

Inhibitory Potentials of Datura Metel to Prevent Mild Corrosion

S. Sulochana¹, J. Maria Praveena², A. John Amalraj^{3,*}

Abstract

The resistance of mild steel to corrosion was evaluated by immersing it in well water and determining the weight it lost after being allowed to return to room temperature after the submersion. The effectiveness of mild steel's ability to withstand corrosion was evaluated using this approach. A reduction in total body mass has an influence that is connected to and helps play a role in the prevention of rusting from taking place. When dealing with rust, one approach that can be utilised to gain some time is using rust inhibitors that are safe for the environment in which they are employed. This may be done in order to delay the inevitable. This will delay the inevitable for a longer period. By painting the metals green, it is possible to prevent the metals from corroding over time. The surface of the mild steel is protected from harm when the inhibitor's concentration is brought up to its maximum level. This causes the active site to become more restricted, preventing the surface from being damaged. During the research that was conducted utilising mild steel, it was discovered that there was a layer of preservation. The technique of distinguishing between the two may use various analytical instruments, including the FTIR and the SEM, amongst others. The smoothness and roughness of mild steel are compared with those of blank and inhibitor systems during this experiment.

Keywords: Corrosion, Datura metal, FTIR, Scanning Electron Microscopy and Weight loss method.

INTRODUCTION

Frames made of mild steel are reliable. It may be welded, sliced, and coated at little cost. There was a refinement of crude oil that had deteriorated. It's used to fabricate various things like frames and panels. Due to its widespread application in industry [1–3], research into mild steel corrosion in acidic media is essential. This includes processes like acid pickling, acid descaling, petrochemical processes, and oil-well acid in oil recovery. Equipment used in manufacturing may be damaged by corrosion and

water contamination. Submersion in both acidic and alkaline water causes corrosion. Materials that have been corroded may alter in mass and shape as a result of the process [4–6]. There must be additives or inhibitors. Corrosion inhibitors prevent metals from dissolving under a range of pH conditions. Corrosion may be slowed by the presence of heteroatoms, -electron-containing aromatic rings, and electron-donating or polar functional groups. These inhibitors prevent corrosion by chemically or physically adsorbing onto metal surfaces. Equipment security, dependability, and performance may all be compromised by corrosion [7]. Under acidic, alkaline, and neutral conditions, organic compounds were evaluated on zinc, copper, aluminium alloys, mild steel, carbon steel, and

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Received Date: August 17, 2022

Accepted Date: September 16, 2022

Published Date: November 12, 2022

Citation: S. Sulochana, J. Maria Praveena, A. John Amalraj. Inhibitory Potentials of Datura Metel to Prevent Mild Corrosion. Journal of Polymer & Composites. 2022; 10(Special Issue 2): S58–S67.

composites [8, 9]. These pricey chemicals pose a threat to both human health and the natural world. ineffective inhibitors of corrosion. making non-harmful, low-priced corrosion inhibitors a priority. Green corrosion inhibitors include plant extracts [10]. Datura metel, or the medical fennel, is a kind of the nightshade. Utilized in both animal feed and vegetable production. Biological activities and chemical compositions.

This research tests the efficacy of Datura metel leaf extract as a mild steel corrosion inhibitor in subsurface water. During weight loss, the rate of corrosion and the efficiency of the inhibitors are measured. Corrosion may be controlled using electrochemical means, such as AC impedance spectra and polarisation. The coating on mild steel was analysed using an FTIR spectrometer. SEM analysis of the relative smoothness of polished, corroded, and inhibitor-treated mild steel (SEM).

Substances and Techniques

Mild steel in well water has been studied for its potential to be protected against corrosion using an aqueous extract of the leaves of the Datura metel plant.

Preparation of Mild Steel Specimens

Polished to a mirror finish and degreased with acetone, iron containing 0.1% carbon, 0.026% sulphur, 0.06% phosphorus, 0.4% manganese, and the balance iron was employed as a weight reduction technique.

