



Inhibition of the Corrosion of Aluminium in 0.1 M HCl by Ethanol Extract of Mango Peel Waste (EMPW)

Richard A. Ukpe, Steven A. Odoemelam, Anduang O. Odiongenyi and Nnabuk Okon Eddy*

Department of Chemistry, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria.

*Corresponding author: Nnabuk Okon Eddy, E-mail: nabukeddy@yahoo.com

Received: November 2, 2014, Accepted: December 5, 2014, Published: December 5, 2014.

ABSTRACT

This study was conducted to investigate the effectiveness of ethanol extract of mango peel waste for the inhibition of the corrosion of aluminium in solution of HCl using weight loss and gasometric methods. The results obtained indicated that ethanol extract of mango peel waste displayed average inhibition potential for the corrosion of aluminium in solution of HCl. The inhibited corrosion reaction supported a first order kinetic while its adsorption was exothermic, spontaneous and consistent with the mechanism of physisorption. The adsorption behaviour of the inhibitor was best described by the Langmuir, Temkin, Elawady et al and Dubinin-Raduskevich adsorption models.

Keyword: Corrosion, aluminium, inhibition, mango peel waste

INTRODUCTION

One of the major challenges facing actualization of a friendly environment is waste management. Indeed green approach, resource recovery and recycling have gained wider attention in environmental science [1]. Domestic waste is constantly generated in Nigeria by homes and even factory. Most often, disposal creates a major problem in most environments (especially, residential environment). Waste management is the generation, prevention, characterization, monitoring, treatment, handling, reuse and residual disposition of solid wastes. Resource recovery is the selective extraction of disposed materials for a specific next use, such as recycling, composting or energy generation. The aim of the resource recovery is to extract the maximum practical benefits from products, delay the consumption of virgin natural resources, and to generate the minimum amount of waste.

Few studies have been conducted on the corrosion inhibition potentials of some plant waste. Salami *et al.* [2] found that acid extract of *Musa sapientum* peels is a good corrosion inhibitor for mild steel in acidic medium. Similar findings had been reported by Eddy and Ebenso [3] for mild steel in solution of HCl. In both cases, the extract was found to be adsorption inhibitor, which functions through the mechanism of physical adsorption. An aqueous extract of *Musa accuminata* was used as an inhibitor for the corrosion of carbon steel by Sangeetha *et al.* [4]. The extract was found to exhibit excellent inhibition efficiency (IE) of 98% for Zn^{2+} (at 15 ppm) by the weight loss method and its potential was attributed to the presence of bananadine

[(3Z,7Z,10Z)-1-oxa-6-azacyclododeca-3,7,10-triene] in the extract. The protective film of the metal was analysed using Atomic Force Microscopic (AFM) and FTIR spectroscopic

techniques and the existent nature of the film were confirmed by using potentiodynamic polarization and AC impedance techniques. Polarization study revealed that this system functions as mixed type of inhibitor.

In view of the above, the present study is aimed at investigating the corrosion inhibition potential of mango peel waste for aluminium in 0.1 M HCl using weight loss and gasometric methods.

MATERIAL AND METHODS

Materials

Aluminium sheet (AA 1060 type) of 98.5% purity was used in this study. Acid solutions of 0.1 M HCl was prepared by diluting analytical grade with distilled water. Ethanol extract of mango waste was obtained by extracting dried sample of mango peel waste using a cold extractor. Serially diluted concentration of the extract (0.1 to 0.5 g per liter of the blank solution) was prepared and preserved for used.

Weight loss measurement

Weight loss measurements were carried out in accordance with an earlier report [5]. Tests were conducted under total immersion conditions in 150 mL of the aerated and unstirred test solutions. Immersion time varied from 1 to 7 days (168 hrs) in 0.1 M HCl. The coupons were retrieved from test solutions after every 24 hrs, appropriately cleaned, dried and re-weighed. The weight loss was taken to be the difference between the weight of the coupons at a given time and its initial weight. The effect of temperature on corrosion inhibition of aluminium was investigated by performing experiments at 303, 313, 323 and 333 K. All tests were run in triplicates and from the results of the weight loss experiment, percentage inhibition efficiency,

degree of surface coverage and corrosion rate of aluminium were calculated using equation 1 to 3 respectively [6-7],

$$\%I = \frac{w_1 - w_2}{w_1} \times 100 \quad 1$$

$$\theta = \left[1 - \frac{w_1}{w_2} \right] \quad 2$$

$$CR = \frac{w_1 - w_2}{At} \quad 3$$

where w_1 and w_2 are the weight losses of mild steel (in grams) in the absence and presence of the inhibitor respectively. θ is the degree of surface coverage of the inhibitor, CR is the corrosion rate of mild steel, A is the surface area of the mild steel coupon in cm^2 and t is the period of immersion in hours.

