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ORIGINAL ARTICLE

Inhibition of the Corrosion of Mild Steel in Acidic Medium by Penicillin V Potassium

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ABSTRACT

The inhibition of the corrosion of mild steel by penicillin V potassium has been studied. Penicillin V potassium is a good inhibitor for the corrosion of mild steel in H_2SO_4. The inhibition efficiency of the inhibitor decreases with increase in temperature and with the period of immersion. However, increase in the concentration of the inhibitor resulted in increase in the inhibition efficiency of penicillin V potassium. Adsorption characteristics of the inhibitor has also been studied and it is found that penicillin V potassium inhibit the corrosion of mild steel by being adsorbed on the surface of mild steel by a physical adsorption mechanism. The adsorption of the inhibitor was also found to be spontaneous and consistent with the assumptions of Langmuir and Frumkin adsorption isotherms.

Key word: Corrosion of mild steel, inhibition, penicillin V potassium.

Introduction

Most corrosion inhibitors protect the corrosion of metals when they are adsorbed on the surface of the metal (Abdallah, 2004a,b, 2002; Agrawal *et al*., 2003; Eddy and Odoemelam, 2008a,b,c; Eddy and Ekop, 2008a; Eddy *et al*., 2008a,b). The adsorption and inhibitive properties of some corrosion inhibitors containing hetero atoms in their long carbon chain/aromatic structure have also been studied (Abiola *et a*., 2007,2004; Ashassi-Sorkhabi *et al*., 2006). Studies have also been conducted on the adsorptive and inhibitive properties of some natural products (Ashasssi_Sorkhabi and Ghalebsaz-Jeddi, 2005). In most of these studies, these properties are found to be strongly influenced by the chemical structure of the compound, the corrosive medium, temperature, concentration of the inhibitor, period of contact, etc.(Arora *et* al., 2007; Babi-Samordzia *et al*., 2005). Adsorption characteristics of an inhibitor can be studied by the used of adsorption isotherms and the application of the theory of thermodynamics (Eddy and Odoemelam, 2008a).

Recently, studies on the use of drugs as corrosion inhibitors have been intensified (Awad, 2006; Bendahou *et al*., 2006; Bouyanzer and Hammouti, 2004). According to Eddy and Odoemelam (2008b), the used of drugs for the inhibition of the corrosion of metals has some advantages over the use of some organic/inorganic inhibitors because of their eco-environmental nature. Therefore, the present study is aimed at investigating inhibitive and adsorptive properties of penicillin V potassium for the corrosion of mild steel in acidic medium. Penicillin V potassium is an antibiotic that is used for the treatment of some infection. This compound can be synthesized from plant and it does not contain heavy metals or other toxic substance.

Experimental

Materials used for the study were mild steel sheets of composition (wt %) Mn (0.6), P(0.36), C(0.15) and Si(0.03) and dimension, 5x4x0.11cm. Each coupon was degreased by washing in ethanol, dried in acetone and preserved in a desiccator. The inhibitor was supplied by VERBATA pharmaceutical store, Ikot Ekpene, Nigeria.

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All reagents used for the study were analar grade. Double distilled water was used for the preparation of all solutions. Concentrations of H_2SO_4 used for the study were 1.0, 1.5, 2.0 and 2.5M while the concentrations of the inhibitor were 3 x 10^{-4}, 6 x 10^{-4}, 9 x 10^{-4}, 12 x 10^{-4} and 15 x 10^{-4}M. These were respectively dissolved in 2.5M H_2SO_4.

Gasometric method

Hydrogen evolution measurements were carried out at 303 and 333K as described in literature (Eddy and Ebenso, 2008; Eddy and Ekop, 2008). From the volume of hydrogen evolved per minutes, inhibition efficiency (h), and degree of surface coverage (q) were calculated using Equation 1 and 2 respectively.

$$\%I = \left\{1 - \frac{V'_{Ht}}{V^0_{Ht}}\right\} \times 100 \quad (1)$$

$$\theta = \%I/100 \quad (2)$$

where V'_{Ht} is the volume of hydrogen evolved at time t for inhibited solution and V^0_{Ht} is the volume of hydrogen evolved at time t for unhibited solution.

