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Adhutodavasica nees leaf extract as corrosion inhibitor for mild steel in acid medium

ABSTRACT

Sustainable corrosion control methods have emerged due to stringent environmental laws and growing ecological awareness. This study explores the inhibition efficiency of AdhatodavasicaNees ethanolic leaf extract on mild steel corrosion in HCl. Using data from mass-loss methods, potentiodynamic polarization, AC impedance, UV-visible spectra, FTIR, and SEM analyses, the corrosion inhibition mechanism was evaluated.The extract achieved a maximum inhibition efficiency of 79.72% at 95 ppm, with no significant improvement beyond this concentration. The adsorption activation energy was 36.6275 kJ/mol. A shift in corrosion potential (Ecorr) to less negative values and a decrease in cathodic slope indicated predominant control of the cathodic reaction, acting as a cathodic inhibitor. The double layer capacitance (Cdl) also decreased, suggesting efficient inhibition. UV-visible spectra indicated the formation of a protective film, while FTIR and SEM reports confirmed the adsorption of active compounds on the metal surface. The extract shows potential as an effective, eco-friendly corrosion inhibitor for mild steel in HCl.

Keywords: *Adhutodavasica Nees, potentiodynamic polarisation, AC impedance spectrum, FTIR spectroscopy, SEM*

1. INTRODUCTION

It is generally accepted that steel is composed of iron, carbon, and some additional substances in minute quantities, and the presence of chemically reactive iron causes corrosion. When chemically reactive iron comes into contact with oxygen and water, the rusting process begins. The application of corrosion inhibitors is one of the most widely used strategies for corrosion control and prevention. Inhibitors of corrosion are chemicals that, when applied in trace amounts to corrosive medium, lessen or stop the metal's reaction with the media. The majority of potent inhibitors contain multiple bonds and heteroatoms like O, N, and S in their molecules, which allows them to be adsorbed on the metal surface [1]. The adsorption is primarily dependent on a few physicochemical characteristics of the inhibitor group, including functional groups, electron density at the donor atom, π-orbital character, and the molecule's electronic structure.

Even while many synthetic chemicals show good anticorrosive action, most are extremely harmful to individuals and the environment. Chemical inhibiting agents have the potential to disrupt specific biochemical processes or enzyme systems in the body, and can cause reversible (temporary) or irreversible (permanent) harm to organ systems such as the liver or kidneys. Due to this, their usage has been restricted. The compound's toxicity may become apparent during manufacture or application[2,3].

Natural materials are being used as corrosion inhibitors due to the known risks associated with synthetic inhibitors[4].. Plant extracts are valuable due to their organic nature, inhibitory properties of constituents such as tannins, amino acids, alkaloids, and pigments, renewable sources of materials, ecological acceptability, and cathode polarisation mechanism for protection[5,6], and are also recognised for their scale-inhibiting properties, in addition to reducing mild steel corrosion in a variety of conditions.

Recent studies have explored the potential of various plant extracts as environmentally friendly corrosion inhibitors for mild steel in acidic media. Extracts such as *Azadirachtaindica* (neem), *Moringaoleifera* (drumstick), and *Ocimum*

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sanctum(tulsi) have demonstrated significant inhibition properties by forming protective films on metal surfaces, thereby reducing the corrosion rate[7,8].These studies emphasize the demand for eco-friendly and biodegradable inhibitors as alternatives to synthetic chemicals. However, despite the growing interest in plant extracts, there is limited research on the corrosion inhibition potential of *Adhatodavasica*Nees.

Known locally as *Adhatodai*, *AdhatodavasicaNees*, a member of the *Acanthaceae*family, has been traditionally used in the treatment of various illnesses. Its leaves, which are dark green and lanceolate, contain numerous bioactive compounds. Phytochemical screening of the ethanolic extracts from *Adhatodavasica*Nees leaves has revealed the presence of alkaloids, carbohydrates, steroidal glycosides, pseudo tannins, chlorogenic acids, saponins, and flavonoids [9, 10]. These phytocompounds, containing heteroatoms, are known for their scale inhibition properties and have shown potential as corrosion inhibitors in various environments.

Despite this, comprehensive studies on the corrosion inhibition of *AdhatodavasicaNees* extract, particularly for mild steel in acidic environments such as 1 M HCl, are lacking. The existing literature does not provide detailed evaluations of its inhibition efficiency or protective mechanisms using mass-loss or electrochemical methods, nor has its interaction with metal surfaces been explored using techniques such as FTIR, UV-Visible spectroscopy, and SEM analysis.

This research aims to address the gap by investigating the corrosion inhibition efficiency of *Adhatodavasica*Neesethanolicleaf extract for mild steel in 1 M HCl. A systematic study utilizing mass-loss methods, electrochemical techniques, and surface examination using FTIR, UV-Visible spectroscopy, and SEM analysis was conducted to explore the extract's protective mechanism and inhibition efficiency. This work provides new insights into the potential of *Adhatodavasica*Nees as a green corrosion inhibitor, contributing to the ongoing search for eco-friendly alternatives in corrosion science.