Making up Stock Solutions

When preparing solutions, only double-distilled water was utilised. Datura metel plant leaves were dissolved in the bare minimum of water before being topped up to the correct volume with double-distilled water to create a stock solution of aqueous extract of Datura metel plant leaves at the specified concentration. The appropriate concentration of inhibitor was achieved by adding the necessary amount of the inhibitor stock solution to the well water solution.

Term for a Weight-loss

By submerging mild steel specimens in well water without and with varying concentrations (2, 4, 6, 8, 10 ml) of aqueous extract of Datura metel plant leaves inhibitor, we were able to evaluate the weight loss over the course of 24 hours.

The sample was collected once the allotted time had passed, and further procedures included thorough cleaning, drying, and precise weighing. The following equation [11] was used to calculate the inhibitory efficiency (IE%).

$$IE (\%) = \frac{W_o - W_i}{W_o} * 100$$

Where W_i and W_o are the weight-loss values in grammes when the Datura metel plant leaves inhibitor is present and when it is not.

Applications of Electrochemical Methods

In this work, we used a polarisation analysis and an alternating current (AC) impedance spectrum to quantify the inhibitory activity of mild steel submerged in a variety of test solutions. The CHI-electrochemical work station model 660A impedance was used for the electrochemical experiments.

Inquiry into Polarization

Experiments on polarisation were performed using a three-electrode cell setup. As the reference electrode, a SCE was used. The other electrode was made of platinum. The electrode was made of mild steel. Corrosion characteristics were calculated from the polarisation research, including corrosion potential (E_{corr}), corrosion current (I_{corr}), Tafel slopes (anodic = b_a , cathodic = b_c), and linear polarisation resistance (LPR) [12].

Evaluation of AC Impedance

An impedance analyzer included inside a CHI-electrochemical work station, type 660A. The experimental cell arrangement was the same as that used in polarisation tests. There was a 5- to 10-minute window allowed to the gadget to settle into its steady-state open-circuit potential. This steady-state potential was then overlaid with an alternating current potential of 10 mV. The impedance of a cell was measured in ohms at both its real (Z) and imaginary (z'') frequency components as the alternating current frequency was changed from 100 kHz to 100 MHz. The charge transfer resistance (R_t) and double layer capacitance (C_{dl}) were calculated. C_{dl} levels were evaluated using the following correlation.

$$C_{dl} = \frac{1}{2 \times 3.14 \times R_t \times f_{max}}$$

Strategies for Analyzing the Surface

For 24 hours, the mild steel samples were submerged in blank and inhibitor solutions, the latter of which included an aqueous extract of the leaves of the *Datura metel* plant. The samples were taken out after 24 hours and air dried. Several methods of analysis were used to determine the composition of the film that had developed on the mild steel samples.

FTIR Spectroscopy for Surface Analysis

Perkin-Elmer 1600 spectrophotometer FTIR spectra were collected. With great care, we peeled away the film, completely mixed in KBr pellets, and recorded the FTIR spectra. Once the test specimens had been submerged for a full day in each of the different conditions, they were removed from the test solutions and allowed to dry. Scratching it gently and mixing it well helped to create a homogeneous layer on the surface [13]. Using a Perkin-Elmer 1600 FTIR spectrophotometer with a resolution of 4 cm, we were able to capture the FTIR spectra of the powder (KBr pellet).

Scanning Electron Microscopy (SEM)

In order to see how the presence of an inhibitor modifies the surface of mild steel, SEM has been used to compare images taken before and after the metal was exposed to the corrosive solution [9, 14]. This meant that SEM could be used to examine the topography of the mild steel surface following corrosion, both with and without the inhibitor. This SEM picture was captured using a JEOL MODEL JSM 6390 scanning electron microscope.

RESULTS AND DISCUSSION

Results of Weight Loss Method

The effects of an aqueous extract of *Datura metel* plant leaves on weight loss were measured in both the absence and presence of the extract at varying concentrations in well water. Mild steel is submerged in well water and then tested for inhibition efficiency (IE) and corrosion rate (CR) in the absence and presence of an inhibitor made from an aqueous extract of *Datura metel* plant leaves. Corrosion rates and inhibition efficiencies are listed in Table 1.