Gasometric method

In gasometric experiment, the test solution (was poured into the reaction vessel. Upon the introduction of mild steel, the flask was quickly corked and the rise in volume of the paraffin due to hydrogen evolution was noted after every minute until a steady volume was observed. Inhibition efficiency was calculated as quotient of the difference between volume of hydrogen evolved (by the blank and that of the test solution) to the volume of hydrogen evolved by the blank. From the gasometry method, the inhibition efficiency was evaluated using equation 4 [8]

$$\%IE = \left(1 - \frac{v_{H_2}^t}{v_{H_2}^0} \right) \times 100 \quad 4$$

where $v_{H_2}^t$ is the volume of hydrogen evolved at time t for solution with inhibitor, $v_{H_2}^0$ is the volume of hydrogen evolved at time t for solution without inhibitor.

FTIR analysis

FTIR analysis of EMPW was carried out using Scimadzu FTIR-8400S Fourier transform infra-red spectrophotometer.

The sample was prepared in KBr and the analysis was carried out by scanning the sample through a wave number range of 400 to 4000cm^{-1} .

RESULTS AND DISCUSSIONS

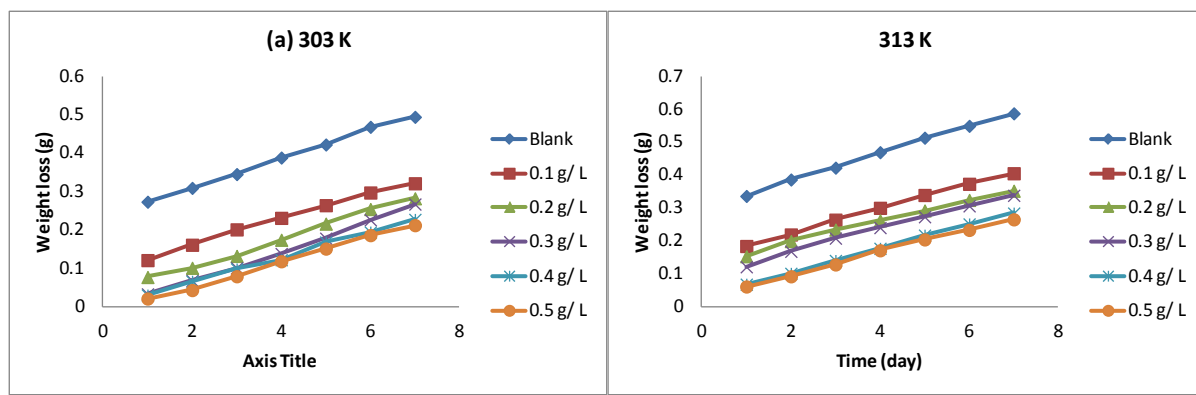
Weight loss measurement

Fig. 1 shows plots for the variation of weight loss with time for the corrosion of aluminium in 0.1 M HCl containing various concentrations of EMPW at 303 to 333 K. The plots reveal that weight loss of aluminium increases with increase in the period of contact but decreases with increase in the concentration of EMPW. It is also obvious from the plots that in the presence of EMPW, weight loss of aluminium are lower than that of the blank. From the above trends, it is evident that the rate of corrosion of aluminium in solution of HCl increases with increase in the period of contact and that EMPW retarded the corrosion of aluminium in solution of HCl.

In order to establish the effect of temperature on the corrosion of aluminium, weight loss experiment were also conducted at different temperatures (303 to 333 K) and the results obtained are also represented in Fig. 1. A close examination of the plots revealed that the rate of corrosion of aluminium progressively increases with increase in temperature. Equations 1 and 2 were used to calculate the corrosion rate of aluminium and inhibition efficiency of EMPW at various system compositions and the results obtained are presented in Table 1. The results show at a glance that the corrosion rate of aluminium increases with increase in temperature but decreases with increase in the concentration of EMPW. On the other hand, inhibition efficiency of EMPW is seen to decrease with increase in temperature but increased with increasing concentration, indicating that EMPW is an adsorption inhibitor for the corrosion of aluminium in acidic medium and that the adsorption of the inhibitor on the surface of aluminium favours the mechanism of physical adsorption [9].

