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ANTI-CORROSION POTENTIALS OF *ABELMOSCHUS ESCULENTUS* PLANT IN SODIUM CHLORIDE SOLUTION

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ABSTRACT

The weight loss method discovered that the amount of corrosion that took place in mild steel (MS) at 303K could be decreased by submerging the material in a sodium chloride solution. The weight loss data were used to calculate the inhibitory effectiveness and the degradation rate. These calculations were carried out using the information. The strategy for avoiding corrosion works more effectively thanks to a higher inhibitor concentration, which may be found in an extract of the *Abelmoschus esculentus* plant. The pace of corrosion may be slowed down if the efficacy of the green inhibitor could be boosted. Because of the increasing concentration of the inhibitor solution, a protective layer will form on top of the MS. As a consequence of this, the reactive site on the MS will become inactive. Utilizing electrochemical methods, which would be of tremendous aid in this endeavour, may make it easier to develop a protective layer on the surface of the MS, which would be a significant step in the right direction. Scanning electron microscopy (SEM) and Fourier transform infrared spectroscopy are two techniques that have been used to evaluate its surface, and both of these techniques have contributed to its solid reputation (FTIR). Scanning electron microscopy (SEM) was used to evaluate the surface smoothness and roughness of mild steel. The findings were compared to those obtained from a blank that included an inhibitor.

Keywords: *Abelmoschus esculentus*, Corrosion, FTIR, Scanning Electron Microscopy, Sodium chloride solution and Weight loss method.

INTRODUCTION

Corrosion is a result of chemical and electrochemical processes that metals and alloys go through. Due to its high strength, MS is frequently used as a construction frame material as well as a structural steel beam. This material has good weldability and physical properties and is appropriate for a range of cutting and coating procedures. When well and surface water are utilized in cooling systems, storage tanks, concrete moulds, and water transport pipes for injection systems, corrosion risks increase. It is possible to stop corrosion by using a corrosion inhibitor[1-7]. These characteristics make it useful for making frames, panels, and other decorative elements. Two of the biggest issues with industrial water use are water contamination and metal equipment corrosion. Every substance that comes into contact with water or acid will eventually corrode. Corroded parts will lose their qualities in addition to weight and cross-sectional damage. Therefore, it is necessary to use corrosion inhibitors or additives to reduce or prevent corrosion. Corrosion inhibitors control how easily metals dissolve when exposed to the environment, especially when the environment is acidic, neutral,

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or basic. Excellent corrosion inhibitors include hydrocarbons containing electron-donating groups or polar functional groups, oxygen, nitrogen, and sulphur atoms, and aromatic rings with -electrons. An impermeable layer that protects metal from corrosive substances is created by chemical or physical interactions with metallic surfaces[8-11]. Scientists have attempted to understand the inhibitory effect of different hydrocarbons on corroding MS, zinc and copper alloys, carbon steel, and composites in acid, base, and neutral situations[12-14]. Most of these hydrocarbons are expensive and dangerous for both people and the environment. They have limited potential applications as a result. Novel inhibitors must be developed to be as effective and safe as possible as a result[15,16] suggest that plant extracts could be used to create a corrosion inhibitor that is both ecologically beneficial and biodegradable. Malvaceae family member *Abelmoschus esculentus* has long been used in traditional medicine to treat a variety of diseases. Numerous veggies are produced by the plant and are frequently fed to animals. Numerous studies have been done on the pharmacological effects and phytochemical characteristics of this plant[17,18].

Abelmoschus esculentus plant leaves are being used in this study to examine the effectiveness of an aqueous extract as a corrosion inhibitor on mild steel that has been dipped in a sodium chloride solution. Weight loss tests can be used to measure the amount of corrosion that has been stopped as well as how quickly it is occurring. To determine how effectively MS inhibits corrosion, various electrochemical studies can be performed. The protective layer of the MS was examined using Fourier Transform Infrared Spectroscopy (FTIRS). The surface's smoothness was examined using a scanning electron microscope.

EXPERIMENTAL TECHNIQUES

The effectiveness of an aqueous extract of the leaves of the *Abelmoschus esculentus* plant in halting mild steel corrosion in sodium chloride solution was investigated.

Preparation of mild steel specimens

Polished iron was used to assess weight loss; it had 0.1 percent carbon, 0.026 percent Sulphur, 0.06 percent phosphorus, and 0.4 percent manganese, with the remaining iron being utilized for all other calculations.

