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CORROSION INHIBITION BY AQUEOUS EXTRACT OF *TEPHROSIA VILLOSA* LEAVES

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ABSTRACT

The present work aims to evaluate the inhibitive effect of *Tephrosia villosa* extracts to minimize the corrosion rate of mild steel in acidic medium. The study was finding a process of low cost and environmentally friendly also safe inhibitor to minimize the mild steel corrosion rate. Corrosion inhibition of mild steel in 1.0N HCl and 0.5M H_2SO_4 solution by *Tephrosia villosa* extract is achieved. The inhibition process is ascribed to the formation of an adsorbed layer of inhibitor on the surface of metal which prevent the metal from corrosion. The inhibition efficiency (%IE) and surface coverage (θ) of leaves extract of *Tephrosia villosa* increases with increase in concentration of inhibitor. Polarisation and impedance studies show that the inhibition efficiency increases with increase in inhibitor concentration. The maximum efficiency was observed to be 98.90% in 1.0N HCl and 97.64% in 0.5M H_2SO_4. The adsorption of leaves extract on the surface of mild steel was based to obey Langmuir and Tempkin isotherm. The free energy value (ΔG_{ads}) indicated that the adsorption inhibitor molecule was typical of physisorption. The results obtained show that *Tephrosia villosa* extract could serve as an excellent eco-friendly green corrosion inhibitor. This green inhibitor could find apposite applications in anodizing and coatings of metal surface.

KEYWORDS: *Tephrosia Villosa*, Corrosion inhibitor, Mild Steel, Weight loss, Polarisation study, Impedance study, Langmuir & Tempkin adsorption isotherm.

INTRODUCTION

Corrosion is a actual process, that converts a polished metal to extra stable form, for instance in the form of hydroxide or oxide. It is the gradual retrogression of metal by chemical reaction among their atmosphere. For electrochemical corrosion, the generation of iron oxides is a well-noted example for corroding. This sort of destroying is normally generates salts or oxides of the original metal, and outcomes in essential orange color. Corrosion deforms the most effective properties of metals and systems including force, image and permeableness to gas and liquid.

Green inhibitors

Inhibitor is a constituent added in a very less concentration to handle the metal surface that exhibited to a corrosive surrounding that stops the corrosion rate of a metal. It is also called as place hindering element, blocking elements or, due to their adsorptive qualities. The name inhibitor applies to the materials that have bio productivity in nature. The plant extracts inhibitors probably possess bio-productivity due to the origin of nature.

Significance based on green corrosion inhibitors

Managing of corrosion in metals is of aesthetical, industrial, mechanical, and environmental significance. The advantage of inhibitors is one of the greatest choices of preventing metals opposed to corrosion. The harmfulness of organic corrosion inhibitors has inspired the seeking for green corrosion inhibitors as they are decomposable, does not holding heavy metals or harmful composites. As in accession to be environmentally friendly and commercially agreeable, natural plant products are cheap, easily available and recoverable.

It is significant to reduce or prevent the metals from corrosion mechanically, commercially, ecologically environmentally friendly and completely. It is a main and technical problem. Green corrosion inhibitors are established to be efficient from an environmental aspect and can act a main task upon toxic inhibitors. It is yet wonderful that the reverse corrosion efficiency of green corrosion inhibitors are equivalent to more efficient than chemical inhibitors. It is sure that natural plant products appear out as efficient corrosion inhibitors in the future due to their readily availability, cheap, decomposable and non-harmful nature.

Analysis in the area of corrosion inhibition of metals by natural plant products has rising the importance about the controlling corrosion ability of amino acids, terpenoids, tannins, alkaloids, organic dyes and glycosides has occurred in stable interest on the inhibition of corrosion of natural compounds of green plant.

Rana et al. have applied the extract of various plants of Nepalese origin as green inhibitor for corrosion on mild steel in 0.5M NaCl solution. They noticed about the adsorption of all the three plant extracts on mild steel surface agreed both Langmuir and Tempkin adsorption.[1] Antibacterial activity and corrosion inhibiting nature of mild steel in 1.0M hydrochloric acid by M. piperita and M. pulegium essential oils have been evaluated by Chraibi et al. Reports displayed that essential oils plays as a mixed-type inhibitor. When we increasing the charge transfer resistance, decreasing the double layer capacitance by the concentration of essential oil increasing for both plants.[2] Plant extracts used as corrosion inhibitors have been broadly analyzed and are introduced as an alternative to manmade organic compounds. Investigation of Alpinia galanga and its strong principle, 1'-acetochavicol acetate as environmental-friendly inhibitors of corrosion on mild steel in acidic medium has been finished by Ajeigbe et al.[3] Potentiodynamic polarization examinations revealed that the inhibitors acted as mixed inhibitors. Sivakumar and Srikanth have explored the activity of a anticorrosive using Schreabera swietenioids leaves as green inhibitor on mild steel in acidic medium. They have applied weight loss method, polarization extents and electrochemical impedance spectroscopy at room temperature. Nyquist plot discovered that the concentration of plant extracts increases the charge transfer resistance and consequently increases the corrosion inhibition efficiency.[4] Inhibition action of corrosion on carbon steel in 1M H_2SO_4 solution by Thapsia villosa extracts(Ethyl acetate extract (EAE) and butanolic extract (BE)) have been analyzed by Kalla et al. utilizing electrochemical impedance spectroscopy (EIS), potentiodynamic polarization and mass loss methods .The EAE and BE playing as a mixed types inhibitors. The extract on carbon steel surface obeys Langmuir isotherm adsorption.[5] Rajendran et al. have applied the extracts of diverse plant materials including henna leaves, curcumin, caffeine, spirulina to manage corrosion of metals.[6-29] In spite of the fact that a number of acute publications have been dedicated to corrosion inhibition by plant extracts but the elaborate study of the adsorption mechanism are restricted and drawback of maximum of the publications on plant extracts as corrosion inhibitor is that more active component has not been determined. The present work is initiated to examine the inhibition efficiency of an aqueous extract of *Tephrosia Villosa* leaves in preventing corrosion on mild steel in hydrochloric and sulphuric acid solutions. Mass loss measurements and electrochemical methods as in polarization and AC impedance spectra techniques have been applied.

EXPERIMENTAL METHODS

Extract of *Tephrosia Villosa* leaves

Extract of *Tephrosia Villosa* leaves is applied as inhibitor for corrosion in the present work. The given below figure-1 shows the leaves and flowers of *Tephrosia Villosa*.

Figure 1: *Tephrosia Villosa.*

Details and medicinal uses of *Tephrosia Villosa are given below*

Botanical name: *Tephrosia Villosa;* Family: Fabaceae Kingdome: Plantae; Class: Magnoliosida; Order: Fabales; Genus: Tephrosia; Division: Tracheo Phyta; Tamil name: Punaikkaivetlai, Vayakkavalai.

Pharmacological action: Blood purifier, heart disorders, blood disorders, inflammation, cough, dyspnoea, skin disorders anti-inflammatory, diuretic, anti-diabetic.

Collection of the plant material: The leaves were collected from the area of Villupuram district, Tamilnadu, India.

Preparation of Extract

Solvent extraction using soxhlet method

A crude extract of *Tephrosia Villosa* leaves was prepared by using soxhlet extraction process. About 150g of dried powdered leaves of *Tephrosia Villosa* were uniformly packed into the thimble and extracted by using 250ml of double distilled water. The method of extraction process was continued for a day or upto the solvent present siphon tube of an extracting sample getting colorless. Since the extract was captured in a beaker and taken on the hot plate and heated at 4^0C for the use of corrosion studies.

Preparation of the specimens

Mild steel specimen (0.026%-S, 0.06%-P, 0.4%-Mn, 0.11%-C and the remaining iron) of the dimensions 1x5x0.2 cm were polished to mirror finish they are degreased with acetone by using cotton and used for the weight loss, polarization and impedance studies.

