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Corrosion Inhibition of Mild Steel by Alkaloid Extract of *Ocimum Sanctum* in HCl and HNO_3 Solution

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Abstract

Corrosion of mild steel in hydrochloric and nitric acid solution was studied by weight loss and thermometric methods in presence of ocimum sanctum extract. From weight loss data it was observed that the inhibition efficiency increases with the increases in the concentration of the extract of stem in HCl and HNO_3 solution as compare to extract of leaves of ocimum sanctum. Maximum inhibition efficiency was found (98.67%) in 0.5N HCl acid with 1.2% stem extract, whereas it was (71.62%) in 2N HNO_3 acid with same concentration i.e. 1.2%. The corrosion rate was found to decrease with the increases in concentration of extract up to 0.3% to 1.2%. In the case of thermometric method it was observed that the reaction number decreases with the increases in the concentration of extract while inhibition efficiency increases with increasing concentration of extract of ocimum sanctum in HCl and HNO_3 solution.

Keywords: Ocimum sanctum, corrosion inhibition, reaction number, weight loss, surface coverage.

Introduction

Mild steel is widely used for mechanical and structural engineering purpose, boiler, plates, steam engine parts and automobile etc. it finds a variety of uses in most of chemical industries due to its low cost and easy availability for fabrication of various reaction vessel, tanks and pipes etc. In acidic medium metal tends to corrode. HCl and HNO_3 acids have been used for drilling operation.

The present study is based on the fact that some nitrogen and sulphur containing natural products like Tarmerind tea leaves, Beet root[1-2], Saponin[3], Terminalia bellerica[4], Oxandra asbeckii[5], Argemone mexicana[6], Betanin[7], Henna[8], Wheat[9], Ginger[10], Marraya koeningii[11], Garlic extract[12], Ananas sativum[13] have been found effective corrosion inhibitors for mild steel.

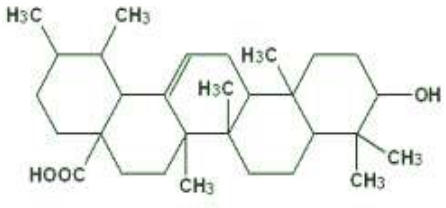
The importance of the study lies in the fact that naturally occurring plant products are non-polluting, ecofriendly, less expensive, less toxic and easily available. They are biodegradable so can widely be used without side effect.

Various heterocyclic compounds synthesized in laboratory [14-18] having heteroatom O, N and S are found to have higher basicity and electron density thud assist corrosion inhibition. N, O and S are active centre for the process of absorption on the metal surface. The electric charge, orientation, shape and size of the molecule play an important role in the effectiveness of inhibition. They are used as corrosion inhibitor since they are get adsorbed on the metal surface which essentially block the discharge of H^+ and dissolution of metal ion in acidic environment, the extract of different parts of plant like seeds, stem, bark and leaves can be used as inhibitor to reduce the corrosion rate of mild steel.

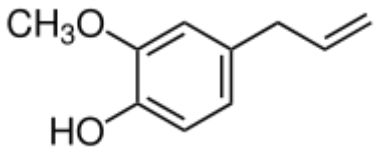
Ocimum sanctum is a very common plant in Indian system, which has been used as antimaterial and antibacterial, air purifier from ancient time in Indian homes. It's stem and leaves powders are used as medicine in many diseases viz. useful in blood glucose management, maintain a healthy digestive system, encourage efficient use of oxygen, enhance the efficacy of many therapeutic treatments etc.

The chemical composition of ocimum sanctum is highly complex, containing many vitamins like A and C, calcium, zinc, iron, chlorophyll and many other phytonutrients are present in extract of ocimum sanctum.

Major chemical constituents responsible for physico-chemical action of ocimum sanctum are volatile oil (0.1 to 0.9%), eugenol (60-70%), cavacrol (about 3.0%), eugenol methyl ether (20%) and other minor chemical constituents of ocimum sanctum are alkaloids, glycoside, saponin, tannin, maleic acid, ursolic acid, citric acid and tartaric acid.



Eugenol



Ursolic Acid

β-bisabolene (13-20%), methyl chavicol (3-19%), 1-8 cineole (9-33%), α- bisabolene (4-7%), α- terpineol (1.7-7%), campestrol, cholesterol, stigma sterol, β- sisterol and methyl ester of common fatty acid were the main constituents of the oil during observation period. In continuation to our earlier investigation[19-20] on mild steel in acid media with extract of ocimum sanctum as corrosion inhibitor the present work deals with corrosion inhibition of mild steel by alkaloid of ocimum sanctum in HCl and HNO_3.

