

Use of *Tamarindus indica* extract as potential Corrosion Inhibitor for Aluminium in Acidic Medium



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Abstract

The ethanolic extracts of fruit, stem bark and leaves from the *Tamarindus indica* are tested for their effectiveness to combat corrosion of aluminium in hydrochloric acid and sulphuric acid by the mass loss and thermometric measurement. It was found that the presence of the extracts reduces the corrosion rate of aluminium in acidic solution.

The adsorption of corrosion inhibitor over the surface of aluminium was explored to be exothermic, physisorption and spontaneous. Langmuir adsorption isotherm was observed to be optimal appropriated. The well known thermodynamic adsorption parameters such as adsorption equilibrium constant (K_{ads}) and free energy change (ΔG_{ads}^0) were evaluated. It indicates a predominant interaction amongst the inhibitor and the aluminium metal surface.

The *Tamarindus indica* extract endows a benign auspices to aluminium against acid corrosion.

Keywords: Aluminium, Acid Corrosion, *Tamarindus Indica*, Corrosion Rate, Adsorption Parameter.

Introduction

Corrosion of aluminium metal is an ever persisting problem since archaeological era and it has shown its radical effects on aluminium metal [1-2]. Indigenous influences of corrosion on industrially significant aluminium metal are enormous thus corrosion quenching is significant process in terms of economic growth, technical development, environment and safety of humans [3]. The corrosion of aluminium metal in aqueous acidic solution occurs in two electrochemical reactions: oxidation reaction takes place at the anodic site and reduction occurs at the cathodic site. In acidic medium, hydrogen evolution reaction predominates whereas in neutral/alkaline medium, reduction of oxygen takes place. Aluminium is potentially an anodic material for power sources with high energy densities owing to the low atomic mass (27 g/mol) and the negative value of standard electrode potential ($E^0 = -1.66$ V) [4]. It has a face centered cubic (FCC) crystal structure [5-6] owing to which it has resistance to brittle cleavage at low temperature, this enable aluminium to be used for making tanks and vessels to hold reactants and products at a very low temperature. Aluminium protective invisible oxide films are generally stable in aqueous solution of pH range of 4.5-8.5 [7] but unstable in strong acid and alkaline solution, aluminium metal exhibits high rate of corrosion. One of the most challenging and sophisticated task for industries is the protection of aluminium from corrosion [8-9]. To different methods used to suppress corrosion of aluminium, addition of inhibitor to aggressive medium is one of the most practical used methods [10]. The inhibitors include hetero atoms (N, O, S and P) which act as an adsorption sites are considered to be influential corrosion inhibitors under acidic conditions [11]. The strong interaction among low unoccupied molecular orbitals (LUMO) of aluminium metal surface and high occupied molecular orbitals (HOMO) of inhibitor molecules enables corrosion inhibition occur via adsorption of inhibitor molecules on the surface of metal is another significant characteristic of an effective corrosion inhibitor. This property is basically dependent on the presence of π -electron in the structure of inhibitor [12]. Toxicity of chemical inhibitor is a major issue among the researchers of current era hence environmental compatibility of corrosion inhibitors has changed their view point and the immense demand of green, low toxicity, eco-friendliness, natural, acceptability, biocompatible corrosion inhibitors is

persistence emerging[13]. Numerous plant extracts have been evaluated in literature, as potential corrosion inhibitors. Some of them involve *Prosopis cineraria* [14], *Tamarindus indica* [15], *Breadfruit peels* [16], *Aloe barbadensis*[17], *Calotropis*[18], *Capparis decidua*[19], *Sapindus*[20], *Calotropis gigantean* leaves ark[21] and *Piper nigrum*linn. Seeds [22] in our study.

The present work is directed to evaluate the extract of *Tamarindus indica* was selected as green inhibitor for the mitigation of corrosion of aluminium in hydrochloric acid and sulphuric acid. It is tropical plant which is found indigenous to subcontinent belonging to the leguminous family and has been extensively cultivated in India since long period of time and commonly named as "imli" in Urdu and Hindi. Literature survey reveals that mostly *Tamarindus indica* contains limonene, linalool, p-cymene, anthranilate, oleic acid, linoleic, palmitic acid, fat, protein, carbohydrates, sugars, calcium, potassium, phosphorous, zinc, iron, sodium[23]. Nevertheless, the compounds such as longifolene, diphenyl ether and caryophyllene are also present in its essential oils [24].