Materials and chemicals used

Cylindrical mild steel rod firmed in Teflon with an disclosed area of 1 cm^2 were used for polaraization. The electrodes were polished by using emery papers of 0/0, 1/0, 2/0, 3/0, and 4/0 grades and degreased by using acetone, dried and then used.

Table 1: Results of phytochemical screening of aqueous extract of *Tephrosia Villosa* leaves.[30,31,32]

Constituents	Test	Phytochemical aqueous extract
Alkaloids	Hager's test	-
Flavonoids	NaOH test	+
Saponins	Foam test	-
Carbohydrate	Molisch test	+
Protein and amino acid	Xanthoprotein test	-
Phenols	Ferric chloride test	+
phytoSterols	Salkowski's test	+
Tannins	Gelatin test	+
Glycosides	Libermann's test	+
Tri terpenoids	Haemolysis test	+
Saponins	Foam test	+
Fixed oils and fats	Saponification test	+

Weight loss method

Weight loss calculations were functioned in 1.0N HCl and 0.5M H_2SO_4 acid solutions in the presence and absence of inhibitor. Concentrations in these acids was carried out by different concentrations by using the given below formula:

$$\text{Inhibition efficiency (\%)} = W_0\text{-}W_i/W_0\times100$$

Where

W_0= Weight loss in plain acid

W_i= Weight loss in presence of inhibitor

Electrochemical method

Polarization and AC impedance spectra were registered in a potentiostat.The investigation were observed in a three electrode cell assembly.

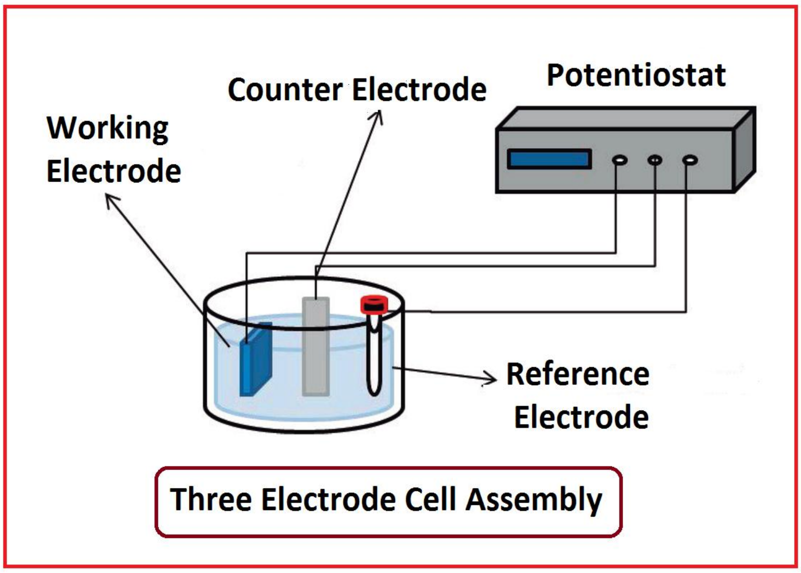

Figure 2: Three electrode cell assembly.

Mild steel was taken as working electrode. SCE was taken as reference electrode and a platinum foil was taken as counter electrode. The working electrode used as a mild steel rod of the same components embedded in araldite and with an exposed area of 1 cm^2.

Potentiodynamic polarization measurements

Potentiodynamic polarization measurements were determined for mild steel specimen with and without the inhibitors. Polarization studies were performed to conclude the corrosion potential, corrosion current and the Tafel slope.

Mild steel rod of the same proportions embedded in araldite and with an exposed area of 1cm^2 was used as a working electrode. Three electrode assembly acts as a potential cell. A rectangular foil acts as the counter electrode. The area of the auxillary electrode is too larger compared with the area of the working electrode. The reference electrode is represented as $Hg/HgCl_2/0.5M\ H_2SO_4$ for HCl and H_2SO_4medium.

A 100ml quantity of the test solution was used in a polarization cell. The working electrode was polished with 0/0, 1/0, 2/0, 3/0, and 4/0 emery papers completely and degreased with acetone, the working electrode, reference and auxiliary platinum electrodes were gathered and connections were created.

Stirring was allowed to the test solutions to ignore tor the system the concentrations polarization before starting experiment. A time gap of about 15 minutes was given for the system to obtain state and open circuit potential was measured. Polarization calculations were made carried out from 800mV to 250mV at a constant identical to weight loss calculations. Polarization measurements were created from mild steel specimens in 1.0N HCl and 0.5M H_2SO_4 with and without the inhibitor. Current in mA and potential in mV were plotted. From the graph the Tafel slope (in mV/decade) and the corrosion potential (in mV/decade) were measured.

RESULTS AND DISCUSSION

It is well known fact that research activities directing to the improvement of corrosion inhibitors banded on natural products have enormous scope in most of the industries, due to their non-harmfulness, decomposable nature and are also readily available. Investigation of natural inhibitors is particularly interesting because they are non-expensive, ecologically friendly and possess no threat to the surroundings.

The efficiency of an extract as a corrosion inhibitor can be assigned to the number of mobile electron pairs present, free electrons from π-orbital and the electron density around the hereto atoms. In the present investigation, inhibition effect of *Tephrosia Villosa* leaves extract in 1.0N HCl and 0.5M H_2SO_4 solutions has been evaluated by using weight loss techniques and potentiodynamic polarization and AC impedance studies. The efficiency of the leaves extract on the scope of inhibition of corrosion on mild steel in 1.0N HCl and 0.5M H_2SO_4 solutions by using the extract of the plant leaves can be described by means of its adsorption on the mild steel surface. The metal surface adsorbed the extract by applying when mild steel is soaked in the acid solution the phyto-constituents floats from the bulk of solution around the surface of the metal. The inhibitive effect of *Tephrosia Villosa* leaves extract on the mild steel corrosion in 1.0N HCl and 0.5M H_2SO_4 has been evaluated by weight loss process, potentiodynamic polarization and AC impedance methods. Inhibition efficiency rates found by the above techniques shows the closed similarities. The highest inhibition efficiency was determined to be 98.90%.

Increasing the concentration of *Tephrosia Villosa* decreases the corrosion probably due to the adsorption of the inhibitor on the mild steel surface. The inhibition efficiency percentage increases with increase in the concentration of inhibitor. The corrosion inhibition by leaves extract of *Tephrosia Villosa* is assigned to the adsorption of the additives on the metal surface. The readings observed from the weight loss method for the considered inhibitor bind properly into the Langmuir isotherm and the Tempkin isotherm. The readings are obtained from the free adsorption method suggests that set of physisorption and chemisorptions valuated for the surface of mild steel.

The extract of *Tephrosia Villosa* leaves controls the corrosion, due to the presence of the phytochemical constituents are deviating the corroded metal surface into the noble. The polarization techniques shows the similarities with inhibition efficiency obtained from weight loss methods.

Weight loss experiment

Tables-2&3 give the inhibitive effect of various concentrations of *Tephrosia Villosa* leaves extract in 1.0N HCl and 0.5M H_2SO_4 solution. The efficiency of inhibition depends upon the character and manner of adsorption of the mild steel surface. The adsorption is expected to be a quasi-sustitution methods between any of the natural constituents present in the green inhibitor and the water molecules on the surface. It is noted that the inhibitor concentration increases the effect of inhibition on mild steel.

