J | P | S | T

http://jpst.irost.ir

Journal of Particle Science and Technology

IROST

Talinum triangulare leaf and *Musa sapientum* peel extracts as corrosion inhibitors on ZA-27 alloy

Segun Michael Abegunde[1]*, Robert Oluwaseyi Ogede[1], Babajide Oluwagbenga Fatile[2], Ebenezer Tayo Aliu[3]

[1] *Department of Science Technology, Federal Polytechnic, Ado-Ekiti, Ekiti State, Nigeria*

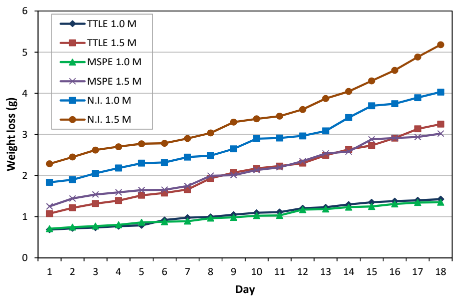
[2] *Department of Glass & Ceramics Technology, Federal Polytechnic, Ado-Ekiti, Ekiti State, Nigeria*

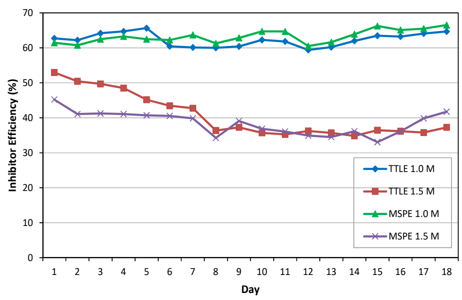
[3] *Centre for Entrepreneurship Development and Vocational Studies, Federal Polytechnic, Ado-Ekiti, Ekiti State, Nigeria*

HIGHLIGHTS

- ZA-27 alloy is gaining wide spread popularity for its lightness, strength, corrosion resistance, excellent bearing and wear resistance properties.
- Evaluation of *Talinum triangulare* leaf and *Musa sapientum* peel extracts performances as green inhibitors on the ZA-27 in acidic media.
- The mass loss method of corrosion measurement is known for its simplicity, direct and versatile for determination and evaluation of corrosion rate and inhibition.

GRAPHICAL ABSTRACT





ARTICLE INFO

Article history:

Received 8 May 2018
Revised 15 June 2018
Accepted 9 July 2018

Keywords:

Corrosion inhibitor
Talinum triangulare
Musa sapientum
Efficiency

ABSTRACT

With the current emergence of green chemistry to keep the environment safe, attention is being shifted towards using plant extracts as corrosion inhibitors. The inhibitive performances of *Talinum triangulare* leaf extract and *Musa sapientum* peel extract on the ZA-27 in 1.0 M and 1.5 M hydrochloric acid solutions were studied for 18 days using mass loss measurement. The corrosion inhibition efficiencies of the extracts were evaluated. The results showed promising anticorrosive performance in 1.0 M HCl. The average inhibition efficiencies recorded for *Talinum triangulare* leaf extract and *Musa sapientum* peel extract in 1.0 M HCl using 1% w/v of each extract after 18 days were evaluated as 62.30% and 63.27%, respectively, while in 1.5 M HCl; 40.54% and 38.45% were recorded for *Talinum triangulare* leaf extract and *Musa sapientum* peel as inhibitors, respectively, in 1.5 M HCl.

* *Corresponding author: Tel.: +23470-36400909 ; E-mail address: abegundes@gmail.com*