Phytochemical prospection conducted on the *Tamarindus indica* extracts revealed the existence of numerous active constituents such as, phenolic compounds, L-(-)mallic acid, cardiac glycosides, mucilage, tartaric acid, arabinose, pectin, xylose, galactose and uronic acid which are known to exhibit potential medicinal, nutritional value as well as physiological activities. It also indicates that *Tamarindus indica* extract has a positive result for tannin, alkaloid, flavonoids and glycosides [25]. In the plant leaves, two triterpenes, lupeol and lupanone has been found [26].

Tamarindus indica has number of pharmacological activities owing to anti-microbial, anti-oxidant potentials and laxative properties.

Experimental

Preparation of *Tamarindus indica* extracts and test solutions

Air and shade dried different parts (leaves, stem bark and fruits) of *Tamarindus indica* were grinded and ground to powdered. The stock solution of the plant extracts were prepared by soaking known amount of finely powdered dried materials of *Tamarindus indica* in a properly corked 1000 ml capacity round bottom flask (RBF) containing sufficient extent of distilled ethyl alcohol.

On completion of soaking period, the ethanolic solution was refluxed, later on, the solvent was distilled off and residue was treated with the inorganic acid where the base is extracted as their soluble salts. The free acids are liberated by the addition of any base and extracted with varied solvents, e.g. chloroform etc. The mixture of bases thus obtained is separated by various methods into the individual compounds [27], distilled to concentrate the inhibiting chemicals and finally filtered to remove any suspended impurities. The mass of plant extracts were dried and evaluated as corrosion inhibitor for the present study. Bideionized water was used for the preparation of solutions.

From the respective stock solutions, test concentration of 0.5N, 1N, 2N, 3N, 4N and 5N HCl and H₂SO₄ acid with inhibitor concentration of 0.09, 0.18, 0.27, 0.36 and 0.45 % were prepared by using diluting with appropriate concentrations of the HCl and H₂SO₄ acid. A blank solution of only the HCl and H₂SO₄ acid were also prepared.

Preparation of test coupons

The rectangular aluminium sheet which was 0.029 cm in thickness and has the following chemical composition (wt%): Si-0.362%, Fe-0.549%, Cu-0.077%, Mn-0.1219%, Ti-0.026%, Pb-0.063%, Zn-0.004% and the remainder being Al was used for the corrosion. It was mechanically pressed and cut to form different strips, each of dimension 2.54 cm × 1.52 cm with small hole of about 2 mm diameter near the upper edge for the purpose of hanging were used as test coupons. The test strips were cleaned by buffing using different grades of SiC emery papers in order to remove any impervious oxide layer and eliminate the reaction that would have otherwise working surface with the acid and oxide layer to produce a mirror finish and degreased with ethyl alcohol, dried in acetone and they were subjected to further heating, cooling and weighing till a constant weight loss was obtained using CAH 123 electronic weighing balance with accuracy of ± 0.001 mg and preserved in moisture free desiccator prior to use for the corrosion study.

Mass loss measurement

This technique is the conventional and simplest of all corrosion monitoring technique. The basic measurement which is determined from corrosion coupon is weight loss, the weight loss taking place over the period of exposure being expressed as corrosion rate [28]. Each coupon was suspended by a V-shape glass hook and completely immersed in covered beaker containing 50 ml of the unstirred test solution of acidic environment in the presence and absence of the inhibitor at room temperature for a defined period of time. At the end of exposure period, test strips were removed from corrosive environment later were cleaned with benzene dried in an oven for 20 minutes and finally they were reweighed to evaluate weight loss. A set of triplicate experiments were performed in each case to get concordant results at 30±1°C and average values of mass loss data were calculated.

All the chemicals, acids and reagents used for the corrosion study were of analytical reagent quality. In order to satisfactory assessment of corrosion, it is essential to remove corrosion products from the specimen at the same time. The corrosion rate in mm/y (millimiles per year) can be achieved by the following equation [29]

$$\text{Corrosion rate (mmy}^{-1}\text{)} = (\text{Mass loss} \times 87.6) / (\text{Area} \times \text{Time} \times \text{Metal density})$$

Where mass loss is expressed in mg, area is expressed in cm² of metal surface exposed, time is expressed in hours of exposure, metal density is expressed in g / cm³ (density of aluminium is 2.7 g/cm³) and 87.6 is conversion factor.

The fractional surface coverage (θ) can be calculated by the formula [30]

$$\theta = \frac{\Delta M_u - \Delta M_i}{\Delta M_u}$$

Where θ fractional surface coverage and ΔM_u and ΔM_i are the mass loss of the metal in uninhibited and inhibited acid respectively.