Making of stock solutions (preparation)

An AR grade of sodium chloride was diluted with double-distilled water to create the sodium chloride solution (NaCl). Then, using this solution, the chemical sodium chloride was produced. A crucial component used to correctly generate the solutions was DD water. The *Abelmoschus esculentus* plant leaves were dissolved in a small amount of water to produce the aqueous extract of the plant's leaves with the needed potency. This was accomplished by employing double-distilled water to increase the volume to the appropriate level.

Weight loss evaluation method

Mild steel specimens were submerged in sodium chloride solution for a day, both without and with varying amounts of an aqueous extract of *Abelmoschus esculentus* plant leaves. Weight loss was then measured. The concentrations were 2, 4, 6, 8, and 10 milliliters, respectively. The object was completely cleaned, dried, and weighed again after some time had passed.

The percentage of inhibitory effectiveness (IE) was calculated using the following relationship, which was found to be[19].

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$$\textbf{IE (\%)} = \frac{W_O - W_i}{W_O} \textbf{ X 100}$$

Where W_i and W_O are the weight loss values in g in presence and absence of an aqueous extract of *Abelmoschus esculentus* plant leaves inhibitor.

Polarization

A CHI-660A impedance type electrochemical work station was used for the electrochemical experiments. A cell, which consists of three electrodes, is where it occurs. The SCE serves as the benchmark. The counter electrode used in this experiment was constructed of platinum. The MS electrode was used to complete the challenge. According to Banu et al. (2017), the polarization investigation allowed for the determination of corrosion parameters such as corrosion potential (Ecorr), corrosion current (Icorr), Tafel slopes anodic = ba and cathodic = bc, and LPR (linear polarization resistance) values.

Measurements of alternating current impedance

Impedance Analyzer for Electrochemical Workstation (CHI-Electrochemical Impedance Model 660A). A comparable apparatus to the one used in this experiment was used for polarisation testing. The device was given the time interval, and a five to ten minute open-circuit voltage was attained. The steady-state potential was then supplemented by an alternating current potential of 10 mV. The real (Z) and imaginary (z") components of the cell impedance were measured in ohms when the alternating current frequency of the cell impedance was increased to 100 MHz. In this process, a wide range of frequencies were taken into account. It has been established that double layer capacitance and charge transfer resistance (Cdl and Rt) exist. The connections on the following list had to be used in order to calculate Cdl values.

Techniques for Examining the Surface

MS samples were immersed in inhibitor solutions containing both blank and *Abelmoschus esculentus* plant leaf extract for one day. After a day, the samples were dried. For mild steel specimens, the surface layer composition was evaluated using a variety of analytical techniques.

FTIR spectra are used to characterize the surface of a protective layer

FTIR pictures were taken on the Perkin-Elmer 1600 spectrophotometer. The KBr pellets were thoroughly mixed after the layer was removed, and FTIR spectra were obtained. The test specimens were taken out of the test solutions and dried after spending a day submerged in various environments. To ensure homogeneity, the entire mixture was aggressively agitated after the top layer was scraped off.

Microscopy using Scanning Electron (SEM)

SEM was used to compare the topography of the MS surface with and without the inhibitor after corrosion. A SEM was used. With the use of SEM, it will be possible to observe how the surface character of mild steel is affected by corrosive solution both before and after direct contact. The SEM image you see here was taken using the JEOL MODEL JSM 6390 SEM.

RESULTS AND DISCUSSIONS

The results of weight loss strategies

The amount of weight lost in a sodium chloride solution with and without the addition of an inhibitor made from plant leaves from the *Abelmoschus esculentus* species was measured. This study tested the mild steel's corrosion resistance (CR) and inhibitory effectiveness (IE) in well water with and without an aqueous extract of *Abelmoschus esculentus* plant leaves prepared utilizing the weight loss method. Table 1 shows the substance's ability to inhibit corrosion as well as its rate of corrosion.