Table 2: Inhibition action on mild steel corrosion in 1.0N HCl by leaves extract of *Tephrosia Villosa.*

[Inhibitor], ppm	Rate of corrosion, g cm^{-2} hr^{-1}	Inhibition Efficiency (%)
Blank	-	-
100	0.00013	78.14
200	0.00010	82.78
300	0.00009	85.24
400	0.000073	87.97
500	0.000061	89.89
600	0.000040	93.44
700	0.000026	95.62
800	0.000015	97.54
900	0.000006	98.90

Table 3: Inhibition action on mild steel corrosion in 0.5M H_2SO_4 by leaves extract of *Tephrosia Villosa.*

[Inhibitor], ppm	Rate of corrosion, g cm^{-2} hr^{-1}	Inhibition Efficiency (%)
Blank	-	-
100	0.000088	75.12
200	0.000070	80.18
300	0.000050	85.84
400	0.000045	87.26
500	0.000031	91.03
600	0.000025	92.92
700	0.000020	94.33
800	0.000015	95.75
900	0.000008	97.64

Adsorption isotherm

Adsorption isotherms are practically used to explain the adsorption process. The most commonly used isotherms include Langmuir, Flory-Huggins, Tempkin and the currently developed isotherm model of El-Awady et al. The endowment of adsorption isotherms explains the adsorption of inhibitor can produce major idea to the nature of the inhibitor-metal interaction. Adsorption of phyto-components occurs as the energy of interaction between molecules and surface of metal is greater than the interaction energy between the water molecules and the surface of metal.

Langmuir adsorption isotherm

Adsorption isotherms are most important to describe the action of mechanism of phyto-electrochemical reaction. Langmuir adsorption isotherm is:

$\Theta = K_{ads}.C/1+k_{ads}\ .C$

$\Theta\ (1+k_{ads}.C) = K_{ads}\ .C$

$\Theta = K_{ads}.C - K_{ads}.C\Theta$

$\Theta = (1-\Theta)\ K_{ads}.C$

$\Theta/1-\Theta = K_{ads}.C$

The observed values are given in tables-4&5.The plot of 3+log (Ө/1-Ө) against 3+logC is a straight line shown in the below figures-3&4. Hence the Langmuir isotherm is effective for the process of inhibition.

Table 4: Langmuir adsorption isotherm for the inhibition action on mild steel corrosion in 1.0N HCl by leaves extract of *Tephrosia Villosa.*

[Inhibitor], Ppm	θ/(1-θ)	3+logθ/(1-Θ)	3+log C
Blank	-	-	-
100	3.5662	3.389	5.000
200	4.780	3.679	5.3010
300	5.756	3.768	5.4771
400	7.264	3.961	5.6020
500	8.803	4.012	5.6989
600	14.151	4.150	5.7781
700	21.727	4.203	5.8450
800	39.00	4.412	5.9030
900	89.90	4.600	5.9542

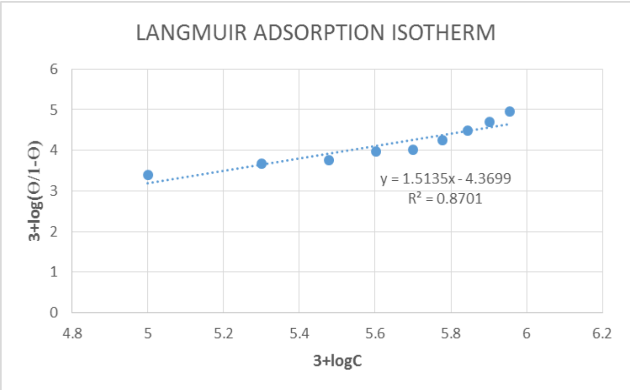

Figure 3: Langmuir adsorption isotherm for the inhibition action on mild steel corrosion in 1.0N HCl by leaves extract of *Tephrosia Villosa.*

Calculation

Intercept = -4.3699; K_{ads} = -0.2288; ΔG_{ads} = -6426.8;

Slope = 1.5135; R^2 = 0.870; 1/y = 0.66072.

Table 5: Langmuir adsorption isotherm for the inhibition action on mild steel corrosion in 0.5M H_2SO_4 by leaves extract of *Tephrosia Villosa.*

[Inhibitor], ppm	Θ/(1-θ)	3+logθ/(1-Θ)	3+log C
Blank	-	-	-
100	3.016	3.379	5.000
200	4.025	3.604	5.3010
300	6.042	3.781	5.4771
400	6.812	3.833	5.6020
500	10.111	4.004	5.6989
600	13.08	4.116	5.7781
700	16.54	4.218	5.8450
800	22.25	4.347	5.9030
900	40.66	4.459	5.9542

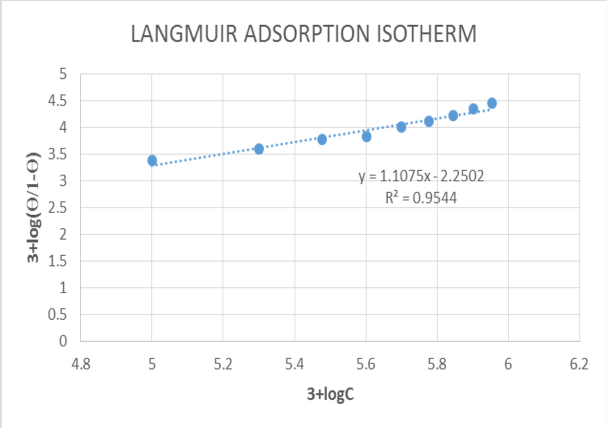

Figure 4: Langmuir adsorption isotherm for the inhibition action on mild steel corrosion in 0.5M H_2SO_4 by leaves extract of *Tephrosia Villosa.*

Calculation

Intercept = -2.2502; K_{ads} = -0.4444; ΔG_{ads} = -8102.80;

Slope = 1.1075; R^2 = 0.9544 ; 1/y = 0.9029.

Tempkin adsorption isotherm

It is given by the expression;

Ѳ = -2.303 log K/2a-2.303 log C/2a.

Where "K" represents the adsorption equilibrium constant, "a" represents interaction parameter. The values are given in tables-6&7. The plot of Ѳ against log C is shown below figure-5&6. The linear plot indicates that Tempkin adsorption isotherm was obeyed and negative, value of "a" indicated the refusal existing in adsorption layer.

Table 6: Tempkin adsorption isotherm for the inhibition action on mild steel corrosion in 1.0N HCl by leaves extract of *Tephrosia Villosa.*

[Inhibitor], ppm	θ	2+log C
Blank	-	-
100	0.781	4.0000
200	0.827	4.3010
300	0.852	4.4771
400	0.879	4.6020
500	0.898	4.6989
600	0.934	4.7781
700	0.956	4.8450
800	0.975	4.9030
900	0.989	4.9542

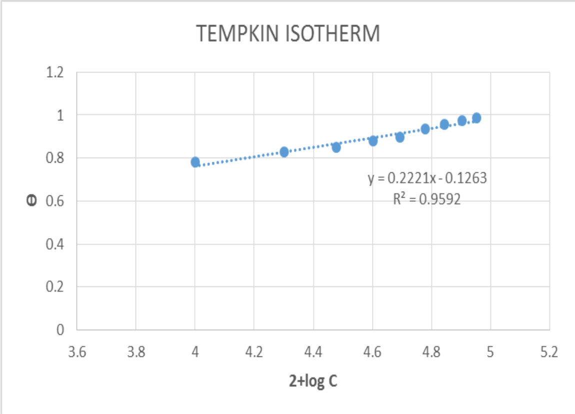

Figure 5: Tempkin adsorption isotherm for the inhibition action on mild steel corrosion in 1.0N HCl by leaves extract of *Tephrosia Villosa.*

Calculation

Intercept = -0.1263; K_{ads} = -7.9176; ΔG_{ads} = -15385.7; Slope = 0.2221;

R^2 = 0.9592; 1/y = 4.5024; a = -5.1846

Table 7: Tempkin adsorption isotherm for the inhibition action on mild steel corrosion in 0.5M H_2SO_4 by leaves extract of *Tephrosia Villosa.*

[Inhibitor], ppm	θ	2+log C
Blank	-	-
100	0.751	4.0000
200	0.801	4.3010
300	0.858	4.4771
400	0.875	4.6020
500	0.910	4.6989
600	0.929	4.7781
700	0.943	4.8450
800	0.957	4.9030
900	0.976	4.9542

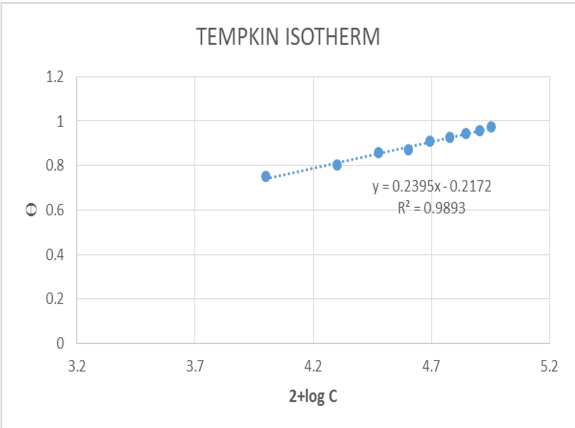

Figure 6: Tempkin adsorption isotherm for the inhibition action on mild steel corrosion in 0.5M H_2SO_4 by leaves extract of *Tephrosia Villosa.*

Calculation

Intercept = -0.2172; K_{ads} = -4.6040; ΔG_{ads} = -14015.1; Slope = 0.2395;

R^2 = 0.9893; 1/y = 4.1750; a = -4.8079;

Florry-Huggins adsorption isotherm

It is given by the expression

log Θ/C = log K+ x log (1-Θ).