DOI: 10.22104/JPST.2018.2889.1123

1. Introduction

Recently, the development of engineering materials that are resistant to corrosion, stronger, lighter and less expensive is one of the focuses of researchers in the field of materials science and engineering. Selection of these materials for various industrial applications based on their properties is a challenge that must be met. In industries, most processes, including industrial cleaning, acid pickling, refining crude oil and petrochemical processes use iron and steel. The quest for new materials that can perform better than iron and steel in service applications had led to the development of various alloys. Among the various alloys being considered, zinc-based alloys are gaining wide spread popularity as a cost effective substitute to ferrous and non-ferrous alloys for various engineering applications [1]. Among zinc-based alloys, ZA-27 alloy is the lightest which offers highest strength, corrosion resistance, as well as excellent bearing and wear resistance properties [2-3]. ZA-27 alloy can perform better than most popular engineering materials, such as cast iron, steel, Al, and Mg, and virtually any other metal or alloy for various applications [4]. ZA-27 alloy has found applications as engineering material in wide areas such as industrial fittings and hardware, pressure tight housings, sleeve bearings, and wear plates [5]. Results of previous investigations carried out on zinc-aluminium alloys showed that they have excellent resistance to corrosion in a variety of environments [2]. The presence of aluminium in the alloy has been reported to enhance the well-known corrosion resistance of zinc, which is the main constituent of the alloys. Zinc-aluminium alloys corrode in a uniform manner. ZA alloys in the as-cast condition have adequate corrosion resistance for most atmospheric environments due to the formation of a passive layer on the metal surface which generally inhibits further corrosion attack [6]. Under more aggressive conditions, such as marine environments, additional corrosion protection should be considered.

Exposure of ZA-27 alloys to certain environmental conditions, such as air, water, humidity, temperature and pressure, during manufacture, processing, storage, or the shipment result in corrosion or can aggressively accelerate the degradation. Corrosion has been defined as an electrochemical process by which metallic surfaces react with their environment causing the metal to lose its material properties due to surface deterioration [7-8]. The process of corrosion is a natural action of any given material, in most cases a metal tends to return to its original state through an electrochemical process caused by a reaction with the surrounding environment. Corrosion processes are responsible for numerous losses mainly in industries. Successful enterprises cannot tolerate major corrosion failures, especially those involving personal injuries, fatalities, unscheduled shutdowns, and environmental contamination. For this reason considerable efforts are generally expended in corrosion control. It has been reported by Leelavathi and Rajalakshmi that large numbers of N, S and O containing organic compounds are promising inhibitors, while most of these compounds are not only expensive, but also toxic to living beings [9]. The use of chemical inhibitor to decrease the rate of corrosion processes is quite varied. A great number of scientific studies have been devoted towards the subject of corrosion inhibitors.

Corrosion inhibitors are chemical substances that when added in small concentration to an environment effectively decrease the corrosion rate. Inhibitors are substances or mixtures that in low concentration and in aggressive environment inhibit, prevent or minimize the corrosion [10]. Green corrosion inhibitors are biodegradable and do not contain heavy metals of toxic compounds [11]. Earlier scientific and technical corrosion literatures have described and given lists of numerous chemical compounds that exhibit inhibitive properties. Of these, only a few are actually used in practice. This is because the desirable properties of an inhibitor usually extend beyond those simply related to metal protection. Considerations of cost, toxicity, availability, effectiveness and environmental friendliness are of considerable importance.

Considering the numbers of measures to protect and prevent corrosion today, the use of natural product, also known as green inhibitor stands out because it is readily available, cost effective and eco-friendly.

The role of inhibitors is to form a barrier of one or several molecular layers against acid attack. Generally the mechanism of the inhibitor is one or more of three that are cited below:

- The inhibitor is chemically adsorbed (chemisorptions) on the surface of the metal and forms a protective thin film with inhibitor effect or by a combination between the inhibitor ions and metallic surface;
- The inhibitor leads to the formation of a film by

oxide protection of the base metal;

- The inhibitor reacts with a potential corrosive component present in an aqueous media and the product is a complex [12,13,14].

Plants extracts, such as extracts of Ananas leaves [15], black pepper [16] and *Strychnos nux-vomica* [17], have been reported for their successful anticorrosion properties. Currently, little is known of extracts of waterleaf (*Talinum triangulare*) and banana peel (*Musa sapientum*) as corrosion inhibitors.