The percentage inhibition efficiency (η %) was calculated as

$$\eta\% = 100 (\Delta M_u - \Delta M_i / \Delta M_u)$$

Thermometric Measurement

Inhibitory efficacy were also investigated by using Mylius thermometric technique. Mylius introduced this technique and originally developed to assess the corrosiveness of aluminium alloys. This technique included, thermometer bulb and single strip (2.54 cm length \times 1.52 cm width \times 0.029 cm thick) was employed in a glass hook and were completely immersed in reaction chamber containing 50 ml of the test solution at $30 \pm 1^\circ\text{C}$ and left exposed to air. Variation in temperature were measured at successive intervals of 1 minute with the help of calibrate thermometer with a precision of $\pm 0.5^\circ\text{C}$. The temperature increased slowly in the beginning then quickly and attain a maximum value of temperature before declining. Highest temperature was reported.

In this technique, the variation of temperature is followed as a function of time. Test was carried out in 3N, 4N and 5N HCl and H_2SO_4 solution at $30 \pm 1^\circ\text{C}$. The acidic solution were prepared by using deionized water. This technique allowed for the estimation of the reaction number (RN) and inhibition efficiency (η %). At the end of experiment, test strips were carefully cleaned with acetone [31] to quench further corrosion from taking place and then reweighed to evaluate mass loss (ΔM). Percentage inhibition efficiency was calculated as [32]

$$\eta\% = 100 (RN_{\text{free}} - RN_i) / RN_{\text{free}}$$

Where RN_{free} and RN_i are the reaction number in the absence and presence of inhibitors respectively and RN (K / min) is defined by Mylius as

$$RN = (T_m - T_0) / t$$

Where T_m and T_0 are the maximum and initial temperature respectively and t is the time required to reach the maximum temperature.

Results and Discussion

Values of mass loss (ΔM), corrosion rate (ρ_{corr}), fractional surface coverage (θ) and percentage inhibition efficiency (η %) were evaluated from mass loss technique for varying concentration of hydrochloric acid and sulphuric acid solution and inhibitor are depicted in Tables (1-4). It is observed that the inhibition efficiency increases with increase in the concentration of inhibitor and decreases with increases in acid strength.

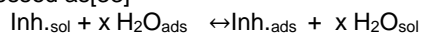
All the inhibitors deteriorate the corrosion rate to a significant extent. The corrosion rate (ρ_{corr}) decreases with increases in concentration of inhibitors. Values of corrosion rate signified that corrosion rate is directly inverse proportional to extract concentration. The maximum efficiency was achieved in 0.5N HCl acid solution. The inhibitor indicates efficiencies in the range from 38.47% to a maximum 85% for fruit extract (table 2).

Inhibition efficiency values were also evaluated using thermometric procedure. No significant temperature changes were recorded at

0.5N, 1N and 2N acid concentration. Therefore, use of thermometric technique was adopted only 3N, 4N and 5N HCl and H_2SO_4 acid solution. The results abbreviated in table (5-6) are in wide agreement with those obtained from mass loss measurement. Fluctuation of reaction number with inhibitor concentrations, presented graphically (Fig.1-2) indicates crucially linear behaviour with the negative slope showing that the reaction number decreases with increasing inhibitor concentration.

Adsorption Isotherms

Adsorption isotherm signified the mechanism of adsorption of inhibitor molecule on the surface of metal in aqueous solution. It should be considered as a substitution reaction and the adsorption process can be expressed as [33]



Where x , the size ratio, is the number of water molecules displaced by one molecule of inhibitor during adsorption mechanism. In this process Bockris et al [34] have assumed that water molecules dipoles have to be oriented and their orientation depends on the metal charge adapting the appropriate adsorption isotherm. Adsorption isotherm provides useful insights into the mechanism of corrosion inhibition. It was found that higher concentration of *Tamarindus indica* extract is essential for maximum adsorption over aluminium surface. Numbers of adsorption isotherms were applied but the best fit for the adsorption for *Tamarindus indica* is Langmuir adsorption isotherm.

Numerous investigators have used the Langmuir adsorption isotherm to study inhibitors characteristics assuming that the inhibitors adsorbed molecule on the metal surface decreases the surface area available for the corrosion reaction to occur [35-36].

The relationship among the fractional surface coverage (θ) and inhibitors concentration (C) in % can be expressed by the following Langmuir adsorption isotherm

$$\log (\theta / 1 - \theta) = \log K_{\text{ads}} + \log C$$

It should give a straight line of unit gradient for the plot of $\log (\theta / 1 - \theta)$ versus $\log C$. The corresponding plot (Fig.3-5) was linear but the slopes are not equal to unity as would be expected for the Langmuir adsorption isotherm equation.

