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Original Article

Punica Granatum Leave Extract as Green Corrosion Inhibitor for Mild Steel in Hydrochloric Acid

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ABSTRACT

Corrosion is a significant issue that has resulted in the expenditure of millions of dollars by businesses worldwide for the restoration of machinery and structures. An environmentally benign corrosion inhibitor derived from Punica granatum leaves was employed in this investigation. The objectives of this study were to evaluate the effectiveness of Punica granatum leaf extraction as a corrosion inhibitor of mild steel in a hydrochloric acid solution. In this paper, we used mild steel as the sample and 1M hydrochloric acid as the acid solution. This research involved two tests: scanning electron microscopic studies and energy dispersive spectroscopy. In order to enhance the mild steel specimen's characterisation, scanning electron microscopy and energy dispersive spectroscopy will be implemented for surface examination. We removed and dried the specimens after 72 hours. Comparing the specimens that were immersed in PGLE inhibitor solutions to those that were immersed in 1M HCl alone, scanning electron microscopic studies (SEM) images showed that the specimens that were immersed in the PGLE inhibitor solutions were in better shape and had smoother surfaces. Energy dispersive spectroscopy (EDX) was used to find out what the mild steel sample's surface was made of when inhibitors were present and when they were not present in the 1M HCl solution. To calculate the corrosion efficiency (Ƞw%), we measured the weight loss of mild steel in uninhibited and inhibited solutions after 3, 6, and 9 days. Finally, the results demonstrate that Punica granatum leaves reduce the rate of corrosion on mild steel or other metals.

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INTRODUCTION

The most frequently used form of steel today is mild steel, also known as plain-carbon steel, due to its desirable mechanical properties and economical price for numerous industrial applications [1]. The chemical, food, petroleum, power generation, and electrochemical sectors are merely a few of the numerous potential applications [2]. Mild steel is employed extensively in the construction of a variety of structures, including massive ships and buildings. Controlling the corrosion rate in a corrosive environment is one of the primary obstacles, as this metal is increasingly utilised in industrial apparatus, residences, buildings, traffic, and railway bridges [3]. The utilisation of nanomaterial corrosion inhibitors is widespread [4–8]. Hydrochloric acid is notoriously difficult to work with due to its extremely caustic nature, even in diluted versions, despite its ubiquitous use [9]. Hydrochloric acid is employed in a variety of industries, including industrial cleansing, oil well cleaning, and acid pickling. Mild steel, a primary building material, is extensively utilised in a diverse array of industries. Alkaline, acidic, and saline solutions [10].

Increasingly, individuals are beginning to recognise the detrimental effects of chemicals used in numerous industries and environmental concerns. Corrosion inhibitors that are environmentally benign, also referred to as "green corrosion inhibitors," are currently experiencing an increase in popularity. These inhibitors, which are naturally occurring, offer numerous advantages. They are also readily accessible, in addition to being renewable, efficient, eco-friendly, and biodegradable [11–15]. Extracting these environmentally favourable inhibitors from plants is a straightforward process. The subsequent critical phase in assessing the efficacy of inhibition is the identification and separation of the species. Furthermore, in order to ascertain the optimal level of inhibition, researchers investigated the effects of the isolated species either individually or in combination to ascertain whether there was any synergy or antagonism [16-20]. Organic plant extracts (leaves, resins, seeds, fruits, and roots) are effective in a variety of aggressive media as a green corrosion inhibitor. The extracts exhibit remarkable inhibition of functional groups of nitrogen, sulfur, and oxygen. The dissolving process is slowed and corrosion is prevented by the ability of these groups to connect to partially dissolved metal ions, which is facilitated by the presence of unbound electrons [21-24].

