



Evaluation of the Inhibitory Properties of *Guiera Senegale* on the Corrosion of Mild Steel in 0.1M Hydrochloric Acid

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ABSTRACT

This study was aimed at evaluating some properties exhibited by *Guiera senegale* when used as green inhibitors on corrosion of mild steel in an acidic medium. The effect of various parameters which include: exposure time, inhibitor concentration and temperature; on the inhibition efficiency of *Guiera senegale* was studied. Mild steel samples were immersed in 100 ml solution containing 0.1 M HCl solution in the absence and presence of varying inhibitor concentrations (0.2 g/dm³, 0.4 g/dm³, 0.6 g/dm³, 0.8 g/dm³, 1.0 g/dm³ and 1.2 g/dm³) of plant inhibitor (*Guiera senegale* leaves extract). A weight loss technique was adopted and recorded at a time range of 6 to 24 hours and a temperature range of 313 K to 343 K. The best inhibition efficiency for the plant extract was 96.653 % at 1.2 g/dm³ and 313 K. The least inhibition efficiency for the plant extract was 45.293% obtained at 0.2 g/dm³ and 343 K. From the result of the study, *Guiera senegale* has proven to be a very good green alternative to inorganic corrosion inhibitors because it is highly efficient, readily available, cheap and biodegradable.

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INTRODUCTION

The environmental toxicity of inorganic corrosion inhibitors has prompted the search for green corrosion inhibitors as they are biodegradable and do not contain heavy metals or other toxic compounds. In addition to being environmentally friendly and ecologically acceptable, plant products are inexpensive, readily available and renewable. Investigations of corrosion inhibiting abilities of tannins, alkaloids, organic, amino acids, and organic dyes of plant origin are of interest (Gerengi H. and Sahin H.I., 2012). However, the toxic nature of most inorganic metal corrosion inhibitors and their exorbitant prices are the major setbacks for their continuous use.

The search for an efficient inhibitor for metal corrosion in different aggressive media has, in recent times, taken a new dimension owing to the clarion call for green chemistry. Moreover, since the whole idea of metal protection is anchored on economic gain and environmental sustainability, the substance to be used as a metal corrosion inhibitor must be cheap, readily available, and environmentally friendly (Nnanna L.A., *et al.*, 2012). Hence, research activities are geared toward finding a replacement for inorganic and organic metal

corrosion inhibitors. The plant is one of the sources of cheap, readily available, and non-toxic green metal corrosion inhibitors. Plant products are organic in nature, and contain certain photochemical including tannins, flavonoids, saponins, organic and amino acids, alkaloids, and pigments which could be extracted by simple less expensive procedures. Extracts from different parts of the plant have been widely reported as effective and good metal corrosion inhibitors in various corrosive environments (Okafor P.C. *et al.*, 2008).

METHODOLOGY

The mild steel sheets to be used were mechanically pressed and cut into 2.0 cm x 4.0 cm coupons and were used without further polishing (Eddy N.O. *et al.*, 2009). They were degreased in absolute ethanol, dried in acetone and stored in moisture-free desiccators before corrosion studies commenced.

Extraction of Plants Extracts

The leaves of the *Guiera senegale* were cut into pieces which were placed in the oven and dried at 105 °C for two hours, cooled, and trimmed uniformly. The leaves were grounded into powder and soaked in ethanol for



five days to obtain the extract by leaching. The plant extract was filtered at the end of the extraction period. The solutions were distilled at 79 °C to evaporate the ethanol from the extract and concentrate the plant extract.

Preparation of the Test Media

Into different beakers, 100 ml of 0.1 M HCl was measured. In addition to the 0.1 M HCl, different concentrations of the inhibitor were then added. One beaker was used as a control and contained only the acidic medium.

Preparation of Inhibitor Concentrations

For the plant inhibitor, a concentration of 2 g/dm³ of the plant extract was prepared and used as a stock solution to attain 0.100 g/dm³, 0.200 g/dm³, 0.300 g/dm³, 0.400 g/dm³ and 0.500 g/dm³ through serial dilution using the acid (Al Mubarak *et al.*, 2010).