This deviation from the unity may be interpreted on the basis of the strong interaction among the adsorbed species onto the metal surface.

The K_{ads} is adsorption equilibrium constant, the K_{ads} value can be calculated from the intercept line on the $\log(\theta/1-\theta)$ axis, and is related to the standard free energy of adsorption (ΔG_{ads}^0) as

$$\Delta G_{\text{ads}}^0 = -2.303 RT \log(55.5 K_{\text{ads}})$$

Where 55.5 is the molar concentration of water in the solution, $R = 0.008314$ KJ/mol, is the universal gas constant and T is the absolute temperature in kelvin.

From the table 7, values of ΔG_{ads}^0 are negative in all cases and lie in the range of -15.59 to -14.32 KJ/mol.

The negative values of ΔG_{ads}^0 ensure the spontaneity of the adsorption process as well as

stability of the adsorption layer which is made by *Tamarindus indica* onto the metal surface.

Commonly, value of ΔG^0 upto -20 KJ/mol are consistent with the electrostatic interactions among the charged molecules and the charged metal indicating physisorption while $\Delta G^0 \geq -40$ KJ/mol are

attributed with chemisorption owing to sharing or transfer of electron from the inhibitor molecule to the metal surface to form a coordinate type of bond. The values ΔG^0_{ads} obtained in this experiment being less negative than -20 KJ/mol support physisorption process.

Table1. Mass loss (ΔM) and corrosion rate (mm/y) for aluminium in various concentration of hydrochloric acid with and without ethanolic extract of leaves, stem bark and fruits of *Tamarindus indica* at 30 ± 1 °C. Effective area of specimen: 7.72 cm² Immersion time: 24 hrs.

Concentration of Inhibitor (%)	0.5N HCl		1N HCl		2N HCl	
	Mass loss (ΔM (mg))	Corrosion rate(mm/y)	Mass loss(ΔM) (mg)	Corrosion rate(mm/y)	Mass loss(ΔM) (mg)	Corrosion rate(mm/y)
Uninhibited	172.6	30.22	278.4	48.75	352.6	61.74
Leaves extract						
0.09	109.4	19.15	202.3	35.42	251.4	44.02
0.18	98.6	17.26	173.4	30.36	230.3	40.32
0.27	74.2	12.99	145.6	25.49	188.1	32.93
0.36	59.2	10.36	109.4	19.15	136.2	23.85
0.45	32.4	5.67	81.3	14.23	103.4	18.10
Stem bark extract						
0.09	105.3	18.49	204.6	35.82	245.3	42.95
0.18	83.6	14.63	174.5	30.55	213.4	37.36
0.27	72.4	12.67	144.8	25.35	166.3	29.12
0.36	53.8	9.42	109.2	19.12	115.4	20.20
0.45	44.2	7.73	78.3	13.71	104.8	18.35
Fruit extract						
0.09	106.2	18.59	213.2	37.33	243.7	42.67
0.18	102.4	17.93	199.6	34.95	213.4	37.36
0.27	98.5	17.24	155.4	27.21	182.6	31.97
0.36	44.8	7.84	106.2	18.59	125.7	22.01
0.45	25.7	4.50	71.5	12.52	89.3	15.63

Table 2. Fractional surface coverage (θ) and percentage inhibition efficiency($\eta\%$) for aluminium in various concentration of hydrochloric acid solution with and without ethanolic extract of leaves, stem bark and fruit of *Tamarindus indica* at 30 ± 1 °C. Effective area of specimen: 7.72 cm² Immersion time: 24 hrs.

