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A Study Of Corrosion Inhibition Efficacy Of Leaves Extract Of *Solanum Xanthocarpum* And *Salvodera Persica* On Aluminium And Mild Steel In HCl

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Abstract - *Weight loss and gasometric method were used to determine the inhibitive power of Salvodera persica and Solanum xanthocarpum leaf extracts toward acid corrosion of aluminium and mild steel. Plant extracts contain mixture of compounds having oxygen, nitrogen and sulphur which are considered as eco-friendly, economic and renewable inhibitors. Chemisorption on the metal surface is due to the presence of electron rich regions and heteroatoms. It was found that the leaves extract act as good corrosion inhibitor for mild steel and aluminium at all concentrations. 0.8% leaf extract of Salvodera persica proved to be the best inhibitor with the highest inhibition efficiency of 97.83% while 0.2% extract of Solanum xanthocarpum leaves displayed the least inhibition efficiency of 26.26%.*

Key Words- *Solanum xanthocarpum; Salvodera persica*; corrosion rate; weight loss, Inhibition efficiency, hydrogen evolution.

1.INTRODUCTION

Mild steel finds a variety of uses in most of chemical industries due to its low cost and easy availability for fabrication of various reaction vessels, tanks, pipes etc [1,2]. Aluminium is a soft, durable, lightweight, malleable metal, nonmagnetic and non-sparking. Aluminium and its alloys are recommended for various industries, food packaging, and highly polluted places [3-5].

Metal tends to get corroded when exposed to acidic media which decreases its utility [6-9]. Corrosion is an irreversible interfacial reaction of a material with its environment which results in its consumption or dissolution into a component of the environment [10, 11]. Many inorganic and synthetic organic inhibitors have been extensively applied to prevent deterioration of materials but due to their toxic nature and high cost of some chemicals currently in use, it is necessary to develop environmentally acceptable and less expensive inhibitors which are biodegradable in nature [12-14].

Extracts of natural plants is one of the most important metallic corrosion inhibitors [15]. Bio active compounds in plants include alkaloids, terpenoids, coumarins, flavonoids, nitrogen containing compounds etc.[16,17]. The corrosion inhibiting property of these compounds is due to the presence of π electrons and heteroatoms due to which the inhibitor molecules have a greater adsorption efficiency on to the mild steel and aluminium surface [18].

Phytochemical screening of the ethanolic extract of *Salvodera persica* and *Solanum xanthocarpum* leaves revealed the presence of sterols, terpenes, flavonoids and saponins [19-22]. The present study aims to investigate the inhibitive properties of leaves extract of *Salvodera persica* and *Solanum xanthocarpum* on the corrosion behavior of mild steel and aluminum in HCl solution.

2. EXPERIMENTAL DETAILS

2.1 Preparation of metal specimen

Square size metal specimen having dimension (2.5 ×2.5×0.05) cm containing a small hole near the upper edge were employed for inhibition study. Specimens were cleaned by emery paper, washed with distilled water, dried and then weighed.

2.2 Preparation of plant extract

The leaves were hand plucked and washed under running tap water. The leaves were air dried at room temperature for one week then they were grinded in a blender into powder form. Dried sample was placed in a thimble, which was placed inside the soxhlet extractor. Extract concentration of 0.2%, 0.4%, 0.6%and 0.8% were prepared in ethanol.

2.3 Preparation of acid solution

The solutions of different concentrations of HCl were prepared using double distilled water and using chemicals of AR grade.

3. METHODOLOGY

3.1 Weight loss method –

The weighed coupons were suspended with the help of glass hooks in beaker containing 50 mL of corrodent containing the inhibitor with different concentration. After sufficient exposure of time the coupons were removed and washed

with water and then were weighed accurately with a weighing balance of accuracy up to four decimal place to determine its change in weight.