2. MATERIALS AND METHOD

2.1.Plant powder preparation

The plant leaves used in this study were collected from in and around Trichy District, Tamil Nadu, India. Disease-free leaves, confirmed to be free from visible symptoms such as discoloration, spots, wilting, or fungal growth, were spread out and dried in the laboratory at room temperature for 5-8 days. The disease-free status was ensured through thorough visual inspection and confirmed by the absence of pest activity and physical deformities. The leaves were allowed to dry until they became brittle enough to be easily broken by hand. Once thoroughly dried, the leaves were ground into a fine powder using an electronic blender.

2.2. Preparation of solvent extract

The powdered plant material (50 g) were steeped separately in 300 mL of ethanol in a soxhlet apparatus for 48 hours at 31°C until fully extracted. After 48 hours, the extract was filtered using Whatman No. 1 filter paper and concentrated with a rotary evaporator. The paste-like extract was stored in pre-weighed screw scrapped bottles and refrigerated at 4°C until use.

2.3. Preparation of the mild steel specimens

Experiments were conducted on commercial-grade mild steel sheets obtained from the local market. Elemental analysis was performed using a BAIRD-DV4 vacuum emission spectrometer. The weight percentage composition was determined to be carbon = 0.13%, silicon = 0.03%, manganese = 0.65%, sulfur = 0.26%, phosphorus = 0.15%, copper = 0.016%, nickel = 0.018%, chromium = 0.029%, and iron = 98.837%. The sheets were mechanically pressed and cut into samples measuring 1 x 5 x 0.2 cm^3. These samples were polished with various grades of emery paper, cleaned with double distilled water, degreased with acetone, and then dried and stored in a desiccator for further examination.

2.4. Determination of corrosion rate

The polished specimens were first weighed using an electronic balance. The weighed samples were then immersed in 100 ml of 1 N HCl acid, with and without varying inhibitor dosages, for different periods of time. After immersion, they were carefully removed, washed with tap water, rinsed with distilled water, dried, placed in desiccators, and weighed again. All mild steel specimens were weighed before and after corrosion using an ACCULAB Electronic top loading balance with a readability/sensitivity of 0.1 mg in the 210 g range. This balance has a repeatability (standard deviation) of 0.02 mg in the 40-g range and 0.1 mg in the 200-gram range. From the change in weight of specimens the corrosion rate was calculated using the equation 1, [11].

$$Corrosion rate = \frac{87.6\times W}{A\times T\times D}\ (mpy) \qquad (1)$$

W = Loss in weight in mg

A = surface area of the specimen (cm^2)

T = Time in hours,

D = Density (7.2 g / cm^3)

Corrosion inhibition efficiency (IE) was then calculated using the equation 2

$$IE - 100\left[1 - \left(\frac{W_2}{W_1}\right)\right]\% \qquad (2)$$

Where

W_1 = Corrosion rate in the absence of the inhibitor and

W_2 = Corrosion rate in the presence of the inhibitor.

The parameters used for the present study are given below:

1. Time (hrs): ½ , 1, 3, 5, 7, 9.
2. Concentration of the inhibitor: 65 ppm to 95 ppm
3. Temperatures: (303 K, 313 K, 323 K, 333 K) ± 2 K

2.5. Potentiodynamic polarisation study

Potentiodynamic polarization studies were carried out using CHI electrochemical impedance analyzer, model 660 A. A three-electrode cell assembly was used. The working electrode was a rectangular specimen of mild steel with one face of the electrode (1 cm^2 area) exposed and the rest shielded with red lacquer. A saturated calomel electrode (SCE) was used as the reference electrode and a rectangular platinum foil was used as the counter electrode.

The working electrode and platinum electrode were immersed in 1 M HCl in the absence and presence of inhibitor. Saturated calomel electrode was connected with the test solution through a salt bridge. Potential (E) Vs log current (I) plots were then recorded. Corrosion potential (Ecorr) and Tafel slopes ba and bc were determined from E Vs log I plots [12].

2.6. AC impedance measurements

The AC impedance was measured using a CHI electrochemical analyzer (model 660 A). The system was given five to ten minutes to reach its full open-circuit potential. Then, the real part (Z') and imaginary part (Z'') of the cell impedance were measured in ohms at different frequencies (f). Calculations were performed to determine the double-layer capacitance (C_{dl}) and the charge transfer resistance (Rt). The following relationship was used to calculate the C_{dl} values from equation 3.

$$C_{dl} = \frac{1}{2 \times 3.14 \times R_t \times f_{max}} \qquad (3)$$

2.7. The UV-visible spectra of solutions

The Lambda 35 UV-Visible spectrophotometer, an advanced PC-controlled single beam scanning spectrophotometer, was utilized to carefully mix specific solutions and capture their UV-Visible absorption spectra. This was pivotal in exploring the potential for film formation on the metal surface. Notably, this high-precision spectrophotometer boasts a setting accuracy of ±1 nm and an impressive wavelength range of 200 nm to 1000 nm.

2.8. Surface analysis by FTIR spectroscopic and SEM study

The samples were taken out of the test liquids and dried after being immersed for three hours in the acidic solution. To ensure uniformity, the layer that had formed on the surface was carefully scratched and thoroughly mixed. The FTIR spectrum of the powder (KBr) pellet was obtained using a Perkin-Elmer 1600 FTIR spectrophotometer with a resolving capacity of 4 cm^{-1}.Under a FEI Quanta FEG 200 - High-Resolution Scanning Electron Microscope, the texture and pore structure were examined.