Concentration of Inhibitor(%)	0.5N HCl		1N HCl		2N HCl	
	Surface coverage (θ)	Inhibition Efficiency ($\eta\%$)	Surface coverage (θ)	Inhibition Efficiency ($\eta\%$)	Surface coverage (θ)	Inhibition Efficiency ($\eta\%$)
Uninhibited	-	-	-	-	-	-
Leaves extract						
0.09	0.3661	36.61	0.2733	27.33	0.2870	28.70
0.18	0.4287	42.87	0.3771	37.71	0.3468	34.68
0.27	0.5701	57.01	0.4770	47.70	0.4665	46.65
0.36	0.6570	65.70	0.6070	60.70	0.6137	61.37
0.45	0.8122	81.22	0.7079	70.79	0.7067	70.67
Stem bark extract						
0.09	0.3899	38.99	0.2650	26.50	0.3043	30.43
0.18	0.5156	51.56	0.3732	37.32	0.3947	39.47
0.27	0.5805	58.05	0.4798	47.98	0.5283	52.83
0.36	0.6882	68.82	0.6077	60.77	0.6727	67.27
0.45	0.7439	74.39	0.7187	71.87	0.7027	70.27
Fruit extract						
0.09	0.3847	38.47	0.2341	23.41	0.3088	30.88
0.18	0.4067	40.67	0.2830	28.30	0.3947	39.47
0.27	0.4293	42.93	0.4418	44.18	0.4821	48.21
0.36	0.7404	74.04	0.6185	61.85	0.6435	64.35
0.45	0.8511	85.11	0.7431	74.31	0.7467	74.67

Table 3. Mass loss(ΔM) and corrosion rate(mm/y) for aluminium in Sulphuric acid solution with and without ethanolic extract of leaves, stem bark and fruit of *Tamarindus indica* at 30 ± 1 °C.
Effective area of specimen: 7.72 cm² Immersion time: 24 hrs.

Inhibitor addition (%)	0.5N H ₂ SO ₄		1N H ₂ SO ₄		2N H ₂ SO ₄	
	Mass loss(ΔM) (mg)	Corrosion rate (mm/y)	Mass loss(ΔM) (mg)	Corrosion rate (mm/y)	Mass loss(ΔM) (mg)	Corrosion rate (mm/y)
Uninhibited	104.8	18.35	154.3	27.02	204.7	35.84
Leaves extract						
0.09	84.2	14.74	112.4	19.68	154.4	27.03
0.18	68.1	11.92	99.6	17.44	128.3	22.46
0.27	52.7	9.22	78.3	13.71	103.5	18.12
0.36	44.3	7.75	64.7	11.33	89.3	15.63
0.45	32.4	5.67	53.6	9.38	71.6	12.53
Stem bark extract						
0.09	86.3	15.11	123.7	21.66	150.4	26.33
0.18	71.6	12.53	97.4	17.05	125.6	21.99
0.27	58.4	10.22	80.6	14.11	92.8	16.25
0.36	46.5	8.14	66.4	11.62	80.7	14.13
0.45	35.4	6.19	58.6	10.26	62.3	10.90
Fruit extract						
0.09	73.4	12.85	116.2	20.34	151.3	26.49
0.18	59.2	10.36	98.3	17.21	122.4	21.43
0.27	44.3	7.75	76.5	13.39	97.9	17.14
0.36	36.9	6.46	61.3	10.73	81.6	14.28
0.45	26.3	4.60	48.2	8.44	57.8	10.12

Table 4. Fractional surface coverage (θ) and percentage inhibition efficiency ($\eta\%$) for aluminium in sulphuric acid solution with and without ethanolic extract of leaves, stem bark and fruit of *Tamarindus indica* at 30 ± 1 °C.

Effective area of specimen: 7.72 cm² Immersion time : 24 hrs.

Inhibitor addition (%)	0.5N H ₂ SO ₄		1N H ₂ SO ₄		2N H ₂ SO ₄	
	Surface coverage (θ)	Inhibition Efficiency ($\eta\%$)	Surface coverage (θ)	Inhibition Efficiency ($\eta\%$)	Surface coverage (θ)	Inhibition Efficiency ($\eta\%$)
Uninhibited	-	-	-	-	-	-
Leaves extract						
0.09	0.1965	19.65	0.2715	27.15	0.2457	24.57
0.18	0.3501	35.01	0.3545	35.45	0.3732	37.32
0.27	0.4971	49.71	0.4925	49.25	0.4943	49.43
0.36	0.5772	57.72	0.5806	58.06	0.5637	56.37
0.45	0.6908	69.08	0.6526	65.26	0.6502	65.02
Stem bark extract						
0.09	0.1765	17.65	0.1983	19.83	0.2652	26.52
0.18	0.3167	31.67	0.3687	36.87	0.3864	38.64
0.27	0.4427	44.27	0.4776	47.76	0.5466	54.66
0.36	0.5562	55.62	0.5696	56.96	0.6057	60.57
0.45	0.6622	66.22	0.6202	62.02	0.6956	69.56
Fruit extract						
0.09	0.2996	29.96	0.2469	24.69	0.2608	26.08
0.18	0.4351	43.51	0.3629	36.29	0.4020	40.20
0.27	0.5772	57.72	0.5042	50.42	0.5217	52.17
0.36	0.6479	64.79	0.6027	60.27	0.6013	60.13
0.45	0.7490	74.90	0.6876	68.76	0.7176	71.76

Table 5. Reaction number(RN) and Inhibition efficiency($\eta\%$) for aluminium in 3N,4N and 5N HCl solution with or without inhibitor addition of *Tamarindus indica* at 30 ± 1 °C.