The corrosion rate and inhibition efficiency were calculated using equation [23,24]

$$\eta\% = \frac{100\ (\Delta W_o - \Delta W_i)}{\Delta W_o}$$

ΔW_o = weight loss of sample in uninhibited solution
ΔW_i = weight loss of sample in inhibited solution

$$\text{Corrosionrate(C.R)} = \frac{87.6\Delta W}{ATD}$$

ΔW = weight loss of specimen in mg
A = Exposed area of specimen in cm^2
T = Time of exposure in hours
D =density of metal in g/cm^3

The degree of surface coverage (θ) by inhibitor can be calculated as [25].

$$\theta = \frac{(\Delta W_o - \Delta W_i)}{\Delta W_o}$$

3.2 Gasometric method

Metal coupons were dropped into the gasometric chamber containing 50 mL of the acid solution and inhibitor solution of varied concentration (0.2%, 0.4%, 0.6%, 0.8%) and the volume of hydrogen produced in the course of corrosion was recorded by a burette. This is due to the displacement of paraffin oil in the burette by hydrogen gas. The difference in the amount of oil in the burette was recorded [26].

Inhibition efficiencies and the hydrogen evolution rates for *Solanum xanthocarpum* and *Salvodera persica* leaves extract on mild steel and aluminium in HCl were calculated from equation [27].

$$\eta\% = \left(\frac{CR_{blank} - CR_{inh}}{CR_{blank}}\right) x100$$

$$CR_h = \frac{V_t - V_i}{t_t - t_i}$$

V_t = volume of hydrogen evolved at time t_t(mL)
V_i = Change in Volume of gas (mL)
CR_{blank} = Rate of Hydrogen gas evolution in absence of inhibitor
CR_{inh}= Rate of Hydrogen gas evolution in presence of inhibitor.

4. RESULT AND DESCUSSION

In this study, Inhibition efficiency of the different concentration of plant extract was determined by comparing the corrosion rates in presence and in absence of inhibitor by weight loss and gasometric method. Effect of various concentration of *Solanum xanthocarpum* and *Salvodera persica* leaves extract on inhibition efficiency for mild steel and Aluminium in HCl as determined by weight loss method are summarized in Table 1 and Table 2 and corresponding graphs are plotted in figure 1 to 4.

Table -1: Percentage inhibition efficiency of *Solanum xanthocarpum and Salvodera persica* on corrosion of aluminium in HCl

Concentration of Inhibitor	Weight loss in mg (ΔW)	Inhibition efficiency (η %)	Surface coverage (θ)	Corrosion rate (mmpy) *(C.R)*	log $\left(\frac{\theta}{1-\theta}\right)$	Concentration of Inhibitor	Weight loss in mg (ΔW)	Inhibition efficiency (η %)	Surface coverage (θ)	Corrosion rate (mmpy) *(C.R)*	log $\left(\frac{\theta}{1-\theta}\right)$
Salvodera Persica											
2N HCl (1.25 hr)						**1N HCl (1.5hr)**					
Uninhibited	208.5			8625.55		Uninhibited	319.4			1105.36	
0.2%	42.4	79.63	0.7963	1756.67	0.5920	0.2%	24.4	92.36	0.9236	84.44	1.082
0.4%	39.8	80.90	0.8090	1646.62	0.6269	0.4%	22.5	92.95	0.9295	77.86	1.120
0.6%	6.52	96.87	0.9687	269.93	1.4906	0.6%	19.3	93.95	0.9395	66.79	1.191
0.8%	4.52	97.83	0.9783	186.88	1.6540	0.8%	17.0	94.61	0.9461	58.83	1.244
0.5 N HCl (72 hr)						**0.1 N HCl(192hr)**					
Uninhibited	159.0			11.46		Uninhibited	102.4			2.76	
0.2%	51.9	67.35	0.6735	3.74	0.3144	0.2%	65.09	36.43	0.3643	1.75	-0.241
0.4%	47.0	70.44	0.7044	3.38	0.3771	0.4%	63.48	38.00	0.3800	1.71	-0.212
0.6%	45.8	71.19	0.7119	3.30	0.3928	0.6%	52.42	48.80	0.4880	1.41	-0.020
0.8%	45.2	71.57	0.7157	3.25	0.3948	0.8%	35.16	65.66	0.6566	1.77	0.281
Solanum xanthocarpum											
2N HCl						**1N HCl (1.5hr)**					
Uninhibited	208.5			4329.38		Uninhibited	319.4			1105.36	
0.2%	51.3	75.39	0.7539	1065.21	0.4862	0.2%	34.59	89.17	0.8917	119.70	0.9155
0.4%	27.9	86.61	0.8661	579.32	0.8107	0.4%	29.38	90.80	0.9080	101.67	0.9942
0.6%	15.7	92.47	0.9247	326.00	1.0892	0.6%	26.92	91.57	0.9157	93.16	1.0359
0.8%	11.4	94.53	0.9453	236.71	1.2330	0.8%	25.93	91.88	0.9188	89.73	1.0536
0.5 N HCl (72 hr)						**0.1 N HCl(192hr)**					
Uninhibited	159			11.46		Uninhibited	102.4			2.76	
0.2%	52.10	67.23	0.6723	3.75	0.3120	0.2%	75.50	26.26	0.2626	2.04	-0.4484
0.4%	50.00	68.55	0.6855	3.60	0.3383	0.4%	63.80	37.69	0.3769	1.72	0.2183
0.6%	47.20	70.31	0.7031	3.40	0.3744	0.6%	58.10	42.87	0.4287	1.57	-0.1247
0.8%	45.41	71.44	0.7144	3.27	0.3981	0.8%	57.80	43.55	0.4355	1.56	-0.1126