Weight Loss Experiment

Weighed test specimens (mild steel) were fully immersed in each of the test media contained in a 250 cm³ beaker for 6 hours. The specimens were taken out of the test media after 6, 12, 18 and 24 hours respectively, washed with distilled water, rinsed with acetone, air-dried, and re-weighed. All the experiments were performed at 313 K and 343 K. The percentage inhibitor efficiency (IE), corrosion rate and surface coverage were calculated.

Determination of Corrosion Rate

The corrosion rate expressed as millimetre per year (mpy) was calculated using the formula.

$$\rho = \frac{\Delta W}{AT}$$

Where: W is the weight change (mg), A is the total surface area of mild steel (8 cm²), T is the total time sample was immersed in hours, and D is the density of the specimen (7.86 gcm⁻³), CR is the corrosion rate.

Surface coverage

The degree of surface coverage (Θ) was calculated from the equation:

$$\Theta = \frac{(W_0 - W_1)}{W_0}$$

Determination of percentage of inhibition efficiency

The percentage inhibitor efficiency, IE, was calculated from the equation:

$$IE (\%) = \frac{(W_0 - W_1)}{W_0} \times 100$$

Where W_0 and W_1 are the weight loss value of the mild steel in the absence and presence of an inhibitor respectively

RESULTS AND DISCUSSION

The use of inhibitors apart from being the cheapest amongst the several techniques available offers a versatile and viable approach. However, the over-reliance on the use of chemical inhibitors has brought to the fore the problems of pollution, litigation, contamination of plant and animal life as well as the burden of disposal. Therefore, this makes the use of environmentally friendly inhibitors viable and appropriate. The reason is that plant extracts are clean, cheap and sustainable sources of addressing metal wastage arising from an aggressive environment.

Phytochemical screening of plant material

The data from this study revealed that this plant leaves extract has a rich content of phytochemicals namely, tannins, alkaloids, flavonoids, and cardiac glycosides which enhance the process of corrosion inhibitor adsorption on the mild steel (Popoola L.T. *et al.*, 2013). These active constituents had been reported to promote the corrosion inhibition of mild steel in aggressive acid media (Umoren S.A. *et al.*, 2013) and they are responsible for the inhibition efficiency of the extract, especially that of the alkaloid due to the presence of heterocyclic atoms of nitrogen (Okafor P.C. *et al.*, 2009). Molecules containing nitrogen and acetylenic alcohols are claimed to form a film on the metal surface and can retard the metal dissolution process (an anodic reaction) as well as hydrogen evolution (a cathodic reaction) (Breakell J.E. *et al.*, 2005).

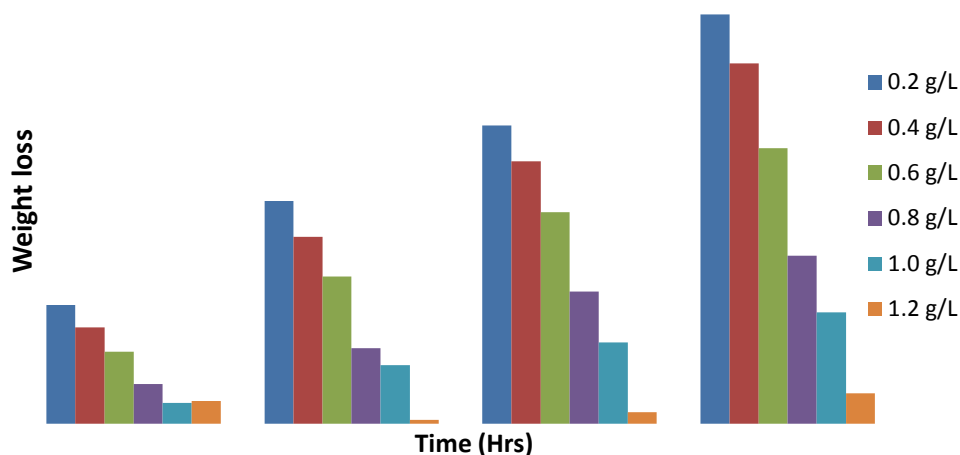


Figure 1: Variation of weight loss with time (hrs) for mild steel in 0.1M HCl for plant inhibitor at 313K