Thermometric method

This was also carried out as reported elsewhere (Eddy and Ebenso, 2008). From the rise in temperature of the system per minutes, the reaction number (RN) and inhibition efficiency were calculated using equation 3 and 4 respectively:

$$RN\ (°C\ minutes) = \frac{T_m - T_i}{t} \quad (3)$$

$$\%I = \frac{RN_b - RN_w}{RN_b} \times 100 \quad (4)$$

Results and discussion

Fig. 1 shows the variation of the volume of hydrogen gas evolved with time during the corrosion of mild steel in various concentrations of H_2SO_4. The Figure revealed that the rate of evolution of hydrogen increases as the concentration of the acid increases indicating that the rate of corrosion of mild steel increases with increase in the concentration of H_2SO_4. Values of corrosion rate of mild steel in various concentrations of H_2SO_4 are recorded in Table 1. The results obtained also indicate that the rate of corrosion of mild steel increases with increase in the concentration of H_2SO_4.

Figs. 2 and 3 show the variation of the volume of hydrogen gas evolved with time for the corrosion of mild steel in 2.5M H_2SO_4 containing various concentrations of penicillin V potassium at 303 and 333K respectively. These Figures revealed that the rate of corrosion of mild steel increase as the temperature increases but decreases as the concentration of penicillin V potassium increases indicating that penicillin G inhibited the corrosion of mild steel in H_2SO_4.

Table 1 shows values of corrosion rate of mild steel in H_2SO_4 containing various concentrations of penicillin V potassium. Values of inhibition efficiency of penicillin V potassium are also recorded in the Table. From the results, it was seen that the rate of corrosion of mild steel in H_2SO_4 decreases as the concentration of penicillin V potassium increases but increases with increase in temperature. These findings confirmed that penicillin V potassium inhibited the corrosion of mild steel and that the inhibition efficiency of penicillin V potassium for mild steel corrosion decreases as the concentration of penicillin V potassium increases but decreases as the temperature increases. Fig. 4 shows the variation of inhibition efficiency of penicillin V potassium with concentration at 303 and 333K. The Figure clearly shown that the inhibition efficiency of penicillin V potassium for mild steel corrosion decreases with increase in temperature but increases as the concentration of penicillin V potassium increases supporting the mechanism of physical adsorption. For a physical adsorption mechanism, the inhibition efficiency of the inhibitor is expected to decrease with increase in temperature as observed in this work (Ebenso, 2004, 2003; Ebenso *et al.*, 2005).

The Arrhenius equation (Equation 5) was used to investigate the effect of temperature (T) on the rate of corrosion (CR) of mild steel in the presence and absence of penicillin V potassium (Emregul *et al.*, 2004a,b; 2005a,b).

$$CR = A\exp(-E_a/RT) \quad (5)$$

Table 1: Values of corrosion rate(cm^3/minute) and reaction number (°C/minute) for the corrosion of mild steel in H_2SO_4

Con. of H_2SO_4 (M)	CR(303K)	RN(303K)
1.0	0.175	0.0167
1.5	0.180	0.0200
2.0	0.220	0.0267
2.5	0.380	0.0500

Table 2: Values of corrosion rate (CR) and reaction number (RN) for the corrosion of mild steel in H_2SO_4 containing various concentrations of penicillin V potassium

Con. of penicillin V potassium(M)	CR (333K)	CR (303K)	RN (303K)	Gasometric		Thermometric
				%I(303K)	%I(333K)	%I (303K)
3×10^{-4}	0.2625	2.3063	0.0370	30.00	16.89	26.00
6×10^{-4}	0.2000	2.3063	0.0313	46.67	16.89	37.32
9×10^{-4}	0.1813	2.2250	0.0255	51.67	19.82	49.08
12×10^{-4}	0.1750	2.0875	0.0255	53.33	24.70	49.08
15×10^{-4}	0.1375	2.0063	0.0238	63.33	27.70	52.33

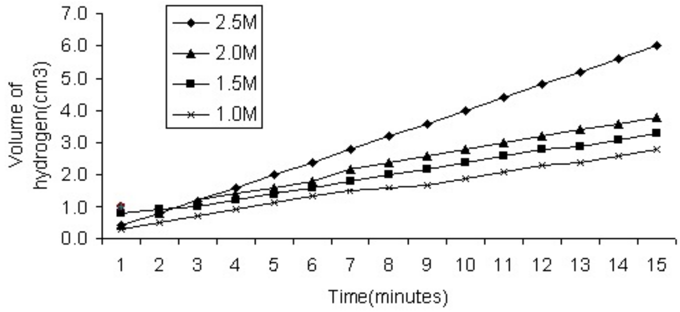

Fig. 1: Variation of hydrogen gas evolved with tim for the corrosion inhibition of mild steel at various concentrations of methocarbamol at 303K.