Table 2. Percentage inhibition efficiency of *Solanum xanthocarpumand Salvodera persica* on corrosion of mild steel in HCl

Concentration of Inhibitor	Weight loss in mg (ΔW)	Inhibition efficiency (η %)	Surface coverage (θ)	Corrosion rate (mmpy) *(C.R)*	log $\left(\frac{\theta}{1-\theta}\right)$	Concentration of Inhibitor	Weight loss in mg (ΔW)	Inhibition efficiency (η %)	Surface coverage (θ)	Corrosion rate (mmpy) *(C.R)*	log $\left(\frac{\theta}{1-\theta}\right)$
Salvodera Persica											
2N HCl (18 hr)						**1N HCl (48 hr)**					
Uninhibited	983			97.25		Uninhibited	1182			43.85	
0.2%	201	79.55	0.7955	19.88	0.5920	0.2%	186	84.26	0.8426	6.90	-0.4484
0.4%	138	85.96	0.8596	13.65	0.6269	0.4%	98	91.70	0.9170	3.63	0.2183
0.6%	132	86.57	0.8657	13.06	1.4906	0.6%	85	92.80	0.9280	3.15	-0.1247
0.8%	109	88.91	0.8891	10.78	1.6540	0.8%	82	93.06	0.9306	3.04	-0.1126

0.5 N HCl (96 hr)						0.1 N HCl (120 hr)					
Uninhibited	776			14.39		Uninhibited	179			2.65	
0.2%	149	80.79	0.8079	2.76	0.6238	0.2%	121	32.40	0.3240	1.79	-0.3194
0.4%	138	82.21	0.8221	2.56	0.6647	0.4%	118	34.07	0.3407	1.75	-0.2867
0.6%	117	84.29	0.8429	2.17	0.7295	0.6%	115	35.75	0.3575	1.70	-0.2545
0.8%	116	85.05	0.8505	2.15	0.7550	0.8%	101	43.57	.04357	1.49	-0.1123
Solanum xanthocarpum											
2N HCl (18hr)						**1N HCl (48hr)**					
Uninhibited	983			97.25		Uninhibited	1.182			43.85	
0.2%	101.5	89.67	0.8967	10.04	0.4862	0.2%	92.9	92.14	0.9214	3.44	1.0690
0.4%	95.4	90.29	0.9029	9.43	0.8107	0.4%	77.7	93.42	0.9342	2.88	1.1520
0.6%	92.9	90.45	0.9045	9.19	1.0892	0.6%	71.7	93.93	0.9393	2.66	1.1896
0.8%	86.2	91.23	0.9123	8.52	1.2330	0.8%	62.6	94.70	0.9470	2.32	1.2520
0.5 N HCl (96 hr)						**0.1 N HCl (120 hr)**					
Uninhibited	776			14.39		Uninhibited	179			2.65	
0.2%	125.7	83.80	0.8380	2.33	0.7137	0.2%	115.4	35.51	0.3551	1.71	-0.2591
0.4%	123.8	84.04	0.8404	2.29	0.7214	0.4%	112.1	37.38	0.3738	1.66	-0.2240
0.6%	121.9	84.28	0.8428	2.26	0.7292	0.6%	107.1	40.18	0.4018	1.58	-0.1728
0.8%	105.3	86.42	0.8642	1.95	0.8037	0.8%	81.98	54.20	0.5420	1.21	0.0731

