ANTI-CORROSIVE PROPERTIES OF *Delonix regia* EXTRACT ON MILD STEEL CORROSION IN ACID FLUID FOR INDUSTRIAL OPERATIONS

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Abstract: The corrosion inhibition properties of *Delonix regia* leaf extract (DLE), flower extract (DFE) and seed extract (DSE) in 0.5M HCl solutions were studied using weight loss technique. *Delonixregia* extracts inhibited the corrosion of mild steel in HCl solution. The inhibition efficiency increased with increasing concentration of the extracts at 30^{o}C. The seed extract (DSE) was found to be more effective than both the leaf (DLE) and flower extracts (DFE) at the lowest concentration. The results obtained revealed that the adsorption of the inhibitor molecule onto mild steel surface accords with Langmuir adsorption isotherm.

Keywords: Acid corrosion, acid fluids, corrosion inhibitor, *Delonix regia*, mild steel

Introduction

The use of corrosion inhibitors is one of the most practical, effective and economic methods to protect metals in acid fluid environment encountered in industrial operations such as oil well stimulation, oil well cleaning, industrial acid cleaning, acid pickling, cleaning of oil refinery, heat exchanger and vapour liquid systems (Abiola and James, 2010; Abiola and Tobun, 2010; Obi – Egbedi *et al*., 2012). HCl solution is the acid fluid of choice for oil well stimulation, oil well cleaning, industrial acid cleaning, acid pickling, cleaning of oil refinery and heat exchanger (Abiola and Tobun, 2010).

A number of industrial inhibitors of metals in acid solutions are based on organic compounds containing heteroatom of oxygen, nitrogen or Sulphur (Abiola *et al.*, 2009; Noor, 2006). However, some of these inhibitors are toxic and non-biodegradable (Abdel – Gaber *et al*., 2006; Abiola and James, 2010; Abiola *et al.*, 2016; Abiola and Tobun, 2010; Bhawsar *et al*., 2015) and this limit their applications. Consequently, attention has been focused on the need to design and develop non-toxic corrosion inhibitors from plants to replace toxic ones used in acid fluids for industrial operations.

In previous works (Abiola *et al*., 2007, 2016), the effect of *Delonix regia* extract on corrosion and kinetics of corrosion process of aluminium alloy in HCl solution was studied using chemical techniques. The *Delonix regia* extract inhibited the acid corrosion of aluminium in HCl solution and the inhibitive action was ascribed to the presence of phytochemicals in the extract. A first –order kinetics relationship with respect to aluminium alloy was obtained with and without the extracts.

In furtherance of our interest on the development of non- toxic corrosion inhibitors, this paper reports the preliminary investigation on the inhibitive effects of the extracts of leaf, flower and seed of *Delonix regia* on the acid corrosion of mild steel in 0.5M HCl solution at 30^{o}C.

Materials and Methods

The test specimens of dimensions 5 x 2 x 0.07 cm were mechanically press-cut from mild steel sheet of 0.04 cm in thickness and 97.9% purity. The mild steel samples were prepared, degreased and cleaned as described earlier (Abiola and Oforka, 2002, 2004). HCl was of analytical grade and 0.5M HCl was employed as the aggressive solution for this study. The stock solution of the plant extract was prepared as reported previously (Abiola *et al.*, 2016). The stock solution of the extract was diluted with appropriate quantity of 0.5 M HCl solution to obtain inhibitor test solutions of 50 – 1000 mg/L concentrations. The procedure for weight loss determination was similar to that reported earlier (Abiola and Oforka, 2002, 2004).

According to this method (Abiola and Oforka, 2002, 2004), previously weighed mild steel coupons were immersed in 100 ml open beakers containing 100 ml of 0.5M HCl (blank) and then with addition of different extract concentrations to the 0.5M HCl (50 – 1000 mg/L) at 30 ±0.3^{o}C. The variation of weight loss was monitored after 4 h immersion per coupon progressively for a total of 24 h at 30^{o}C. The weight loss was calculated in mg as the difference between the initial weight and the weight after the removal of the corrosion product. The experimental readings were recorded to the nearest 0.0001 g on a Mettler digital analytical balance (digital analytical balance with sensitivity of ±1 mg). Duplicates experiments were conducted for each concentration of the extract.

Results and discussion

The results obtained are presented in Figs. 1 – 2 and Table 1 for three different extracts of *Delonix regia* from weight loss measurements. The amount of material loss (mg cm^{-2}) decreases significantly with increasing concentration of DLE, DFE and DSE extracts, as presented in Fig. 1. The addition of the three extracts resulted in noticeable reduction in the amount of material loss from the surface of the mild steel in comparison with that of control (0.5M HCl) at 30^{o}C. As seen in Fig. 1, the weight loss decreased by a factor of 2.9, 5.8 and 8.7 over that of control at 100 mg L^{-1} concentration for the three extracts. This indicates that the three additives inhibit the acid corrosion of mild steel in HCl solutions.

The values of percentage inhibition efficiency (% E) and surface coverage (θ) were determined for 4 h immersion periods from the material loss using Equations 1 and 2 (Abiola *et al*., 2011):

$$E\% = [w_u - w_b / w_u] \times 100 \qquad (1)$$

$$\theta = E\,\% / 100 \qquad (2)$$

Where: w_u and w_b are the uninhibited and inhibited weight loss, respectively.