3. RESULTS AND DISCUSSION

3.1. Effect of concentration

Table.1 shows how the level of inhibitor concentration (in ppm) affects inhibition efficiency (IE in%) and corrosion rate (mpy). The results demonstrate that the presence of the inhibitor significantly reduces the corrosion rate. AdhutodavasicaNees leaf extract contains alkaloids, polysaccharides, pseudo tannins, chlorogenic acids, steroidal glycosides, saponins, and flavonoids. These phytochemicals, present in the plant extract serving as inhibitors, contain heteroatoms such as O, N, and S, as well as various linkages that enable the molecules to be adsorbed on the metal surface. With the increased adsorption of these phytochemicals on the metal's surface, a thin film forms, preventing corrosion at the active sites as the inhibitor concentration increases[13].

Table 1. Corrosion rates of mild steel in 1MHCl obtained by the mass-loss method

Inhibitor concentration (ppm)	Corrosion Rate (mpy)	Percentage inhibition efficiency
Blank	37.74	-
65	18.18	51.82
70	17.92	52.51
75	15.70	58.41
80	13.08	65.33
85	12.89	65.86
90	11.84	68.63
95	7.65	79.72

3.2. Effect of immersion time

Table.2 lists the rates at which mild steel corrodes when an inhibitor system is present in an acidic media for varying immersion times. It is evident from the Table that the IE increases in 1M HCl from 25.62% to 79.72% in just 30 to 180 minutes. Nevertheless, the IE diminishes as the immersion time increases. The IE is discovered to be just 57% after a full day.

Table 2. Effect of duration of immersion on the IE of AVNLE in 1 M HCl

S. No.	Time period (hrs)	InhibitorConcentration (ppm)	Percentage inhibition efficiency	Corrosion rate (mpy)
1	½	95	25.62	14.71
2	1	95	40.50	14.65
3	3	95	79.72	7.65
4	7	95	70.25	11.48
5	9	95	57.0	34.21

The molecules may be physically adsorbed on the surface, and as physical adsorption has a lower activation energy for desorption, the molecules eventually readily desorb from the surface, resulting in a fall in inhibitory efficiency. This could account for the observed decline in IE over time[14].

3.3. Effect of temperature

The weight loss method was used to study the effect of temperature on the inhibitor's ability to inhibit corrosion over a fixed immersion time of three hours at different temperatures (303, 313, 323, and 333 K). According to the data in Table 3, the inhibitory effectiveness decreases as the temperature increases. This behavior can be explained by the physical adsorption of phytochemical molecules onto the metal surface. Some of the adsorbed phytochemical molecules were able to detach from the metal surface as the temperature rose, indicating that physical adsorption is the main type of adsorption.

Table 3. Effect of temperature on the CR of mild steel in 1MHCl by Adhutodavasicaneesleaf extract (AVNLE) at different temperatures

S. No.	Temperature (K)	Inhibitor concentration, (ppm)	Corrosion rate (mpy)	Inhibition efficiency(%)	Log CR (mpy)	$1/T \times 10^{-3}$
1	303	Blank	37.74	_	1.58	3.33
		95	7.65	79.72	0.88	
2	313	Blank	44.12	_	1.64	3.19
		95	23.29	47.22	1.37	
3	323	Blank	48.14	_	1.68	3.09
		95	37.09	22.96	1.57	
4	333	Blank	105.80	_	2.02	3.00
		95	82.81	21.73	1.92	

The following equation 4 utilizes the formula developed by Arrhenius to examine how temperature affects the rate of corrosion for mild steel in 1 M HCl, depending on the presence or absence of ethanolic *Adhatodavasica* Neesleaf extract.

$$Log\ CR = Log\ A - \frac{Ea}{2.303RT} \qquad (4)$$

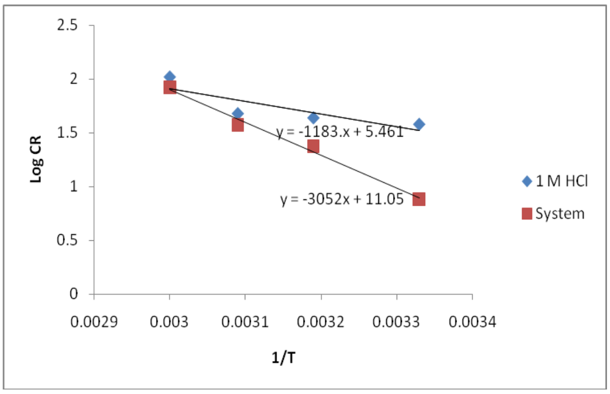

Figure 1. Arrhenius plot of corrosion of mild steel in 1MHCl

The Arrhenius plot for mild steel corrosion in 1MHCl with *AaduthodavasicaNees* leaf extract (AVNLE) is shown in Figure 1. Log A values, obtained from the intercepts of the plots, are presented in Table 4. It has been observed that the log A value increases in the presence of the plant extract. This difference in log A values when plant extracts are present indicates that plant extracts have an influence on the mechanism of the hydrogen evolution reaction. Table 4 provides the adsorption activation energies (Ea(inh)), equation 5, and the calculated activation energy (Ea(sys)) derived from the slopes of the plot(Figure 1).

$$Ea\ (inh) = Ea(sys) - Ea(blank) \qquad (5)$$

The rise in Ea suggests that the inhibitor's presence alters the corrosion mechanism. It has been found that the activation energy for adsorption is 36.6275 kJ/mol, demonstrating conclusively that the extract is physically adsorbed on the surface.

