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AZADIRACHTA INDICA PLANT EXTRACT AS A EFFECTIVE CORROSION INHIBITOR FOR ALUMINIUM IN ACIDIC MEDIA

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Abstract

In order to investigate whether or whether the crude extract of the Azadirachta indica plant might limit the corrosion of aluminium metal coupons in an atmosphere containing 1.85 M hydrochloric acid, the gasometric method was utilised. At room temperature, the coupons were submerged in test solutions consisting of uninhibited 1.85 M HCl as well as solutions containing extract concentrations of 10%, 20%, 30%, 40%, and 50% (v/v), respectively. Monitoring the amount of hydrogen gas that was produced as a byproduct of the contact allowed for the determination of the rate of the reaction. The inhibitory efficiency of the extracts as well as the adsorption isotherm of the process were determined with the help of Frumkin, Freundlich, Langmuir, and Temkin adsorption theories. Scanning electron microscopy (SEM) was used to study the surface morphology. It was discovered that the extract from the plant slowed down the corrosion of aluminium caused by acid, and the amount of hydrogen gas that was produced decreased as the quantity of the extract increased. According to the findings of the adsorption investigations, the Langmuir isotherm is the most appropriate model for the adsorption of Azadirachta indica (R2 = 0.998) on the surface of aluminium. This led researchers to conclude that the Azadirachta indica extracts underwent chemisorption when combined with aluminium metal.

keywords: *Azadirachta, indica, plant, Aluminium*

Introduction

When the topic of corrosion and its effect is brought up, one cannot ignore the fact that the interaction of metal with its surroundings is a process that takes place. The effect occurs when a metal that is in the combined state has a tendency to revert back to its most stable native state when it is exposed to particular environmental circumstances. According to Barbara and Robert (2006) and Rosliza (2012), the process of corrosion has had a significant impact on a number of different businesses, resulting in significant losses, damages, and financial shortfalls. The impact of corrosion on the aqueous environment of sea water, salt water, and rain may be felt when pipes corroded with toxic metals are allowed to sips into the environment, consequently bringing health issues to the living system that is contained in the aquatic environment. Corrosion can also be felt when pipes corroded with toxic metals are allowed to sips into the environment. Other reasons may also be dangerous, which may result in the loss of capital, loss of equipment, and alienation of workers, as well as fire and explosion, among other outcomes (Holsen et al., 1991). Electroplating and the use of inhibitors are just two of the many methods that have been utilised in the fight against corrosion. Having the capacity to safeguard metallic materials, particularly those that are utilised in engineering, is becoming increasingly crucial. According to Chauhan and Gunasekaran (2007), these are compounds that are added to corrosive media at low concentrations in order to slow down or stop the reaction of the metal that is present in the media. The inhibitors can be organic or inorganic, but the usage of natural inhibitors is the most trustworthy alternative because it is also the most environmentally beneficial option. They are highly basic with high electron density, which gives the characteristics of an inhibitor (James et al. 2009; 2011; Rani and Bharathi, 2012). The synthetic inhibitors have heteroatoms such as O, N, and S and multiple bonds in their molecules, which is how they become adsorbed on the metal and prevent the metals from corroding. However, research has revealed that some of the synthetic and inorganic inhibitors are hazardous, which can lead to a variety of health problems such as renal failure, liver failure, and mutations in enzymes, among other things (Singh et al., 2012). Natural compounds, on the other hand, have been subjected to meticulous research and analysis, and they have been determined to be successful in the prevention of corrosion. This is due to the fact that synthetic inhibitors have been shown to have acute dangerous effects on humans. It was discovered by Ambish et al. (2010), Omotoso et al. (2012), and Olusegun et al. (2013) that plant extracts are not harmful to the environment, are not costly, and can be obtained in big amounts. According to research conducted by Abdel-Gaber et al. (2008) and Ajanaku et al. (2012), the inhibitive properties of the natural product can be attributed to the presence of organic substances such tannin, saponins, and alkaloids. Using natural chemicals as inhibitors is becoming increasingly popular, which has drawn the interest of a lot of researchers. It was discovered by Kliskic et al., (2000) that the leaves of rosemary had an inhibitory impact on the corrosion of Al-Mg alloy when it was exposed to chloride solution. Researchers Amuradha et al. (2008) looked into whether or not an aqueous solution of Hibiscus rosa-sinensis Linn may suppress the corrosion of carbon steel in low-chloride environments. The process of extracting these natural compounds is not only economical but also simple to carry out. Neem, also known as Azadirachta indica, is an evergreen tree that can be found in nearly every state of India (Ermel, 1995). Neem has been utilised for medical purposes and for the control of pests for hundreds of years in India. According to Schmutterer (1995), neem kernels contain between 30 and 50 percent oil as well as a number of active compounds that include antifeedant, growth-inhibiting, anti-oviposition, and insecticidal effects. The soap, pesticide, and pharmaceutical industries are the most common end users of the various fatty acids that may be found in neem oil. These include oleic, stearic, palmitic, and linoleic acids. According to Prieto et al. (1999), crude extracts made from the tree's bark and leaves have been employed in traditional medicine as a treatment for a variety of ailments, including leprosy, intestinal helminthiasis, and respiratory system conditions. There are various more publications on the biological and pharmacological effects, such as antiviral, antibacterial, antifungal, anti-inflammatory, antipyretic, antiseptic, and antiparalitic applications (Prieto et al., 1999; Eshrat and Ali, 2002; Britto and Sheeba, 2011). In addition to these uses, there are also antiparasitic, antibacterial, antifungal, and anti-inflammatory uses. The purpose of this study is to determine the effect that the extract of Azadirachta indica has on aluminium metal when it is exposed to 1.85 M concentrations of hydrochloric acid.