Conventional methods of nanomaterial production frequently utilise toxic compounds as stabilising and reducing agents, which are both environmentally harmful and labour-intensive [25–28]. In the present day, plant extracts that contain mixtures of compounds with oxygen, sulfur, and nitrogen components are employed to greenly inhibit acidic solutions from corroding. Plant extracts are frequently environmentally benign, safe, easy to access, economical, and renewable [29]. Consequently, a significant amount of research and investigation has been conducted to develop inhibitors that are environmentally safe. The use of

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corrosion inhibitors that are environmentally benign, often called "green inhibitors," has been discovered by researchers Bribri [30] and Loto [31]. Naturally occurring inhibitors are a more environmentally friendly alternative that is highly regarded for their ability to safeguard a diverse array of metals and alloys [32, 33]. Eco-friendly natural inhibitors are non-toxic, economical, and have the potential to transfer electrons rapidly [34, 35]. These inhibitors, which possess a high electron density, are adsorbent and form a thin protective layer on the surface of mild steel. The anodic and cathodic reactions are slowed by this substance. Green inhibitors are environmentally benign, non-toxic, biodegradable, and inexpensive, which is why they are the subject of intense research. It is typical practice to employ natural plant extraction due to the abundance and low cost of the raw materials. In this research, Punica granatum leaf extract has been used as a green corrosion inhibitor for mild steel in HCl medium. Punica granatum is commonly referred to as Anar in India. It is a member of the Punicaceae family and is able to flourish in tropical and subtropical climates across the globe [36].

MATERIALS AND METHODS

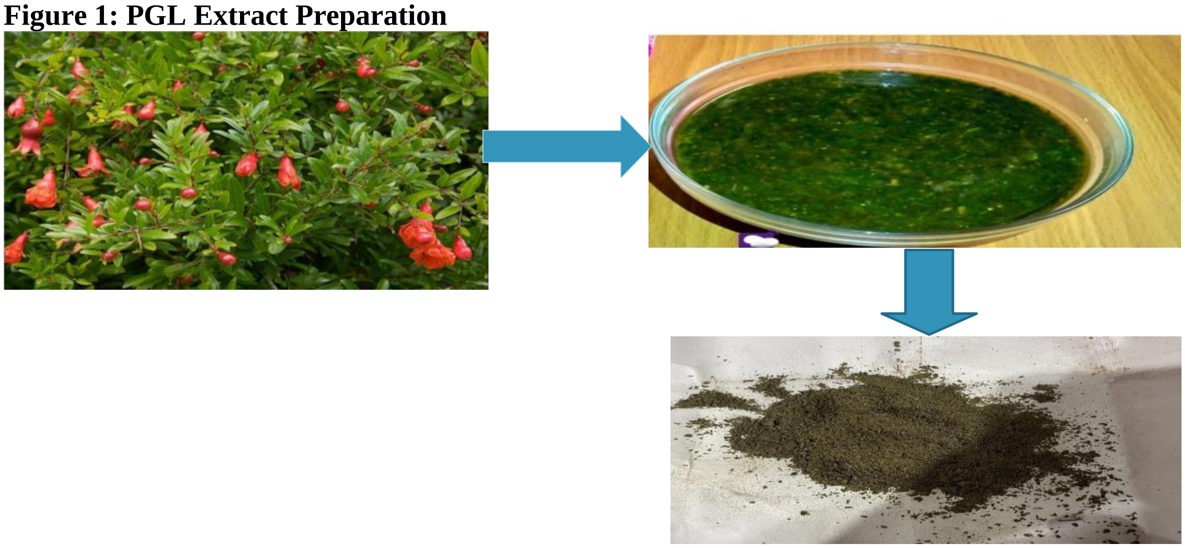
Sample Preparation

The mild steel was cut into a variety of coupons with varying lengths of 5.5cm, widths of 4cm, and thicknesses of 0.04cm by using a Vernier caliper. Before conducting the corrosion test, we physically polished each mild steel coupon using energy papers with a grain of up to 800-grit, washed it with tap water, and allowed it to dry at room temperature. We employed a high-precision analytical scale to determine the weight of the vouchers. Three vouchers were submerged in a solution of hydrochloric acid (HCl), while the remaining three were submerged in a solution of HCl that contained natural inhibitors.