Table 1: Calculation of Corrosion rates (CR) and inhibition efficiency (IE %)

Concentration of aqueous extract of AEPL inhibitor (%)	Corrosion rate (mdd)	Inhibition Efficiency (%)
Blank	76.66	-
2	61.90	42.10
4	53.13	51.35
6	46.26	62.10
8	29.53	73.70
10	18.09	85.60

Inhibitor System: Aqueous extract of Abelmoschus esculentus plant leaves, immersion period: One Day

The percentage of inhibitory effectiveness (IE) that is increased when the potency of the plant extract inhibitor increases peaks at a concentration of 10 ml of aqueous extract of *Abelmoschus esculentus* plant leaves. The inhibitory efficiency of an aqueous extract from the leaves of the *Abelmoschus esculentus* plant is 85.60 percent. As the amount of *Abelmoschus esculentus* plant leaves in the aqueous extract increases, the corrosion rate reduces [20]. In other words, when the concentrations of corrosion-inhibiting agents rise, MS surface coverage also rises, preventing the mild steel from dissolving by locking its corroding sites and thereby minimizing corrosion. The corrosion resistance of mild steel may be due to the phytochemicals found in plant extracts. The results of earlier studies are quite consistent with this monitoring [21-23].

Findings from a potentiodynamic polarization experiment

This study, which identifies the protective layer that grows on top of mild steel surfaces, may assist them tremendously. It allows for the rapid determination of the inhibitor's activity, the stability of the surface layer, and the inhibitor's inhibitory efficiency. The application of a protective layer increases linear polarization resistance (LPR) and corrosion current (Icorr). The potentiodynamic polarization curves of MS in sodium chloride solution without and with the plant extract inhibitor are shown in Fig. 1. Table 2 includes these characteristics, as well as the corrosion potential and slopes, as well as the linear polarization resistance and corrosion current (Icorr).

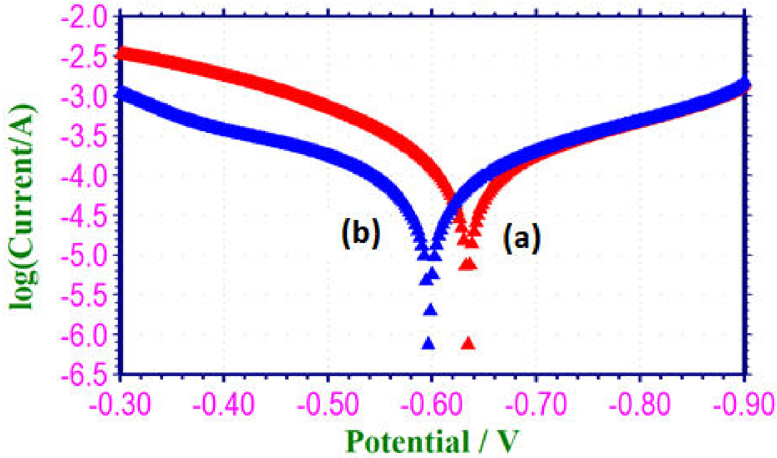

Figure. 1: Potentiodynamic polarization curves for corrosion of mild steel in sodium chloride solution in absence and presence of AEPLE inhibitor (a) Mild steel in sodium chloride solution (blank) (b) Mild steel in sodium chloride with 10% aqueous extract of AEPL

Table 2: Potentiodynamic Polarization parameters for the corrosion of mild steel in sodium chloride solution for the aqueous extract of AEPL system

Concentration of the aqueous leaves extract of AELP (%V/V)	E_{corr} mV/SCE	Tafel slope		I_{corr} A / cm^2	LPR Ω/cm^2
		ba, mV/dec	bc, mV/dec		
blank	- 634	657	480	1.327×10^{-4}	289
10	- 597	483	540	7.978×10^{-5}	534

The corrosion potential of MS in sodium chloride solution is – 634 mV Vs SCE, as illustrated in Fig. 1(Saturated Calomel Electrode). The LPR has a value of 289 Ohm/cm2. It has 1.327 10-4 A/cm2 corrosion current density. When 10% AEPLE is added to a corrosive solution, the corrosion potential moves to the anodic side (- 597 mV / SCE). The corrosion potential moves to the anodic side as a result of the formation of a protective layer on the MS surface. The Fe2+-AEPLE complex formed on the anodic regions of the mild steel surface, regulating the anodic response of MS dissolution. Corrosion resistance is increased in inhibitor systems with lower Icorr and higher LPR values[24-26].