Thermodynamic / Adsorption Considerations

The heat of adsorption, Qads, can be calculated using the formula:

$$Q_{ads} = 2.303R\left[log\left(\frac{\theta_2}{1-\theta_2}\right) - -log\left(\frac{\theta_1}{1-\theta_1}\right)\right] \times \left[T_1 \times \frac{T_2}{T_2-T_1}\right] KJmol^{-1} \qquad (6)$$

In this formula, θ_1 and θ_2 represent the degree of surface covering at temperatures T_1 and T_2, and R is the gas constant. It's important to note that the computed heat of adsorption value for *Adhutodavasica*Nees ethanol extract adsorbing to mild steel surfaces is negative, indicating an exothermic process[15]. This is demonstrated by the data in Table 4.

Table 4. Thermodynamic data for the corrosion of mild steel in 1MHCl containing ethanol extract of AVNLE

S. No.	Environment	EakJ/mol	Qads kJ/mol	Log A
1	Blank (1 M HCl)	21.8096	-	5.461
2	Inhibitor system (95 ppm)	58.4371	-35.6080	11.05

E_a for the inhibitor = 36.6275 kJ/mol

3.4. Electrochemical studies

In Figure 2, the potentiodynamic polarization curves of mild steel are displayed, both with and without *Adhutodavasica*Nees leaf extract in an acidic liquid. Table 5 provides the corrosion characteristics of mild steel submerged in 1MHCl containing 95 ppm of the extract, both with and without the presence of the extract. The corrosion potential (Ecorr) and corrosion current (Icorr) of mild steel in the acidic solution are -566 mV Vs SCE and 1.253 x 10^{-5} A/cm², respectively. When 95 ppm of the extract is added to the acidic medium, the corrosion current decreases to 9.860 x 10^{-6} A/cm³ and the Ecorr value changes to -509 mV Vs SCE. This indicates that the extract has an inhibitory effect, preventing mild steel from corroding in acidic environments.From 183.3 mV/dec to 128.1 mV/dec, the cathodic slope changes, indicating that the inhibitor primarily functions as a cathodic inhibitor and controls the cathodic response.

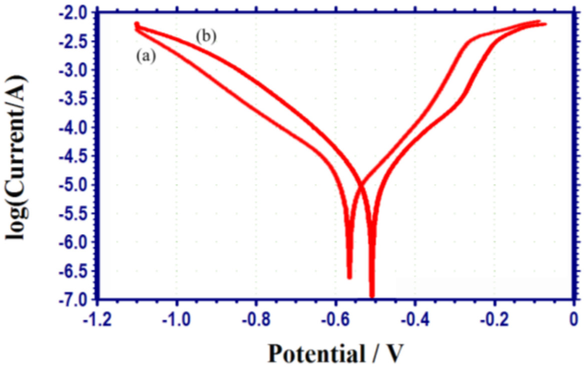

Figure 2. Potentiodynamic polarization curves of mild steel immersed in various environments a) Blank (1 M HCl) b) Inhibitor system (95 ppm)

Table 5. Results of potentiodynamic polarization studies

S.No.	Environment	E_{corr} (mV)	b_a (mV/dec)	b_c (mV/dec)	I_{corr} (A/cm^2)	LPR (ohm cm^2)
1	Blank	-566	134.4	183.8	1.253×10^{-5}	2.6942×10^{3}
2	Inhibitor system (95 ppm)	-509	135.1	128.1	9.860×10^{-6}	2.9007×10^{3}

3.5. Analysis of the results of AC impedance studies

Figure 3 and Table 6 illustrate the AC impedance spectrum and values for mild steel dipped in 1M HCl and inhibitor. The R_t and Cdl values of mild steel immersed in 1M HCl are found to be 32.34 Ωcm^2 and 1.5770 x 10^{-7} F/cm^2, respectively. The R_t value increased from 32.34 Ω cm^2 to 34.56 Ω cm^2 when 95 ppm of the extract was used, whilst the Cdl value dropped from 1.5770 x 10^{-7} F/cm^2 to 1.4786 x 10^{-7} F/cm^2 in acidic conditions. An inhibitor's excellent efficacy in a corrosive medium is supported by the increased Rt and lowered Cdl value shown in impedance measurements. This demonstrates that the created layer acts as a barrier to the corrosion process[16].