Where 'x' represents the size parameter, and it is a determination of the amount of adsorbed molecules of water replaced by a molecule of inhibitor. The plot of log Θ/C against log (1-Θ) is linear. It is shown in the figures-7&8. It indicating that Florry-Huggins isotherm was obeyed. The adsorption parameter is shown in the tables-8&9.

Table 8: Florry-Huggins adsorption isotherm for the inhibition action on mild steel corrosion in 1.0 N HCl by leaves extract of *Tephrosia Villosa.*

Θ	C	Θ/C	log θ/C+4	1-Θ	log(1-Θ)+4
0.781	100	0.0078	1.8920	0.219	3.3404
0.827	200	0.0041	1.6160	0.173	3.2380
0.852	300	0.0028	1.4533	0.148	3.1702
0.879	400	0.0021	1.3419	0.121	3.0827
0.898	500	0.0017	1.2528	0.0102	3.0086
0.934	600	0.0015	1.1921	0.066	2.8195
0.956	700	0.0013	1.1135	0.044	2.6434
0.975	800	0.0012	1.0891	0.025	2.3979
0.989	900	0.0010	1.0409	0.011	2.0413

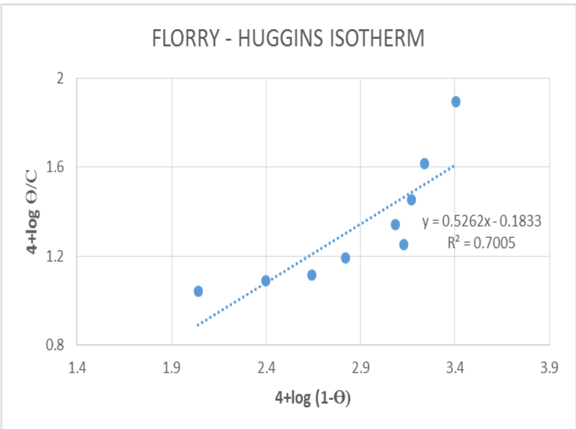

Figure 7: Florry-Huggins adsorption isotherm for the inhibition action on mild steel corrosion in 1.0N HCl by leaves extract of *Tephrosia Villosa.*

Calculation

Intercept = -0.1833; K_{ads} = -5.4555; ΔG_{ads} = - 14444.1;

Slope = 0.5262; R^2 = 0.7005; 1/y = 1.9004.

Table 9: Florry-Huggins adsorption isotherm for the inhibition action on mild steel corrosion in 0.5M H_2SO_4 by leaves extract of *Tephrosia Villosa.*

ϴ	C	ϴ/C	log θ/C+4	1-ϴ	log(1-ϴ)+4
0.751	100	0.0075	1.7750	0.249	3.3961
0.801	200	0.0040	1.6020	0.199	3.2988
0.858	300	0.0028	1.4471	0.142	3.1522
0.875	400	0.0021	1.3222	0.128	3.1072
0.910	500	0.0018	1.1335	0.090	2.9540
0.929	600	0.0015	1.2752	0.071	2.8512
0.943	700	0.0013	1.1860	0.057	2.7558
0.957	800	0.0012	1.0791	0.043	2.6334
0.976	900	0.0010	1.0000	0.024	2.3802

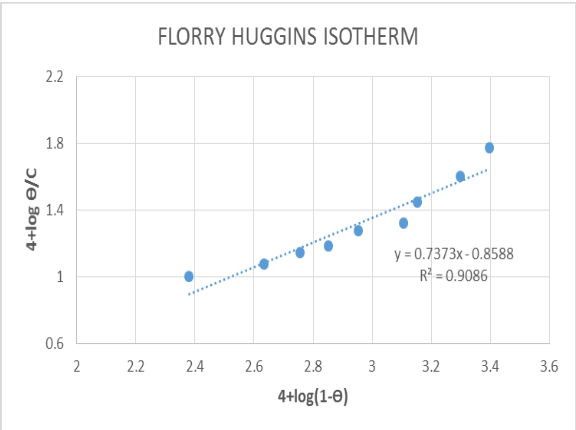

Figure 8: Florry-Huggins adsorption isotherm for the inhibition action on mild steel corrosion in 0.5M H_2SO_4 by leaves extract of *Tephrosia Villosa.*

Calculation

Intercept = -0.8588; K_{ads} = -1.1644; ΔG_{ads} = - 10540.0;

Slope = 0.7373; R^2 = 0.9086; 1/y = 1.3563;

El-awady isotherm

It is given by the expression:

log (ϴ/1-ϴ) = logK + ylogC

Here K_{ads} is the term of equilibrium constant for adsorption process was determined by the relationship, $K_{ads} = 1/k$. A plot of 2+log(1-ϴ) Vs. 2+ logC is linear .it is shown in figures-9&10. The calculated values are given in the tables-10&11. The value of 1/y is more than one exhibiting that the inhibitor employs to higher than one active spot on the surface of metal.

Table 10: El-awady adsorption isotherm for the inhibition action on mild steel corrosion in 1.0N HCl by leaves extract of *Tephrosia Villosa.*

C	2+logC	ϴ	1-ϴ	ϴ/1-ϴ	2+logϴ/1-ϴ
100	4.000	0.781	0.219	3.5662	2.5522
200	4.301	0.827	0.173	4.780	2.6794
300	4.447	0.852	0.148	5.756	2.7601
400	4.602	0.879	0.121	7.264	2.8611
500	4.692	0.898	0.102	8.803	2.9446
600	4.778	0.934	0.066	14.151	3.1507
700	4.845	0.956	0.044	21.727	3.3369
800	4.903	0.975	0.025	39.00	3.5910
900	4.954	0.989	0.011	89.90	3.9537

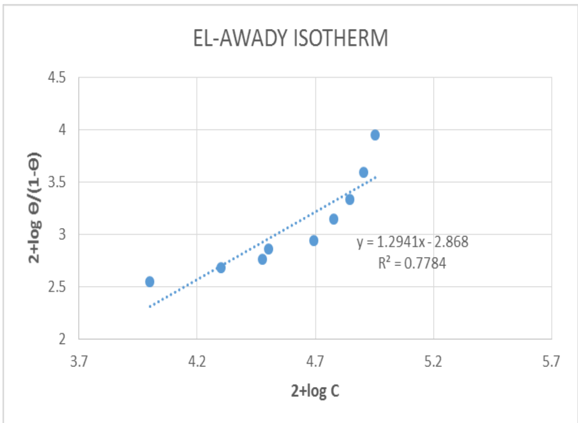

Figure 9: El-awady adsorption isotherm for the inhibition action on mild steel corrosion in 1.0N HCl by leaves extract of *Tephrosia Villosa.*

Calculation

Intercept = -2.8680; K_{ads} = -0.3486; ΔG_{ads} = -7491.24;