Datura metel leaf aqueous extract had the highest inhibitory effectiveness (IE%) at a quantity of 10 millilitres (ml). Inhibition efficiencies of 87.50% have been recorded in aqueous extract of *Datura metel* plant leaves. The inhibitory effectiveness and corrosion rate both improve with increasing concentrations of an aqueous extract of *Datura metel* plant leaves [15]. As inhibitor concentrations rise, they become more effective at covering more of the metal's surface, slowing the corrosion rate and preventing further dissolving of the mild steel. Inhibition of mild steel corrosion may be attributed to the presence of several phytochemical elements in plant leaf extracts. Many studies [16, 17] have shown that this monitoring closely matches their findings.

- *Inhibitor System:* Aqueous extract of *Datura metel* plant leaves
- *Immersion period:* 24 hours

Table 1. Corrosion rates (CR) and inhibition efficiency (IE %) data obtained by weight loss measurements for mild steel is immersed in well water without and with various concentration of aqueous extract of Datura metel plant leaves.

Concentration of aqueous extract of DMPL inhibitor (%)	Corrosion rate (mdd)	Inhibition Efficiency (%)
blank	78.60	-
2	60.32	45.25
4	46.30	59.60
6	32.23	71.74
8	21.53	80.91
10	10.70	87.50

Electrochemical Methods

To determine the rate of corrosion of mild steel, electrochemical tests may be performed. It allows for the rapid assessment of inhibitor efficacy, surface film durability, and corrosion inhibition efficiency.

In order to determine whether the DMPLE inhibitor system acts as a cathodic, anodic, or mixed type inhibitor and to develop a suitable mechanism for its inhibitory effect on mild steel corrosion in well water, the following methods were utilised.

Summaries of Potentiodynamic Polarisation Experiments

Using the results of this research, scientists can describe how a protective coating forms on the surface of mild steel. An increase in linear polarisation resistance (LPR) and a reduction in corrosion current (I_{corr}) are seen when a protective coating is created on the surface of mild steel. Figure 1 depicts the lack and presence of a DMPLE inhibitor on the potentiodynamic polarisation curves of mild steel submerged in well water. Table 2 provides the values for the corrosion parameters used to assess the state of corrosion, including the corrosion potential (E_{corr}), Tafel slopes (b_c , b_a), linear polarisation resistance (LPR), and corrosion current (I_{corr}) Figure 1.

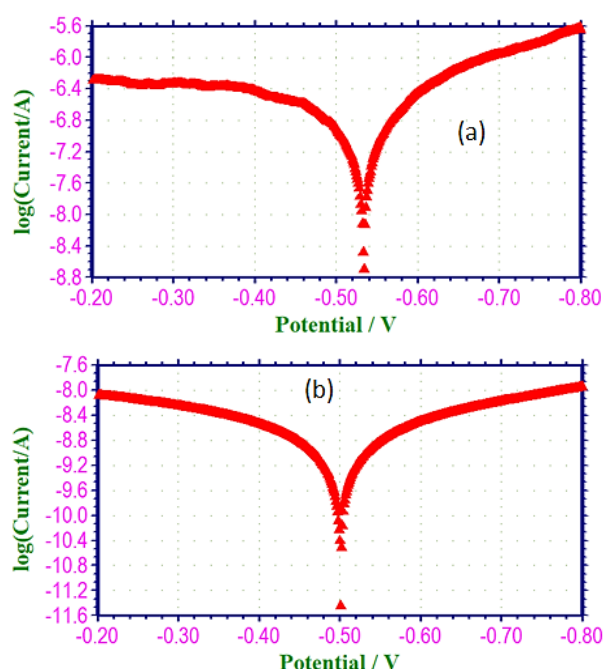


Figure 1. Potentiodynamic polarization curves for corrosion of mild steel in well water in absence and presence of DMPLE inhibitor (a) Mild steel in well water (blank) (b) Mild steel in well water with 10% aqueous extract of DMPL

Table 2. Potentiodynamic Polarization parameters for the corrosion of mild steel in well water for the aqueous extract of DMPL system