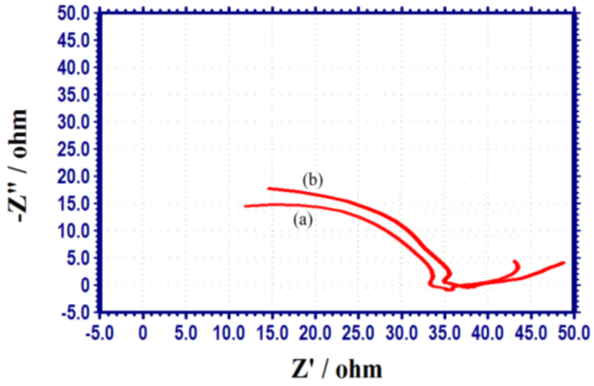

Figure 3. AC impedance of mild steel immersed in various environments a) Blank (1 M HCl), b) Inhibitor system (95 ppm)

Table 6. AC impedance study

S.No.	Environment	Rt, Ω cm^2	Cdl, F/cm^2
1	Blank	32.34	1.5770×10^{-7}
2	Inhibitor system (95ppm)	34.56	1.4786×10^{-7}

3.6. Spectroscopic Studies

3.6.1. Analysis of FTIR spectra

The FTIR spectrum of the pure extract in Figure 4 shows a signal at 3412 cm^{-1}, indicating the presence of -OH. The band at 3412 cm^{-1} widens, and the –OH frequency lowers from 3600 cm^{-1}, suggesting the presence of intermolecular hydrogen bonding. The bands at 1645.38 cm^{-1} and 1394.81 cm^{-1} are due to the combination of -C-O stretching and -C-O-H in-plane bending vibration. Finally, the bands at 1057.94 cm^{-1} and 879.65 cm^{-1} are caused by the vibration of the -C-O ring. In Figure 5, the FTIR spectrum of mild steel in an acidic environment with the extract shows some changes. The -OH frequency of the extract shifts from 3412.06 cm^{-1} to 3424.19 cm^{-1}. Additionally, the bands associated with the carboxylate anion's -C-O stretching and -C-O-H in-plane bending shift from 1645.38 cm^{-1} and 1394.81 cm^{-1} to 1620.38 cm^{-1} and 1384.15 cm^{-1}. The bands at 1057.94 cm^{-1} and 879.65 cm^{-1}, related to the ring oxygen, have moved to 1115.79 cm^{-1} and 840.83 cm^{-1}. These changes indicate that the chemical composition of the active constituents has been altered due to the interaction with the metal[17].