MATERIALS AND METHODS

Test materials

System Metal Industries Limited in Calabar, Nigeria provided the aluminium sheet of type AA1060 with a purity of 98.5% that was required for this project. Each sheet had a thickness of 0.4 millimetres and was mechanically press cut into coupons measuring 4 centimetres by 5 centimetres. Before the coupons were used in the corrosion tests, the surface of the coupons was prepared by degreasing them in 100% ethanol, then drying them in acetone, and finally keeping them in a moisture-free desiccator.

Preparation of Azadirachta indica leaves extract

A farm in Calabar, Nigeria, provided the source for the fresh Azadirachta indica leaves that were gathered. They were then cleaned and hung to dry in the shade at a temperature of 30 degrees Celsius for seven days. After that, they were reduced to a powder. In a huge glass trough that had a cover over it, the samples of dried powdered Azadirachta indica were macerated with 90% ethanol for seven days at room temperature. After then, the mixture went through a filter. The filtrate was heated to 40 degrees Celsius and evaporated in a water bath until the weight remained the same. This left a dark green extract in the beaker. In the investigations on weight loss, extract concentrations of 0.5 g/L, 1.0 g/L, 1.5 g/L, and 2.0 g/L, respectively, were employed in 0.5M HCl solution. These concentrations were utilised at both 30°C and 60°C. In the thermometric experiments, the same extract concentrations were utilised in the 2M HCl solution as were used previously.

Weight loss measurements

The apparatus and technique that were used for the measures of weight loss were the same as those that had been published earlier (Abakedi and Moses, 2016). The volume of the test solution that was employed was 100 millilitres, and the corrosive content was maintained at 0.5 millimolars of hydrochloric acid. The calculation for the corrosion rate was based on the weight loss, which was determined by subtracting the weight of the coupons at a particular time from their starting weight. The formula for this calculation may be found in Abakedi, 2016:

$$CR\ (mg\ cm^{-2} hr^{-1}) = \left(\frac{W}{A\ t}\right) \qquad (1)$$

where W represents the amount of weight lost in milligrammes, A represents the surface area of the specimen in square centimetres, and tis the exposure time in hours. The formula that was used to determine the percentage of inhibition (I%) provided by the ethanol leaf extract of Azadirachta indica (AZI) in 0.5M HCl was as follows:

$$\%I = \left(\frac{CR_0 - CR_1}{CR_0}\right) \times 100 \qquad (2)$$

where CR0 and CR1 are the corrosion rates of aluminium coupons when there are no inhibitors present in the corrodent and when there are inhibitors present in the corrodent, respectively, at the same temperature.