Concentration of the aqueous leaves extract of DMP (%V/V)	E_{corr} mV/SCE	Tafel slope		I_{corr} A/cm ²	LPR Ω /cm ²
		ba, mV/dec	bc, mV/dec		
blank	-534	268	621	1.997×10^{-7}	245526
10	-501	476	515	1.367×10^{-9}	32122114

Figure 1a shows that the corrosion potential of mild steel in well water is -534 mV Vs SCE (Saturated Calomel Electrode). The low-power resistance is 245526 Ohm/cm². Exactly 1.999×10^7 A/cm² is the corrosion current. Adding 10% DMPLE to the aforementioned corrosive environment shifts the corrosion potential to the anodic side (-501 mV/SCE) (Figure 1b). As a result of the creation of a protective coating on the surface of the mild steel, the corrosion potential is transferred to the anodic side, as shown by this. By producing Fe²⁺-DMPLE complex on the anodic sites of the mild steel surface, this film exerts control over the anodic reaction of dissolution [18–21]. A more corrosion-resistant inhibitor system is shown by an increase in LPR and a drop in I_{corr} readings.

The Impedance Spectra of AC Current

The creation of a protective layer on the surface of mild steel has been verified using electrochemical impedance spectra. Charge transfer resistance (R_t) rises, double layer capacitance (C_{dl}) falls, and impedance log (z/ohm) rises if a protective layer is formed on the surface of mild steel. Figure 2 (Nyquist plots) and Figure 3 illustrate the AC impedance spectra of mild steel submerged in well water with and without the DMPLE inhibitor system (Bode plots). Table 3 lists the values for the AC impedance characteristics charge transfer resistance (R_t) and double layer capacitance (C_{dl}).

The R_t value of mild steel in well water is 8836000 ohm cm², and the C_{dl} value is 14552892 106 F cm⁻². When 10% DMPLE is given to a blank system containing well water, the R_t value rises from 8836,000 to 36170000 ohm cm². As a result, the C_{dl} value drops from 14552892 F cm⁻² to 5957199 F cm⁻². The log (z)/(ohm) impedance value goes up from 2.138 to 2.317. In addition, the inhibitor system has a larger phase angle of 89.0° compared to the blank system's 67.0° [21–24]. It is suggested that a layer of protection be developed over the mild steel.

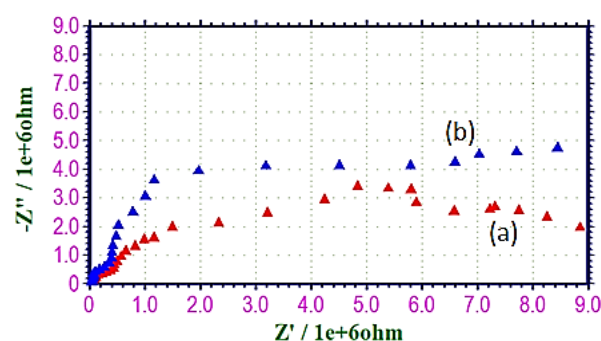


Figure 2. AC impedance spectra of mild steel immersed in to well water in the absence and presence of DMPLE inhibitor (Nyquist plots) (a) Mild steel in well water without inhibitor (b) Mild steel in well water with 10% aqueous extract of DMLP leaves.

Table 3. Electrochemical impedance parameters from Nyquist plots for the corrosion of mild steel for aqueous extract of DMP leaves well water

Concentration of the aqueous extract of DMPL (%v/v)	Nyquist plot		Impedance Log (z/ohm)	Phase angle (degree)
	R _t Ω /cm ²	C _{dl} F/cm ²		
blank	8836000	14552892×10^{-6}	2.138	67.0
10	36170000	5957199×10^{-6}	2.317	89.0