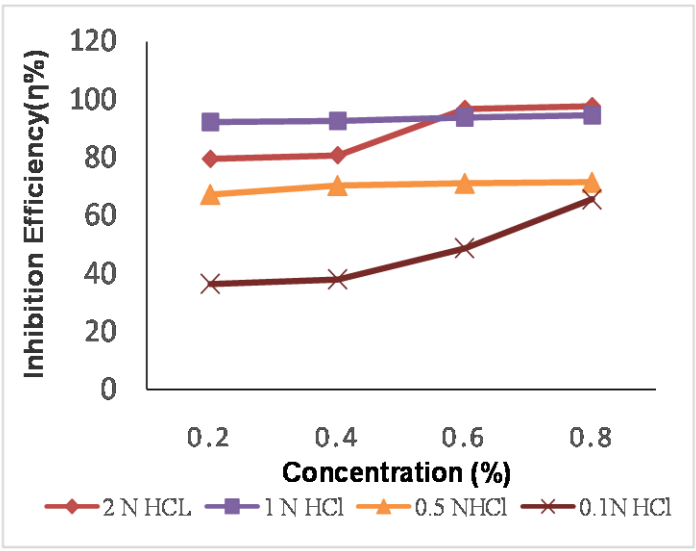

Figure 1- Plot of Inhibition efficiency against extract concentration in the presence of different concentrations of *Salvodera persica* leaves extract in HCl Solution on Aluminium by weight loss method

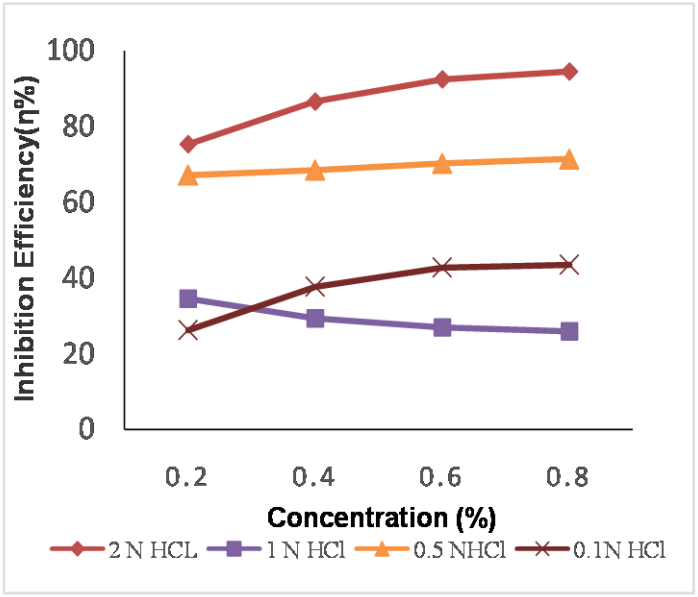

Figure 2 - Plot of Inhibition efficiency against extract concentration in the presence of different concentrations of *Solanum xanthocarpum* leaves extract in HCl Solution on Aluminium by weight loss method

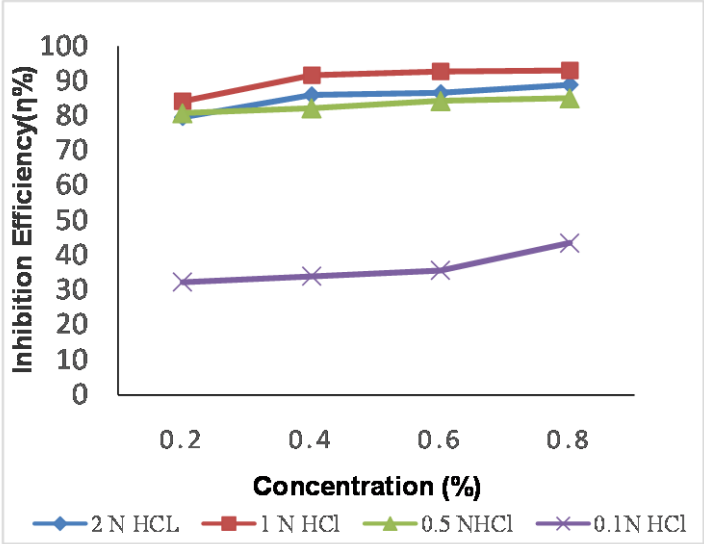

Figure 3 – Plot of Inhibition efficiency against extract concentration in the presence of different concentrations of *Salvodera persica* leaves extract in HCl Solution on mild steel by weight loss method