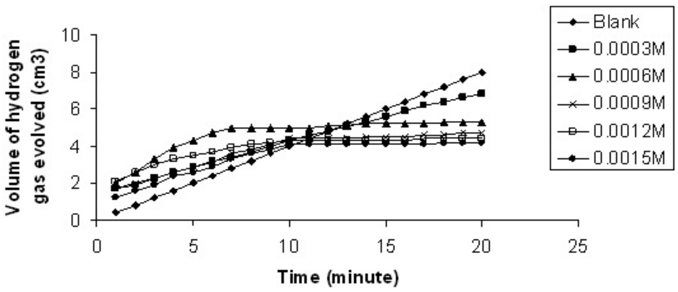

Fig. 2: Variation of the volume of hydrogen gas evolved with tim for the inhibition for the corrosion of mild steel by various concentrations of penicillin V potassium at 303K.

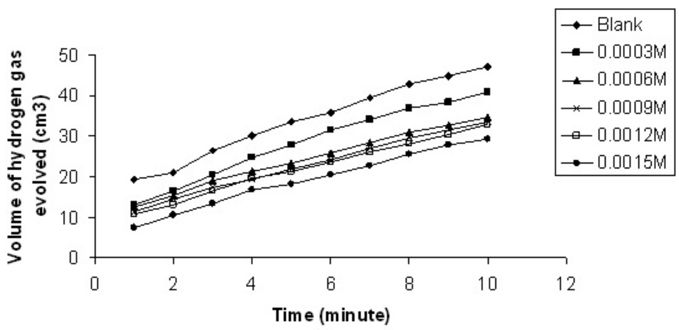

Fig. 3: Variation of the volume of hydrogen gas evolved with tim for the inhibition for the corrosion of mild steel by various concentrations of penicillin V potassium at 333K.

where E_a is the activation energy and R is the gas constant. Taking the logarithm of both sides of Equation 5, Equation 6 is obtained,

$$\log CR = \log A - E_a/2.303RT \quad (6)$$

Assuming that the corrosion rates of mild steel at 303K (T_1) and 333K (T_2) are CR_1 and CR_2, then Equation 6 is transformed to Equation 7,

$$\log(CR_2/CR_1) = E_a/2.303R(1/T_1 - 1/T_2) \quad (7)$$

Values of E_a calculated from Equation 7 were recorded in Table 3. These values ranged from 60.8445 to 75.0473KJ/mol. The values are greater than the value (-55.667J/mol) obtained fro the blank indicating that the penicillin V potassium retarded the corrosion of mild steel in H_2SO_4. The values are also consistent with data expected for the mechanism of physical adsorption (E_a < 80KJ/mol).

Values of the heat of adsorption of penicillin V potassium on mild steel surface were calculated using Equation 8 (Eddy and Ebenso, 2008).

$$Q_{ads} = 2.303R[\log(\theta_2/1-\theta_2) - \log(\theta_1/1-\theta_1) \times (T_2T_1)/(T_2 - T_1) \quad (8)$$

where R is the gas constant, q_1 and q_2 are the degree of surface coverage at temperatures, T_1 and T_2 respectively. Values of Q_{ads} calculated from Equation 8 ranged from -15.6509 to -31.5849KJ/mol indicating that the adsorption of penicillin V potassium on mild steel surface is exothermic.

Data obtained for degree of surface coverage were used to fit curves for different adsorption isotherms including Langmuir, Frumkin, Freundlich, Bockris-Swinkel, Temkin and Florry - Huggins adsorption isotherms. The results revealed that the isotherms that best described the adsorption characteristics of penicillin V potassium on mild steel surface are Langmuir and Frumkin adsorption isotherms.

Starting from Langmuir adsorption isotherm, the degree of surface coverage (θ) and the concentration of the inhibitor in the bulk electrolyte are related according to Equation 9 (Eddy and Odoemelam, 2008a,b; Oguzie, 2007,2006a,b).

$$C/\theta = 1/k + C \quad (9)$$

where k is the equilibrium constant of adsorption of penicillin V potassium on mild steel surface. Taking the logarithm of both sides of Equation 9, Equation 10 is obtained (Sheatty *et al.*, 2006; Shockry *et al.*, 2006; Rajendran *et al.*, 2005)

$$\log(C/\theta) = \log C - \log K \quad (10)$$

From Equation 10, a plot of log(C/θ) is expected to produce a straight line provided the assumptions of Langmuir isotherm are valid. Fig. 5 shows Langmuir isotherm for the adsorption of penicillin V potassium on the surface of mild steel.

