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Corrosion Inhibitory Properties of Eucalyptus camaldulensis (red gum) Leaves Extract on Iron in Acidic Media

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Abstract

The corrosion inhibition process is a complex phenomenon, and if one uses a plant extract, then the complexity increases several times. The plant extract contains different kinds of phytochemicals, and they may interact with the metal surface through some organometallic complex formation, which is responsible for the inhibition effect.The aqueous extract of leaves ofEucalyptus camaldulensis (red gum)was tested for corrosion inhibition on the iron in 1M, 2M & 4M hydrochloric acid solutions at 30^0Cusing the weight loss technique.The data obtained by weight loss measurement revealed that the leaf extract has a good inhibitory nature and mitigates the rate of corrosion. Inhibition efficiency increases with increasing inhibitor concentration, and after a certain concentration, efficiency decreases.

Keywords: Corrosion, Plant extract, Inhibitor, Weight loss Method, Inhibition efficiency.

Introduction

In different conditions, metals can corrode in different ways. Metals may lose some of their mechanical qualities as a result of corrosion. Steel is referred to as tarnishing, while iron is referred to as rusting. Several direct and indirect costs, including lost productivity, malfunctions, environmental contamination, and even some legal actions, result from corrosion, making it a negative factor. Corrosion inhibition research is crucial to the global economy. These days, greater attention must be paid to corrosion because of the growing use of metals in all technological domains and the rise in air and water pollution, which creates a more corrosive environment.According to a global study conducted by the National Association of Corrosion Engineers (NACE), corrosion prevention of metals can save around 2.5 trillion dollars, or 2.4% of the entire gross domestic product (Goyel et al., 2018). Iron is one of the primary metals and accounts for 60% of the Industrial Revolution on its own. Almost every industry, including machinery, building, and transportation, uses iron and steel. The only issue with iron, however, is that it rusts readily, and the byproducts of that corrosion can cause buildings to fall, fluids to leak, and the environment to be threatened.Particularly in industry, many parts of machines are cleaned with acid, which causes the parts to deteriorate throughout the acid pickling process. These days, the acid pickling process creates a significant challenge for costly machinery components. Approximately thirty percent of industrial losses can be prevented with suitable corrosion protection methods. The corrosion of the above-mentioned metals in acidic solutions is one of the costly issues. Hydrochloric acid has been utilized in the industrial sector for chemical cleaning, de-scaling, pickling, and other processes on metallic surfaces (Sorkhabi and Jeddi, 2005; Ahamed and Quraishi, 2009). It is impossible to stop rusting in an acidic atmosphere. The rusting process can be slowed down by modern science.

There are different types of methods to prevent corrosion.One of the best methods to prevent corrosion is to use inhibitors.Eco-friendly or green corrosion inhibitors are the terms used to describe the physiologically appropriate inhibitors found in nature. These inhibitors can react appropriately to stop corrosion without harming the environment's ecosystem (Bentiss et al., 2004; Lagrenée et al., 2002). Because of the biological nature of plants, these inhibitors are often obtained through an extraction procedure. There are several different inhibitors on the market. For these uses, a variety of inorganic and organic substances are employed. However, not many of them are eco-friendly. In essence, choosing the right inhibitor is a very challenging undertaking. Utilizing natural products, such as plant extracts, is currently a growing idea to create an environmentally friendly world.Plant-based corrosion inhibitors have been employed in a number of studies (Abdallah et al., 2018; Karthiga et al., 2015). Some of the benefits of green inhibitors, such as their non-toxicity, biodegradability, and lack of heavy metals, have recently brought them to light (Krishnaveni et al., 2013; Raja and Sethuraman, 2009; Obot and Obi-Egbedi, 2010; Badiea and Mohona, 2009; Li et al., 2010; Noor, 2009). Phytochemicals contained in plant extracts are abundant and can serve as a good alternative to conventional, harmful inhibitors. Researchers have been interested in leaf extract because it contains more phytochemicals than other plant parts (Verma et al., 2018; Buchweishaija, 2009).