Preparation of Plant Extracts.

Punica Granatum leaves were collected from a local farm in Thakurgaon, Rājshāhi, Bangladesh. After being collected from a farmer, the leaves of Punica granatum were rinsed with room temperature water. The leaves were blended in a beverage mixer to generate a green juice. Until approximately 15g of powder was present at the bottom of the experiment vessel, we employed evaporation to heat the green liquid. **Figure 1** illustrates the process of preparing the plant extracts until they become powder.

Figure 1: PGL Extract Preparation



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Solution Preparation:

200ml of hydrochloric acid were extracted from the chemical stockrooms. The corrosive medium (1M HCl) was produced by diluting the HCl acid with double-distilled water. We combined 7.5 grammes of pulverized Punica granatum with 200ml of diluted hydrochloric acid. Afterward, we equitably distributed the pulverized Punica granatum among three bottles and inserted three pieces of mild steel into each for 3, 6, and 9 days per bottle, and other three bottles we inserted three pieces of mild steel with only hydrochloric acid into each **Figure 2** for same days as mentioned above.

Figure 2: Solution Setup

Weight Loss Measurement:

The weight loss tests utilised coupons made of mild steel. The coupons were buffed and polished with energy sheets, then rinsed with water and dried before each experiment. Before immersing the coupons, their original weight was measured using an analytical balance **Figure 3**. After that, the specimens were left at room temperature for 3, 6, or 9 days in a 1M HCl solution, either with or without the Punica granatum leaf extract. Once the immersion time was over, the specimens were removed, rinsed, dried, and weighed once again. The specimens' starting and ending weights were used to determine the weight difference. The weight loss data were averaged after each experiment was repeated three times. After that, the corrosion efficiency (w%) is calculated using [1, 2] the following equation:

$$\eta w\% = \frac{Wcorr - Wcorr(inh)}{Wcorr} \times 100$$

Where Wcorr is the weight loss of the mild steel sample in the uninhibited solution, and Wcorr(inh) is the weight loss of the sample in the inhibited solution.

Figure 3: Digital Balance

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Characterization

The mild steel samples were immersed in acid solutions with and without the optimal inhibitor concentration for 72 hours. After 72 hours, the specimens were extracted and desiccated. In order to ascertain the composition of the mild steel specimen, we examined the surface coating that had formed using a scanning electron microscope. In order to obtain information regarding the composition of the mild steel sample's surface in the presence and absence of inhibitors in a 1M HCl solution, the energy dispersive x-ray analysis (EDX) technique was implemented.

RESULT AND DISCUSSION

Weight Loss Measurements

Table 1: Shows the Weight Loss Data of Mild Steel in Uninhibited and Inhibited Solution After 3, 6 and 9 Days. The Corrosion Efficiency (ηw%) is Calculated Using the Equation Mentioned Above. The Results Show That a Maximum of 66% Corrosion Efficiency is Observed After 3 days of Immersion.

Solution	Weight before corrosion test (g)	Weight after corrosion test (g)	Weight change (g)	Efficiency (%)
For 3 days				
Uninhibited solution	13.2443	11.345	2.098	66
Inhibited solution	13.2089	12.4953	0.7136	
For 6 days				
Uninhibited solution	13.0594	11.4372	1.6272	60
Inhibited solution	13.2548	12.5953	0.6595	
For 9 days				
Uninhibited solution	13.2433	11.653	1.5903	57
Inhibited solution	13.3274	12.6472	0.6802	

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Figure 4: Shows the Efficiency vs. Time for Mild Steel in Uninhabited 1M HCl Solution and Inhibited of 1M HCl Solution Containing Leaf Extract of Punica granatum.