Table 3: Some thermodynamic parameters for the adsorption of penicillin V potassium on mild steel surface

Concentration. of penicillin V potassium (M)	E_a (KJ/mol)	Q_{ads} (KJ/mol)
3×10^{-4}	60.8445	-15.6509
6×10^{-4}	68.4582	-30.6254
9×10^{-4}	70.2095	-30.7169
12×10^{-4}	69.4060	-26.1792
15×10^{-4}	75.0473	-31.5849

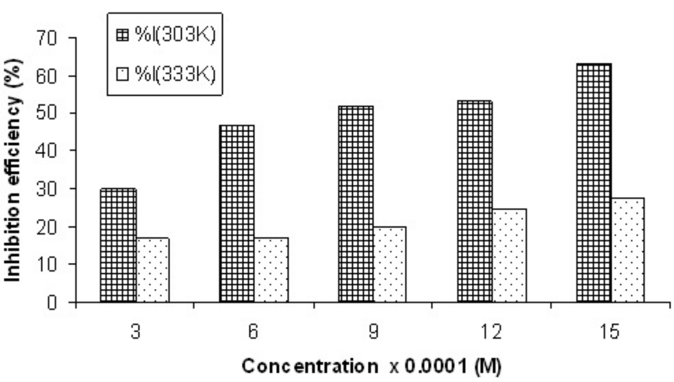

Fig. 4: Variation of the inhibition efficency of penicillin V potassium with concentration at 303 and 333K.

The expression for Frumkin isotherm is as given by Equation 11(Eddy and Ebenso, 2008),

$$\theta/1-\theta \;=\; B.C.e^{2aq} \tag{11}$$

From the logarithm of Equation 11, Equation 12 is obtained:

$$\log[(\theta/(1-\theta))]*[C]=\log K+2a\ \theta \tag{12}$$

where q is the of surface coverage, C is the concentration of the adsorbate, K is the adsorption-desorption equilibrium constant and a is an interaction parameter. From Equation 12, a plot of log[(θ/(1-θ)]*[C] versus q should produce a straight line if Frumkin isotherm is applicable. Fig. 6 shows Frumkin isotherm for the adsorption of penicillin V potassium on the surface of mild steel. Values of Frumkin adsorption parameters are recorded in Table 4. From the results, it was seen that values of the adsorption parameters were positive indicating the attractive behaviour of the inhibitor (Eddy and Ebenso, 2008).

The free energy of adsorption of penicillin V potassium is related to the equilibrium constant of adsorption according ot Equation 13 (Okafor *et* al., 2008,2007a,b;Rajappa and Vekateshal, 2002).

$$\Delta G_{ads} = -2.303RT\log(55.5K) \tag{13}$$

where R is the gas constant and T is the temperature. Values of K obtained from Langmuir and Frumkin adsorption isotherms were used to calculate values of DG_{ads} according to Equation 13. These values are recorded in Table 4. The results indicated that the adsorption of penicillin V potassium is spontaneous (DG_{ads} is negative) and suggest the applicability of the mechanism of physical adsorption (DG_{ads} < 40KJ/mol) (Eddy and Odeoemalm, 2008a,b; Eddy and Ekop, 2008).

The chemical structure of penicillin V potassium is as shown by Fig. 7. From the structure, it can be stated that the inhibition ability of this compound is largely contributed by the presence of nitrogen and sulphur in their aromatic/cyclic structure. These atoms tend to enhance the electron donation ability of the inhibitor. The compound also contained amino and carbonyl functional groups. We therefore proposed that the mechanism of adsorption of penicillin V potassium (hence its inhibition efficiency) is due to the donation of electron by the molecule of penicillin V potassium to a vacant d-orbital of Fe in mild steel (Fig. 8). The formation of Fe-penicillin V potassium complex thereby stabilized the mild steel and prevent it against further corrosion attack.