Results of impedance spectra for alternating current

The validation procedure for creating a protective layer on MS surfaces may make use of EI spectra. When a protective coating is applied to the surface of the MS, the double layer capacitance (Cdl) decreases, the impedance log (z/ohm) rises, and the charge transfer resistance (Rt) rises. Figures 2 and 3 (respectively) display Nyquist plots of the AC impedance spectra of the sodium chloride solution absorbed by the MS (Bode plots). Table 3 lists double-layer capacitance and charging resistance (Rt) as AC impedance variables (Cdl).

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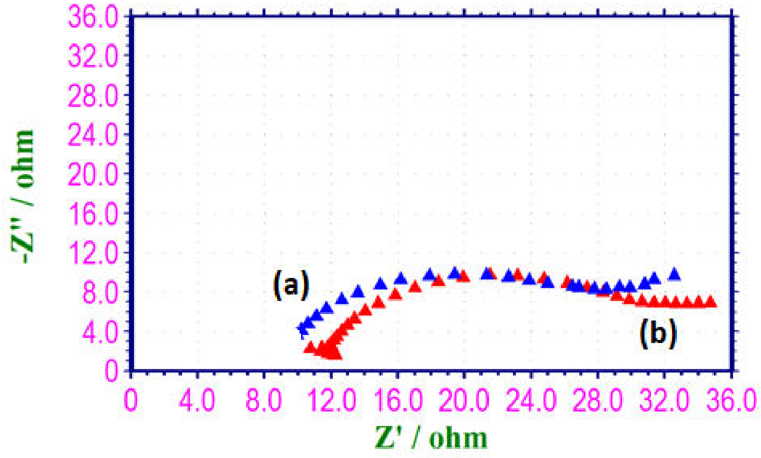

Figure. 2: AC impedance spectra of mild steel immersed in sodium chloride solution in the absence and presence of AEPLE inhibitor (Nyquist plots)(a) Mild steel in sodium chloride solution without inhibitor (b) Mild steel in sodium chloride solution with 10% aqueous extract of AEP leaves.

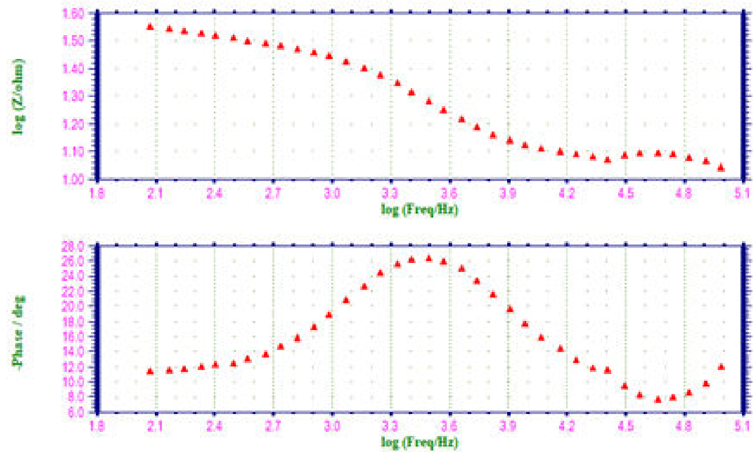

Figure. 3a: AC impedance spectra of mild steel immersed in sodium chloride solution (Bode Plot).

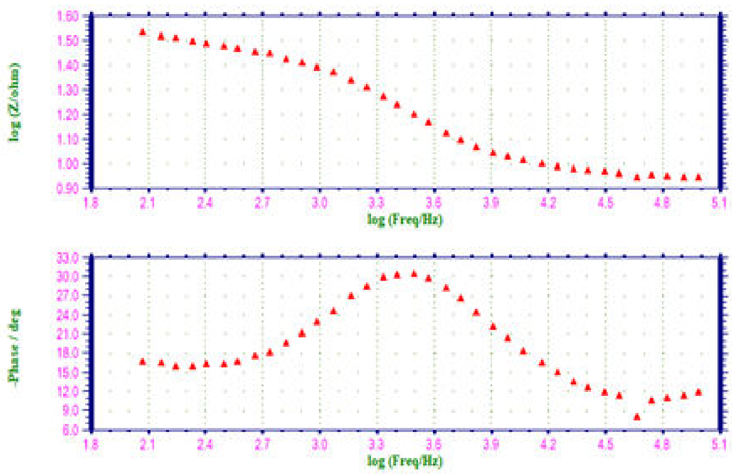

Figure. 3b: AC impedance spectra of mild steel immersed in sodium chloride solution with 10% aqueous extract of AEP leaves (Bode Plot)

