid and sulphuric acid solutions by the extract of Murrayakoenigii leaves," *Materials Chemistry and Physics*, vol. 122, no. 1, pp. 114–122, 2010.
[15]. Gaidhani, Kalyani & Khurpade, Pratiksha & Nandi, Somnath, "Hibiscus leaves extract: A green corrosion inhibitor," *Journal of the Indian Chemical Society*, vol. 97, pp. 865-869, 2020.
[16]. F. S. de Souza and A. Spinelli, "Caffeic acid as a green corrosion inhibitor for mild steel," *Corrosion Science*, vol. 51, no. 3, pp. 642–649, 2009.

[17]. A. M. Badiea and K. N. Mohana, "Corrosion mechanism of low-carbon steel in industrial water and adsorption thermodynamics in the presence of some plant extracts," *Journal of Materials Engineering and Performance*, vol. 18, no. 9, pp. 1264–1271, 2019.
[18]. L. R. Chauhan and G. Gunasekaran, "Corrosion inhibition of mild steel by plant extract in dilute HCl medium," *Corrosion Science*, vol. 49, no. 3, pp. 1143–1161, 2007.