Table 4: Values of Langmuir, Frumkin and Freundlich adsorption parameters

	Temperature (K)	Slope	logK	R^2	ΔG_{ads} (KJ/mol)
Langmuir	303	0.5748	0.9978	0.9554	-15.9085
	333	0.7477	0.8810	0.9557	-16.7389
	Temperature (K)	α	logK	R^2	ΔG_{ads} (KJ/mol)
Frumkin	303	2.0121	3.7917	2.2141	-22.9650
	333	2.2984	0.9869	0.8818	-25.7762

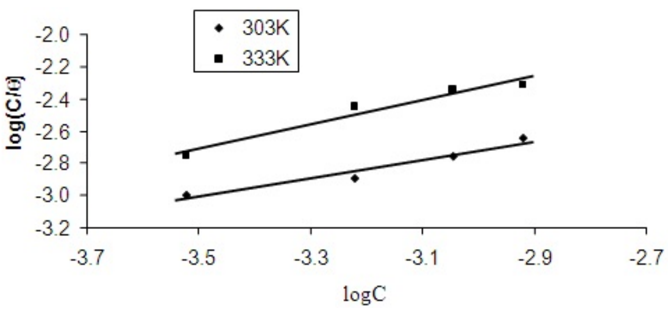

Fig. 5: Langmuir isotherm for the adsorption of penicillin V potassium on mild steel sueface.

Conclusion

From the results and findings of the study, the following conclusions were drawn,

- Penicillin V potassium is a good inhibitor for the corrosion of mild steel in H_2SO_4.
- The adsorption of the inhibitor on mild steel surface is exothermic, spontaneous and is consistent with the mechanism of physical adsorption. Langmuir and Frumkin isotherms best described the adsorption characteristics of the inhibitor.

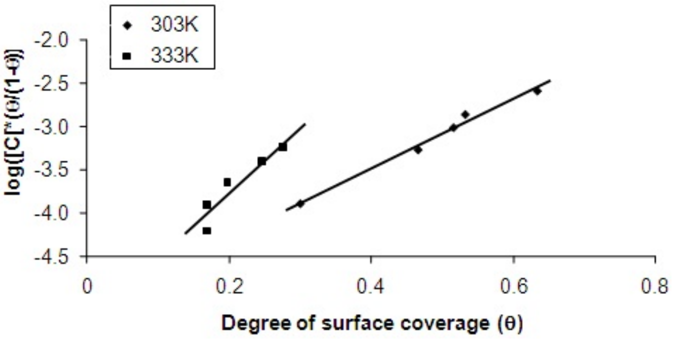

Fig. 6: Frumkin isotherm for the adsorption of penicillin V potassium on mild steel surface.

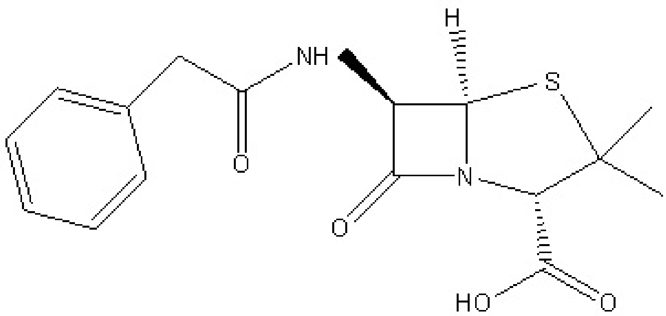

Fig. 7: Chemical structure of penicillin V potassium.