MS's Rt and Cdl values are 23.70 ohm cm2 and 39.6268 10-6 F cm2, respectively, after being submerged in a sodium chloride solution. A solution of sodium chloride gains 10 percent AEPLE, increasing the Rt value from 23.70 cm2 to 24.06 cm2. Cdl decreases from 39.6268 10-6 F cm-2 to 39.0339 10-6 F cm-2 as well. The impedance rises together with the value of log (z/ohm). The phase angle of the inhibitor system increases from 26.5 °C to 30 °C in comparison to the blank system[27-30]. According to what we know, MS has a layer of exterior defence.

Table 3. Electrochemical impedance parameters from Nyquist plots for the corrosion of mild steel for aqueous extract of AEP leaves in sodium chloride solution

Concentration of the aqueous extract of AEPL (%v/v)	Nyquist plot		Impedance Log (z/ohm)	Phase angle (degree)
	R_t, Ω/cm^2	C_{dl} F/cm^2		
blank	23.70	39.6268×10^{-6}	0.510	26.5
10	24.06	39.0339×10^{-6}	0.594	30.0

Data processing for infrared spectroscopy

Identification of the surface MS absorption bands of inhibitor molecule functional groups is aided by FTIR analysis. According to researchers, FTIR analyses are a crucial method for figuring out how the phytochemical inhibitor components interact with the MS surface[31]. The functional groups of phytochemical elements and films for the various systems' absorption bands are listed in Table 4.

Table 4: FTIR spectral data for the aqueous extract of AEPL and the scratched film from mild steel surface after immersion in sodium chloride solution with 10% AEPL

IR bands of crude AE plant extract	IR bands of film from mild steel surface	Frequency assignment to functional groups
3444.13	3416.18	-OH
2075.15	2079.53	C-H stretching
1679.49	1634.19	C-O stetching
1406.18	1271.48	C-C stretching
1271.26	1121.11	C=C
640.46	684.23	N-H
-	443.86	$Y\text{-}Fe_20_3$

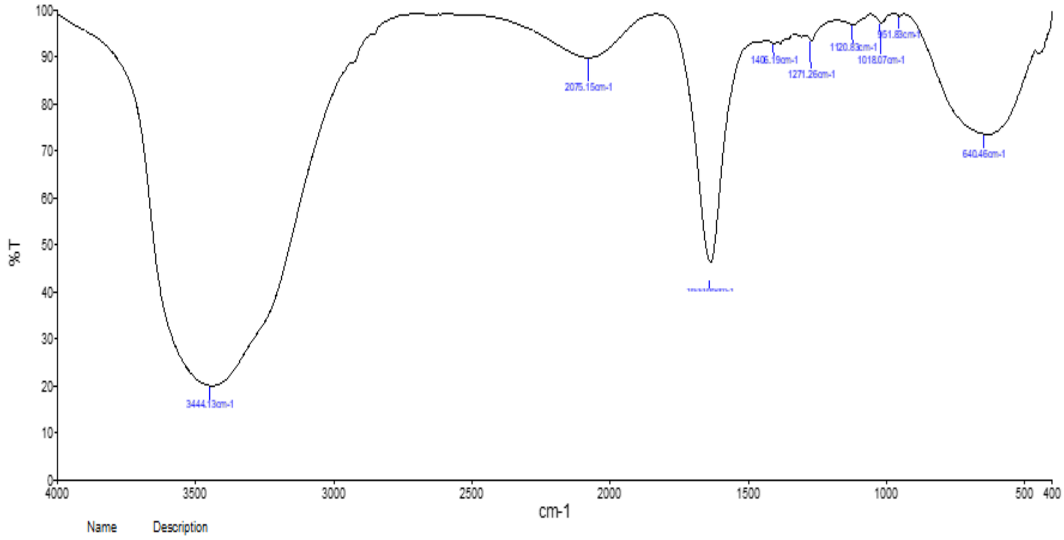

Figure. 4a: FTIR spectrum of aqueous extract of AEPL

The FTIR spectra of AEP leaves is displayed in Figure 4a. According to Rajendran et al. (2019), the frequency of OH stretching is reported to be 3444.13 cm^{-1}. C-H stretching appears to occur at a frequency of 2075.15 cm^{-1}. The peak brought on by C-O may be seen at 1679.49 cm^{-1}. The N-H frequency may be seen at 640.46 cm^{-1}. Stretching frequencies for C-O and C-C are respectively 1679.49 $cm^{-1}$and 1406.18 cm^{-1}. The C=C peak is located at 1271.26 cm^{-1}.