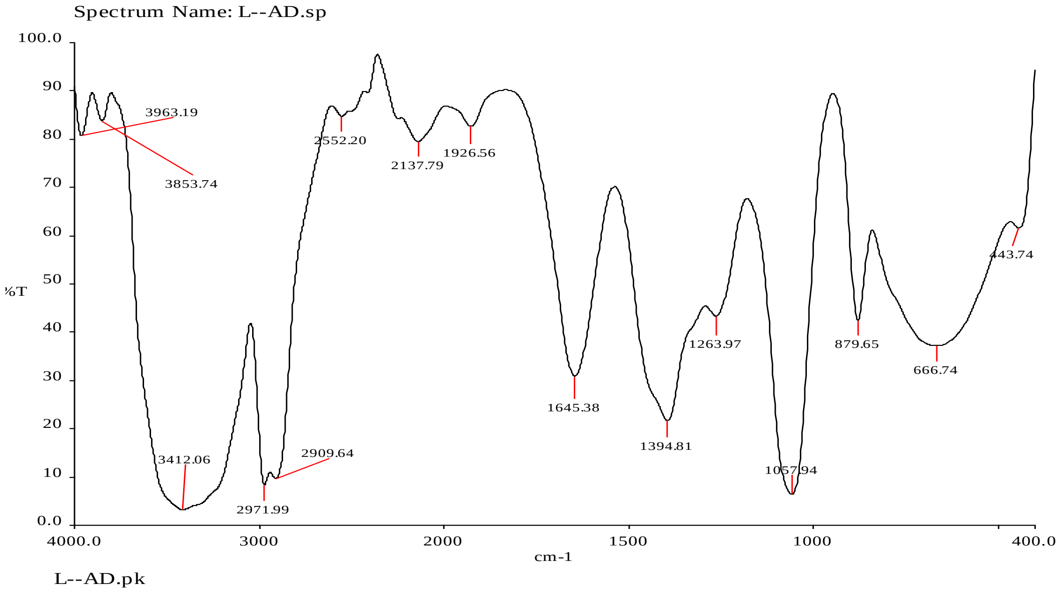

Figure 4. FTIR Spectrum (KBr) of pure AVNLE

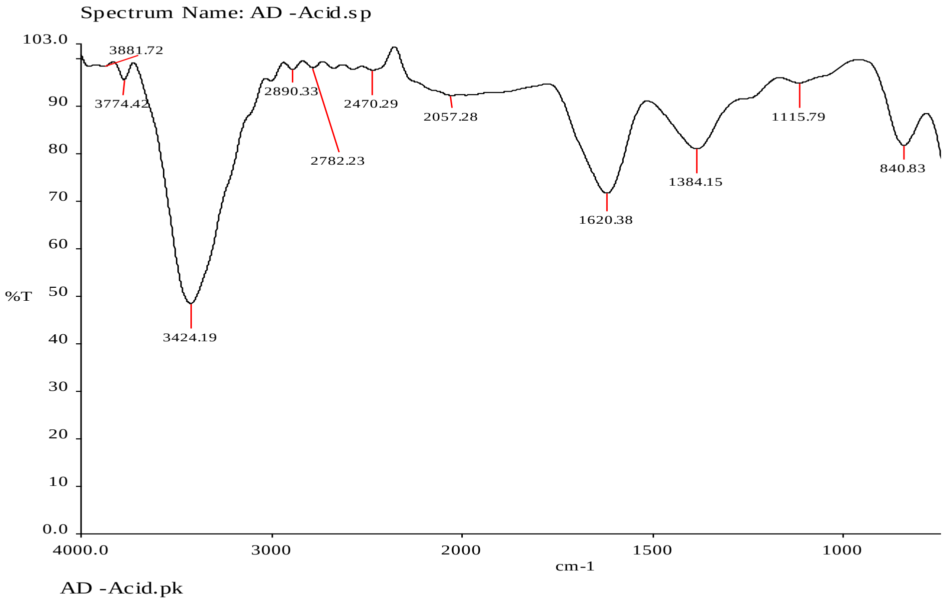

Figure 5. FTIR Spectrum (KBr) of thin film formed on the surface of the mild steel immersed in 1 M HCl containing AVNLE

3.6.2. UV-Visible spectral study

Figures 6a-c display the UV-visible spectra of the Fe^{2+} ion, pure extract, and Fe^{2+} in 1M HCl in the presence of AVNLE. The spectra of the extract (Figure - 6b) showed peaks at 423.11 nm (abs = 4.6254) and 435.80 nm (abs = 2.9840) which combined to appear at 334.00 nm (abs = 0.13290) in the acid spectrum of the extract (Figure - 6c). The peak at 668.47 nm (abs = 1.1601) in the spectra of the iron and extract mixture disappeared. The peak in the Fe^{2+} ion spectra (Figure 6a) at 278 nm (abs = 0.13404) shifted to 202.97 nm (abs = 1.1066) in the extract and acid mixture. Additionally, two new peaks emerged at 199.72 nm (abs = 1.1871) and 196.04 nm (abs = 1.2118) which is absent in the spectrum of both Fe^{2+}ion and the extract. These observations clearly indicate that there is a strong interaction between the extract and the iron. This proves that the extract can form a complex iron ions.