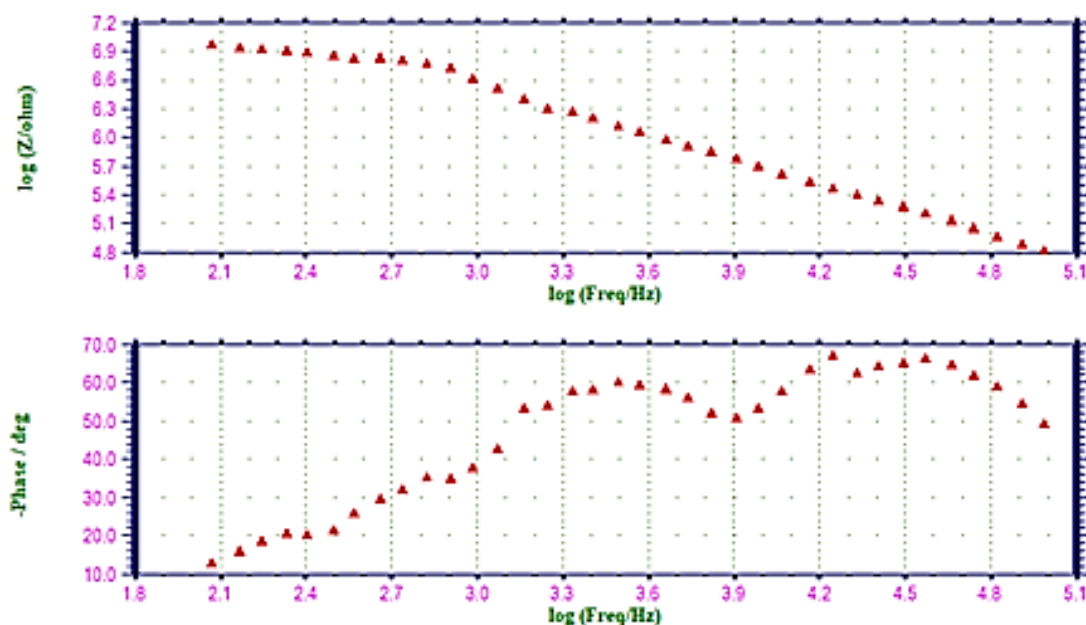


Figure 3. (a) AC impedance spectra of mild steel immersed in well water (Bode Plot).

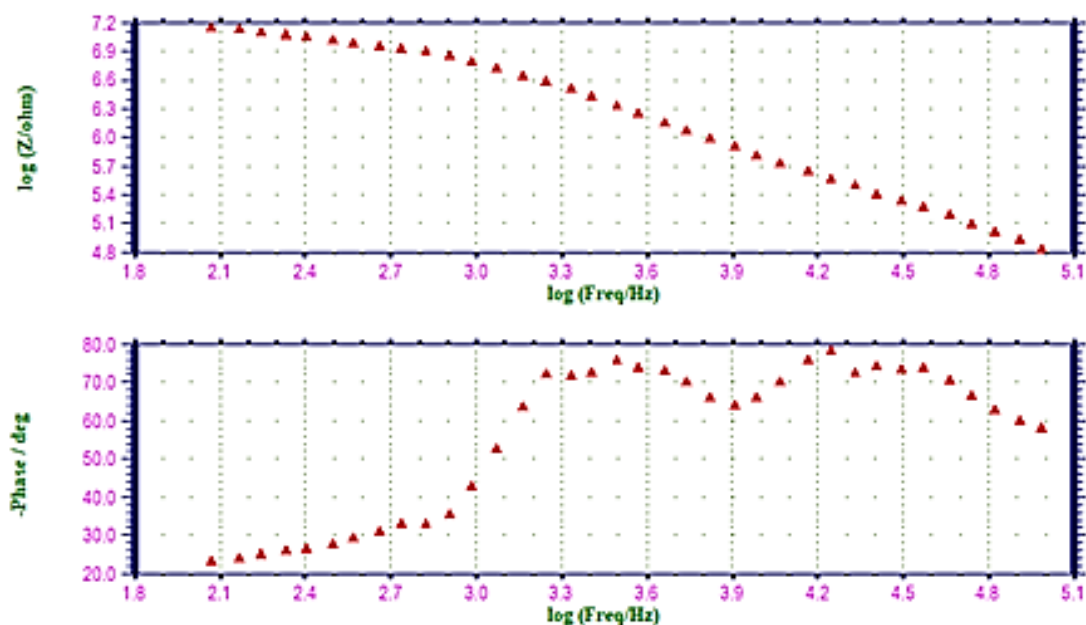


Figure 3. (b) AC impedance spectra of mild steel immersed in well water with 10% aqueous extract of DMP leaves (Bode Plot).