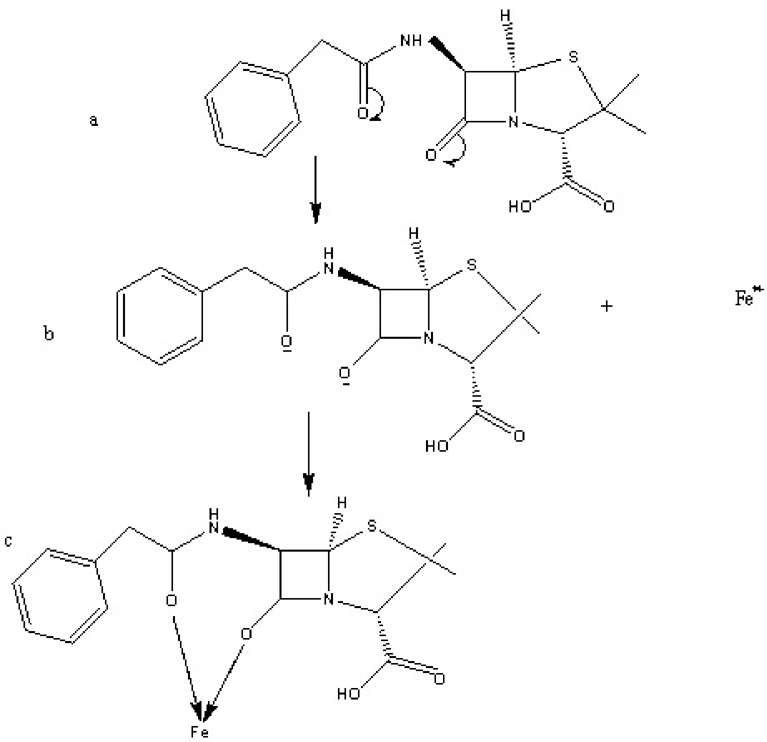

Fig. 8: Mechanism of adsorption of penicillin V potassium on Fe on mild steel surface.

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References

Abdallah, M., 2002. Rhodanine azosulpha drugs as corrosion inhibitors for corrosion of 304 stainless steel in HCl solution. Corrosion Sc. 44: 717-728.

Abdallah, M., 2004a. Guar gum as corrosion inhibitor for carbon steel in sulphuric acid solutions" Portugaliae Electrochimica. Acta, 22: 161-175.

Abdallah, M., 2004b. Antibacterial drugs as corrosion inhibitors for corrosion of aluminium in HCl solution. Corrosion Sc. 46: 1981-1996.

Abiola, O.K., N.C. Oforka, E.E. Ebenso, and N.M. Nwinuka, 2007. Eco - friendly corrosion inhibitors: Inhibitive action of *Delonix regia* extract for the corrosion of aluminium in acidic medium. Anti-Corrosion Methods &Materials, 54(4): 219-224.

Abiola, K.O., N.C. Oforka, and E.E. Ebenso, 2004. Inhibition of mild steel corrosion in an acidic medium by fruit juice of citrus paradisi. JCSE. 5(10): 1-8.

Acharya, S., and S.N. Upadhyay, 2004. The inhibition of corrosion of mild steel by some flouroquinolones in sodium chloride solution. Trans. Indian Inst. Met. 57(3): 297-306.

Agrawal, Y.K., J.D. Talati, M.D. Shah, M.N Desai, and N.K Shah, 2003. Schiff bases of ethylenediamine as corrosion inhibitors of zinc in sulphuric acid. Corrosion Sciences 46: 633-651.

Arora, P., S. Kumar, M.K. Sharma, and S.P. Mathur, 2007. Corrosion inhibition by capparis deciduas in acidic media. E.J. Chem. 4(4): 450-456.

Ashassi-sorkhabi, H., B. Shaabani, B. Aligholipour, and D. Seifzadeh, 2006. The effect of soe Schiff bases on the corrosion of aluminium in HCl solution. Appl. Surf. Sc. 252: 4039-4047.

Ashassi-Sorkhabi, H., and N. Ghalebsaz-Jeddi, 2005. Inhibition effect of polythylene glycol on the corrosion of carbon steel in sulphuric acid. Mat. Chem. & Phys. 480-486.

Awad, M.I., 2006. Ecofriendly corrosion Inhibitors: Inhibitive action of quinine for corrosion of low carbon steel in 1M HCl", J. Appl. Electrochem., 36: 1163-1168.

Babi-Samardzija, K., K.E. Khaled, and N. Hackerman, 2005. N-heterocyclic amines and derivatives as corrosion inhibitors for iron in perchloric acid. Anti-Corrosion methods and mat., 52(1): 11-21.

Bendahou, M.A., M.B.E. Benadellah, and B.B. Hammouti, 2006. A study of rosemary oil as a green corrosion inhibitor for steel in 2M H_3PO_4. Pigment and Resin Technol. 35(2): 95-100.

Bouyanzer, A., and B. Hammouti, 2004. A Study of anti-corrosion effects of Artemisia oil on steel. Pigment and Resin Tech.,33(5): 287-292.

Ebenso, E.E., 2004. Effect of methyl red and halide ions on the corrosion of aluminium in H_2SO_4. Part 2, Bull. Electrochem. 12: 551-559.

Ebenso, E.E., 2003. Effect of halide ions on the corrrosion inhibition of mild steel in H_2SO_4 using methyl red-Part 1. Bull. Of Electrochem. 19(5): 209-216.

