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Mitigating Corrosion in Mild Steel Using Garlic (Allium Sativum) as Corrosion Inhibitor in HCl Medium

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Abstract*— *Corrosion is one of the great challenges faced in the industries today as it accounts for a lot of setbacks and lost. The use of corrosion inhibitors in solving corrosion problems has special advantages in terms of ease of its application and effectiveness in performance. Among various inhibitors, organic inhibitors are mostly used due to their eco-friendliness and availability. The research focused on the inhibitory properties of garlic extract in 0.5M HCl. The inhibitive effect of Garlic (Allium Sativum) on the corrosion of mild steel in 0.5M HCl was investigated using weight loss measurement and electrochemical method. The Garlic extracts were characterized using Atomic Absorption Spectroscopy (AAS) and Fourier Transform Infrared Spectroscopy (FTIR). Results obtained from both weight loss and electrochemical method showed that corrosion rates of mild steel in 0.5M HCl decreases as the concentration of garlic extract increases. Lowest corrosion rates and weight loss of 0.53mm/yr and 0.22g respectively was achieved with 8v/v% garlic extract concentration. The corrosion rate decreased to 0.53mm/yr from 1.66mm/yr using electrochemical method and cumulative weight loss showed a decrease from 1.71g to 0.22g. Corrosion inhibition efficiency increased with an increase in the concentration of garlic extract. Maximum inhibition efficiency of 68% was attained at 8v/v% concentration of the extract. The good inhibitory properties of garlic extract was attributed to the presence of the phenolic and aromatic functional group revealed by Fourier Transform Infrared Spectroscopy (FTIR). The eco-friendliness of the garlic extract was confirmed by Atomic Absorption Spectroscopy.

Keywords—Corrosion; Garlic; Inhibition efficiency; Potentiodynamic polarization

I. INTRODUCTION

Corrosion of equipment is a great challenge faced in industries as it accounts for a lot of setbacks and loss. A huge amount of money is lost each year because of corrosion therefore making it a great concern to the industry [1; 2; 3]. Carbon steels are majorly used in the industry [4; 5] . Corrosion of metals and alloys in acidic media especially hydrochloric acid is an important industrial problem. Hydrochloric acid is one of the most commonly used acids, among the acid solutions for acid [6; 7]. One of the best methods of controlling corrosion is through the use inhibitors. The mode of operation of inhibitors is through adsorbing themselves to the substrate i.e to the metals they are to protect. Through this they form a protective layers on the surface of such metals, thereby protecting them from being corroded [8]. Corrosion inhibitors are chemical substances that are capable of reducing the rate of corrosion especially in metals if apply in the correct proportions [9; 10; 11]. Corrosion inhibitors are used because of their ease of application and effectiveness. Corrosion inhibitors can be broadly categorised into organic and inorganic inhibitors [12]. Higher degree of attentions are being directed towards organic inhibitors than the inorganic inhibitors in research field presently. This has been traced to the high cost and toxicity associating with inorganic inhibitors while organic inhibitors has been reported to be environmental friendly and naturally sustainable materials [13; 14; 15; 16; 17; 18; 19]. Plant extracts are environmentally acceptable and regarded as rich source of naturally synthesized chemical compounds with low cost [6; 20]. Several organic inhibitors have been used as a result of their eco-friendliness and effectiveness and they've been reported to show good inhibitory effect of carbon steel in hydrochloric acid environments
[21]. Garlic, also known as *Allium Sativum*, is known to consist of calcium, vitamin C, vitamin B-6, iron and magnesium [22]. Garlic asides its good medicinal properties is also reported to have good inhibitory properties. The inhibitive effect of garlic powder on corrosion of mild steel in H_3PO_4 solution was researched using weight loss and polarization techniques. Garlic powder was ascertained to have good inhibition properties with a maximum inhibition efficiency of 75% at 250 ppm inhibitor concentration [23]. The effect of garlic extract on corrosion of mild steel in 0.5M HCl and H_2SO_4 was conducted using weight loss and electrochemical method. From the study, garlic concentration of 100% had the best

inhibition efficiency and lowest corrosion rate and this was attributed to the presence of some complex compound . This research examined the inhibitory effect of garlic extract of mild steel in 0.5M HCl using weight loss and electrochemical method.