Inhibitor Addition(%)	3N HCl		4N HCl		5N HCl	
	RN(K/min)	I.E.($\eta\%$)	RN(K/min)	I.E.($\eta\%$)	RN(K/min)	I.E.($\eta\%$)
Blank	0.2843	-	1.7084	-	1.9462	-
Leaves extract						
0.09	0.1842	35.20	0.9640	43.57	1.0728	44.87
0.18	0.1020	64.12	0.4800	71.90	0.5380	72.35
0.27	0.0656	76.92	0.3640	78.69	0.4106	78.90
0.36	0.0520	81.70	0.2749	83.90	0.3016	84.50
0.45	0.0330	88.39	0.1878	89.00	0.2108	89.16
Stem bark extract						
0.09	0.2146	24.51	1.2010	29.70	1.2365	36.46
0.18	0.1520	46.53	0.8362	51.05	0.8316	57.27
0.27	0.1166	58.98	0.5832	65.86	0.6372	67.25
0.36	0.0832	70.73	0.3354	80.36	0.3124	83.94
0.45	0.0456	83.96	0.2263	86.75	0.2314	88.11
Fruit extract						
0.09	0.2000	29.65	1.0525	38.39	1.1960	38.54
0.18	0.1002	64.75	0.5146	69.87	0.5678	70.82
0.27	0.0638	77.55	0.3648	78.64	0.3912	79.89
0.36	0.0476	83.25	0.2320	86.42	0.2586	86.71
0.45	0.0314	88.95	0.1560	90.86	0.1764	90.93

Table 6. Reaction number (RN) and Inhibition efficiency($\eta\%$) for aluminium in 3N, 4N and 5N H₂SO₄ acid solution with or without inhibitor addition of *Tamarindus indica* at 30 ± 1 °C.

Inhibitor addition (%)	3N H ₂ SO ₄		4N H ₂ SO ₄		5N H ₂ SO ₄	
	RN(K/min)	I.E.($\eta\%$)	RN(K/min)	I.E.($\eta\%$)	RN(K/min)	I.E.($\eta\%$)
Uninhibited	0.0928	-	0.1433	-	0.1756	-
Leaves extract						
0.09	0.0448	51.72	0.0648	54.78	0.0646	63.21
0.18	0.0380	59.05	0.0543	62.10	0.0576	67.19
0.27	0.0302	67.45	0.0446	68.87	0.0504	71.29
0.36	0.0248	73.27	0.0369	74.24	0.0426	75.74
0.45	0.0216	76.72	0.0312	78.22	0.0322	81.66
Stem bark extract						
0.09	0.0462	50.21	0.0704	50.87	0.0678	61.38
0.18	0.0426	54.09	0.0596	58.40	0.0608	65.37
0.27	0.0375	59.59	0.0521	63.64	0.0578	67.08
0.36	0.0294	68.31	0.0402	71.94	0.0472	73.12
0.45	0.0251	72.95	0.0356	75.15	0.0348	80.18
Fruit extract						
0.09	0.0452	51.29	0.0682	52.40	0.0648	63.09
0.18	0.0397	57.21	0.0549	61.68	0.0588	66.51
0.27	0.0324	65.08	0.0464	67.62	0.0526	70.04
0.36	0.0248	73.27	0.0378	73.62	0.0445	74.65
0.45	0.0228	75.43	0.0324	77.39	0.0326	81.43

Table7 : Some parameter of the linear regression of Langmuir adsorption isotherm for aluminium corrosion in 0.5N,1N and 2N HCl solution containing *Tamarindus indica* fruit extract

	0.5N HCl	1N HCl	2N HCl
Correlation coefficient (R ²)	0.672	0.883	0.890
slope	1.277	1.388	1.104
K _{ads}	8.8	6.4	5.3
ΔG_{ads}^0 (KJ/mol)	-15.59	-14.79	-14.32