Ebenso, E.E., and E.E. Oguzie, 2005. Corrosion inhibition of mild steel in acidic media by some organic dyes. Mat. Letters, 59: 2163- 2165.

Ebenso, E.E., U.J. Ekpe, S.A. Umoren, E. Jackson, O.K. Abiola, and N.C. Oforka, 2005. Synergistic effect of halides ions on the corrosion inhibition of aluminium in acidic medium by some polymers, J. of Appl. Polymer Sci. 100: 2889-2894.

Eddy, N.O., and Ebenso, 2008. Adsorption and inhibitive properties of ethanol extracts of *Musa sapientum* peels as a green corrosion inhibitor for mild steel in H_2SO_4, African J. Pure & Appl. Chem., 2(6): 046-054.

Eddy, N.O., and A.S. Ekop, 2008. Inhibition of corrosion of zinc in 0.1M H_2SO_4 by 5-amino-1-cyclopropyl-7-[(3r,5s)-dimethylpiperazin-1-yl]-6,8-difluoro-4-oxo-quinoline-2-carboxylic acid. J. Mater. Sci., 4(1): 10-16.

Eddy, N.O., and S.A. Odoemelam, 2008a. Effect of pyridoxal hydro-chloride-2,4-dinitrophenyl hydrazone on the corrosion of mild steel in HCl. J. Surface Sci. Technol., 24(1-2): 1-14.

Eddy, N.O., and S.A. Odoemelam, 2008b. Norfloxacin and sparfloxacin as corrosion inhibitors for zinc. Effect of concentrations and temperature. J. Mat. Sci. 4: 87-96.

Elayyoubi, S.B., S. Hammouti, H.O. Kertit, and E.B. Maarouf, 2004. Corrosion inhibition of mild steel in hydrochloric acid solutions by malonitrile compounds. Rev. Met. Paris, 2: 153-157.

Emregul, K.C., E. Duzgun, and O. Atakiol, 2006. The application of some polydentate shiff base compounds containing aminic nitrogens as corrosion inhibitors for mild steel in acidic media. Corrosion Sci,. 48: 3243-3260.

Emregul, K.C., A.A. Akay, and O. Atakol, 2005a. The corrosion inhibition of steel with schiff base compounds in 2M HCl. Mat. Chem. & Phys., 93: 325-329.

Emergull, K.C., E. Duzgun, and O. Atakol, 2005b. The application of some polydentate Schiff base compounds containing aminic nitrogen as corrosion inhibitors fro mild steel in acidic media. Corrosion Sc. 48: 3243-3260.

Oguzie, E.E., 2007. Corrosion Inhibition of aluminum in acidic and alkaline media on *Sanseviera trifasciata* extract. Corros. Sci., 49: 1527-1539.

Oguzie, E.E., 2006a. Studies on the inhibition effect of *Occinum vivridis* extract on acid corrosion of mild steel". Mater. Chem. Phys., 99(2-3): 441-446.

Okafor, P.C., M.I. Ikpi, I.E. Uwah, E.E. Ebenso, U.J Ekpe, and S.A. Umoren, 2008. Inhibitory action of *Phyllanthus amarus* on the corrosion of mild steel in acidic medium. Corros. Sci. doi:10.1016/j. corsci. 2008. 05.009.

Okafor, P.C., V. Osabor, and E.E. Ebenso, 2007a. Eco friendly corrosion inhibitors: Inhibitive action of ethanol extracts of *Garcinia Kola* for the corrosion of aluminium in acidic medium. Pigment and Resin Technol., 36(5): 299-305.

Okafor, P.C., and E.E. Ebenso, 2007b.Inhibitive action of *Carica papaya* extracts on the corrosion of mild steel in acidic media and their adsorption characteristics. Pigment and Resin Technol., 36(3): 134-140.

Rajappa, K.S., and T.V. Venkatesha, 2002. Inhibition studies of a few organic compounds and their condensation products on the corrosion of zinc in hydrochloric acid medium. Turk. J. Chem. 27: 189-196.

Rajendran, S., S.V. Ganga, J. Arockiaselvi, and A.J. Amalraj, 2005. Corrosion inhibition by plant extracts- An overview", Bulletin of Electrochem. 21(8): 367-377.

Sheatty, D.S., P. Shetty, and H.V.S. Nayak, 2006. Inhibition of mild steel corrosion in acidic medium by N-(2-thiophenyl)-N-phenyl thiourea. J. Chidean Chem. Soc., 51(2): 849-853.