Thermometric measurements

The literature (Mousa et al., 1988; El – Etre, 2001) provides a description of the reaction vessel and the methods for detecting the corrosion behaviour using this method. Within the framework of the thermometric method, the corrosive concentration was maintained at 2M HCl. The amount of test solution that was utilised was fifty millilitres. In each of the trials, the starting temperature was maintained at 30.0 degrees Celsius. To track the progression of the corrosion reaction, a calibrated thermometer ranging from 0 to 100 degrees Celsius was used to measure the temperature at regular intervals and record the results to the closest 0.1 degrees Celsius. This approach made it possible to compute the reaction number, also known as RN, which is defined as follows (Oza and Sinha, 1982):

$$RN\ (^{\circ}C\ min^{-1}) = \frac{T_m - T_i}{t} \qquad (3)$$

where Tm and Ti represent the highest and beginning temperatures, respectively, and t represents the amount of time in minutes it took to achieve the maximum temperature. The inhibition efficiency, denoted by %I, was calculated using the following equation, which was derived from the percentage reduction in the reaction number:

$$\%I = \left(\frac{RN_0 - RN_1}{RN_0}\right) \times 100 \quad (4)$$

where RN0 represents the reaction number when there are no inhibitors present (a blank), and RN1 represents the reaction number when there is an inhibitor being researched.

RESULTS AND DISCUSSION

Effect of extract concentration on inhibition efficiency

Figure 1 demonstrates that there was a considerable reduction in the corrosion rates of aluminium in 0.5M HCl solution in the presence of Azadirachta indica (AZI) leaf extract concentration when compared to the blank at 30 degrees Celsius. This was the case regardless of whether or not the blank was present. At 60 degrees Celsius, a same result was achieved; however, the corrosion rates were significantly greater. According to the findings of Ita et al. (2013), this demonstrates that the metal coupons corrode at a slower rate in the HCl solution that contains the additives than in the solution that does not include the additives. Figure 2 demonstrates that the level of AZI leaf extract required to achieve a certain level of inhibitory effectiveness is proportional to the temperature at which the experiment was conducted. According to Ita et al. (2013), an indication of a significant interaction between the extract and the metal surface is an increase in the inhibition efficiency that occurs with an increase in the concentration of the extract.

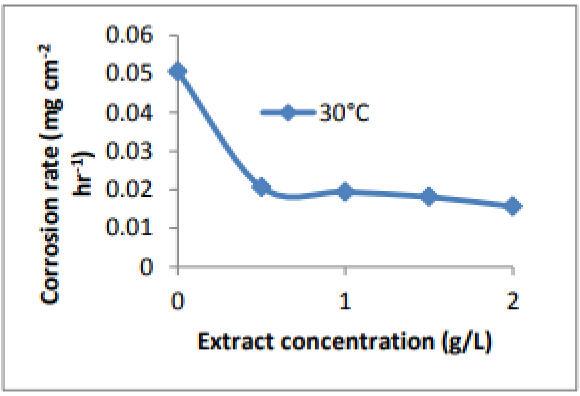

Figure 1: The rate of corrosion of aluminium in 0.5M HCl at 30 degrees Celsius varies according to the concentration of AZI leaf extract used.

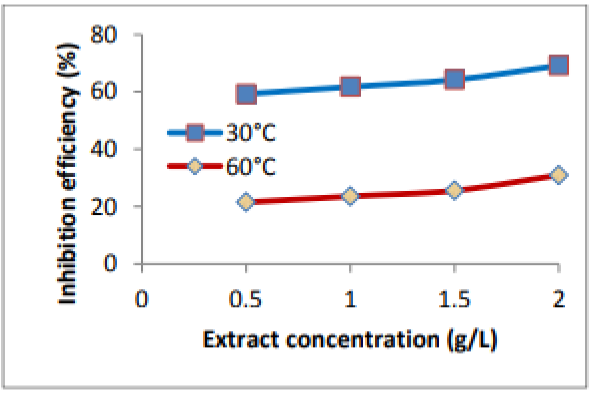

Figure 2: A graph showing the inhibitory efficacy of Azadirachta indica (AZI) leaf extract vs its concentration for aluminium corrosion in 0.5M HCl at 30 and 60 degrees Celsius.