II. MATERIALS AND METHODS

Mild steel with main chemical composition of 0.15% C, 0.2% Si, 1.3% Mn, 0.02% P, 0.02% Cr, 0.02% Ni and 98.5% Fe was used for the research. The full composition of the mild steel as obtained from spark analysis is shown in Table 1. The steel was mechanically cut into dimension of 10 mm x 10 mm, and then polished using different grades of emery paper from 320 down to 2,000 grits. The surfaces of the steel was washed with distilled water and degreased with ethanol. Analytical grade HCl and distilled water was used for the preparation of the acid solution.

A. Preparation of Garlic Extract

Another important material that was used in this research was garlic, the raw garlic is shown in plate 1. The garlic was sourced locally after which the peels were removed. The garlic was chopped and sundried for 14 days and then milled to reduce the particle size to powder. Ethanol was used as the extraction solvent. 400g of milled garlic was mixed with 625ml ethanol. The mixture was left for 7 days in a covered container after which it was filtered. The filtrate was heated to 80°C until all ethanol evaporated and the concentrate was used for the research. Garlic extract of various concentrations ranging between 0v/v% - 8v/v% at an interval of 2v/v% were used for this work.

Plate 1: Raw garlic

B. Characterisation of Extract

The elemental composition of the extract was determined using Atomic Absorption Spectroscopy (AAS). Determination of the functional group present in the extract was carried out using fourier transform infrared Spectroscopy (FTIR). The characterizations of the garlic extract were carried out at Federal University of Technology, Akure, Ondo State.

C. Tafel Plots

The electrochemical test was carried out at room temperature in the Department of Metallurgical and Materials Engineering, (FUTA) using a potentiostat, Verstat 4 equipped with versa software The experiments were conducted using a three-electrode set up comprising of platinum rod as counter electrode (CE), silver/silver chloride as reference electrode (RE) and the mild steel as working electrode (WE). The working electrodes were prepared by attaching an insulated copper wire to one face of the sample using an aluminum conducting tape, and cold mounting it with epoxy resin. The test set-up and testing procedure was in accordance with the standard [24]. The working electrodes were immersed in the environment which is 0.5M HCl with and without the inhibitor at a scan rate of 1 mV/S. The percentage inhibition efficiency (I.E %) from the polarization measurement was calculated using (1);

$$(\%)I.E = \frac{CR_0 - CR_1}{CR_0} X\ 100 \quad (1)$$

Where I.E = inhibition efficiency, CR_0 = corrosion rate without inhibitor and

CR_1= corrosion rates with inhibitor addition

D. Gravimetric Test and Analysis

Gravimetric test was carried out for the various mild steel samples so as to determine the influence of the different garlic extract concentration on the weight loss of the mild steel. Mild steel samples with same composition and size as that of electrochemical test were used as shown in Plate 2. The mild steel specimens were immersed in 100ml of 0.5M HCl containing various concentrations of garlic extract at room temperature for 30 days. The mild steel specimens were measured before and after immersion using a digital weighing balance. The test was carried out at room temperature and lasted 30 days. Garlic extract concentrations between 0v/v% - 8v/v% at 2v/v% interval were used.