So far, Bamboo leaves extract, black pepper extract, *Murrayakoenigii* leaf extract, Olive leaf extract, Mango, Orange, passion and Cashew peel extract, *annas stavium* leaf extract, *Pactin terrestrial* plant extract, and *Ver monia amygdalina* leaf extract (Khan, et. al., 2015) are some reported good green inhibitors. Mango/Orange peels, Aloe leaves, *Azydracta indica*, *Auforpiocurkiale*, *Gracinia kola* seeds, banana peels (*Musa sapientum*), *Lawsonia extract* (Henna), Eucalyptus oil, *Terminalia bellerica*, *Emblicalofficinals* also have shown an excellent inhibitory action towards different acid pickling processes(Rani and Basu, 2011). The methanolic leaf extraction of *Mangifera indica* (mango) has been reported as a good corrosion inhibitor due to the presence of polyphenols, flavonoids, and Xanthanones, which show excellent antioxidant, anti-inflammatory, and allopathic effects (Veedu, et. al., 2019). It inspires us to investigate the corrosion inhibition properties of the leaf extract of Eucalyptus camaldulensis (red gum) on iron in HCl solution by the weight loss method. Red gum tree is available in the local area, and it is well known for its medicinal properties(Veedu, et. al., 2019).Eucalyptus leaves contain various phytochemicals, including essential oils, phenolic compounds, flavonoids, tannins, and terpenoids. These compounds contribute to the plant's medicinal and industrial applications. Common phytochemicals found in eucalyptus leaves include eucalyptol (1,8-cineole), limonene, citronellal, citral, eudesmol, pinene, and cymene.

Figure-1: Leaves of the Eucalyptus camaldulensis (red gum)

Figure-2: Leaves extract of E. camaldulensis

Materials and Methods

Material preparation

Iron sheets were purchased from the local market of Damak-Jhapa, Nepal.Rectangular fragments (6.5 cm in length and 2.5 cm in width) were boiled for 15 minutes after having their surfaces cleaned with emery paper. The pieces were then cleaned with double-distilled water, allowed to air dry, and then heated up. Once they were cold, their weight was measured. Until the weight remained stable, the same procedure was repeated.

Preparation of the leaves extract of Eucalyptus camaldulensis (red gum)

At first, leaves of E.camaldulensis (**Figure**1) were collected from the local area of Damak-Jhapa.The leaves were then dried in an oven after being cleaned with water. After that, 300 milliliters of double-distilled water were used to boil roughly 10.0 grams of leaves. 75 ml of distilled water was added to the solution after it had decreased to 150 ml, and it was then lowered to 200 ml. After cooling, it was filtered through Whatman 40 and stored(**Figure2**) (Chen, et. al., 2013) for the study. All experiments were conducted at 30ºC and for each run, a freshly prepared solution was used.

Solution preparation

4(M), 2(M), 1(M) HCl solutions were prepared with double distilled water. Then, different concentrations of inhibitor were prepared, and concentration varied between 1 and 2.5g per 100 ml of corrosive medium.

Methods

Corrosion rate of iron was measured by the weight loss method (Akalezi,et. al., 2015). After taking the weight of the dried metal pieces, the finely polished metal pieces were dipped in the 50ml prepared test solution in a 100 mL beaker. After a certain immersion time, the sheets were collected from the solution, and washed with double-distilled water. Then it was dried in the oven, and allowed to cool and reweighted to determine the weight loss. The same process was repeated until a constant weight was obtained. This gravimetric data was utilized to calculate the rate of corrosion and inhibition efficiency.

Results and Discussions

The gravimetric (weight loss) method was carried out on polished rectangular iron sheets by immersing them in a 1(N) HCl medium in the absence and presence of different concentrations of inhibitors. Corrosion rate and inhibitor efficiency were calculated by following formulas (Saha, et. al., 2012).