Thermometric studies

Thermometric data of aluminium corrosion in a 2M HCl solution containing Azadirachta indica leaf extract are presented in Figure 3. A look at Figure 3 reveals that increasing the concentration of AZI leaf extract results in a drop in the highest temperature as well as an increase in the amount of time needed to achieve the maximum temperature. In Table 1, you'll find a presentation of the computed values for reaction number and inhibition efficiency. According to the information shown in Table 1, the effectiveness of the AZI leaf extract as an inhibitor improved when the concentration of the extract was raised. When compared to the weight loss technique, the thermometric method's inhibitory effectiveness followed a pattern very similar to that of the method.

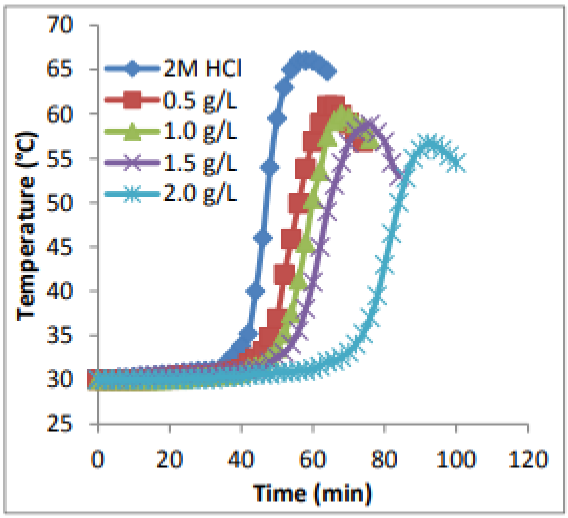

Figure 3: Temperature–time curves for aluminium corrosion in 2M HCl obtained in the absence and presence of Azadirachta indica leaf extract were determined.

Effect of temperature on inhibition efficiency

At each and every concentration of AZI leaf extract that was investigated, the efficacy of the inhibition reduced as the temperature increased (Table 2). A lower inhibition efficacy in response to an increase in temperature is suggestive of a weakening of the adsorption bonds between the metal and the inhibitor, in addition to the physical adsorption process. As a direct result of this, AZI chemically adsorbs onto the surface of the aluminium. The Arrhenius equation was used to determine the activation energy, or Ea, of the corrosion process both in the absence and presence of the leaf extract (Ita and Abakedi, 2006):

$$log\left(\frac{CR_2}{CR_1}\right) = \frac{E_a}{2.303R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right) \qquad (5)$$

where CR1 and CR2 are the corrosion rates at temperature T1 (303K) and temperature T2 (333K), respectively, and R is the universal gas constant (8.314 JK-1 mol-1). The values of heat of adsorption (Qads) that are reported in Table 3 were derived by applying the following equation, which was provided by Bhajiwala and Vashi (2001):

$$Q_{ads} = 2.303R\left[log\left(\frac{\theta_2}{1-\theta_2}\right) - log\left(\frac{\theta_1}{1-\theta_1}\right)\right] \times \left[\frac{T_1T_2}{T_2 - T_1}\right] \quad (6)$$

where 1 and 2 are the degrees of surface covering at time t1 and time t2, respectively, and R is the constant for all gases. Table 3 displays the results of the calculations made using equation 5 to get the values of activation energy (Ea). It has been noticed that the Ea values, when AZI leaf extract is present, are greater than the Ea value, which was calculated to be 107.737 kJ mol-1, when the blank was used. According to Dehri and Ozcan (2006), the higher Ea values in the presence of the inhibitor in comparison to the blank can be regarded as an indicator of physical adsorption of the inhibitor on the surface of the metal. This interpretation is supported by the fact that the inhibition efficacy decreases with an increase in temperature.Table 3 shows that the Qads values for aluminium corrosion in 0.5M HCl containing AZI leaf extract are negative and range from – 46.681 kJ mol-1 to – 44.975 kJ mol-1. These values are reported in kilojoules per mole. According to Anozie et al. (2011), negative values of Qads suggest that the adsorption of AZI leaf extract onto the surface of aluminium and, as a consequence, the inhibitory efficacy decreased with an increase in temperature.According to Ejikeme et al. (2014), negative Qads values are compatible with the properties of physical adsorption, also known as physisorption.

Table 1: Thermometric evaluation of the effect of an extract of the leaves of Azadirachta indica on the effectiveness of inhibiting the corrosion of aluminium in a solution of 2M hydrochloric acid.