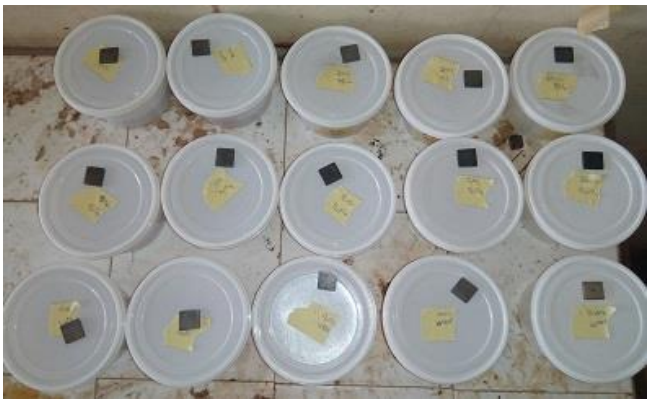

Plate 2: Experimental Set up for Gravimetric Test

III. RESULT AND DISCUSSION

A. *Atomic Adsorption Spectrometric Analysis Result*

Elemental constituents of garlic extract as obtained from AAS are presented in Table 1. From the table, heavy metals are observed to be below detection limits thereby ascertaining its eco-friendliness. Figure 2 shows the FT-IR spectra of the garlic extract. The broad band at 3300cm-1 is attributed to O-H stretching. The frequency at 2950 cm-1 corresponds to C-H stretching, and the one at 1633.33 cm-1 corresponds to C=C stretching, 1033.33 cm-1 corresponds to C-O stretching and the 866.67 cm-1 corresponds to C=C bending. Extract of secang heartwood was also reported to contain some of the functional groups as garlic extract [25].

TABLE 1: ELEMENTAL COMPOSITION OF GARLIC EXTRACT

Element(pp	Ca	Fe	Cu	Mn	Pb	Ni	Cr	Cd	Zn
Garlic	**168**	**158.0**	**1.00**	**8.00**	**3.00**	**14.00**	**8.00**	**ND**	**72.00**

B. *Tafel Plots*

Figure 1 shows the polarization curves of mild steel in 0.5m HCl in the absence and presence of garlic extract. From the curves and Table 2, it was observed that the highest current density and corrosion rate of 321 µA/cm^2 and 1.66mm/yr respectively was exhibited by mild steel in the absence of garlic extract in 0.5M HCl.

Table 2 further shows that the current density and corrosion rates decrease as the garlic extract concentration increases. Lowest current density and corrosion rates of 102 µA/cm^2 and 0.53mm/yr respectively was achieved by mild steel in the presence of 8v/v% garlic extract. Inhibition efficiency was also observed to increase from 54.8% to 68.1% with an increase in extract concentration from 2v/v% to 8v/v%. Increase in inhibition efficiency was attributed to the effectiveness of garlic extract to block the anodic and cathodic reaction sites [26; 27]. Maximum inhibition efficiency of 68.1% was attained by the mild steel in the presence of 8v/v%.

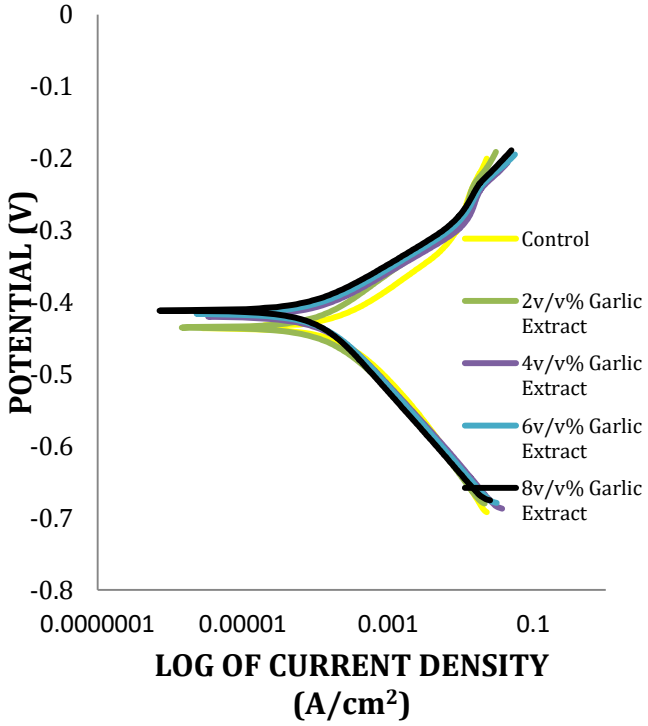

Figure 1: Potentiodynamic polarization curves of mild steel in the absence and presence of garlic extract in 0.5M HCl