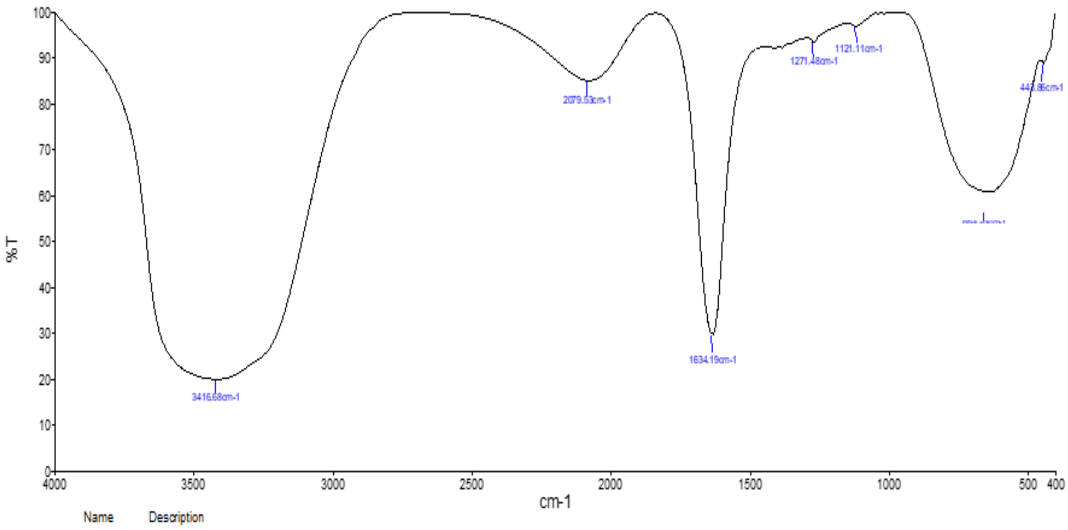

Figure. 4b: FTIR spectrum of scratched film from the mild steel surface after immersion in sodium chloride solution with 10% aqueous extract of AEPL

Fig. 4b depicts the MS coated with a 10% aqueous extract of AEPL for protection and submerged in a salt chloride solution. According to Jasiniki and Lob (1998), a change in the O-H from 3444.13 to 3416.18 cm^{-1} demonstrates that molecule adsorption can occur through the O-H. For the C-H group, the frequency increased from 2075.15 cm^{-1} to 2079.53 cm^{-1}. The greatest frequencies for the C-C and C=C groups are 1271.48 cm^{-1} and 1271.26 cm^{-1}, respectively, while the frequency of the C-O group decreases from 1679.49 cm^{-1} to 1634.19

cm^{-1}. It was noted that the N-H frequency was 684.23 cm^{-1}. The band at 443.86 cm^{-1} can only be explained by the iron-complex[32]. The bands above clearly display the complex structure that appears on mild steel's surface.

SEM analysis of the surface of MS

To distinguish between the protective layer that occurs without and with AE plant leaf extract inhibitor at the exterior of the MS, SEM images of the surface of the MS must be scanned. SEM analysis may identify the mild steel's external shape and degree of corrosion, which reveals whether corrosion inhibitors are present or not. Fig. 5 displays SEM images of mild steel samples with and without an AEPLE inhibitor system after being submerged in sodium chloride for one day.

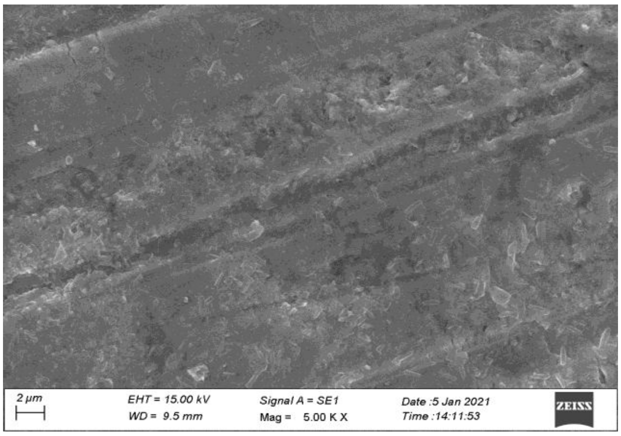

Figure. 5a: SEM image of polished mild steel specimen before immersion in sodium chloride (control)