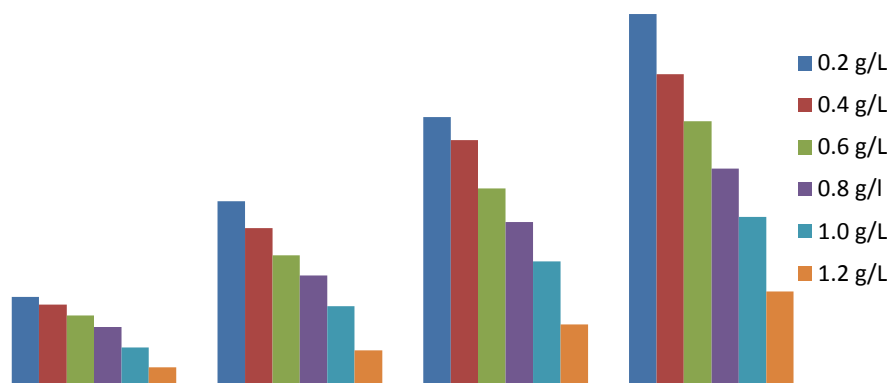


Figure 2: Variation of weight loss with time (hrs) for mild steel in 0.1M HCl for plant inhibitor at 343K

Mass Loss Studies

The results obtained from mass loss measurements are presented in Fig. 1 and 2 which show the variation of the weight of the mild coupons and time in 0.1 M hydrochloric acid for an immersion period of 6 to 24 hours.

Effect of Temperature

The effect of temperature on corrosion inhibition of mild steel in 0.1 M hydrochloric acid with 0.2 g/dm³, 0.4 g/dm³, 0.6 g/dm³, 0.8 g/dm³, 1.0 g/dm³ and 1.2 g/dm³ of inhibitor between the temperature of 313 K and 343 K has been studied, there was much weight loss at higher temperature (343 K) for all of the inhibitor used. From the result, it was observed

that the rates of corrosion of mild steel in 0.1 M hydrochloric acid with inhibitor decreased with an increase in the concentration of inhibitor at all temperatures, while the percentage inhibition efficiency increases when compared to blank.

This signifies that the dissolution of the metals increased at higher temperatures. This observation is attributed to the general rule guiding the rate of chemical reaction, which says that chemical reaction increases with increasing temperatures. Also, an increased temperature favours the formation of activated molecules, which may be doubled in number, with 10°C rises in temperature, thereby increasing the reaction rate. This is because the reactant molecules gain more energy and can

overcome the energy barrier more rapidly [5]. An increase in temperature may also increase the solubility of the protective films on the metals, thus increasing the susceptibility of the metal to corrosion (Okafor P.C. *et al.*, 2008). The solubility of oxygen gas decreases with an increase in temperature.

Thus, oxygen concentration is expected to be more at a higher temperature which in this case is higher at 343K than at 313 K. The presence of a high concentration of oxygen thereby causes the metal to corrode faster. Also, for solids, solubility generally increases with increasing temperature. This explains why the solid protective film becomes more soluble as the temperature increases.

The highest inhibition efficiency (99.618 %) was attained at 343 K for 0.05 M concentration of the inorganic inhibitor, with further increase in the temperature; inhibition efficiency was increased for the inorganic inhibitor. While for the plant extracts, the highest inhibition efficiency was 96.653 % at 1.2 g/dm⁻³, 313 K. The least inhibition efficiency (45.293 %) was attained at 343 K for 0.1 g/dm³ green inhibitor. This may be due to desorption of the metal surface (Zarrouk A. *et al.*, 2010).

Kinetics Studies

Fitting experimental data into different kinetic models enables us to study the inhibition

rate, model the process and predict information about inhibitor/mild steel interaction. In this study, two different models were used such as the pseudo-first-order and the pseudo-second-order (Al Mubarak *et al.*). Pseudo-first order and pseudo-second-order kinetic models were used to test the equilibrium data to investigate the mechanism of adsorption and potential rate controlling step of the inhibition process. However, in selecting optimum conditions for carrying out full-scale corrosion inhibition processes, information on the kinetics of dye adsorption is required.