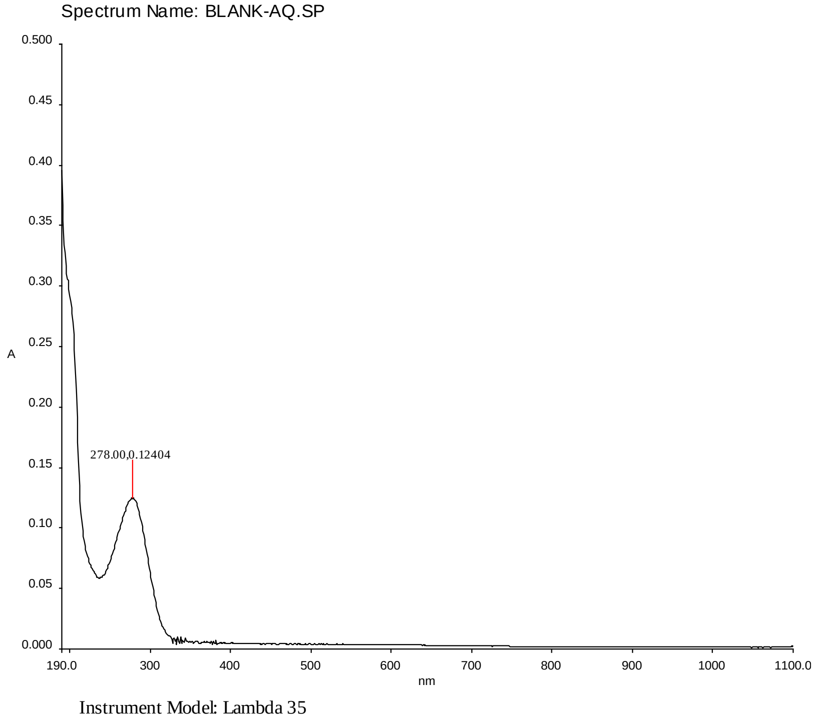

Figure 6a. UV-Visible absorption spectrum of Fe^{2+} ion

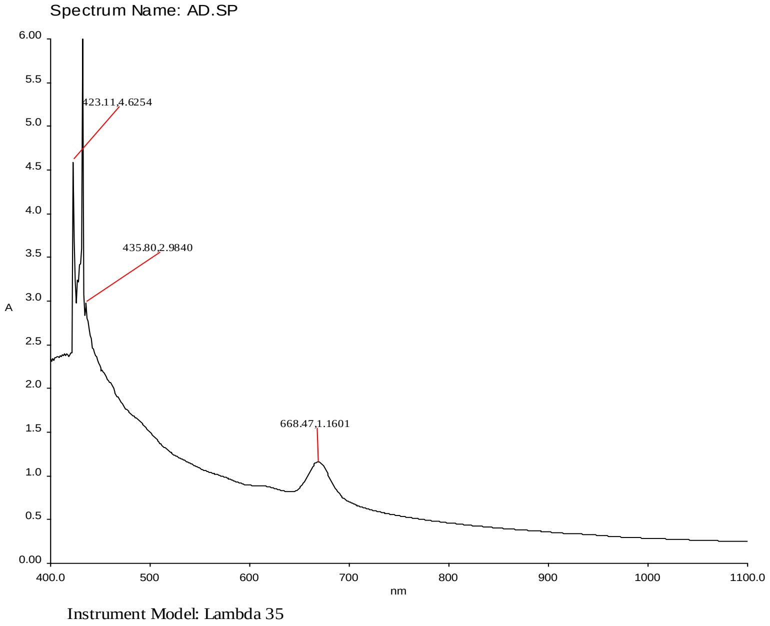

Figure 6b. UV-Visible absorption spectrum of pure extract

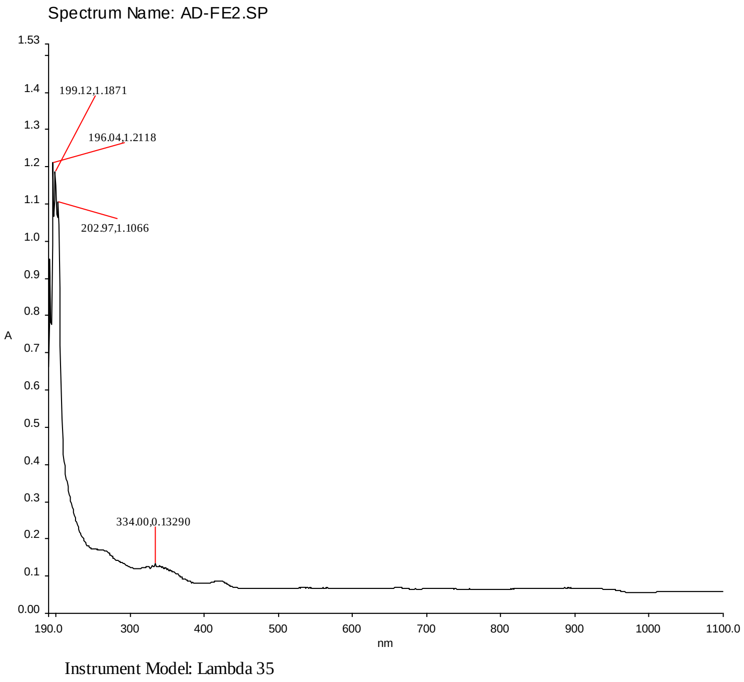

Figure 6c. UV-Visible absorption spectrum of Fe^{2+} ion and AVNLE in 1 M HCl

3.7. SEM observation

Figure 7a,b illustrates the pore structure and texture of the inhibited and uninhibited surfaces in an acidic medium. The figure confirms that, in an acidic environment, the inhibitor has formed a dense coating over the metal surface[18].The SEM investigation was performed to examine the surface characteristics of mild steel both in the presence and absence of the *Adhatodavasica*Nees leaf extract as a corrosion inhibitor.

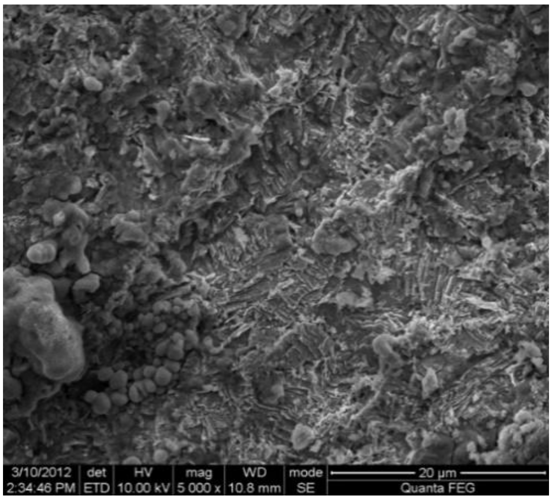

Figure 7a. Sem image of mild in 1MHCl

Figure 7a displays the SEM image of mild steel after exposure to 1 M HCl without any corrosion inhibitor. The unprotected steel surface shows extensive corrosion, characterized by visible pits and rough textures, a clear sign of the corrosive attack by chloride ions in the acidic solution.

The SEM investigation was performed to examine the surface characteristics of mild steel both in the presence and absence of the *Adhatodavasica*Nees leaf extract as a corrosion inhibitor. Figure 7a displays the SEM image of mild steel after exposure to 1 M HCl without any corrosion inhibitor. The unprotected steel surface shows extensive corrosion, characterized by visible pits and rough textures, a clear sign of the corrosive attack by chloride ions in the acidic solution.

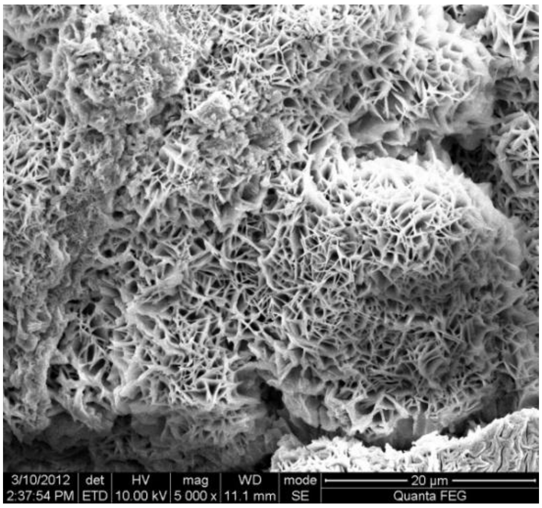

Figure 7b. Sem image of mild steel in 1MHCl + AVNLE

Conversely, Figure 7b, which illustrates the surface of mild steel after immersion in 1 M HCl with the addition of *Adhatodavasica*Nees extract, reveals a smoother and less deteriorated surface. The presence of the plant extract creates a protective barrier, minimizing the interaction between the metal and the acidic medium. This observation suggests that the inhibitor molecules adhere to the metal surface, reducing corrosion by blocking the active sites where degradation typically occurs.