Material and Methods

The mild steel, which was used for the experiment having elemental composition: Fe 98.5%, carbon 1-2%, manganese 0.1-0.2%, phosphorus 0.4-0.5% and sulphur 0.02-0.03%. Specimens were prepared by cutting the mild steel into square shaped pieces having dimension of 2.0cm × 2.0cm× 0.03cm with a small hole of about 2 mm diameter near the upper edge. Specimens were polished to mirror finish by using emery paper. The extract of stem and leaves of ocimum sanctum obtained by refluxing the dried leaves and stem in soxhlet in ethanol by heated at about 80hrs. The solution of HCl and HNO_3 were prepared by using double distilled water. All chemicals used were of AR grade. Solution of different concentration of extract was prepared in ethanol.

Each specimen was suspended by a V shaped glass hook made of capillary and plunge into a beaker containing 50mL of the test solution at room temperature, after the sufficient exposure, test specimens were washed with running water. Duplicate experiments were performed in each case and mean value of weight loss was determined. The percentage inhibition efficiency was calculated as [21].

$$\eta\% = 100\ (\Delta W_u - \Delta W_i)/\Delta W_u$$

Where ΔW_u and ΔW_i are the weight loss of the metal in uninhibited and inhibited solution, respectively. The degree of surface coverage (θ) was calculated as[22].

$$\theta = (\Delta W_u - \Delta W_i)/\ \Delta W_u$$

Inhibition efficiency was also determined by thermometric method. The specimen was plunge into test solution and initial temperature was noted. As soon as the reaction started temperature increased slowly at first, then rapidly and achieved a maximum value before falling. The maximum temperature was noted. Percentage inhibition efficiencies were calculated as

$$\eta\% = 100\ (RN_f - RN_i)/RN_f$$

Where RN_f and RN_i are the reaction number in the free solution and in presence of inhibitor. RN is defined as –

$$RN = (T_m - T_i)/t$$

Where T_m and T_i are maximum and initial temperature, respectively and t is the time in minutes required to attain maximum temperature. The corrosion rate (CR) in mm/yr can be obtained by the following equation[23].

$$\text{Corrosion rate (mm/yr)} = \frac{\Delta W \times 87.6}{A \times T \times d}$$

Where, Δm is weight loss in mg, A is area of specimen in cm^2, T is time of exposure in hours, d is density of metal in gm/cm^3.

Results and Discussion

Weight loss data, percentage inhibition efficiency, corrosion rate and surface coverage for different concentration of HCl and HNO_3 solution with different concentration of inhibitor are given table-1. It is observed from the table 1 that inhibition efficiency decreases with increasing strength of HCl solution and inhibition efficiency increases with increasing concentration of extract in each strength of acid solution. The maximum efficiency has been observed in lowest acid concentration i.e. 0.5N HCl acid with highest concentration of inhibitor i.e. 1.2% (98.67%) for stem extract. Whereas it is (96.02%) for leaves extract in same HCl concentration. The corrosion rate has been observed maximum in bark solution and it decreases with the increasing concentration of inhibitor in HCl solution of different strength. Corresponding variation of inhibition efficiencies with concentration of inhibitor are shown in figure 1 for different concentration of HCl solution.

Table 2 shows results of HNO_3 solution. From the table it is observed that inhibition efficiency increases with increasing strength of HNO_3 solution and it also increases with increasing concentration of extract in each strength of acid solution. The maximum inhibition efficiency has been observed in highest acid concentration i.e. 2N HNO_3 with highest concentration of inhibitor i.e. 1.2% (71.62%) for stem extract, whereas it is (59.04%) for leaves extract in same acid concentration. The corrosion rate has been observed maximum in blank solution and it decreases with increasing concentration of inhibitor in HNO_3 solution of different strength. Corresponding variation of inhibition efficiencies with concentration of inhibitor are shown in figure 2 for different concentration of HNO_3 solution.

Table 3 shows the corresponding data of reaction number (RN) with concentration of inhibitor in 1N, 2N and 3N HCl solution. No significant temperature change were observed in lower concentration of HCl i.e. 0.5N acid. Therefore use of the thermometric method was restricted to 1-3 N acid solution.

Table 3 indicates that reaction number increases with increasing strength of HCl solution as well as it decreases with increasing concentration of inhibitor in each solution. Inhibition efficiency increases with increasing concentration of inhibitor in each solution as well as it decreases with increasing strength of HCl solution. Corresponding curves for the variation in reaction number with concentration of inhibitor are in figure 3 for different concentration of HCl solution.