Inhibitor efficiency = $\eta = 100 \times (\Delta W_0 - \Delta W_I)/\Delta W_0$

Where ΔW_0 and ΔW_I are the weight loss of the metal in solution without and with inhibitor for the same exposure time. The surface coverage (θ) is presented as:

$$\boldsymbol{\theta = (\Delta W_0 - \Delta W_I)/\Delta W_0}$$

The corrosion rate (mg cm^{-2} h^{-1}) is expressed by the following equation:

Corrosion rate (C_R) = weight loss/(area ∗ time)

Where weight loss is expressed in mg, area in cm^2 of metal surface exposed, and time in hours.

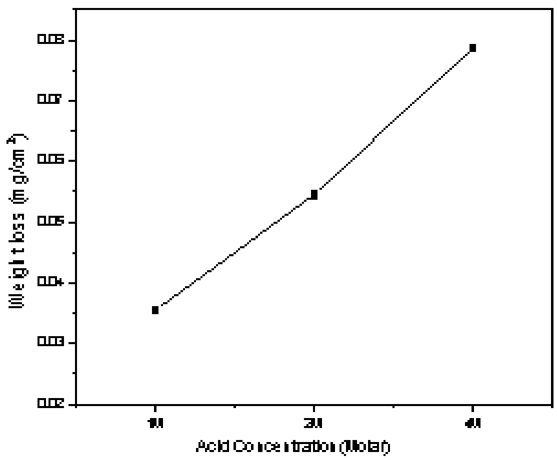

Figure 3: Plot of Weight loss vs hydrochloric (Immersion time 2 hours)

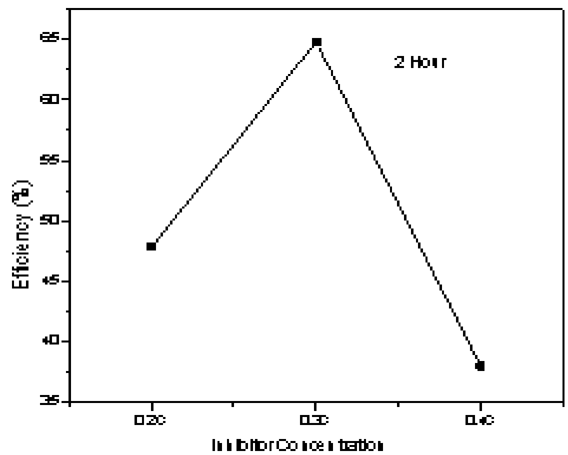

Figure 4: Plot of Inhibition Efficiencyconcentration vs Inhibitor concentration (Immersion time2 hours)

General mechanism of corrosion of iron in HCl medium

A corrosion study has been carried out in different concentration of hydrochloric acid. It is found that with increasing acid concentration, weight loss increases (**Figure 3**). Corrosion rate also increases.

Corrosion of Iron in an acid medium can be explained by the following reaction (evolution of hydrogen reaction) (Gupta and Tiwari, 1964).

$\longrightarrow Fe^{+2}\ \ Fe^{+3} + e^-$ (anode)

$\longrightarrow H^+ + e^-\ \ H$ (cathode)

Followed by the reaction

$\longrightarrow H + H \quad H_2$

The following reaction can also happen in this aggressive environment.

$\longrightarrow 2M + 2H^+ H_2 + M$ (anode)

$\longrightarrow O_2 + 4H^+ + 4e \quad 2H_2O$ (cathode)

Study of inhibitor efficiency with different concentrations of inhibitors and different immersion times:

We have chosen 1(M) HCl for further study as it is mostly used in the industry. Weight loss experiments show that the corrosion rate of iron and inhibition efficiency change with inhibitor concentration. The inhibition efficiency with various exposure times (1 hour,2 hours, and 3 hours) of iron in the presence of different concentrations of inhibitors is presented in **Figures 4, 5 and6.**