TABLE 2: ELECTROCHEMICAL PARAMETERS OF MILD STEEL IN 0.5M HCL WITH DIFFERENT CONCENTRATIONS OF GARLIC EXTRACT

Inhibitor Concentration (v/v %)	-Ecorr (mV)	Icorr (µA/cm^2)	Corrosion Rate (mm/yr)	Inhibition Efficiency (IE %)
0	437	321	1.66	-
2	434	145	0.75	54.8%
4	420	127	0.65	60.8%
6	416	121	0.62	62.7%
8	411	102	0.53	68.1%

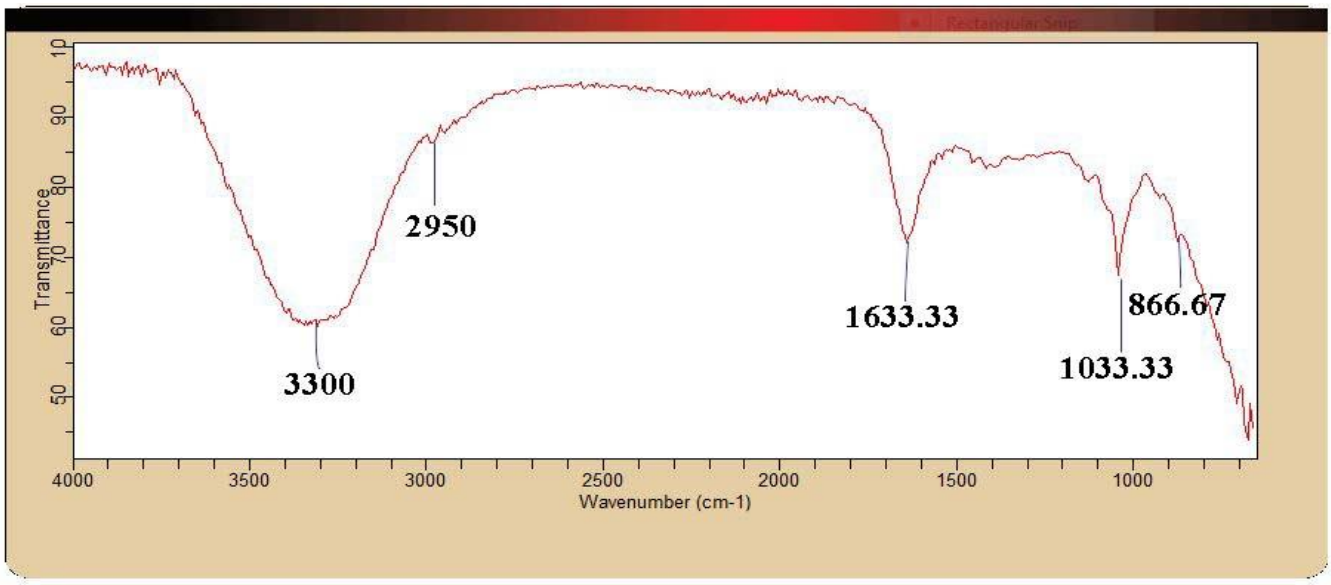

Figure 2: FTIR spectrum of garlic extract

C. Weight Loss

Figure 3 shows the weight loss graph of mild steel in the absence and presence of garlic extract. From the graph, mild steel in the absence of garlic extract had the highest weight loss of 1.71g and this is established from Table 3. On addition of 2v/v% garlic extract, a large decrease in weight loss from 1.71g to 1.07g was observed. Further addition of garlic extract decreases the weight loss till 8v/v% garlic extract concentration which exhibited the lowest cumulative weight loss of 0.22g. From Table 3, it was observed that the cumulative weight loss of mild steel in 0.5M HCl decreases with an increase in garlic extract concentration. A decrease from 1.71g to 0.22g was deduced with an increase of 0 to 8v/v% in garlic extract concentration. This behavior indicates that more molecules of garlic extract constituents are adsorbed on the mild steel surface thereby forming a passive film which protect the mild steel from corroding hereby limiting the corrosion rate [28]. This good inhibitory properties of garlic extract can be attributed to the presence of the very complex compounds revealed by the FTIR result in Figure 2. [22; 29]