Results for HNO_3 solution of reaction number shown in table 4 indicate that reaction number increases with increasing strength of acid solution as well as it decreases with increasing concentration of inhibitor of each solution. Inhibition efficiency increases with increasing concentration of inhibitor in each acid solution as well as also increases with increasing strength of HNO_3 solution. Corresponding curves for the variation in reaction number with concentration of inhibitor are shown in fig. 4 for different concentration of HNO_3 solution.

In case of HCl solution. Inhibition efficiency of inhibitor is maximum at lower concentration i.e. 0.5N but in HNO_3 solution inhibition efficiency of inhibitor is maximum at highest concentration i.e. 2.0N HNO_3. This is because of fact that in the case of HNO_3 oxygen atom formed a protective layer on the metal surface, which essentially block the discharge of H^+ and dissolution of metal ion in acid media so they are reduce the corrosion rate of mild steel with inhibitor.

Conclusion

Both weight loss and thermometric method show that ocimum sanctum is a good corrosion inhibitor for mild steel in HCl solution. It was conclude that extract of stem is better corrosion inhibitor than that of leaves. The maximum inhibition efficiency shown by stem extract was 98.67% for 1.2% concentration in 0.5N HCl. Both method show same trend for corrosion inhibition efficiency. Both methods are in good agreement with each other.

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Table-1

Inhibition efficiencies (η%) for mild steel in HCl solution with *Ocimum sanctum* extract

Temperature: 25 ± 0.1^{0}C **Area of specimen: 8cm^2**

Conc. of inhibitor	0.5 N HCl (71 hrs.)			1N HCl (68 hrs.)			1.5N HCl (48 hrs.)			2N HCl (25 hrs.)		
(%)	Δm (mg)	η%	C.R. (mm/yr)	Δm (mg)	η%	C.R. (mm/yr)	Δm (mg)	η%	C.R. (mm/yr)	Δm (mg)	η%	C.R. (mm/yr)
Uninhibited	377.0		8.98	260.0		6.47	238.0		8.39	302.0		20.44
Stem Extract												
0.3	19.0	94.96	0.45	24.0	90.77	0.59	22.0	90.75	0.77	32.0	89.4	2.16
0.6	14.0	96.29	0.33	19.0	92.69	0.47	16.0	93.28	0.56	23.0	92.38	1.55
0.9	10.0	97.35	0.23	15.0	94.23	0.37	15.0	93.7	0.52	21.0	93.04	1.42
1.2	5.0	98.67	0.11	10.0	97.35	0.24	9.0	96.82	0.31	13.0	95.00	0.88
Leaves Extract												
0.3	25.0	93.36	0.59	37.0	86.54	0.92	41.0	82.77	1.44	97.0	67.88	6.56
0.6	22.0	94.16	0.52	25.0	90.38	0.62	23.0	90.33	0.81	94.0	68.87	6.36
0.9	20.0	94.69	0.47	21.0	91.92	0.52	21.0	91.17	0.74	85.0	71.85	5.75
1.2	15.0	96.02	0.35	15.0	94.23	0.37	20.0	91.59	0.70	61.0	79.80	4.12

Table-2

Inhibition efficiencies (η%) for mild steel in HNO_3 solution with *Ocimum sanctum* extract

Temperature: 25 ± 0.1^{0}C **Area of specimen: 8cm^2**

Conc. of inhibitor	0.5 N HNO_3 (160 min.)			1N HNO_3 (45 min.)			1.5N HNO_3 (30 min.)			2N HNO_3 (20 min.)		
(%)	Δm (mg)	η%	C.R. (mm/yr)	Δm (mg)	η%	C.R. (mm/yr)	Δm (mg)	η%	C.R. (mm/yr)	Δm (mg)	η%	C.R. (mm/yr)
Uninhibited	505.00		320.50	567.00		1279.47	663.00		2244.15	747.00		3792.72
Stem Extract												
0.3	282.00	44.16	178.97	311.00	45.15	701.79	328.00	50.53	1110.23	327.00	56.22	1660.27
0.6	280.00	44.55	177.70	283.00	50.09	638.60	255.00	61.54	863.13	270.00	63.86	1370.86
0.9	244.00	51.68	154.85	259.00	54.32	584.45	242.00	63.49	819.13	260.00	65.19	1320.09
1.2	238.00	52.87	151.04	241.00	57.50	543.83	197.00	70.29	666.81	212.00	71.62	1076.38
Leaves Extract												
0.3	435.00	13.86	276.07	406.00	28.39	916.16	477.00	28.05	1614.57	504.00	32.53	2558.94
0.6	423.00	16.23	268.46	396.00	30.15	893.60	441.00	33.48	1492.72	429.00	42.57	2178.15
0.9	385.00	23.76	244.34	377.00	33.51	850.72	377.00	43.13	1276.08	411.00	44.98	2086.76
1.2	365.00	27.72	231.65	316.00	44.26	713.07	347.00	47.66	1174.54	306.00	59.04	1553.64