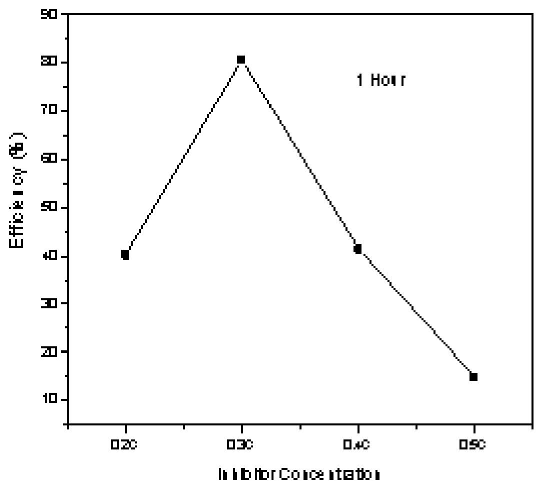

Figure 5: Plot of Inhibition Efficiency vs Inhibitor concentration (Immersion 1 hour)

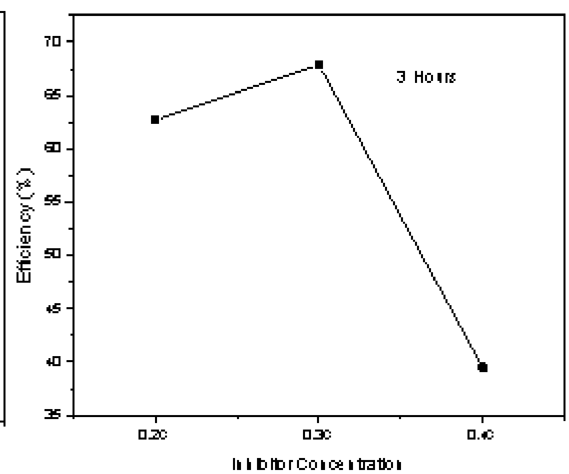

Figure 6: Plot of Inhibition Efficiency vs Inhibitorconcentration (Immersion time 3 hours).

It is seen that weight loss decreases with an increase in the concentration of the inhibitor, and corrosion inhibition efficiency (%) increases with increasing inhibitor concentration, reaches a maximum, and after that falls (Niroula, et. al. 2024). **Figure4** represents the efficiency versus inhibitor concentration at 1 hour exposure time. From this graph,it is clear that efficiency is maximum at 0.3C. Similarly, **Figures 5 and 6**represent efficiency versus inhibitor concentration at 2 hours and 3 hours exposure time, respectively.**Table 1** represents the surface coverage vs different inhibitor concentrations, and **Table 2** shows the dependence of corrosion rate on inhibitor concentration.

Table 1: Surface coverage vs inhibitor concentrations

Inhibitor Concentration (g/100ml)	Surface Coverage (θ)		
	1 hour	2 hours	3 hours
1	0.4033	0.4788	0.627
1.5	0.8066	0.6478	0.6789
2	0.4153	0.3802	0.3949
2.5	0.1495		

Error in 'θ' is±4%

Table 2: Corrosion rate vs Inhibitor concentrations

Inhibitor Concentration (g/100ml)	Corrosion Rate		
	1 hour	2 hours	3 hours
Blank	0.01505	0.01775	0.01443
1	0.009	0.00925	0.00537
1.5	0.00295	0.00625	0.00463
2	0.00875	0.011	0.00873
2.5	0.00128		

Error in 'C_R' is ±3%

Conclusions

The corrosion control effect of E. camaldulensis leaves extract in a corrosive environment at different concentrations of hydrochloric acid for iron has been tested by the weight loss method.The data obtained during the experiment shows that the leaf extract has an excellent inhibitory effect. With increasing inhibitor concentration, surface coverage as well as inhibition efficiency increase, reache a maximum, and then decline. The successive increase in inhibitor concentration was starting to decrease the efficiency, and this is due to coat saturation.The inhibitor is adsorbed on the metallic surface as a result ofa layer of inhibitor that protects the metal from a corrosive environment.

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