Slope = 1.294; $1R^2$ = 0.7784; 1/y = 0.7727

Table 11: El-Awady adsorption isotherm for the inhibition action on mild steel corrosion in 0.5M H_2SO_4 by leaves extract of *Tephrosia Villosa.*

C	2+logC	Ɵ	1-Ɵ	Ɵ/1-Ɵ	2+logƟ/1-Ɵ
100	4.000	0.751	0.249	3.016	2.4794
200	4.301	0.801	0.199	4.025	2.6047
300	4.447	0.858	0.142	6.042	2.7811
400	4.602	0.875	0.128	6.812	2.8332
500	4.692	0.910	0.090	10.111	3.0047
600	4.778	0.929	0.071	13.08	3.1166
700	4.845	0.943	0.057	16.54	3.2185
800	4.903	0.957	0.043	22.25	3.3473
900	4.954	0.976	0.024	40.66	3.6091

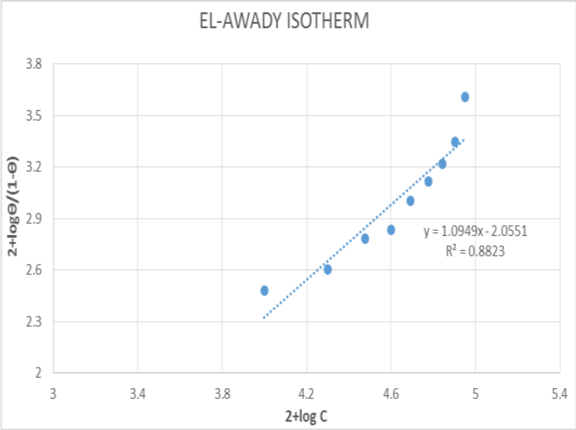

Figure 10: El-Awady adsorption isotherm for the inhibition action on mild steel corrosion in 0.5M H_2SO_4 by leaves extract of *Tephrosia Villosa.*

Calculation

Intercept = -2.0551; K_{ads} = -0.4865; ΔG_{ads} = -8333.8;

Slope = 1.0949; R^2 = 0.8823; 1/y = 0.9133.

Free energy change

The change of free energy for the adsorption (ΔG^0_{ads}) of inhibitor on the surface of mild steel is relevant to the constant of the adsorption based on the equation.

$$\Delta G^0 ads = -2.303RTlog (K_{ads} \times 55.5)$$

From the reports, it is noticed that the values of ΔG^0_{ads} were negative and were below the threshold value of -40kJ/mole mentioning that the adsorption of leaves extract of *Tephrosia Villosa* on the surface of mild steel is spontaneous and the mechanism action of physisorption is feasible.

Table 12: Adsorption isotherm parameters for the inhibition action of mild steel corrosion in 1.0N HCl by leaves extract of *Tephrosia Villosa.*

Isotherm	$-\Delta G^0_{ads}$	Slope	R^2	a	1/y
Langmuir Isotherm	6426.8	1.5135	0.8701	-	0.6607
Tempkin Isotherm	15385.72	0.2221	0.9592	-5.1846	4.5024
Florry-Huggins Isotherm	14444.17	0.5262	0.7005	-	1.9004
El-awady Isotherm	7491.24	1.2941	0.7784	-	0.7727

The R^2 value is highest for Tempkin adsorption mechanism.

Table 13: Adsorption isotherm parameters for the inhibition action of the mild steel corrosion in 0.5M H_2SO_4 by leaves extract of *Tephrosia Villosa.*

Isotherm	$-\Delta G^o_{ads}$	Slope	R^2	a	1/y
Langmuir Isotherm	8102.80	1.1075	0.9544	-	0.9029
Tempkin Isotherm	14015.19	0.2395	0.9893	-4.8079	4.175
Florry-Huggins Isotherm	10540.0	0.7373	0.9086	-	1.3563
El-awady Isotherm	8333.88	1.0949	0.8823	-	0.913325

The highest value of R^2 shows that Langmuir & Tempkin adsorption mechanism are the best fit and suitable isotherms.

Potentiodynamic polarization evaluates

Potentiodynamic polarisation method has been used to evaluate the formation of preventive film throughout the corrosion inhibition process.[33-37] The decreased corrosion current value, increasing the corrosion inhibition.

Tables-14&15, Figures-11to16 shows the values of potentiodynamic parameters such like corrosion current (I_{corr}), corrosion potential (E_{corr}) and the Tafel slopes (bc and ba) for the various concentrations of natural inhibitor under investigation. It can be viewed that the molecules present in the inhibitor were absorbed on surface of metal. It can be also noticed from the tables-18 &19 that there is a close consonance between the observed values of inhibition efficiencies from weight loss, polarization and AC impedance techniques.

Table 14: Corrosion parameters observed from polarization diagram for mild steel in 1.0N HCl in the presence and absence of inhibitor.

SYSTEM	[Inhibitor], ppm	I_{corr}, A/cm²	$-E_{corr}$, mV Vs. SCE	b_a, mV dec^{-1}	b_c, mV dec^{-1}	Inhibition Efficiency %
	Blank	2031.253	528.393	174.8	168.8	-
***Tephrosia Villosa* leaves Extract**	100	551.874	529.193	183.6	148.6	72.83
	900	101.112	551.433	242.6	172.0	95.02

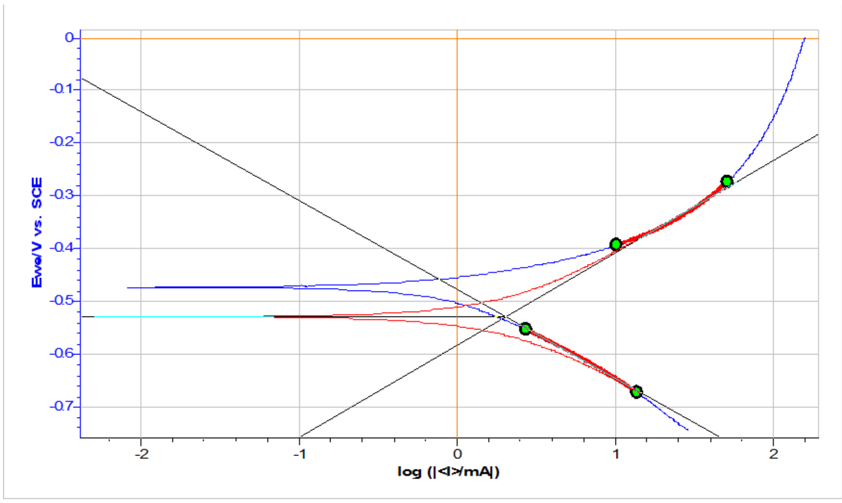

Figure 11: Polarisation diagram for mild steel in 1.0N HCl solution.

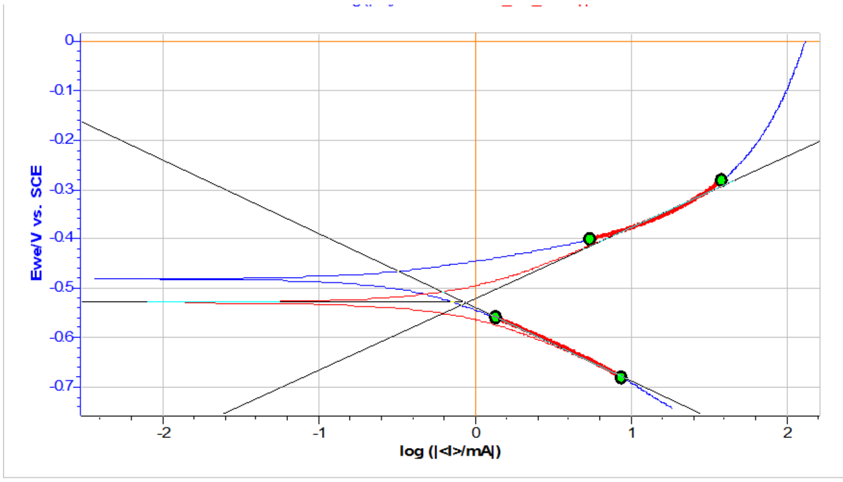

Figure 12: Polarisation diagram for mild steel in 1.0N HCl solution in the presence of 100ppm of leaves extract of *Tephrosia Villosa.*