Therefore, this present research is aimed at investigating the corrosion inhibitive effect of *Talinum triangulare* leaf (TTLE) and *Musa sapientum* peel (MSPE) extracts as green inhibitors for ZA-27 alloy in an acidic media of 1.0 M and 1.5 M concentrations of hydrochloric acid at room temperature using the mass loss method. The choice of the two plants was made because they are readily available and environmentally safe. *Talinum triangulare*, also known as waterleaf, is a type of herb which appears as a small aqua-colored sprout. *Musa sapientum*, also known as banana peel, is a tropical herbaceous plant that grows best in warm conditions and belongs to the family of *Musaceae*.

2. Experimental methods

2.1. Preparation of inhibitors

Fresh *Talinum triangulare* leaf and *Musa sapientum* peel were collected from the farmland in Erifun village Ado-Ekiti and transported to the Research laboratory of Federal Polytechnic, Ado-Ekiti. The leaves and peels obtained from *Talinum triangulare* and *Musa sapientum*, respectively, were washed, shade dried and ground into powder separately in the laboratory. The *Talinum triangulare* leaf and *Musa sapientum* peel inhibitors were extracted by soaking 5 g of each sample separately in 50 ml of ethanol in a beaker for 48 hours with regular agitation. Ethanol was used for the extraction because successful extraction, determination and isolation of biologically active components from plant material are largely dependent on the type of solvent used in the extraction procedure [18]. The sample-water mixtures were filtered and the filtrates were concentrated under reduced pressure using a rotary evaporator to obtain dried inhibitor extracts. A solution of 1% w/v (10000 ppm) of the extracts was prepared.

2.2. Preparation of ZA-27 alloy

ZA-27 alloy with a chemical composition as per ASTM B669-82, presented in Table 1, was used for the present study. The ZA-27 alloy samples with a circular shape and an average of 16.84 cm^2 exposed surface areas were used for mass loss measurement. The mild steel samples were polished, degreased using methanol, washed in double distilled water, oven dried and used immediately. The mass loss experimental procedure described by ASTM G1-03 was used [19].

2.3. Preparation of test solution

Two different concentrations of hydrochloric acid were used as test solutions. 1.0 M and 1.5 M concentrations were prepared using double-distilled water and AR grade hydrochloric acid.

2.4. Weight loss measurement

The weight loss measurement was carried out by using Mettler Toledo balance ME204. Six 250 ml beakers were properly washed, dried and labeled A, B, C, D, E and F. 100 ml of 1.0 M HCl was transferred into each of the beakers labeled A, B and C while 100 ml of 1.5 M HCl was transferred into each of the beakers labeled D, E and F. 1% w/v *Talinum triangulare* leaf inhibitor extract was added to the beakers A (1.0 M) and D (1.5 M HCl). Also, 1% w/v *Musa sapientum* peel inhibitor extract was added to beakers B (containing 1.0 M HCl) and E (containing 1.5 M HCl). Beakers C (containing 1.0 M HCl) and F (containing 1.5 M HCl) were without inhibitor. One pre-weighed ZA-27 alloy sample was immersed in each of the beakers using glass hooks and rods at room temperature. The test specimens were removed after every 24 h, washed with deionised water, dried and reweighed and the new weights recorded.

The corrosion rate was calculated in millimeter per year, (mm/yr) on the basis of the apparent surface area using Eq. (1) as reported in 2011 by Taleb and Muhamed [20].

Table 1. Elemental composition of ZA-27 alloy.

Elements	Al	Si	Mg	Cu	Fe	Zn
Composition (%)	25-30	0.02	0.012	2.06	0.065	Balance

$$Corrosion\ Rate\ (mm/yr) = \frac{Weight\ loss \times K}{Density \times Area \times Time} = \frac{W.K}{\rho.A.T} \quad (1)$$

where W is the weight loss in milligrams, ρ is the metal density in g/cm^3, A is the area of sample in cm^2, T is the time of exposure of the metal sample in hours, and K is the constant = 87500.