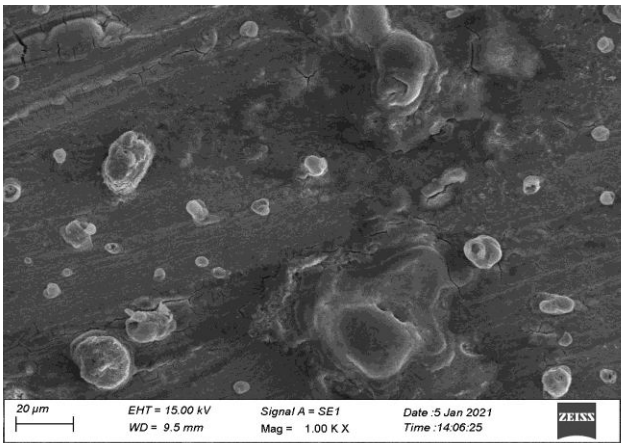

Figure 5b: SEM image of mild steel specimen after immersion in sodium chloride solution (blank)

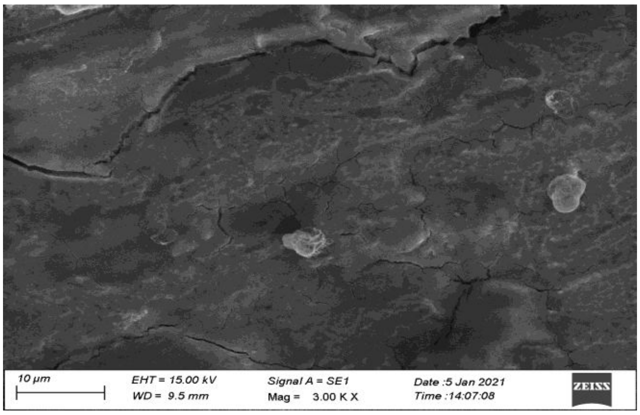

Figure. 5c: SEM image of mild steel specimen after immersion in sodium chloride in the presence of 10% aqueous extract of DMPL.

For one day, the MS specimen is immersed in a sodium chloride and inhibitor solution. After being taken out, dried, and examined, the sample is examined under a scanning electron microscope (SEM). MS images have been polished in Fig. 5a (the control). The mild steel surface in Fig. 5b appears to have been corroded by a sodium chloride solution as a result of metal dissolution. The surface of mild steel after being dipped in a sodium chloride inhibitor is shown in Fig. 5c.

The SEM images in Fig. 5a show polished surfaces made of mild steel[33-34]. An electron microscope image of pitted mild steel is shown in Fig. 5b. Due to the corrosion inhibitor's considerable adsorption on the mild steel surface, the corrosion process is inhibited in Fig. 5c.

Furthermore, the shrinkage of corroded zones shows that the inhibitor (10 percent AEPLE) lowers corrosion. It is almost corrosion-free because the mild steel surface of MS has developed an insoluble compound. When 10% Aqueous Extract of AEPL is added to a sodium chloride solution, a thin layer of inhibitor prevents mild steel from dissolving. Less metal surface deterioration happens as a result of the inhibitor's improved adsorption effectiveness at the mild steel/solution interface[35-37].

CONCLUSION

In the present investigation, mild steel corrosion in sodium chloride solution is reduced using an aqueous extract of *Abelmoschus esculentus* plant leaves. Following data analysis, we reached the following conclusion:

- An aqueous extract of the leaves of the *Abelmoschus esculentus* plant, which has a high corrosion prevention activity, protects low-carbon steel submerged in NaCl solution.
- The weight loss strategy's inhibitory efficacy has reportedly been accounted for to an approximated 85 percent.
- Polarization experiments show that the systems control the anodic response more skillfully by serving as anodic inhibitors.
- As the adsorbent layer thickness rises, the charge transfer resistance (Rt), double layer capacity, and corrosion current all increase (Icorr).
- SEM micrographs of polished and corroded mild steel demonstrate the brittleness of the surface.

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