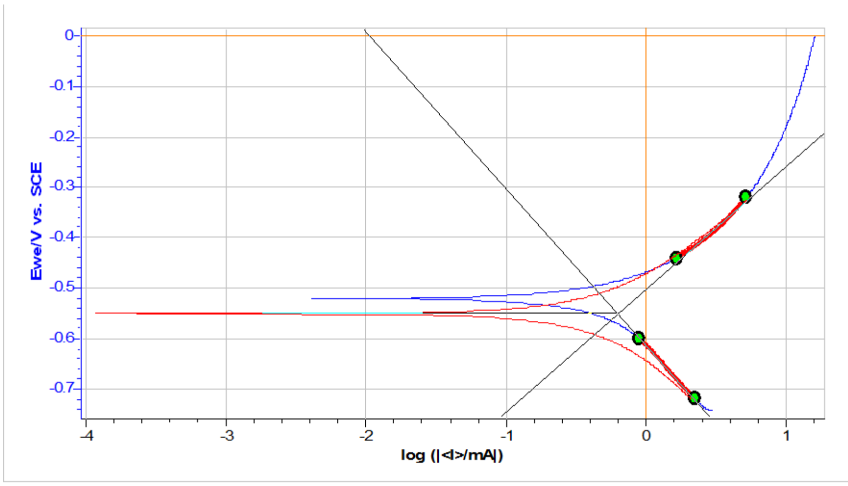

Figure 13: Polarisation diagram for mild steel in 1.0N HCl solution in the presence of 900ppm of leaves extract of *Tephrosia Villosa.*

Table 15: Corrosion parameters observed from polarization diagram for mild steel in 0.5M H_2SO_4 solution in the presence and absence of inhibitor.

SYSTEM	[Inhibitor], Ppm	I corr., A/cm^2	-E corr., mV Vs. SCE	b_a, mV dec^{-1}	b_c, mV dec^{-1}	Inhibition Efficiency %
	Blank	1242.489	491.433	136.3	163.2	-
Tephrosia Villosa Leaves Extract	100	330.92	508.849	202.5	272.0	73.36
	900	73.99	539.076	155.1	206.2	94.12

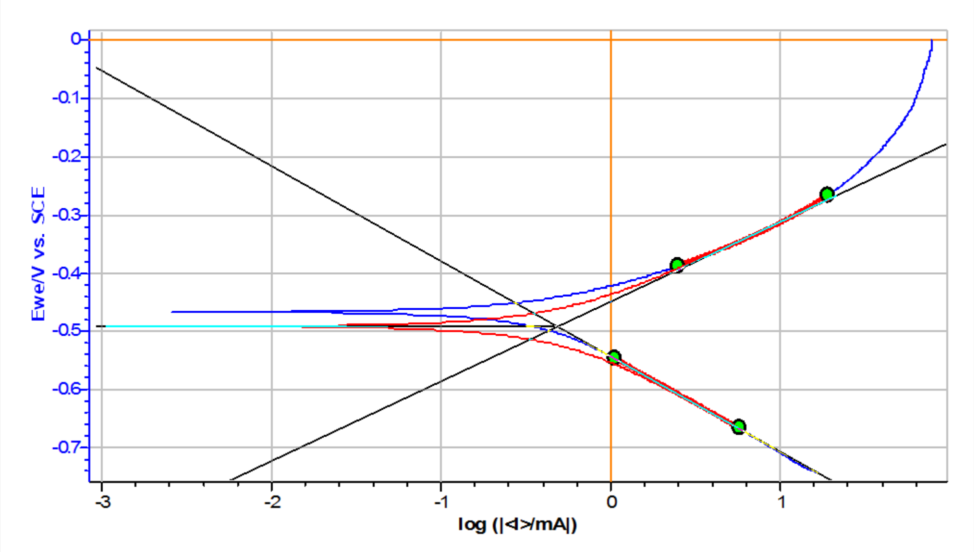

Figure 14: Polarisation diagram for mild steel in 0.5M H_2SO_4 solution.

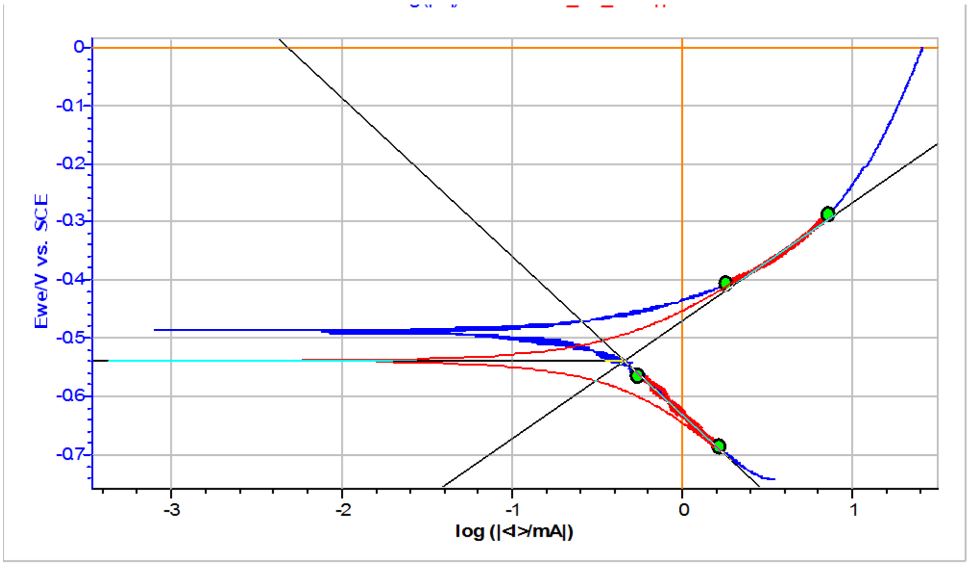

Figure 15: Polarisation diagram for mild steel in 0.5M H_2SO_4 in the presence of 100ppm of leaves extract of *Tephrosia Villosa.*

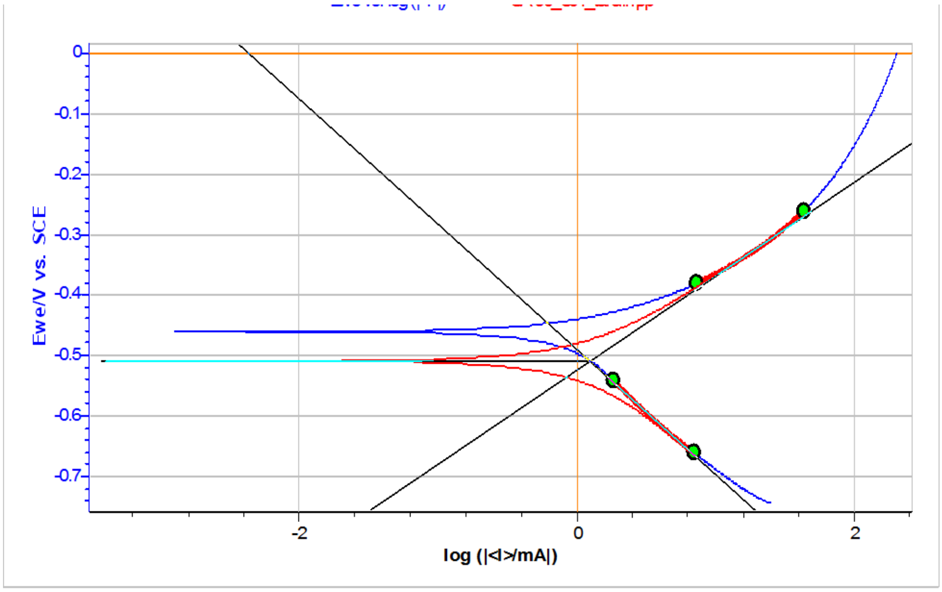

Figure 16: Polarisation diagram for mild steel in 0.5M H_2SO_4 in the presence of 900ppm of leaves extract of *Tephrosia Villosa.*

AC impedance evaluates

AC Impedance spectra have been applied to examine the formation of preventive layer on the surface of metal throughout the process corrosion inhibition. When the corrosion inhibition occurs, it increases the charge transfer resistance value and decreases the double layer capacitance.[38-43] Tables-16&17 and figures-17,18,19,20,21&22 gives the AC impedance readings for various concentrations of plant inhibitor. It is indicated that the increases of the R_t value and decreases of the C_{dl} value with inhibitor concentration. This replies the creation of preventive layer on the surface of metal.

