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LINEAR POLARIZATION STUDIES OF THE CORROSION INHIBITION OF ALUMINIUM USING LEAVES EXTRACT OF ALCALYPHA WILKESIANA

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ABSTRACT
An electrochemical investigation was conducted to evaluate the corrosion behavior of Aluminum in *1M Hydrochloric acid* medium. Corrosion currents were determined using the linear polarization technique. Tafel slopes, *β*a and *β*c were also determined by Tafel polarization measurements. The effect of *Extracts of Alcalypha wilkesiana* on the Aluminum corrosion behavior was observed in electrolyte solutions at room temperature. The results showed a lower corrosion rate (CR) in the *Alcalypha wilkesiana* solution (AS), having a CR of 14.26 mm/yr against that of the blank solution (BS) with a CR of 22.61 mm/yr. The calculated inhibition efficiency was 37 %.

Keywords: Aluminum, Linear polarization method, *Alcalypha wilkesiana*, corrosion

1.0 INTRODUCTION
Corrosion of metals is defined as the spontaneous destruction of metals in the course of their chemical, electrochemical or biochemical interactions with the environment. Corrosion causes dangerous and costly damages to oil and water pipelines, bridges, public buildings, vehicles, water and waste water systems and even home appliances.
On the occasion of Corrosion Awareness Day of 24th April, 2019, it was highlighted that annual cost of corrosion worldwide estimated US$2.5 trillion (3 to 4% of GDP of industrialized countries) reflecting in part many decision-makers in industry and government not fully understanding the consequences of corrosion and how critical it is to control it (WCO, 2019).

Corrosion of metals cost the United States excess of $276 billion per year (Bethencourt.,1998). This loss to the economy is more than the gross national product of many countries around the world. It has been estimated that 40% of U.S steel production goes to the replacement of corroded parts and products.

Analysis of oil pipelines failures in oil and gas industries in the Niger delta area of Nigeria showed corrosion as one of the major causes of failure. Bardal (2003) reported that Nigeria oil and gas industry suffered greatly between 2000 and 2004. The total cost of corrosion of metallic products in Federal University of Agriculture, Abeokuta, Nigeria, from 2013-2015 was estimated to be N 166,955,641 (Orisanmi *et al*., 2017).

Corrosion can be stopped completely only under ideal conditions. However, the attainment of ideal conditions is not possible. It is therefore possible only to minimize corrosion considerably. Since the types of corrosion are so numerous and the conditions under which corrosion occurs are so different. Diverse methods are used to control corrosion. The use of inhibitors is one the most practical methods for the protection of metals in acidic media. Several investigators have reported the use of natural inhibitors, which were extracted from plant leaves or seeds (Manikandan *et al*., 2019). Corrosion inhibitions by organic compounds are widely used in industries. Most organic inhibitors control corrosion by adsorption of inhibitor molecules on the metal surface forming thin films (Manikandan *et al*., 2019).

Aluminum is the third most abundant metal (after oxygen and silicon) and the most abundant metal in the earth's crust. Solid surface aluminum metal is too reactive chemically to occur natively instead, it is found combined in over 270 different minerals (Sangeetha *et al.,* 2013). Aluminum is a good thermal and electrical conductor and it is the most widely used non-ferrous metal. Aluminum is one of the most industrial valuable metals, therefore, protecting it against corrosion damage is necessary.

A variety of methods such as electrical resistance, gravimetric-based mass loss, quartz crystal microbalance-based mass loss, electrochemical, and solution analysis methods enable the determination of corrosion rates of metals. The polarization resistance (LPR) method, based on electrochemical concepts, enables determination of instantaneous interfacial reaction rates such as corrosion rates and exchange current densities from a single experiment (Vuković *et al., 2012*).