Interpretation of FTIR Spectra

Absorption bands for functional groups and the orientation of inhibitor molecules on the mild steel surface may be identified by FT-IR analysis. FTIR investigations have been shown by many researchers to be an important tool for predicting the kind of bonding of the inhibitor's phytochemical components on the mild steel surface [13, 15]. Table 4 lists the absorption bands of the functional groups present in the relevant systems.

In we see the FTIR spectrum of a water extract of DMP leaves. Figure 4a. It seems that 3444.45 cm^{-1} is the OH stretching frequency. At 2076.64 cm^{-1} , the C-H stretching frequency is clearly visible. C-peak O's shows up at 1634.14 cm^{-1} . This is the 687.10 cm^{-1} N-H frequency.

Table 4. FTIR spectral data for the aqueous extract of DMPL and the scratched film from mild steel surface after immersion in well water with 10% DMPL.

IR bands of crude DM plant extract	IR bands of film from mild steel surface	Frequency assignment to functional groups
3444.45	3444.31	-OH
2076.64	2081.51	C-H stretching
1634.14	1607.73	C-O stretching
-	1354.23	C-C stretching
-	1127.12	C=C
687.10	620.07	N-H
-	430.22	Y-Fe ₂ O ₃

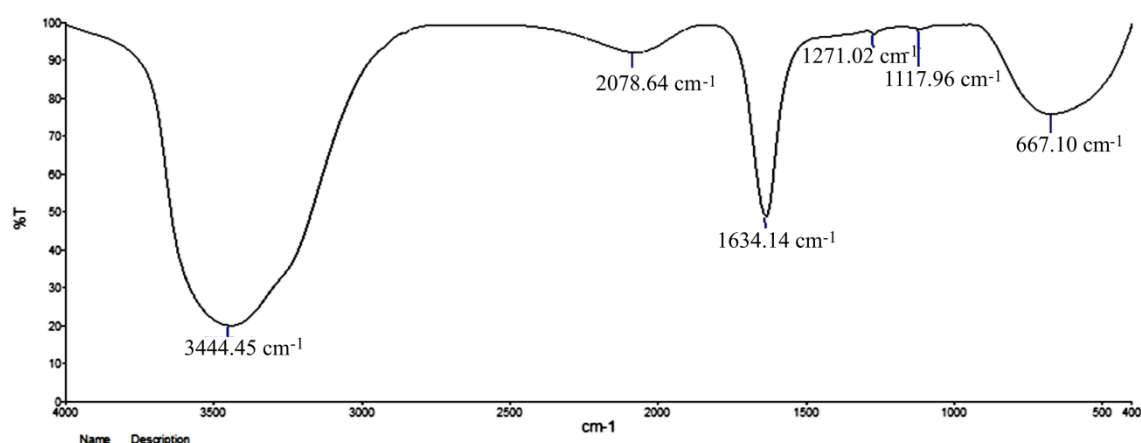


Figure 4. (a) FT-IR spectrum of aqueous extract of DMPL.