Table 16: Corrosion parameters observed from the impedance diagram for mild steel in the presence and absence of inhibitor in 1.0N HCl solution.

[Inhibitor], Ppm	R_t, Ohm.cm^2	C_{dl}, F/cm^2	Inhibition efficiency (%)
0	8.6	9.257	-
100	44.1	2.5	72.99
900	52.3	0.366	96.04

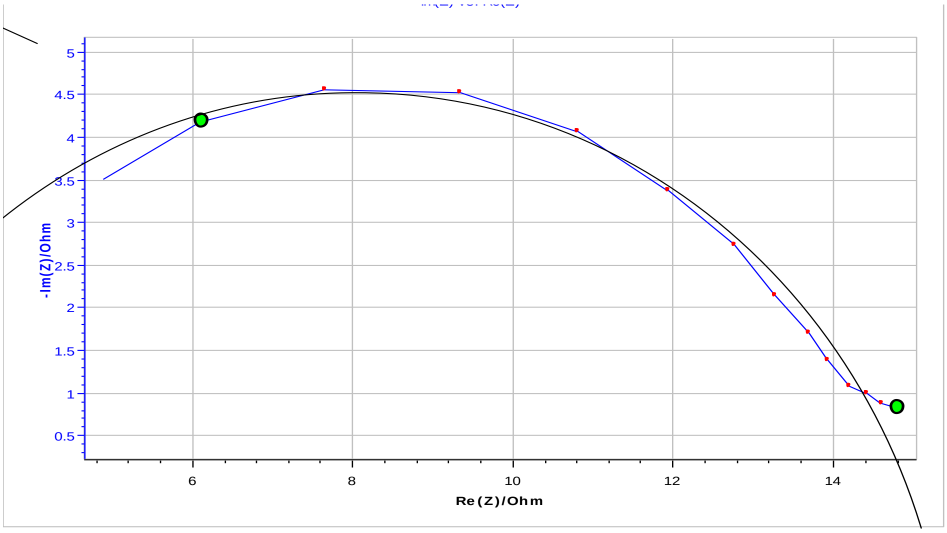

Figure 17: AC Impedance diagram for mild steel in 1.0N HCl solution.

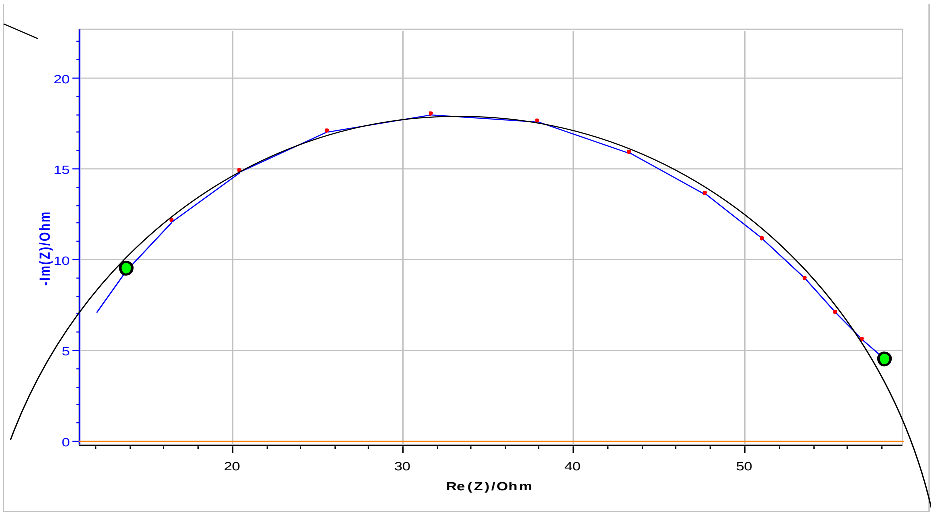

Figure 18: AC Impedance diagram for mild steel in 1.0N HCl in the presence of 100ppm of leaves extract of *Tephrosia Villosa*

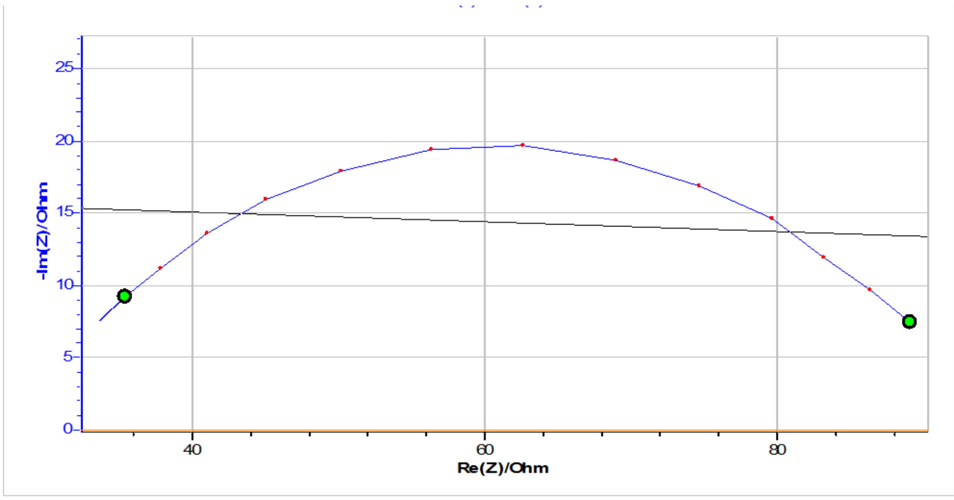

Figure 19: AC Impedance diagram for mild steel in 1.0N HCl in the presence of 900ppm of leaves extract of *Tephrosia Villosa.*

Table 17: Corrosion parameters obtained from impedance curve for mild steel in the presence and absence of inhibitor in 0.5M H_2SO_4 medium.

[Inhibitor], Ppm	R_t , Ohm.cm^2	C_{dl}, F/cm^2	Inhibition efficiency (%)
0	34	0.489	-
100	47	0.128	73.821
900	105	0.029	94.06

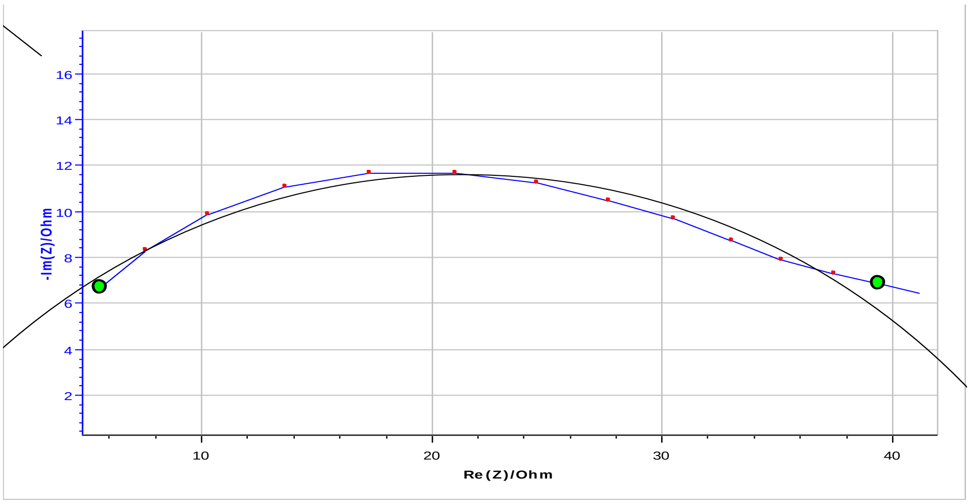

Figure 20: AC Impedance diagram for mild steel in 0.5M H_2SO_4 solution.