The inhibition efficiency measurements were based on the weight loss at the end of each measurement. The percentage inhibition efficiency (IE %) was calculated using Eq. (2) as reported in 2013 by Leelavathi and Rajalakshmi [9].

$$IE\ (\%) = \frac{W - W_1}{W} \times 100 \quad (2)$$

Where W and W_1 are the corrosion rates of steel coupons in the absence and presence of plants extracts, respectively.

3. Results and discussion

3.1. Mass loss measurement

The Mass loss method of corrosion measurement was used for the present study because of it is simple, direct and versatile for the determination and evaluation of corrosion rate and inhibition efficiencies. The experimental arrangement with and without inhibitor extracts in 1.0M and 1.5 M HCl solutions at room temperature are presented in Figures 1, 2, and 3. They present the weight loss measured after every 24 h for 18 days and total mass loss after 18 days, respectively. As expected, the highest weight loss was observed for the ZA-27 alloy in solutions without inhibitor (presented as N.I.) among the solutions. The weight loss was in the order N.I. > 1.5 M > 1.5 M in the solutions. This shows that the presence of plant extracts as inhibitors played important anticorrosive roles. With the same plant extract concentration and at constant temperature for the research, the concentration of acidic medium also played a major role in weight loss of the test samples. It was observed that weight loss was noticeable higher in the solution with a higher concentration.

3.2. Evaluation of corrosion rate

To monitor the stability of the adsorbed inhibitor film at ZA-27 alloy/acid solution interface with time, the

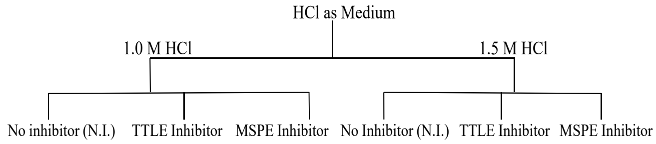


Fig. 1. Distribution of plants extracts in acidic media (TTLE: water *Talinum triangulare* leaf extract, MSPE: *Musa sapientum* extract, N.I.: No inhibitor).

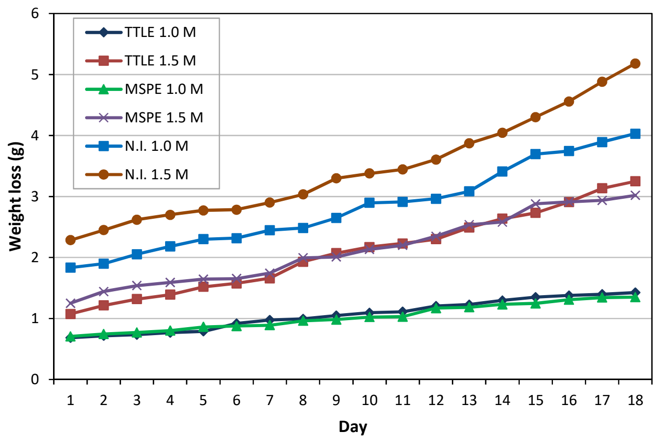


Fig. 2. Plot showing weight loss against time at room temperature.

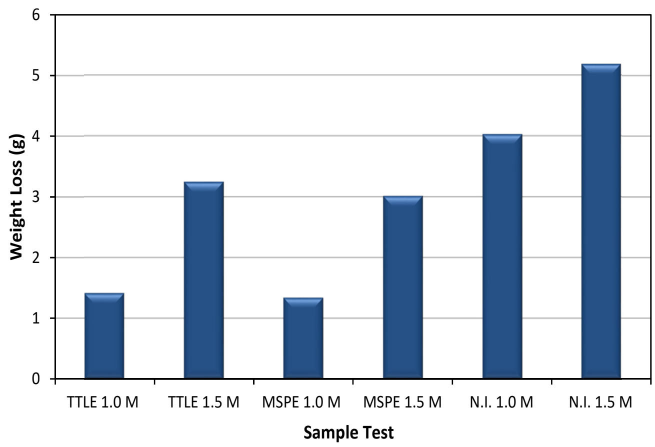


Fig. 3. Weight loss in HCl solution at room temperature after 18 days.