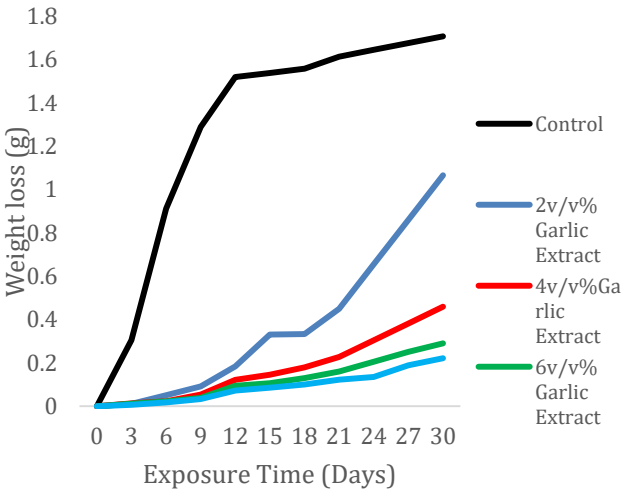

Figure 3: Weight loss graph of mild steel in the absence and presence of garlic extract in 0.5M HCl

TABLE 3: WEIGHT LOSS PARAMETERS OF MILD STEEL IN 0.5M HCL IN THE ABSENCE AND PRESENCE OF GARLIC EXTRACT

Inhibitor Concentration /Immersion Time(days)	0 (v/v %)	2 (v/v %)	4 (v/v %)	6 (v/v %)	8 (v/v %)
0	-	-	-	-	-
3	0.30	0.01	0.01	0.01	0.01
6	0.91	0.05	0.02	0.02	0.02
9	1.29	0.09	0.05	0.04	0.03
12	1.52	0.18	0.12	0.09	0.07
15	1.54	0.33	0.15	0.11	0.09
18	1.56	0.33	0.18	0.13	0.10
21	1.61	0.45	0.23	0.16	0.12
24	1.64	0.66	0.30	0.21	0.13
27	1.67	0.86	0.38	0.25	0.19
30	1.71	1.07	0.46	0.29	0.22

IV. CONCLUSION

Garlic extract exhibits mild steel inhibition in 0.5M HCl. The results gotten from weight loss corroborates that obtained from electrochemical method where corrosion rates of mild steel in 0.5M HCl decreases with an increase in garlic extract concentration. The reduction in the corrosion rate of mild steel in 0.5M HCl by garlic extract is attributed to the good corrosion inhibitory properties of garlic.

REFERENCES

[1] Okafor, P.C., Liu, X., Zheng,Y.G. "Corrosion inhibition of mild steel by ethylaminoimidazoline derivative in CO_2- saturated solution" Corros. Sci. Vol.51: pp. 761-768, 2009. https://www.academia.edu/31056133/Corrosion_inhibition_of_mild_steel_by_ethylamino_imidazoline_derivative_in_CO2-saturated_solution

[2] V. Garcia-Arriaga J. Alvarez-Ramirez, M. Amaya E. Sosa, 2010. H_2S and O_2 influence on the corrosion of Carbon steel immersed in a solution containing 3 Mdiethanolamine. Corrosion Sci. Vol. 52(7), 2268-2279, 2010. DOI: 10.1016/j.corsci.2010.03.016

[3] H. Lgaz, R. Salghi and I.H. Ali, "Corrosion inhibition Behavior of 9-Hydroxyrisperidone as a Green Corrosion inhibitor for mild Steel in Hydrochloric Acid: Electrochemical, DFT and MD simulations studies" Int. J. Electrochem. Sci., 13; 250 – 264, 2018. DOI: 10.2964/2018.01.26

[4] J.S. Chouhan, A. Dixit and D.K. Gupta, D.K. "Green inhibitors for prevention of metal and alloys corrosion: An overview" Chem. and Mater. Res., vol.3 (6), 2013.

[5] M.E. Lozano, C.O Olivares-Xometl, N.V. Likhanova, P. Herrasti, "Corrosion behaviour of API 5L X52 steel in HCl and H_2SO_4 media in the presence of 1,3- dibencilimidazolio acetate and 1,3-dibencilimidazolio dodecanoate ionic liquids as inhibitors," Mater. Chem. and Phys.. Vol. 147, pp. 191-197, 2014.