The corrosion measurement helps us to predict the life of the assets in refineries, petrochemical, water areas where there is likely chance of corrosion. To measure internal corrosion quickly and accurately one can control the level of damage that internal corrosion inflicts on company's production system (Kansara *et al*., 2018)

LPR is a continuous monitoring system. In this method, the solution resistance (Rs) is the resistance between the corroding interface and the reference electrode and polarization resistance (Rp) is related to corrosion rate. LPR application is used in cooling water system, secondary recovery system, Potable water treatment and distribution system, Amine sweetening, Waste water treatment system, Pickling and mineral extraction processes, Pulp and paper manufacturing, Hydrocarbon

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production with free water (Kansara *et al*., 2018).
Polarization methods are faster experimental techniques compared to classical weight loss estimation The major advantage to LPR monitoring is the speed in which it can provide a measurement of the corrosion rate. Changes in the corrosion rate can typically be detected in minutes, providing an almost instantaneous measuring system. This fast response allows an operator to evaluate process changes and is particularly useful in monitoring the effectiveness of a prevention program (Kansara *et al*., 2018). For example, quick feedback means that inhibitor selection and quantities can be evaluated and fine-tuned in minimal time. Another key advantage of LPR monitoring is that it can provide a qualitative pitting tendency measurement, such as whether the tendency for pitting will be shallow and infrequent, or deep and abundant. LPR monitoring can also give an indication of metal behavior, for example when an alloy changes from a passive to an active state, thereby resulting in increased susceptibility to corrosion (Kansara *et al*., 2018).

There is no doubt that the corrosion rate determined by both polarization techniques are credible and the results obtained have similar trend in values which confirms both techniques could be used alternatively (Ekene *et al*., 2018)

The polarization technique used to determine corrosion rate of the Aluminium was linear polarization resistance method (LPR). As the resultant polarization curves obtained are almost accurate after the steady state condition obtained, this method is a non-destructive, quick and reliable to estimate corrosion characteristics of metals. Hence, this method was widely used in order to investigate the corrosion behaviour of aluminium sheets and foils. This research work aimed at investigating the corrosion behavior of Aluminum in 1M Hydrochloric acid medium in presence and in absence of *Alcalypha wilkesiana* leaves extract using the linear polarization technique.

3.0 Materials and methods

3.1 Extraction of Plant Substances

Samples of *Alcalypha wilkesiana* leaves were obtained from the Ahmadu Bello University Botanical garden, Zaria Kaduna State. The leaves were air dried for 10 days. The dried leaves were pounded manually using mortar and pestle to increase the surface area and then stored in a closed container. 30 g of the ground plant leaves was weighed and soaked in 300 cm^3 of ethanol for 24 hours. At the end of the 24 hours, plant mixture was filtered. The filtrate was pre-concentrated using a rotary evaporator and then concentrated in a water bath (Omotioma *et al., 2015*). A 10% v/v of the extract was prepared in 1 M HCl and used as the electrolyte solution. Analar grade concentrated hydrochloric acid purchased from Sigma Aldrich Chemical company, and double distilled water were used for the preparation of the test solution (1 M HCl).

3.2 Preparation of Aluminium

An aluminum sheet was obtained from the department of metallurgy at Ahmadu Bello University. Zaria. The Aluminum sheet was cut into coupons (2cm x 2cm x 0.5cm). The coupons were cleaned followed by polishing with emery paper to expose shining polished surface. The coupons were washed with distilled water, ethanol and then decreased with acetone and finally dried in air and stored in desiccators (Omotioma *et al.,* 2015).

3.3 Corrosion Measurements and Instruments

Polarization measurements were conducted potentiodynamically using a Princeton Applied Research (PAR) Model 283 potentiostat/galvanostat driven by the application software program (SoftCorrTM III). Tafel polarization measurements were carried out at a sweep rate of 0.2 mV/s in the potential range of – 250 mV to +250 mV in regard to the open circuit potential (OCP). Linear polarization measurements were conducted at a sweep rate of 0.166 mV/s in the potential range from –20 mV below the OPC to 20 mV above. A saturated calomel electrode (SCE) was used as the reference electrode, and a platinum electrode was used as the counter electrode. All potentials were referred to the SCE.