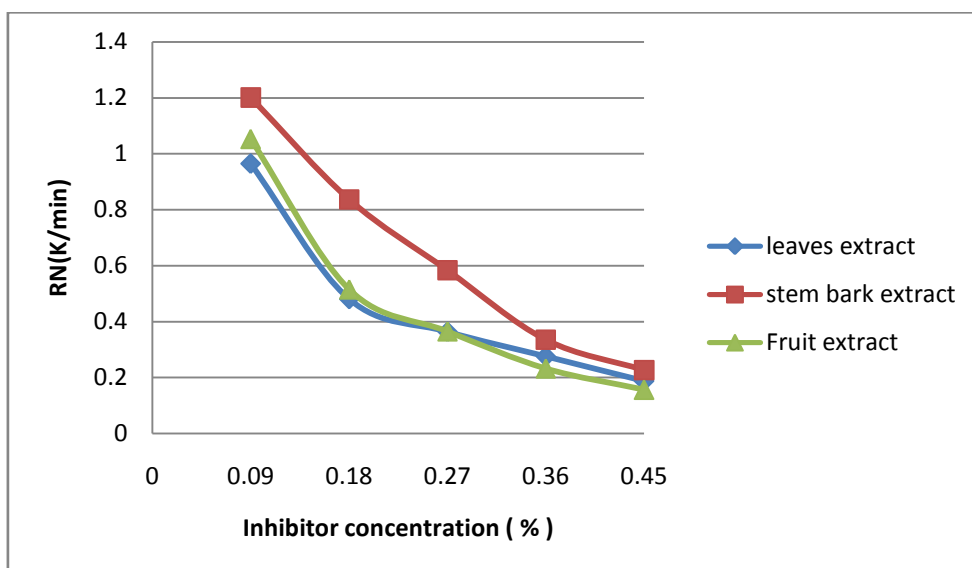


Figure 1. Variation of reaction number(RN) with inhibitor concentration(C) for Al in 4N HCl

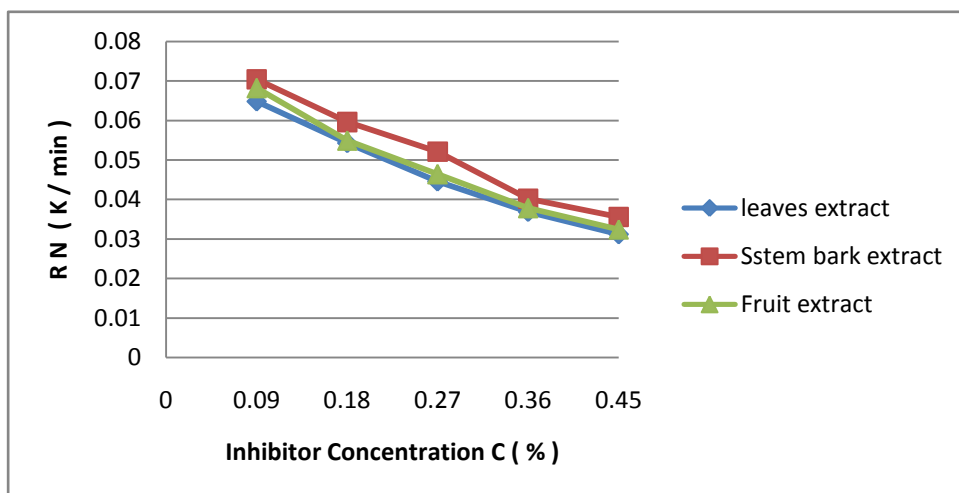


Figure 2. Variation of reaction number(RN) with inhibitor concentration(C) for Al in 4N H₂SO₄