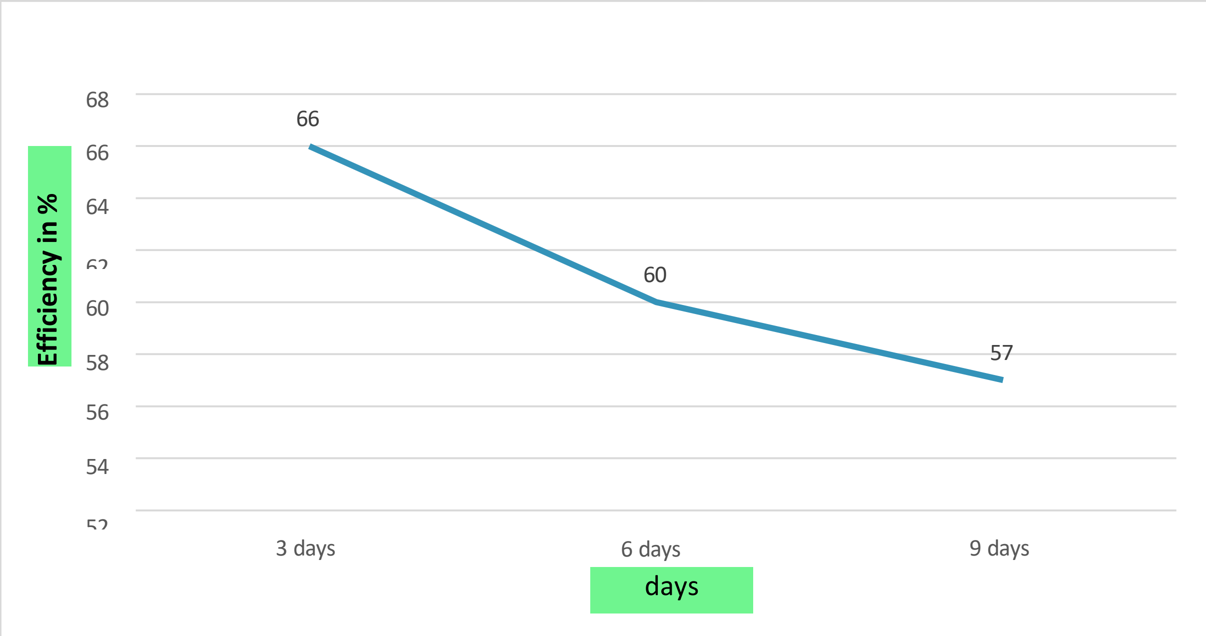
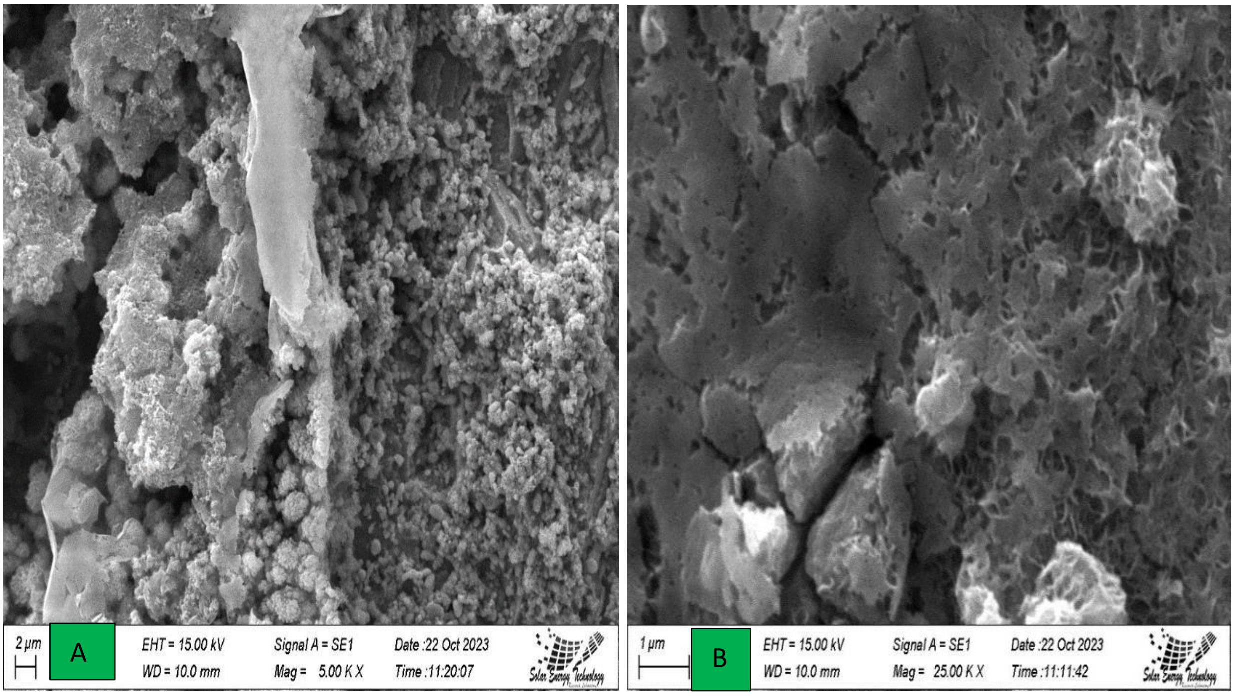