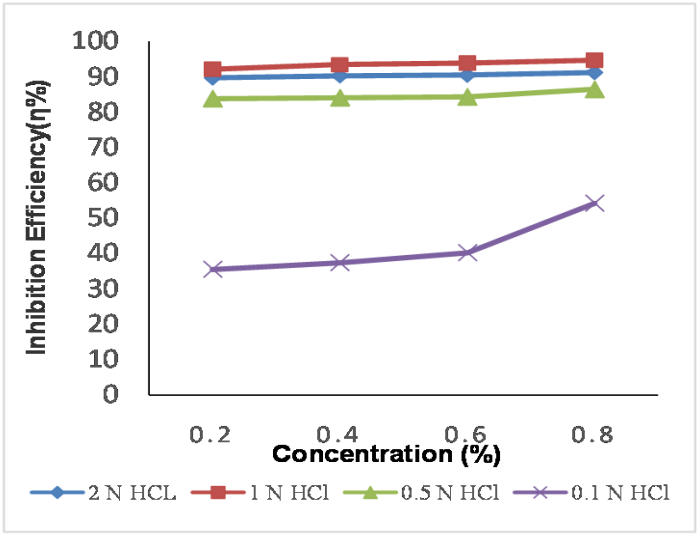

Figure 4 – Plot of Inhibition efficiency against extract concentration in the presence of different concentrations of *Solanum xanthocarpum* leaves extract in HCl Solution on mild steel by weight loss method

The figures and tables above show that the percentage inhibition efficiency of the extract increases with an increase in concentration of Salvodera persica and Solanum xanthocarpum leaves extract .It is also observed that the inhibition efficiency increases with increasing acid and inhibitor concentration because the inhibitor ionizes more easily under more acidic solution and is more easily absorbed on the metal surface, thus increasing the inhibition efficiency.

Table 3& 4 shows the volume change, inhibition efficiency and hydrogen evolution rate for aluminium and mild steel in HCl and the graphs are illustrated in figures 5 to 8.

Table – 3. Calculated values of hydrogen evolution rate and inhibition efficiency for aluminium in the absence and in presence of *Salvodera persica* and *Solanum xanthocarpum* in HCl

Concentration of inhibitor	Volume change (ΔV) in mL	Inhibition efficiency (η %)	Hydrogen evolution rate (CR_h)	Concentration of inhibitor	Volume change (ΔV) in mL	Inhibition efficiency (η %)	Hydrogen evolution rate (CR_h)
Salvodera persica							
3N HCl				**2.5 N HCl**			
Uninhibited	28.6		2.86	Uninhibited	23.5		2.35
0.2%	9.7	66.08	0.97	0.2%	18.4	60.85	0.92
0.4%	6.9	75.87	0.69	0.4%	11.6	75.31	0.58
0.6%	3.8	86.71	0.38	0.6%	7.8	83.40	0.39
0.8%	1.1	95.10	0.11	0.8%	2.3	94.89	0.12
2N HCl				**1N HCl**			
Uninhibited	21.0		2.26	Uninhibited	18.6		1.86

0.2%	6.1	70.79	0.66	0.2%	11.4	59.13	0.76
0.4%	4.6	77.87	0.48	0.4%	8.6	69.35	0.57
0.6%	1.6	92.34	0.17	0.6%	5.2	81.72	0.34
0.8%	1.2	94.00	0.10	0.8%	3.6	87.09	0.24
Solanum xanthocarpum							
3N HCl				**2.5 N HCl**			
Uninhibited	28.6		2.86	Uninhibited	23.5		2.35
0.2%	10.2	76.22	0.68	0.2%	11.5	67.65	0.76
0.4%	7.6	82.51	0.50	0.4%	9.4	`73.61	0.62
0.6%	4.7	89.16	0.31	0.6%	6.4	82.12	0.42
0.8%	2.9	93.35	0.19	0.8%	3.1	91.48	0.20
2 N HCl				**1 N HCl**			
Uninhibited	21.0		1.400	Uninhibited	18.6		1.86
0.2%	5.2	75.71	0.340	0.2%	10.4	62.90	0.69
0.4%	4.3	80.00	0.280	0.4%	8.6	69.35	0.57
0.6%	2.4	88.57	0.160	0.6%	5.4	80.64	0.36
0.8%	1.9	91.00	0.126	0.8%	4.2	84.94	0.28

Table – 4. Calculated values of hydrogen evolution rate and inhibition efficiency for mild steel in the absence and in presence of Salvodera persica and Solanum xanthocarpum in HCl.