Table-3

Reaction Number and Inhibition efficiency (η%) for mild steel in HCl solutions with *Ocimum sanctum* extract

Temperature: 25 ± 0.1^{0}C

Conc. Of Inhibitor	1N HCl (240 min.)		2N HCl (210 min.)		3N HCl (120 min.)	
(%)	RN (K Min^{-1})	η%	RN (K Min^{-1})	η%	RN (K Min^{-1})	η%
Uninhibited	0.10		0.063		0.050	
Stem Extract						
0.3	0.034	66	0.028	55.55	0.026	48.0
0.6	0.028	72	0.024	61.90	0.021	58.0
0.9	0.021	75	0.021	66.66	0.018	64.0
1.2	0.018	81	0.018	71.42	0.015	70.0
Leaves Extract						
0.3	0.040	60	0.036	42.85	0.030	40.0
0.6	0.038	62	0.031	50.79	0.028	44.0
0.9	0.031	65	0.026	58.73	0.025	50.0
1.2	0.029	71	0.022	65.07	0.020	60.0

Table-4

Reaction Number and Inhibition efficiency (η%) for mild steel in HNO_3 solutions with *Ocimum sanctum* extract

Temperature: 25 ± 0.1^{0}C

Conc. of Inhibitor	1N HNO_3 (240 min.)		2N HNO_3 (210 min.)		3N HNO_3 (120 min.)	
(%)	RN (K Min^{-1})	η%	RN (K Min^{-1})	η%	RN (K Min^{-1})	η%
Uninhibited	0.170		0.830		1.190	
Stem Extract						
0.3	0.100	41.18	0.390	53.01	0.430	63.86
0.6	0.090	47.05	0.340	59.03	0.400	66.38
0.9	0.080	52.94	0.300	63.85	0.370	68.90
1.2	0.070	58.82	0.270	67.46	0.320	73.10
Leaves Extract						
0.3	0.140	17.64	0.580	30.12	0.720	39.49
0.6	0.130	23.52	0.520	37.33	0.670	43.69
0.9	0.120	29.41	0.480	42.21	0.500	57.98
1.2	0.100	41.18	0.450	45.78	0.480	59.66

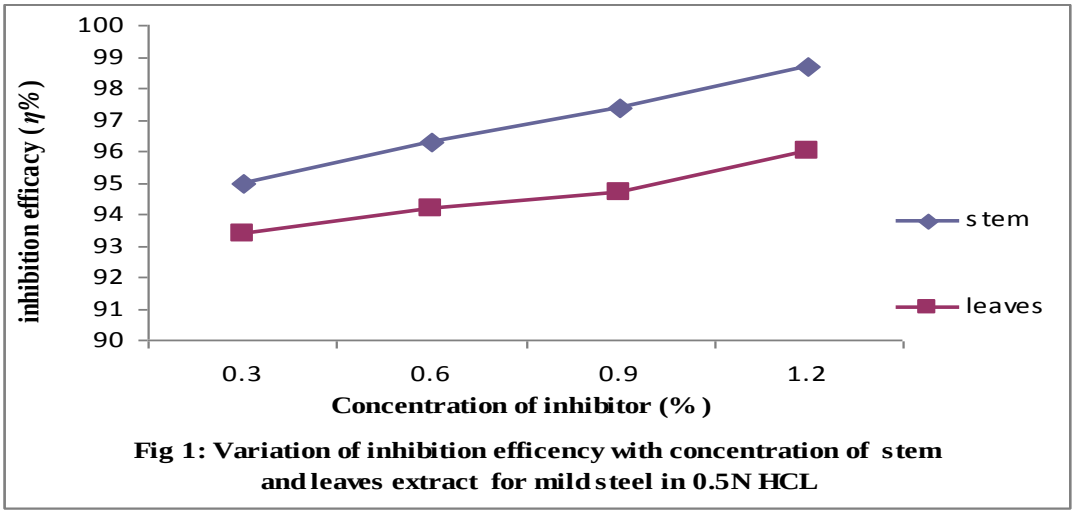

Fig 1: Variation of inhibition efficency with concentration of stem and leaves extract for mild steel in 0.5N HCL