Figure 5: SEM Images of Mild Steel in 1M of HCl. (a) without PGLE. (b) with PGLE.



SEM (Scanning electron microscopic studies) test

Figure 5 illustrates scanning electron micrographs of mild steel surfaces that were captured after 72 hours of immersion in 1 M HCl with and without PGLE. After 72 hours, the specimens were extracted and desiccated. Scanning electron microscopy demonstrated that the former specimens were in superior condition and possessed finer surfaces when contrasted with mild steel specimens with corroded, uneven surfaces that were immersed

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in 1M HCl. The results of this analysis indicated that inhibitors reduced the rate of corrosion.

Energy Dispersive Spectroscopy

The mild steel sample's surface composition was ascertained through the use of EDX analysis. The mild steel piece contained a variety of elements, including Fe, O, C, and F. The compositions of all four elements were determined to be Fe (79.14), O (12.73), C (68.21), and F (1.31). These elements are all K-shell elements. The data in Table 2 demonstrate that iron has a significantly higher percentage of the total mass and atomic number than the other elements, with F having the lowest fraction.

Table 2: Energy Dispersive Spectroscopy

Elements	Weight%	Atomic%
Fe K	79.14	49.72
O K	12.73	27.92
C K	6.82	19.94
F K	1.31	2.42

CONCLUSION

The results of this paper indicate that Punica granatum leaf extract (PGLE) is an effective and environmentally friendly corrosion inhibitor for mild steel in a 1M HCl medium. The weight loss measurements validated that the PGLE considerably lowered the corrosion rate with a maximum inhibition efficiency of 66% perceived after three days. SEM analysis showed that the inhibitor formed a preventative layer on the mild steel surface, diminishing damage compared to the uninhibited sample. In addition, EDX results provided insights into the elemental composition, iron has a significantly higher percentage of the total mass and atomic number than the other elements, with F having the lowest fraction. The observations recommend that PGLE can significantly attenuate the corrosion rate of mild steel, thereby offering a viable, environmentally friendly substitute for traditional chemical inhibitors. The results of this study lend support to the notion that corrosion inhibitors derived from plants could be a sustainable, viable alternative for a variety of industrial applications.

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ABBREVIATION

PGLE - Punica granatum leave extract.

HCl- Hydrochloric Acid.

NI- Natural Inhibit

SEM- Scanning Electron Microscope.

EDX -Energy Dispersive X-Ray

M-Mole