From the above result, it could be seen that the R² value obtained from the Pseudo-second order kinetic plot is higher than that obtained from the Pseudo-first order kinetic plot. Thus, the correlation coefficient value followed the pseudo-second-order kinetic model more than the first, which suggest that the corrosion inhibition is dependent on initial concentration. Hence, the pseudo-second-order inhibition model is more suitable to describe the inhibition kinetics and this relies on the assumption that inhibition may be the rate-limiting step. The obtained kinetic information has a significant practical value for technological applications since kinetic modelling successfully replaces time and material-consuming experiments necessary for process equipment design.

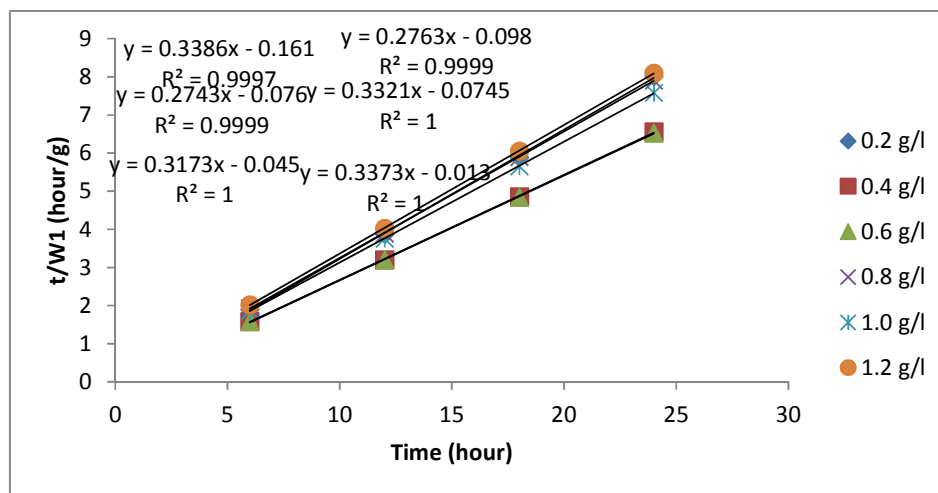


Fig. 3: Pseudo second order kinetic model at 313K

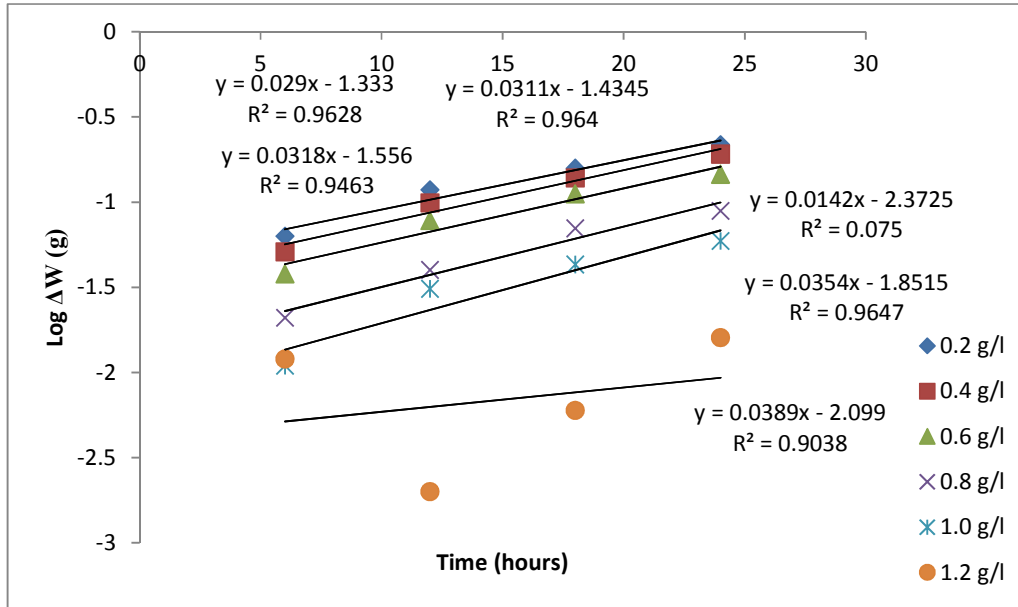


Fig. 4: Pseudo first-order kinetic model at 313K

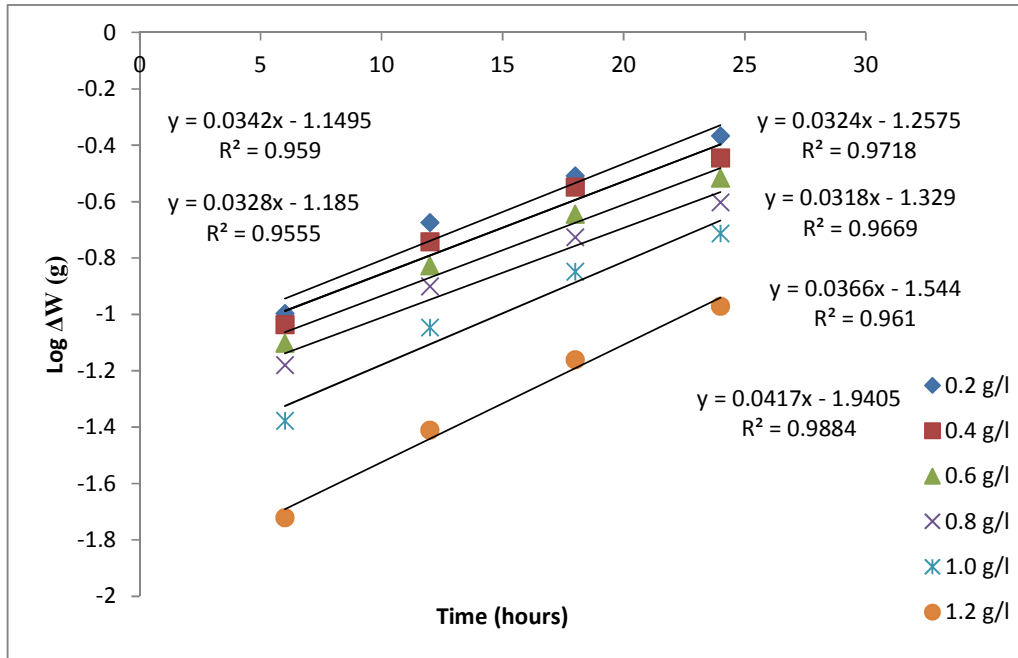


Fig. 4: Pseudo first-order kinetic model at 343K

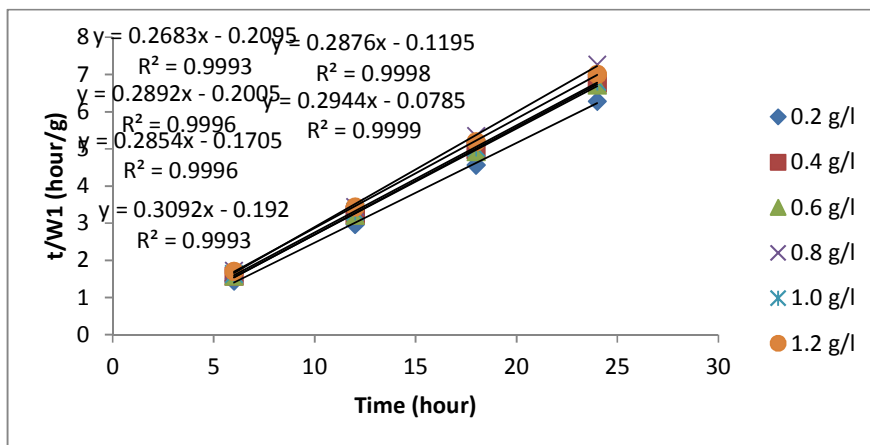


Fig. 5: Pseudo second order kinetic model at 343K

CONCLUSION

The inhibition efficiency increased with an increase in extract concentration but decreased with an increase in temperature. The presence of the extract increases the activation energy of the corrosion reaction. The various indices that characterized the inhibitor behaviour in curtailing metallic deterioration and essentially prolonging the lifespan of the metal are the dynamic surface coverage of each of the inhibitor systems over the entire 24 hours duration of the experiment showed that the best surface coverage values were obtained on the first 6 hours of the experiment. The green inhibition systems showed a mixed-type inhibition mechanism. The inhibitors impacted the anodic metallic dissolution and the cathodic hydrogen evolution reactions. The green inhibitors generated a closely packed almost impenetrable film that stifled the cathodic and anodic reactions. The inhibited samples also showed a finer surface (Omotosho O.A., 2016).

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