ZA-27 alloy were immersed in an acid media of 1.0 M and 1.5 M concentrations in the absence and presence of inhibitors at room temperature using 1% w/v for 18 days. From Figure 4, the corrosion rate decreases noticeably with an increase in time. The 1.0 M HCl solution with plant extracts recorded the least corrosion rate while the 1.5 M solution with the absence of inhibitor showed the highest in each category. The decrease in corrosion rate observed with the use of inhibitors could be attributed to the adsorption of these active molecules of the extract forming thin inhibitor films on the metal surface which relatively isolates the metal surface from the acidic medium causing much reduced corrosion rates with

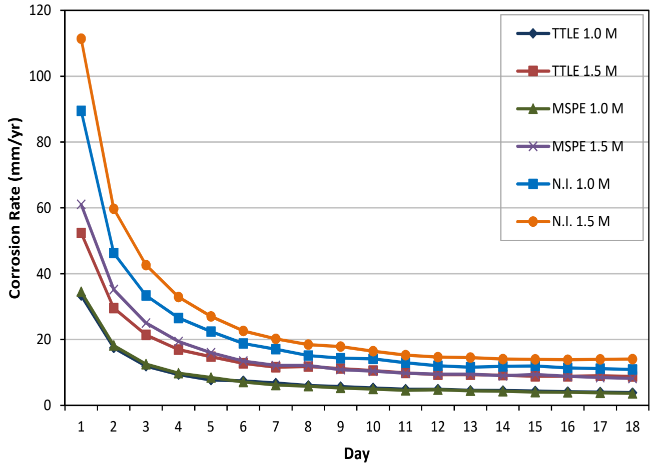


Fig. 4. Variation of corrosion rate with time at room temperature.

time. This attribute depends greatly on the concentration of inhibitor extract, medium concentration, and type [21].

The results obtained and recorded for corrosion rate are in agreement with previous investigations reported by Aladesuyi and Lokesh [3,22]. Aladesuyi *et al.* investigated the Corrosion inhibitive effect of 2-(1-(2-Oxo-2H-Chromen-3-yl) ethylidene) hydrazine carboxamide on zinc-aluminum alloy in 1.8 M hydrochloric acid. The results show that the use of inhibitor decreased the corrosion rate of ZA-27 alloy at both room and elevated temperature. Similar results were also reported by Lokesh *et al.* from the investigation conducted on ZA-27 alloy using cationic surfactants as inhibitors [22].

3.3. Corrosion inhibitor efficiency

Figsures 5 and 6 present the efficiency of extracts studied as corrosion inhibitors from both *Talinum triangulare* leaf (TTLE) and *Musa sapientum* peel (MSPE) in 1.0 M and 1.5 M HCl solutions at room temperature for 18 days. With 1% w/v of each inhibitor, inhibitors in 1.0 M HCl showed a better inhibitive tendency, the average inhibition efficiency of *Talinum triangulare* leaf extract and *Musa sapientum* peel extract in 1.0 M HCl after 18 days were evaluated as 62.30% and 63.27%, respectively. While efficiencies in 1.5 M HCl are 40.54% and 38.45% for *Talinum triangulare* leaf extract and *Musa sapientum* peel extract, respectively. This is an indication that the inhibitory action of the inhibitors is concentration dependent. These results are also in agreement with the previous work reported by Aladesuyi *et al.*, where it was concluded that inhibitory action of the heterocyclic compound on ZA-27 alloy is both concentration and temperature dependent [3].