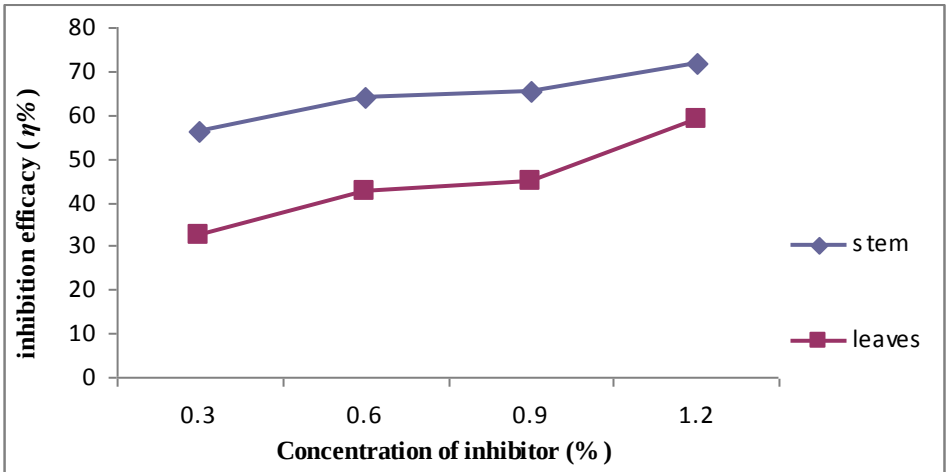

Fig 2: Variation of inhibition efficency with concentration of stem and leaves extract for mild steel in 2N HNO_3

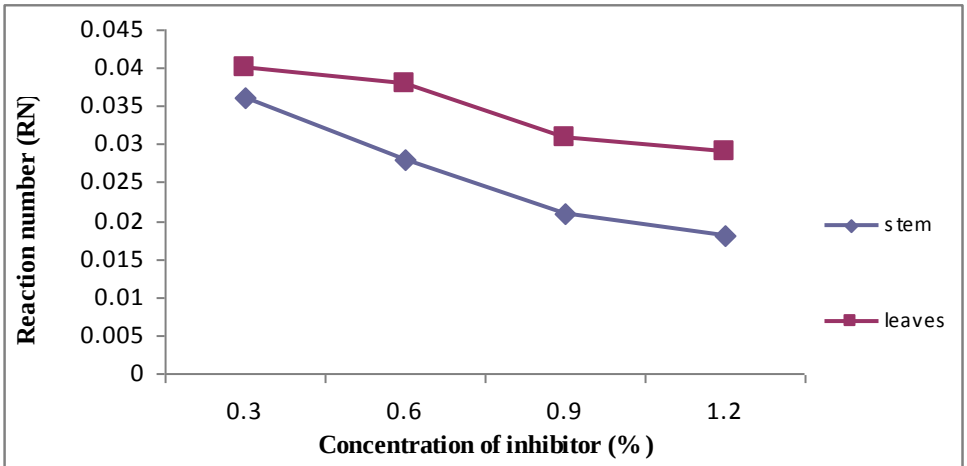

Fig 3:Variation of reaction number with concentration of stem and leaves extract for mild steel in 1N HCL

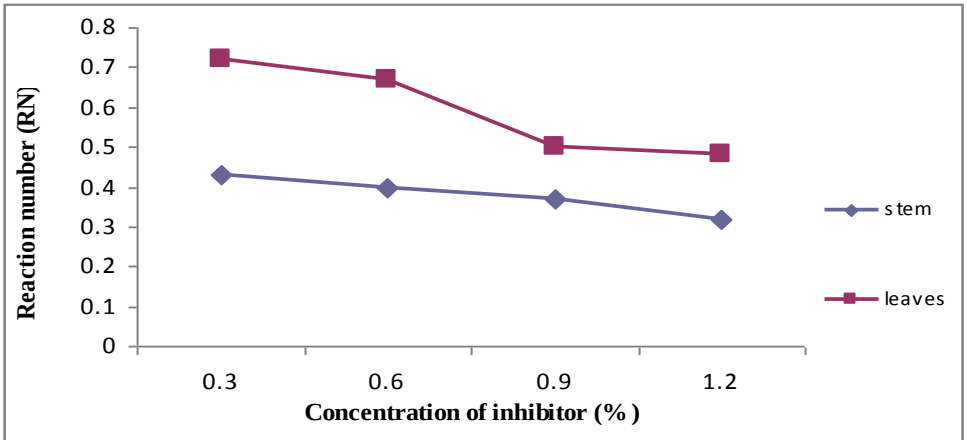

Fig 4:Variation of reaction number with concentration of stem and leaves extract for mild steel in 3N HNO_3