Concentration of inhibitor	**Volume change (ΔV) in mL**	**Inhibition efficiency (η %)**	**Hydrogen evolution rate (CR_h)**	**Concentration of inhibitor**	**Volume change (ΔV) in mL**	**Inhibition efficiency (η %)**	**Hydrogen evolution rate (CR_h)**
Salvodera persica							
3N HCl				**2.5N HCl**			
Uninhibited	23.6		2.36	Uninhibited	20.4		2.04
0.2%	5.3	77.54	0.53	0.2%	17.0	72.50	0.56
0.4%	3.4	85.59	0.34	0.4%	16.0	74.01	0.53
0.6%	2.6	88.98	0.26	0.6%	14.2	76.96	0.47
0.8%	2.1	91.10	0.21	0.8%	12.6	79.41	0.42
2N HCl				**1N HCl**			
0.2%	21.0		1.40	Uninhibited	18.0		1.20
0.4%	18.0	57.14	0.60	0.2%	17.0	53.33	0.56
0.6%	15.2	62.28	0.50	0.4%	11.6	62.50	0.45
0.8%	14.0	67.14	0.46	0.6%	10.5	72.50	0.33
0.8%	10.1	76.42	0.33	0.8%	9.6	75.00	0.30
Solanum xanthocarpum							
3 N HCl				**2.5 N HCl**			
Uninhibited	23.6		2.36	Uninhibited	20.4		2.04
0.2%	12.0	66.10	0.80	0.2%	10.1	58.82	0.84
0.4%	10.2	71.11	0.68	0.4%	8.6	65.19	0.71

0.6%	9.6	72.88	0.64	0.6%	7.4	70.09	0.61
0.8%	7.5	78.81	0.50	0.8%	5.5	77.94	0.45
2 N HCl				**1 N HCl**			
Uninhibited	21.0		1.40	Uninhibited	18.0		1.20
0.4%	16.4	53.57	0.65	0.2%	15.0	43.33	0.68
0.6%	15.7	55.71	0.62	0.4%	14.7	45.00	0.66
0.8%	13.6	61.42	0.54	0.6%	12.8	51.66	0.58
0.8%	12.0	65.71	0.48	0.8%	11.4	57.50	0.51

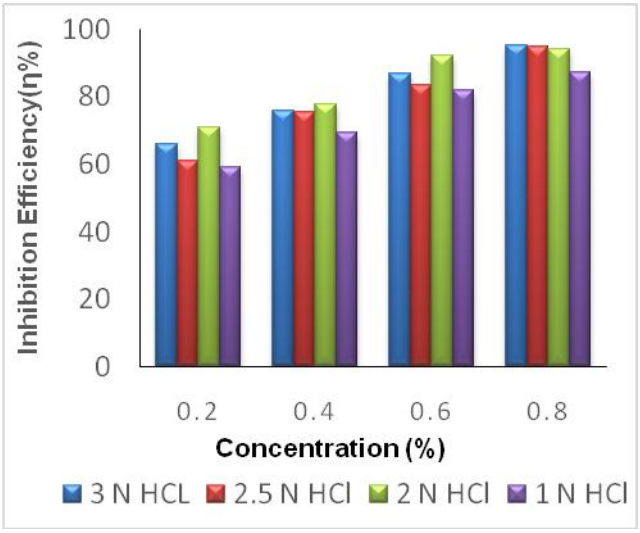

Figure 5 – Variation of inhibition efficiency with concentration of *Salvodera persica* leaves extract for aluminum in HCl by gasometric method