4. Conclusion

The performances of TTLE and MSPE as inhibitors on the corrosion behavior of ZA-27 have been successfully investigated. The results obtained and presented showed that TTLE and MSPE are good corrosion inhibitors in both 1.0 M HCl and 1.5 M HCl, even at the inhibitor dose of 1% w/v. The plants extracts performed better in 1.0 M HCl. This further confirmed that corrosion rate depends on a number of factors which include concentration of corrosive environment. Based on the results recorded, TTLE performed slightly better than MSPE in 1.5 M HCl solutions while MSPE showed a better performance in 1.0 M HCl solutions. Generally, the extracts of *Talinum triangulare* leaf and *Musa sapientum* peel which were used in this study as

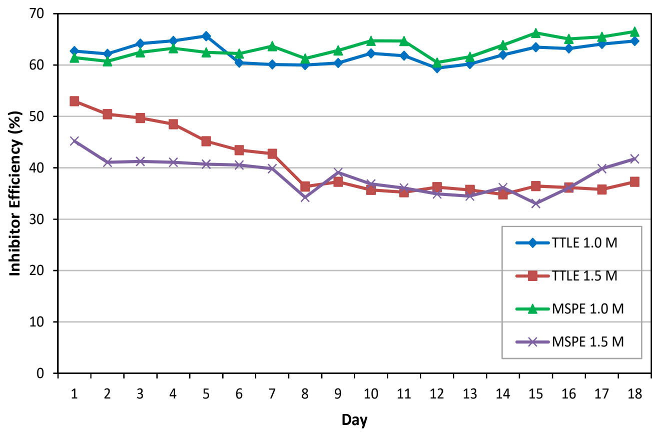


Fig. 5. Plot showing variation of inhibition efficiency with time at room temperature.

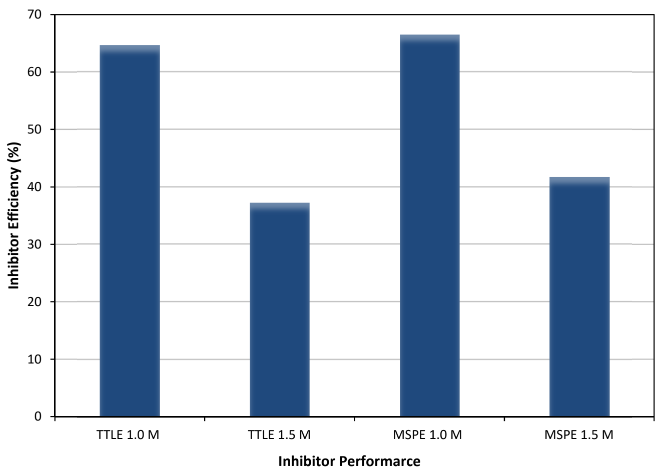


Fig. 6. Average performances of inhibitors at room temperature.

corrosion inhibitors can serve as a scale inhibitors. These plant extracts have the ability to get adsorbed onto the surface of the test sample and form a thin inhibitor film on the metal surface which relatively isolate the metal surface from the acidic environment causing much reduced corrosion rates. This proved that the extracts exhibit inhibitive properties even at low concentrations of the plants extract.

References

[1] O.P. Modi, R.P. Yadav, B.K. Prasad, A.K. Jha, S. Das, A.H. Yegneswaran, Three-body abrasion of a cast zinc-aluminium alloy: influence of Al_2O_3 dispersoid and abrasive medium, Wear, 249 (2001) 792-799.

[2] K.K. Alaneme, B.O. Fatile, J.O. Borode, Mechanical and corrosion behaviour of Zn-27Al based composites reinforced with groundnut shell ash and silicon carbide, Tribol. Ind. 36 (2014) 195-203.

[3] O. Aladesuyi, B.O. Fatile, E.A. Adedapo, A.P. Ogunboyejo, C.O. Ajanaku1, I.O. Olanrewaju, O.O. Ajani, K.O. Ajanaku, Corrosion inhibitive effect of 2-(1-(2-oxo-2H-chromen-3-yl) ethylidene) hydrazine carboxamide on zinc-aluminum alloy in 1.8 M hydrochloric acid, Int. J. Adv. Res. Chem. Sci. 3 (2016) 15-21.

[4] R.D. Pruthviraj, Wear characteristics of chilled zinc-aluminium alloy reinforced with silicon carbide particulate composites, Res. J. Chem. Sci. 1 (2011) 17-24.