Extract concentration	Initial temperature	Maximum temperature	Timetakentoreach maximumtemp.	Reaction number	Inhibition efficiency
(gL^{-1})	T_i(°C)	T_m(°C)	t(min)	RN(°Cmin^{-1})	(%)
2MHCl	30.0	66.0	56	0.6429	-
0.5	30.0	61.2	65	0.4800	25.34
1.0	30.0	57.0	66	0.4091	36.37
1.5	30.0	58.8	76	0.3789	41.06
2.0	30.0	56.7	92	0.2902	54.86

Table 2: The calculated values of the corrosion rate and inhibition efficiency for aluminium corrosion in a 0.5M HCl solution (blank) including Azadirachta indica (AZI) leaf extract (weight loss measurements) are as follows:

Extract concentration	Corrosion rate (mg cm^{-2} hr^{-1})		Inhibition efficiency (%)	
	30°C	60°C	30°C	60°C
0.5M HCl (blank)	0.0506	2.3831	-	-
0.5 g/L AZI	0.0206	1.8706	59.26	21.51
1.0 g/L AZI	0.0194	1.8213	61.73	23.58
1.5 g/L AZI	0.0181	1.7663	64.20	25.58
2.0 g/L AZI	0.0156	1.6450	69.14	30.97

Table 3: The activation energy and heat of adsorption for aluminium corrosion in a 0.5M HCl solution containing Azadirachta indica (AZI) leaf extract were calculated and shown here.

Extract concentration	E_a (kJ mol^{-1})	Q_{ads} (kJ mol^{-1})
0.5M HCl (Blank)	107.737	-
0.5 g/L AZI	126.098	- 46.681
1.0 g/L AZI	127.029	- 46.257
1.5 g/L AZI	128.112	- 46.199
2.0 g/L AZI	130.279	- 44.975

Adsorption isotherm

It was discovered that the adsorption of AZI leaf extract followed the modified Langmuir adsorption isotherm, which may be characterised as follows:

$$\frac{C}{\theta} = \frac{n}{K_{ads}} + nC \qquad (7)$$

where C represents the inhibitor concentration, represents the degree of surface covering, and Kads represents the equilibrium constant of the adsorption process. Straight lines are produced when C/ is plotted against C (Figure 4). The values of Kads were determined by calculating the intercept of the graph, and the results may be found in Table 4. According to Verma and Khan (2016), the following formula describes the relationship between the equilibrium adsorption constant, Kads, and the standard free energy of adsorption, G0 ads:

where C is the total molar concentration of water in the solution, R is the universal gas constant, and T is the temperature at which the solution is being held, in absolute degrees. The fact that the values of G0 ads were negative suggests that the adsorption of AZI leaf extract onto the surface of aluminium took place on its own accord. In addition, values of G0 ads that are less negative than -20 kJ mol-1 can be attributed to an electrostatic connection between the charged inhibitor and the charged metal surface. This interaction suggests that a physical adsorption process is taking place. In contrast, according to Khaled and AlQahtani (2009), values of G0 ads that are less negative than -40kJ mol-1 are often thought to include charge sharing between the inhibitor and the metal surface and signify a chemical adsorption process. Because the values of G0 ads in this study were less negative than -20kJ mol-1, along with a reduction in the inhibition effectiveness with rise in temperature, it can be concluded that a physical adsorption mechanism was responsible for the adsorption of Azadirachta indica leaf extract on the surface of aluminium.

CONCLUSION

The results of this study indicate that the leaf extract of Azadirachta indica was successful in preventing the corrosion of aluminium in a solution of hydrochloric acid. It was discovered that increasing the concentration of the extract increased the inhibitory effectiveness, whilst increasing the temperature had the opposite effect.

The modified Langmuir adsorption isotherm was the model that provided the greatest match for the adsorption of Azadirachta indica leaf extract onto the surface of aluminium. The spontaneous nature of the corrosion inhibition process is shown in the negative values of the G0 ads variable. For the adsorption of the leaf extract on the surface of the aluminium, a process called physical adsorption (physisorption) has been postulated. This mechanism was hypothesised on the basis of the fact that the inhibitory effectiveness decreased as the temperature increased.

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