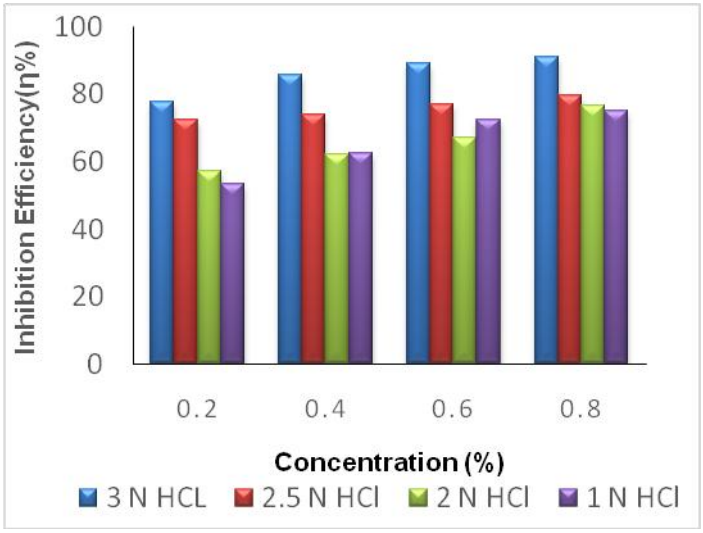

Figure 7– Variation of inhibition efficiency with concentration of *Salvodera persica* leaves extract for mild steel in HCl by gasometric method

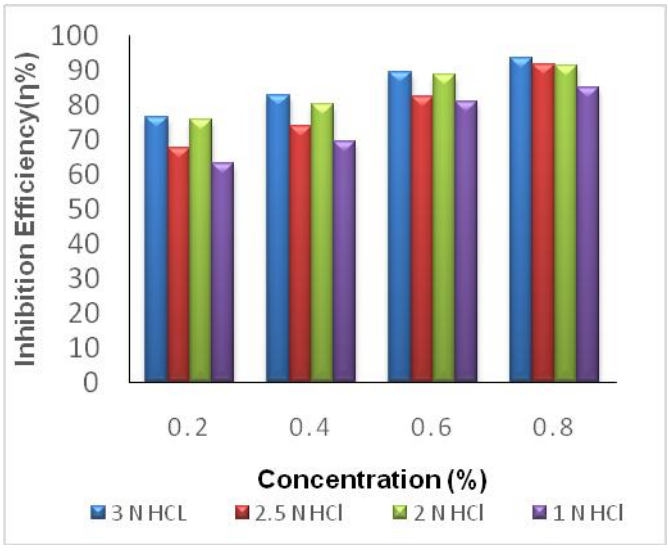

Figure 6 - Variation of inhibition efficiency with concentration of *Solanum xanthocarpum* leaves extract for aluminum in HCl

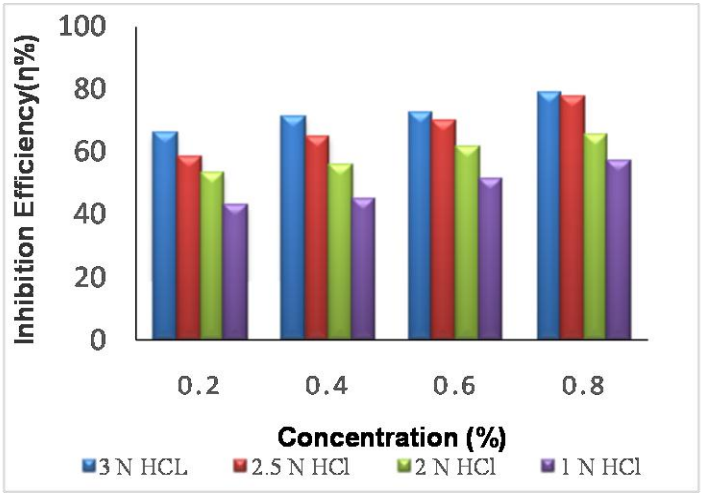

Figure 8 – Variation of inhibition efficiency with concentration of *Solanum xanthocarpum* leaves extract for mild steel in HCl

In the gasometric method a decrease in volume of hydrogen gas evolved was observed as concentration of extract increases. The maximum inhibition efficiency of 97.83% was observed in extract concentration of 0.8% for S*alvodera persica.* The study reveals that this particular plant extract is an effective inhibitor in suppressing the corrosion on the surface of the metal. A similar trend in inhibition behaviour was also shown by weight loss method.

5. CONCLUSIONS

Thus, this study proves that the extracts obtained from plants prove to be effective green corrosion inhibitors for mild steel and aluminium. This is because plant products are organic in nature, containing constituents such as tannins, amino acids, alkaloids, pigments that are known to exhibit inhibitory action. The adsorption of these compounds on the metal surface reduces the surface area available for corrosion.

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