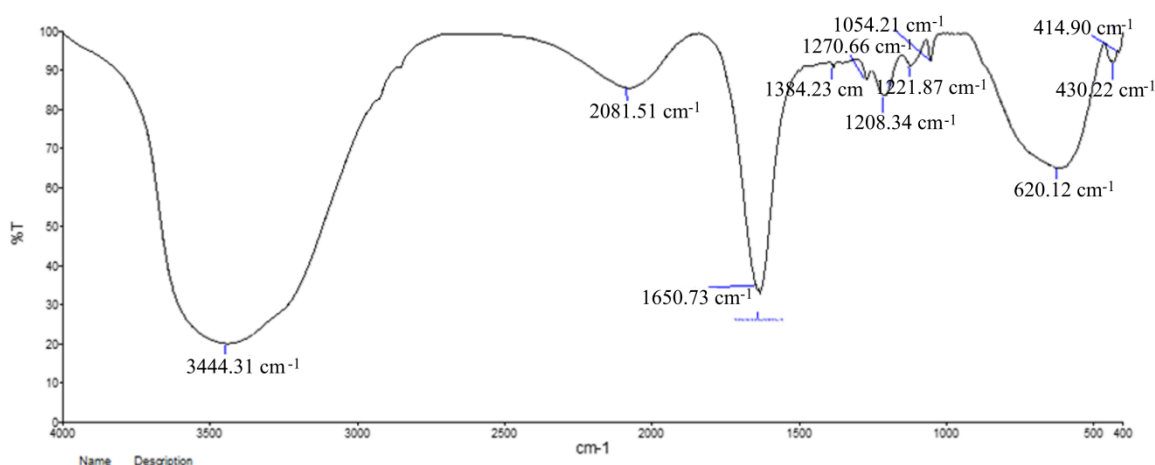


Figure 4. (b) FT-IR spectrum of scratched film from the mild steel surface after immersion in well water with 10% aqueous extract of DMPL.

Figure 4b shows how a 10% aqueous extract of DMPL forms a protective thin coating on the surface of mild steel submerged in well water. O-H stretching has moved from 3444.45 to 3444.31 cm^{-1} , suggesting that O-H adsorption may have a role in the molecular adsorption. The C-H group exhibits a frequency shift, from 2076.64 to 2081.51 cm^{-1} . For the C-O group, the frequency shifts from 1634.14 to 1607.73 cm^{-1} . For the C-C and C=C groups, new peaks are seen at 1354.23 and 1127.12 cm^{-1} . Here we see that the N-H frequency is 620.07 cm^{-1} . The 430.22 cm^{-1} band is mostly emitted by the Fe-complex. Each of the aforementioned bands provides conclusive evidence that a complex has formed on the surface of mild steel [22–24].

Light Steel SEM Surface Analysis

The surface morphology of mild steel with and without corrosion inhibitors, as well as the severity of corrosion, may be inferred from a SEM analysis. SEM micrographs of the surface are analysed to learn about the corrosion of mild steel and the type of the layer generated on the surface in the absence and presence of aqueous extract of DM plant leaves. Figure 5a, b, and c show scanning electron microscopy (SEM) pictures of mild steel specimens submerged in well water for one day with and without the DMPLE inhibitor system.

The mild steel sample is submerged in an inhibitor-laced well water solution for 24 hours. The sample is extracted, dried, and examined by SEM. Figure 5a displays photos of raw mild steel (the standard). Figure 5b depicts mild steel with a damaged surface caused by metal breakdown in well water. Figure 5c shows the mild steel surface after it was submerged in well water that included an inhibitor.

Figure 5a shows SEM pictures of a polished mild steel surface, indicating that there is no corrosion product on the steel [20]. Figure 5b shows a scanning electron micrograph of a rough spot on mild steel, an indication of severe corrosion. The corrosion inhibitor strongly adsorbed on the surface of the mild steel, as shown in Figure 5c's SEM picture, and so inhibited corrosion.

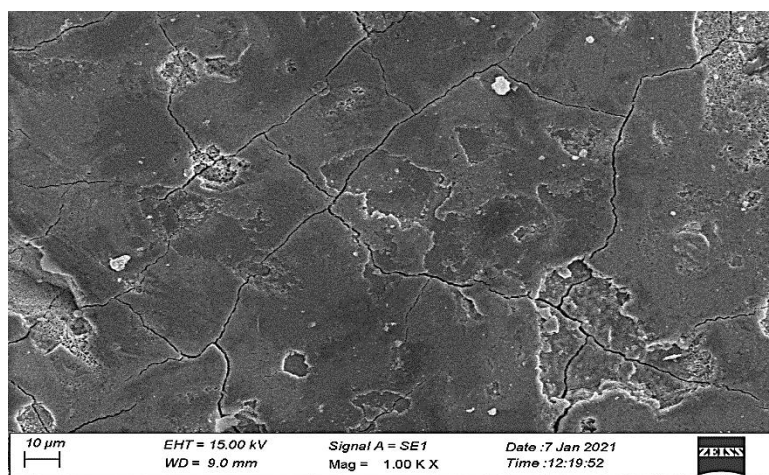


Figure 5. (a) SEM image of polished mild steel specimen before immersion in well water (control).