4.0 RESULTS AND DISCUSSIONS

Table 4.1 shows the results of the electrochemical measurements parameters for the blank 1M HCl and the test solution containing 10 % v/v inhibitor. The associated parameters derived from the PDP curves such as corrosion current density (*i*corr), corrosion potential (*E*corr), anodic Tafel slope (*β*a), cathodic Tafel slope (*β*c) are listed in Table 1. The inhibition efficiency (IE%) was calculated by the following equation 1; The calculated IE% was 37 %.

$$IE\% = \frac{I_{corr} - I_{corr(i)}}{I_{corr}} \times 100 \qquad 1$$

I_{corr} and $I_{corr(i)}$ signify the current density in the absence and presence of inhibitor.
It follows from Table 1 that there is a decrease in the corrosion rate in the presence of the inhibitor, marked by a shift in the position of the anodic and cathodic current curves to lower current densities. The observed decrease in *i*corr (0.001946 to 0.001227 A) confirms the inhibitive nature of *Alcalypha wilkesiana* inhibitor (AS). Based on the shift in the *E*corr in the negative direction upon the addition of AS (Table 1), it suggested that AS is a cathodic type inhibitor. However, the shift in both anodic and cathodic current densities in the presence of AS, indicated that, AS is more of a mixed-type inhibitor, affecting both anodic dissolution of metal and anodic evolution of hydrogen, having predominantly cathodic effect.

Table 1: Electrochemical results for the experiments

Electrochemical Parameters	Blank	Inhibited
ba (V/dec)	0.01735	0.01921
bc (V/dec)	0.1710	0.08820
Ecorr Calc (V)	-0.5443	-0.6159
Ecorr Obs (V)	-0.5530	-0.6048
jcorr (A)	0.001946	0.001227
jcorr (A)	0.001946	0.001227
Corrosion rate (mm/year)	22.6140	14.2580
Polarization resistance (Ω)	3.5159	5.5824

The aluminium used leads to more negative value of the corrosion potential (Ecorr) and changed slightly. The anodic reaction mainly

fluctuates and this specifies that the very thin aluminium oxide (Al_2O_3) layer causes an anodic process nominally. Generally, dissolution of active aluminium is the main anodic reaction. Moreover, the effect of the aluminium oxide layers caused a significant change the cathodic reaction.
The results in Table 1 showed that the cathodic slopes of LPR decreased significantly while the anodic slopes increased slightly. This indicated that the cathodic reaction rates is more obvious than the corresponding anodic ones. This observation also indicated that LPR is a cathodic type inhibitor with significantly more control of cathodic reaction. Cathodic slope indicates the rate of oxygen reduction during corrosion while anodic slope represents the rate of metal oxidation during corrosion (Pradipta *et al.,* 2018)

From Table 1, it is found that compared to the blank solution (1M HCl), the *i*corr values reduces only slightly by addition of the inhibitor. This observation suggests that the rate of Al dissolution was retarded by the formation of a protective inhibitor film on the metal surface which created a barrier between the Al surface and the aggressive medium (Vuković *et al., 2012)*.

Polarization resistance indicates the resistance to external potential/current which may change the electrochemical state of the metal. As shown in Table 1, the inhibited sample had significantly higher polarization resistance than control (Blank). This implies that AS is a good inhibitor in the aggressive medium. The higher polarization resistance is often associated with the formation of a protective film on metal surface (Pradipta *et al.,* 2018).

Conclusion

The research work shows that the extract of *Alcalypha wilkesiana* is a good inhibitor for the corrosion of aluminum in 1M HCl. The results showed a lower corrosion rate in the *Alcalypha wilkesiana* solution (14.26 mm/yr) against that of the blank solution (22.61 mm/yr). The inhibition efficiency was 37 %. The compound seems to function as inhibitor by being adsorbed on the metal surface.

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