[6] A. Khadraoui, A. Khelifa, H. Boutoumi, H. Hamitouche, R. Mehdaoui, B. Hammouti and S.S. Al-Deyab, "Adsorption and inhibitive properties of Ruta chalepensis L. oil as a green inhibitor of Steel in 1 M Hydrochloric Acid medium, " Int. J. Electrochem. Sci., vol. 9, pp. 3334 – 3348, 2014. https://www.scirp.org/(S(i43dyn45teexjx455qlt3d2q))/reference/ReferencesPapers.aspx?ReferenceID=1608041

[7] G. Khan, G.,K.S. Newaz, W.J. Basirun, H.B. Mohd Ali, F.L Faraj and G.M. Khan, Application of Natural Product Extracts as Green Corrosion Inhibitors for Metals and Alloys in Acid Pickling Processes- A review" Int. J. Electrochem. Sci., vol. 10; pp. 6120 – 6134, 2015. http://www.electrochemsci.org/papers/vol10/100806120.pdf

[8] P.Bothi Raja, and M.G., Sethuraman, "Natural products as corrosion inhibitors for metals in corrosive media": A review. Mater. Lett., 62:113–116, 2008, doi:10.1016/j.matlet.2007.04.079

[9] Z. Ahmad "Principles of Corrosion Engineering and Corrosion Control," .Elsevier. Oxford. Butterworth-Heinemann, 2006 ISBN: 9780750659246

[10] M.N. Rahuma,M.B. EL-Sabbah and I.M. Hamad, I.M. 2013. "Effect of serine and methionine on electrochemical behavior of the corrosion of mild steel in aqueous solutions". Hindawi Publishing Corporation, ISRN, Corrosion . pp. 1-7, 2013. http://dx.doi.org/10.1155/2013/895120

[11] M.S. Asep, S.P. Aribella and E.N Ratih, " Corrosion inhibitor of Carbon Steel from onion Peel extract." MATEC Web of Conferences 156, 03050 (2018) https://doi.org/10.1051/matecconf/201815603050 RSCE 2017

[12] V.S. Sastri, "Green corrosion inhibitors: theory and practice" vol 10 (John Wiley & Sons, Inc.), 2012 ISBN: 978-0-470-45210-3 https://www.wiley.com/en-zs/Green+Corrosion+Inhibitors%3A+Theory+and+Practice-p-9780470452103

[13] A.M. Abdel-Gaber, B.A Abd-El-Nabey and M. Saadawy "The role of acid anion on the inhibition of the acidic corrosion of steel by lupine extract" Corros. Sci., vol. 51(5): pp. 1038–1042, 2009. DOI: 10.1016/j.corsci.2009.03.003

[14] M. Lebrini, F. Robert, P.A. Blandinières and C. Roos, C. "Corrosion inhibition by Isertia coccinea plant extract in hydrochloric acid solution". Int. J. Electrochem. Sci.. vol.6,: pp. 2443–2460, 2011 http://www.electrochemsci.org/papers/vol6/606724 43.pdf

[15] S.A. Umoren, U.M Eduok, M.M Solomon, and A.P. Udoh, "Corrosion inhibitor by leaves and stem extracts of Sida acuta for mild steel in 1M H2SO4 solutions investigated by chemical and spectroscopic techniques". Arabian J. of Chem.. 48(S1), 2011 DOI: 10.1016/j.arabjc.2011.03.008

[16] S.A. Asipita, I. Mohammad, Z.A. Muhd, A.M. Zaiton, A. Chesobry and M. Jahangir "Green Bambusa Arundinacea leaves extract as a sustainable corrosion inhibitor in steel reinforced concrete". J. of Cleaner Prod., vol. 67, pp. 139-146, 2014

[17] A.S. Abdulrahman, and I. Mohammad "Electrochemical assessment of concrete ternary inhibitors used in retarding corrosion of steel reinforcementS," ARPN J. of Eng. and Appl. Sci., vol. 9(5): pp. 750-756. 2014., https://espace.curtin.edu.au/handle/20.500.11937/72448