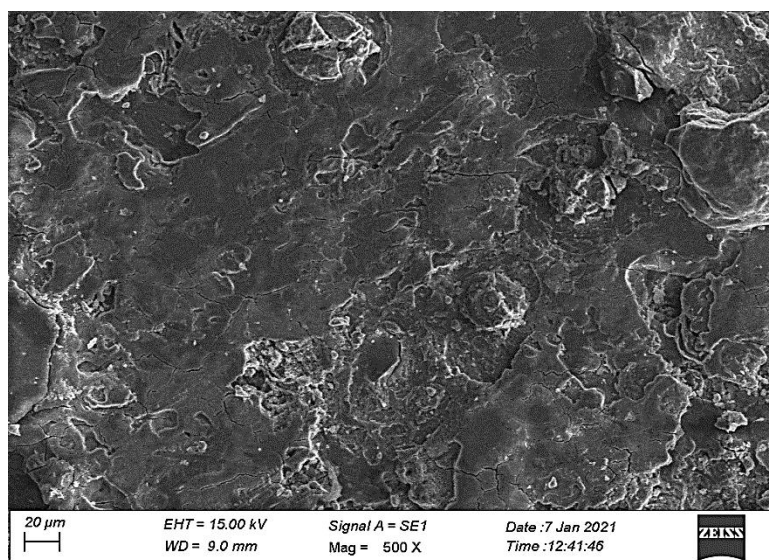


Figure 5. (b) SEM image of mild steel specimen after immersion in well water (blank).

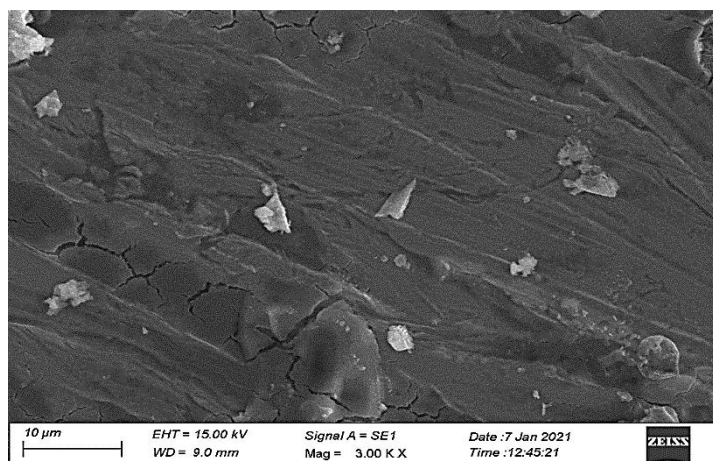


Figure 5. (c) SEM image of mild steel specimen after immersion in well water in the presence of 10% aqueous extract of DMPL.

Corroded patches, however, decrease in size when an inhibitor (10% DMPLE) is present, suggesting that the corrosion process is slowed. Due to the creation of an insoluble compound on the surface of the mild steel, the metal is virtually completely protected against further deterioration [25]. A thin layer of inhibitor forms on the surface of DMPLE, preventing the corrosion of mild steel submerged in well water containing 10% aqueous extract of DMPL. As a result, it can be shown that the inhibitor has improved the adsorption effectiveness at the mild steel/solution interface, suggesting that the inhibitors mitigate the deterioration of the metal's surface.

CONCLUSION

The findings suggest that a *Datura* metal leaf extract may protect mild steel against corrosion when it is immersed in well water. Here's what we learned after analysing the data. An extract from the *Datura* metal plant's leaves has been shown to successfully stop the corrosion of mild steel in pretty good water. Inhibitory mechanism efficiency is 87.50 percent while using this method of weight loss. The polarisation study suggests that the mechanism acts as an inhibitor. Electrochemical impedance analyses show that with increasing adsorption layer thickness, transfer resistance, double layer capacitance, and corrosion current all rise. The SEM micrographs show that the mild steel surface is very smooth, almost polished.

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