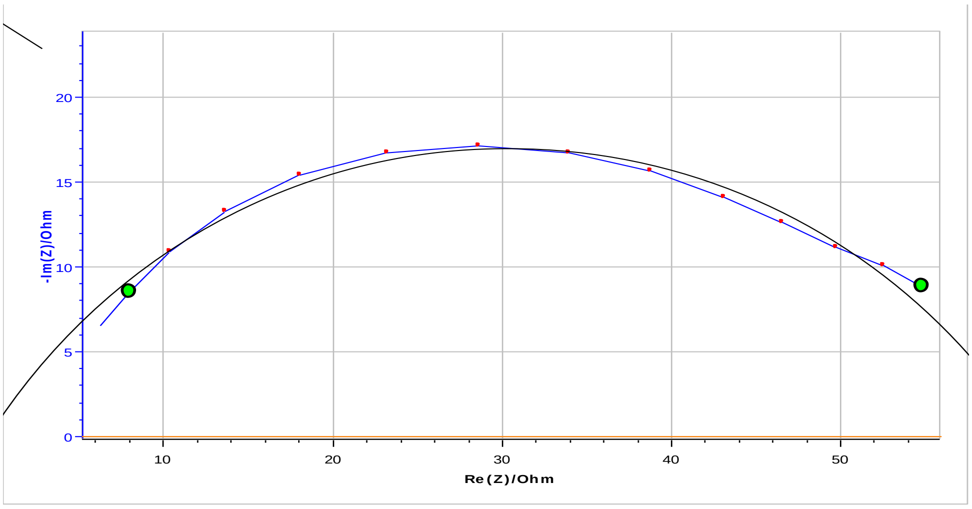

Figure 21: AC Impedance diagram for mild steel in 0.5M H_2SO_4 in the presence of 100ppm of leaves extract of *Tephrosia Villosa.*

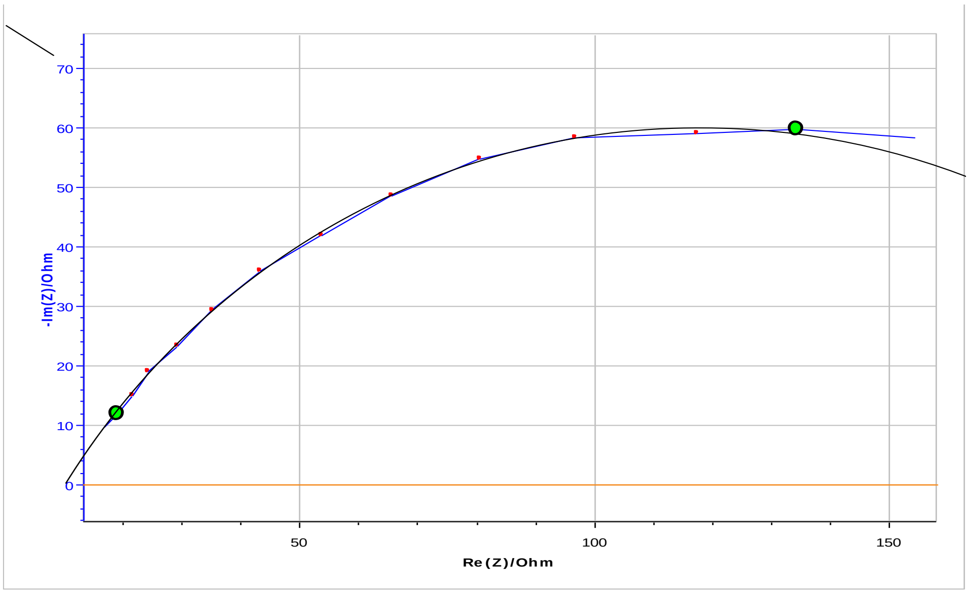

Figure 22: AC Impedance diagram for mild steel in 0.5M H_2SO_4 in the presence of 900ppm of leaves extract of *Tephrosia Villosa*.

It is implied from the Nyquisit plots that the process mentions simple and resistance corrosion. The equivalent circuit diagram for this type of a system is shown in figure-23.

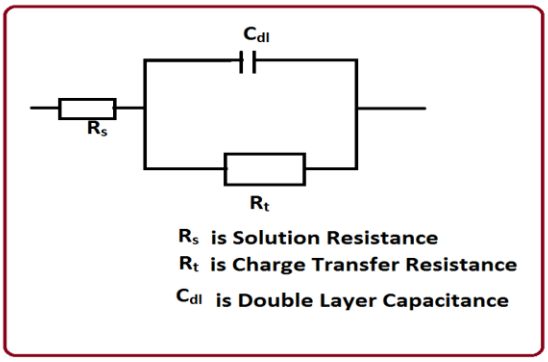

Fig 23: Equivalent circuit diagram for a simple corrosion and corrosion inhibition process.

Table 18: Comparison of inhibition efficiency observed by Weight loss and Polarization and Impedance techniques for mild steel in 1.0N HCl solution.

[Inhibitor], ppm	Inhibition efficiency		
	Weight loss	Polarization	Impedance
100	78.14	72.82	72.99
900	98.90	95.02	96.04

Table 19: Comparison of inhibition efficiency observed by Weight loss and Polarization and Impedance techniques for mild steel in 0.5M H_2SO_4 solution.

[Inhibitor], ppm	Inhibition efficiency		
	Weight loss	Polarization	Impedance
100	75.12	73.36	73.82
900	97.64	94.12	94.06

SUMMARY AND CONCLUSION

The inhibitive predominance of leaves extract of *Tephrosia Villosa* on the mild steel corrosion in 1.0N HCl and also 0.5M H_2SO_4 medium was investigated by weight loss, polarization and AC impedance techniques. When increasing the addition of leaves extract of *Tephrosia Villosa* is decreasing the corrosion on mild steel, possibly due to the suggessive adsorption of the inhibitor on the surface of the metal. The maximum efficiency of inhibition was found to be 98.90% and 97.64 %.

The mild steel corrosion in 1.0N HCl and 0.5M H_2SO_4 solution is inhibited by the extention of leaves extract of *Tephrosia Villosa*.

- The percentage of efficiency of inhibition increase with increase in the concentration of inhibitor.
- The corrosion on mild steel inhibited by leaves extract of *Tephrosia Villosa* is assigned to the adsorption of phytochemical constituents present in the inhibitor on the surface of mild steel.
- The data observed from the weight loss method for the considered inhibitor is appropriating into the the Tempkin adsorption isotherm for 1.0N HCl, Langmuir and Tempkin adsorption isotherm for 0.5M H_2SO_4 and also to the kinetic thermodynamic model. The free energy values of the process of adsorption suggest that the adsorption of the inhibitor on the surface of mild steel exists spontaneously.
- The leaves of *Tephrosia Villosa* protect the corrosion on mild steel because of the phytochemical constituents present in the inhibitor converting the corrosion into the noble.
- The potentiodynamic polarization and AC impedance investigations additionally shows a close agreement with efficiency of inhibitor observed from weight loss evaluates.
- The detailed results observed is suggests that the leaves extract of *Tephrosia Villosa* is a suitable corrosion inhibitor for the mild steel in 1.0N HCl and 0.5M H_2SO_4 solution and it

can be preferably used to replace harmful , non-decomposable and non-biodegradable inhibitor.

- Polarization analyses result that this formulation controls the cathodic reaction predominantly.
- AC impedance analyses report that a protective layer is obtained on the surface of metal.

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