The values of percentage inhibition efficiency at different extract concentration are listed in Table 1. Table 1 indicates that *Delonix regia* extracts act as good corrosion inhibitor for the acid corrosion of mild steel in 0.5M HCl solution. The % inhibition efficiency increases with increasing extracts concentration and % inhibition efficiencies were relatively high in 0.5M HCl solution (65.3% for DLE, 82.6% for DFE and 88.6% for DSE) at 100 mg L^{-1} of extract concentration. The seed extract (DSE) was found to be more effective than both the flower (DFE) and leaf (DLE) extracts at lower concentrations of 50 mg L^{-1} and 100 mg L^{-1}. The *Delonix regia* extract contains 4-hydroxybenzoic acid, gallic acid, 3,4-dihydrroxycinnunmic acid, 3,5-dinitrobenzoic acid, alkaloid, L-azetidine-2-carboxylic acid, amine base , 3,4-diydroxybenzaldehyde, chlorogenic acid, kaempferol-3-glucoside, cyanidine-3-O-glucoside, cyanidine-3-O-rutinoside and coumarin (Chou and Lev, 1992; Sharma and Arora, 2015).

Table 1: Percentage inhibition efficiencies of mild steel immersed for 4 hours at 30ºC in 0.5M HCl solution in the presence of three different extracts of *Delonixregia*

	Percentage inhibition efficiency at different concentrations of inhibitor					
Inhibitor	**50 mg/L**	**100 mg/L**	**300 mg/L**	**500 mg/L**	**700 mg/L**	**1000 mg/L**
DLE	61.1	65.3	86.3	89.3	90.5	92.5
DFE	78.2	82.6	88.3	88.3	89.4	90.8
DSE	88.3	88.6	91.9	92.0	92.6	92.7

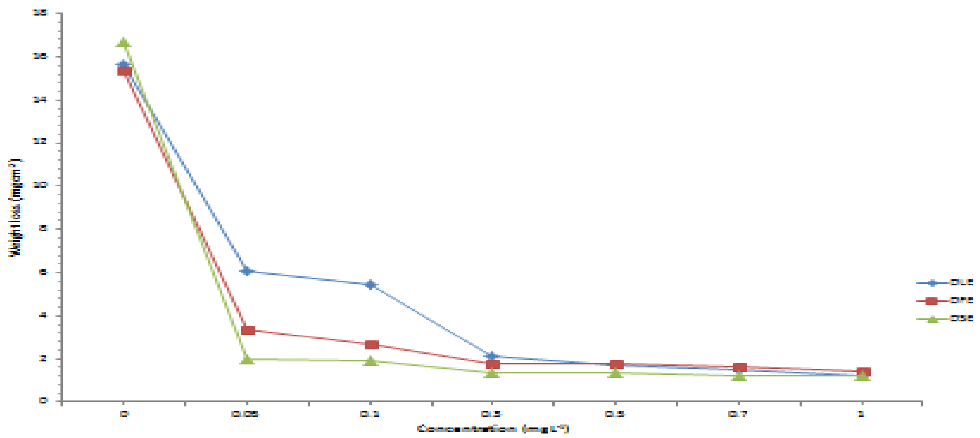

Fig. 1: Relation between material loss and extract concentration for mild steel in 0.5M HCl solution for 4 h immersion period.

The inhibition properties of *Delonixregia* is ascribed to the presence of these organic compounds in the extracts. Organic compounds having centers for pie electrons and functional groups -OR, -NR2 and /or –SR have been reported as corrosion inhibitors for metals in acid solutions (Abdel – Gaber *et al*., 2006; Abiola *et al*., 2015; Abiola and James, 2010). The adsorption of these compounds on the metal surface reduces the surface area that is available for the attack of the aggressive ion from the acid solution. The material losses decrease with increase in extract concentration due to higher degree of surface coverage as a result of enhanced inhibitor adsorption (Fig. 1). Similar view has been expressed in our previous reports (Babatunde *et al*., 2011; Abiola *et al*., 2007; Abiola and James, 2010) and other workers (Abdel – Gaber *et al*., 2006; Bhawsar *et al*., 2015) on inhibition of metals in acid solutions by plant extracts.

Values of θ were tested graphically for fit to different isotherms. As presented in Fig. 2, straight line is obtained when C/θ is plotted against C and the linear correlation coefficients of the fitted data are good (>0.998).

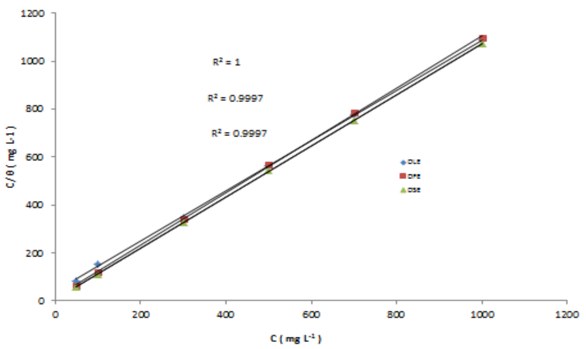

Fig. 2: Langmuir adsorption model on the mild steel surface of *Delonixregia* extracts in 0.5M HCl solution for 4 h immersion period at 30ºC

This confirms that the inhibition is due to the adsorption of the active organic compounds onto the metal surface and the adsorption obeys the Lanqmuir's adsorption isotherm (Abiola *et al*., 2007, 2011, 2016; Abiola and Tobun, 2010) expressed as in Equation 3:

$$\frac{C}{\theta} = \frac{1}{k} + C \qquad (3)$$

Where C is the inhibitor concentration and K the equilibrium constant for the adsorption/ desorption of process of the inhibitor molecules on the metal surface.

Conclusion

Results obtained revealed that the three extracts of *Delonixregia* act as efficient corrosion inhibitors of the mild steel in HCl solution. The inhibitory action of the extract is ascribed to the adsorption of the phytochemicals in the plant. The adsorption of inhibitors on the mild steel surface follows Langmuir adsorption isotherm. *Delonixregia* extract can be added to acid solution as a non-toxic corrosion inhibitor for mild steel in HCl solution.

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