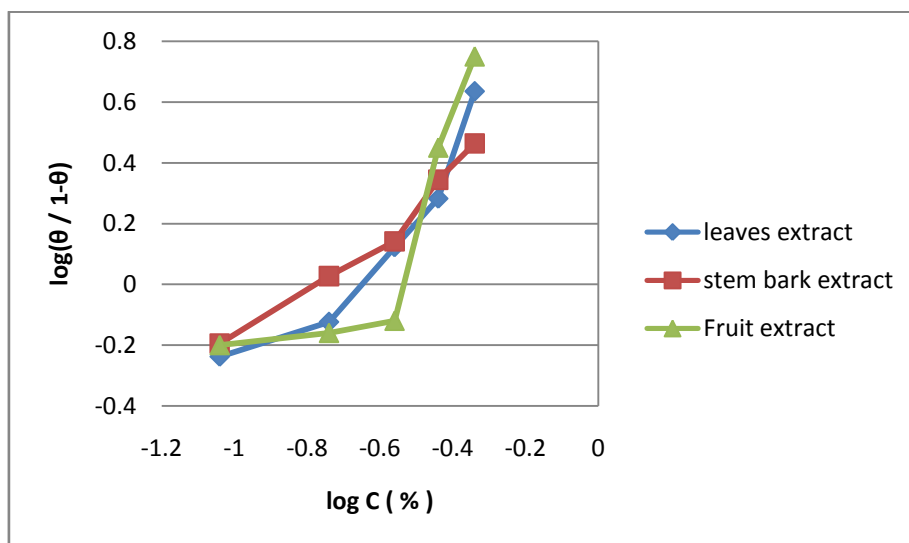


Figure 3. Linear variation of $\log(\theta/1-\theta)$ versus $\log C$ which indicates a Langmuir adsorption isotherm of *Tamarindus indica* extract for Al in 0.5N HCl

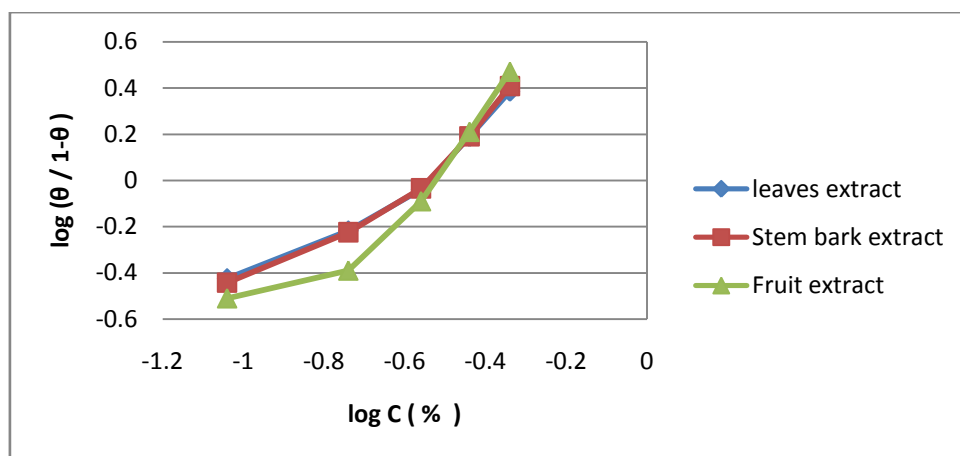


Figure 4. Linear variation of $\log(\theta/1-\theta)$ versus $\log C$ which indicates a Langmuir adsorption isotherm of *Tamarindus indica* extract for Al in 1N HCl

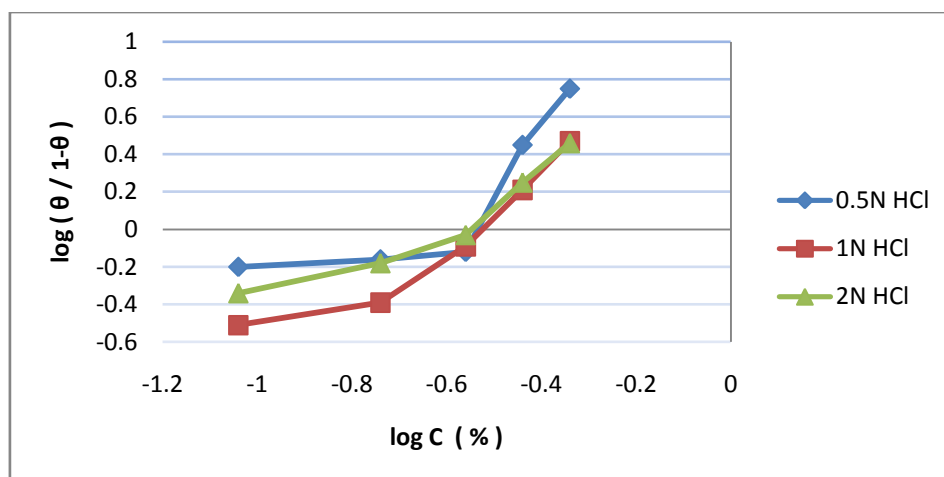


Figure 5. Linear variation of $\log(\theta/1-\theta)$ versus $\log C$ which indicates a Langmuir adsorption isotherm of fruit extract of *Tamarindus indica* for Al in different concentration of HCl

Conclusion

Tamarindus indica was found to exhibit good corrosion inhibitory effects on aluminium in acidic media. The analyses indicate that the in acid medium *Tamarindus indica* inhibited metal dissolution to a large degree (I.E.=90.93%).The adsorption mechanism of *Tamarindus indica* on aluminium surface was well expressed by the Langmuir adsorption isotherm.

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