[18] L.S. Barreto, M.S. Tokumoto, I.C, Guedes, H. Gomes de Melo, F. Amado, and V.R. Capelossi,

"Study and assessment of the efficiency of the cocoa bark extracted from the theobroma cacao as an inhibitor of the corrosion of carbon steel in substitution of Benzotiazole" Mater. Res., 2018

[19] O.A. Olaseinde, O.T. Ogunmodede, O.T. and T.G. Kolawole, "Corrosion inhibition study of Cocoa pod husk extract on API5L in Sulphuric acid" J. of Multidiscip. Eng. Sci. Studies, vol. 5(3) pp. 2548-2559, 2019

[20] Q. Ekhlas, A. Munther and A. Alas. "Investigation of Salvadora Persica roots extract as corrosion inhibitor for mild Steel in 1 M HCl and in cooling Water" Chem. and Mater. Res., vol. 7(4), pp. 147-158, 2015 https://pdfs.semanticscholar.org/cee0/4cec1216c8a224fdff9d30b3248e33712c62.pdf

[21] R. Salghi, S. Jodeh, E.E. Ebenso, H. Lgaz, D. BenHmamou, M. Belkhaouda, H. Ali, M. B. Messali, B. Hammouti, and S. Fattouch, 2017. "Inhibition of C-steel corrosion by green tea extract in Hydrochloric solution" Int. J. Electrochem. Sci., vol. 12, pp. 3283 – 3295, 2017 http://www.electrochemsci.org/papers/vol12/120403283.pdf

[22] C.A. Loto, R.T. Loto and O.J. Oshogbunu, "Corrosion inhibition effect of Allium sativum extracts on mild steel in HCl and H_2SO_4" J.I of Chem. and Pharm. Res., vol. 8(2), pp.216-230, 2016. http://eprints.covenantuniversity.edu.ng/7307/#.XK8Z95hKjIU

[23] Aprael S. Yaro, Anees A. Khadom, and Rafal K. Wael, " Garlic powder as a safe environment green corrosion inhibitor for mild Steel in acidic media; adsorption and quantum chemical studies," J. of the Chinese Chem.l Soc., vol. 61(6), pp.615-623, 2014. https://onlinelibrary.wiley.com/doi/abs/10.1002/jccs.201300480

[24] ASTM G59-97, Standard Test Method for Conducting Potentiodynamic Polarization Resistance Measurements, ASTM International, West Conshohocken, PA, 2014, https://www.astm.org/Standards/G59

[25] M.S. Asep, S.P. Aribella and E.N. Ratih, E.N. "Corrosion inhibitor of Carbon Steel from onion peel extract," MATEC Web of Conferences 156, 03050 https://doi.org/10.1051/matecconf/201815603050 RSCE 2017

[26] S.A. Abd El-Maksoud, "Euro- analysis" Electrochimica Acta, vol. 49(24), pp. 4061- 4252, 2004, https://www.sciencedirect.com/journal/electrochimica-acta/vol/49/issue/24

[27] I.E. Uwah, P.C. Okafor, and V.E. Ebiekpe, "Inhibitive action of ethanol extracts from Nauclea latifolia on the corrosion of mild steel in H_2SO_4 solutions and their adsorption characteristics," Arabian J. of Chem.; vol. 6(3), 285–293.2013, https://doi.org/10.1016/j.arabjc.2010.10.008

[28] A.K. Maaya, and N.A.F. Al-Rawashdeh, "Electrochemical investigation of corrosion and corrosion inhibition of iron in hydrochloric acid solutions," Arabian J. of Chem., vol. 4(4), pp. 397-402, 2011 DOI:10.1016/j.arabjc.2010.07.006

[29] S. Al-Mhyawi, 2014."Corrosion inhibition of Aluminum in 0.5 M HCl by garlic aqueous extract," Oriental J. of Chem., vol. 30(2), pp. 541-552, 2014 DOI : http://dx.doi.org/10.13005/ojc/300218