Other researchers have reported similar outcomes using plant extracts as corrosion inhibitors. For example, studies have shown that mild steel treated with plant-based inhibitors in acidic environments exhibited significantly fewer pits and smoother surfaces compared to untreated samples, which experienced severe corrosion damage [19]. Likewise, a research has demonstrated that extracts from plants like neem and tulsi form protective films on metal surfaces, resulting in visibly smoother surface morphologies under SEManalysis[20].

In agreement with these prior studies, the results from our SEM analysis show that *Adhatodavasica* Nees extract effectively shields the mild steel surface from corrosion by forming an adsorbed protective layer, which limits direct contact with the acidic solution. This confirms the potential of bioactive compounds, such as alkaloids and flavonoids found in the plant extract, to serve as efficient, eco-friendly corrosion inhibitors.

4. MECHANISM OF CORROSION INHIBITION

The mechanism that prevents mild steel from corroding in acidic media is the interaction between the negatively charged Cl^- ions on the metal surface and the protonated species generated in acidic solutions. Adsorbed Cl^- ions on the mild steel surface and protonated heteroatoms (N, O, and S) present in the extract may allow them to adsorb in an HCl medium. Initially, on the mild steel surface, the protonated forms of phytochemicals present in acid media compete with H^+ ions for electrons. The cationic form of the inhibitor reverts to its neutral form following the generation of H_2 gas from 1M HCl, and heteroatoms with lone pair electrons encourage adsorption. More negative charge is applied to the mild steel surface due to its high electron density. The electron from the Fe d-orbital may be transferred to the unoccupied π*-orbital (antibonding) of the inhibitor molecules, strengthening their adsorption on the surface and relieving the mild steel surface of the excessive negative charge.

5. CONCLUSION

The present investigation concludes that *Adhatodavasica*Nees leaf extract serve as a green inhibitor preventing the corrosion of mild steel in acid medium. The inhibitory efficiency increases with the concentration of the inhibitor. In the presence of HCl, the protective film remains stable for seven hours. However, as the immersion period lengthens, the inhibitory efficiency decreases. The decrease in inhibition efficiency with increasing temperature and the increase in activation energy provide evidence that the molecules are physically adsorbed. The adsorption of *Adhatodavasica*Nees leaf extract on the surface of mild steel is exothermic, as indicated by the negative value of Qads. In an acidic environment, the inhibitor system primarily controls the cathodic process.AC impedance spectra reveal that a protective film is formed on the metal surface.UV-Visible absorption spectra suggest that a film containing iron ions and extract might have been formed. The active ingredients of the extract are present on the metal's surface. This is evidenced by the FTIR spectra, which also indicate a change in the chemical composition of the active ingredients. Therefore, it can be concluded that this inhibitor system functions effectively in the presence of acid.

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IZVOD

EKSTRAKT LISTA *ADHUTODAVASICA* NEES KAO INHIBITOR KOROZIJE ZA MEKI ČELIK U KISELOJ SREDINI

Održive metode kontrole korozije pojavile su se zbog strogih zakona o zaštiti životne sredine i rastuće ekološke svesti . Ova studija istražuje efikasnost inhibicije etanolnog ekstrakta lista AdhatodavasicaNees na koroziju mekog čelika u HCl . Koristeći podatke iz metoda gubitka mase , potenciodinamičke polarizacije, AC impedanse, UV-vidljivih spektara, FTIR i SEM analiza, procenjen je mehanizam inhibicije korozije. Ekstrakt je postigao maksimalnu efikasnost inhibicije od 79,72% na 95 ppm, bez značajnog poboljšanja izvan ove koncentracije. Energija aktivacije adsorpcije bila je 36,6275 kJ/mol. Pomeranje potencijala korozije (Ecorr) ka manje negativnim vrednostima i smanjenje katodnog nagiba ukazivali su na pretežnu kontrolu katodne reakcije , delujući kao katodni inhibitor. Kapacitivnost dvoslojnog sloja (Cdl) se takođe smanjila, što ukazuje na efikasnu inhibiciju. UV-vidljivi spektri ukazivali su na formiranje zaštitnog filma, dok su FTIR i SEM izveštaji potvrdili adsorpciju aktivnih jedinjenja na površini metala. Ekstrakt pokazuje potencijal kao efikasan, ekološki prihvatljiv inhibitor korozije za meki čelik u HCl.

***Ključne reči**: Adhutodavasica Nees, potenciodinamička polarizacija, AC impedansni spektar, FTIR spektroskopija, SEM*

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