[5] S.C. Sharma, B.M. Girish, R. Kamath, B.M. Satish, Graphite particles reinforced ZA-27 alloy composite materials for journal bearing applications, Wear, 219 (1998) 162-168.

[6] E.J. Kubel, Expanding horizons for ZA alloys, Advanced Materials & Processes, Metal Progress, 7 (1987) 51-57.

[7] S.S. Abd El-Rehim, H.H. Hassan, Corrosion inhibition of aluminum by 1,1-(laurylamido)propyl ammonium chloride in HCl solution, Mater. Chem. Phys. 70 (2001) 64-72.

[8] E. Chaieb A. Bouyanzer B. Hammouti, M. Benkaddour, Inhibition of the corrosion of steel in 1 M HCl by eugenol derivatives, Appl. Surf. Sci. 264 (2005) 199-206.

[9] S. Leelavathi, R. Rajalakshmi, *Dodonaea viscosa* (L.) Leaves extract as acid corrosion inhibitor for steel- A green approach, J. Mater. Environ. Sci. 4 (2013) 625-638.

[10] I.B. Obot, N.O. Obi-Egbedi, S.A. Umoren, Anti-fungal drugs as corrosion inhibitors for aluminium in 0.1 M HCl, Corros. Sci. 51 (2009) 1868-1875.

[11] O.K. Abiola, N.C. Okafor, E.E. Ebensi, N.M. Nwinuka, Eco-friendly corrosion inhibitors: the inhibitive action of *Delonix Regia* extract for the corrosion of aluminium in acidic media, Anti-Corros. Method. M. 54 (2009) 19-22.

[12] V. Gentil, Corrosão, 4th ed., Livros Técnicos e Científicos S.A. (LTC), Rio de Janeiro, 2003.

[13] J. Hong, K. Zhen-Peng, Li Yan, Aminic nitrogen-bearing polydentate Schiff base compounds as corrosion inhibitors for iron in acidic media: A quantum chemical calculation, Corros. Sci. 50 (1998) 865-871.

[14] L.V. Ramanathan, Corrosão e seu controle, Hemus, São Paulo, 1988.

[15] L. Valek, S. Martinez, Copper corrosion inhibition by *Azadirachta indica* leaves extract in 0.5 M sulphuric acid, Mater. Lett. 61 (2007) 148-151.

[16] P.B. Raja, M.G. Sethuraman, Atropine sulphate as corrosion inhibitor for mild steel in sulphuric acid medium, Mater. Lett. 62 (2008) 1602-1604.

[17] P.B. Raja, M.G. Sethuraman, Inhibitive effect of black pepper extract on the sulphuric acid corrosion of mild steel, Mater. Lett. 62 (2008) 2977-2979.

[18] S.M. Abegunde, R.O. Ayodele-Oduola, Comparison of efficiency of different solvents used for the extraction of phytochemicals from the leaf, seed and stem bark of *Calotropis Procera*, Int. J. Sci. Res. 4 (2015) 835-838.

[19] ASTM G1-03, Standard practice for preparing, cleaning, and evaluating corrosion test specimens, ASTM International, West Conshohocken, PA, 2011.

[20] H.T. Ibrahim, A.Z. Mohamed, Corrosion inhibition of mild steel using Fig leaves extract in hydrochloric acid solution, Int. J. Electrochem. Sci. 6 (2011) 6442 -6455.

[21] E.A. Noor, Temperature effects on the corrosion inhibition of mild steel in acidic solutions by aqueous extract of Fenugreek leaves, Int. J. Electrochem. Sci. 3 (2007) 996-1017.

[22] H.B. Lokesh, P.F. Sanaulla, V.B. Bheema, An electrochemical investigation on the corrosion behavior of ZA-27 alloy in 1 M Na_2SO_4 in the presence of cationic surfactants as inhibitors, IOSR J. Hum. Soc. Sci. 19 (2001) 9-20.