Table 1: Corrosion rate of aluminium and inhibition efficiency of EMPW in solutions of HCl at 303 to 333 K

C (g/L)	Corrosion rate x 0.0001 (g/cm ² h)				Inhibition efficiency (%)			
	303K	313K	323K	333K	303K	313K	323K	333K
Blank	14.70	17.47	20.71	23.15	-	-	-	-
0.1	9.55	12.05	15.42	17.68	35.02	31.01	25.57	23.65
0.2	8.39	10.48	14.49	16.40	42.91	40.03	30.03	29.18
0.3	7.95	10.06	13.18	15.12	45.95	42.42	36.35	34.70
0.4	6.76	8.45	10.68	12.95	54.05	51.62	48.42	44.09
0.5	6.31	7.89	9.70	12.20	57.09	54.86	53.16	47.30



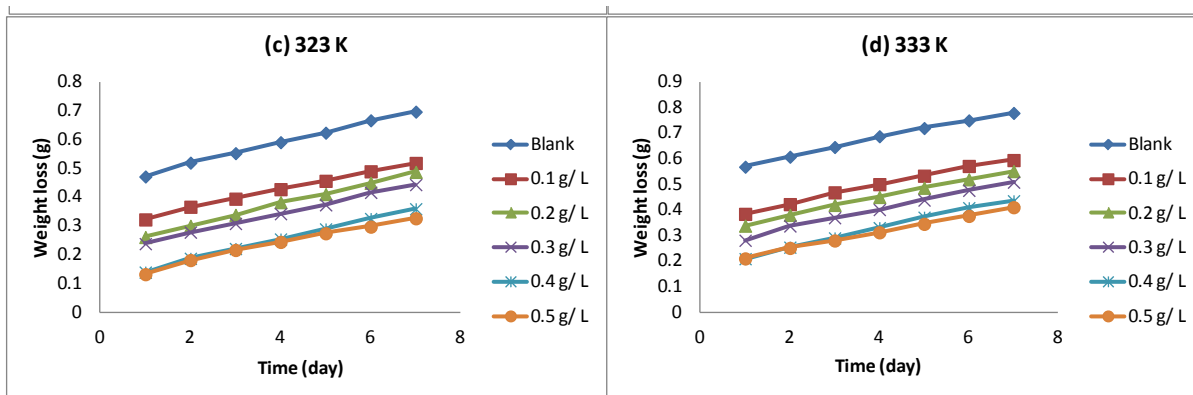


Fig. 1: Variation of weight loss with time for the corrosion of aluminium in 0.1 M HCl containing various concentrations of EMPW

Table 2: Kinetic parameters for the inhibition of the corrosion of aluminium in 0.1 M HCl by MPW

System	Slope	K_1	$t_{1/2}$ (day)	R^2
Blank (0.1 M HCl)	0.0436	0.1004	2.00	0.9904
0.1 g/L MPW at 303 K	0.0686	0.1580	2.20	0.9377
0.2 g/L MPW at 303 K	0.0966	0.2225	2.10	0.9780
0.3 g/L MPW at 303 K	0.1433	0.3300	3.10	0.9431
0.4 g/L MPW at 303 K	0.1360	0.3132	4.40	0.9157
0.5 g/L MPW at 303 K	0.1631	0.3756	7.00	0.9218
Blank (0.1 M HCl)	0.0399	0.0919	2.90	0.9866
0.1 g/L MPW at 313 K	0.0571	0.1315	4.00	0.9788
0.2 g/L MPW at 313 K	0.0573	0.1320	4.30	0.9060
0.3 g/L MPW at 313 K	0.0706	0.1626	5.20	0.9516
0.4 g/L MPW at 313 K	0.1016	0.2340	5.30	0.9589
0.5 g/L MPW at 313 K	0.1044	0.2404	8.00	0.9508
Blank (0.1 M HCl)	0.0278	0.0640	3.00	0.9907
0.1 g/L MPW at 323 K	0.0334	0.0769	4.90	0.9857
0.2 g/L MPW at 323 K	0.0445	0.1025	4.50	0.9872
0.3 g/L MPW at 323 K	0.0444	0.1023	6.80	0.9891
0.4 g/L MPW at 323 K	0.0655	0.1508	9.00	0.9660
0.5 g/L MPW at 323 K	0.0611	0.1407	10.80	0.9387
Blank (0.1 M HCl)	0.0228	0.0525	4.40	0.9880
0.1 g/L MPW at 333 K	0.0317	0.0730	5.70	0.9827
0.2 g/L MPW at 333 K	0.0347	0.0799	7.40	0.9865
0.3 g/L MPW at 333 K	0.0409	0.0942	9.70	0.9758
0.4 g/L MPW at 333 K	0.0526	0.1211	9.50	0.9779
0.5 g/L MPW at 333 K	0.0469	0.1080	13.20	0.9851

Table 3: Arrhenius parameters for the inhibition of the corrosion of aluminium by MPW

System	Slope	Intercept	E_a (J/mol)	A	R^2
Blank	1.5368	-3.7408	12.78	0.023735	0.9914
0.1 g/L MPW	2.0922	-2.333	17.39	9.7E-05	0.9867
0.2 g/L MPW	2.3335	-1.675	19.40	0.000187	0.9749

0.3 g/L MPW	2.1922	-2.1872	18.23	0.000112	0.9834
0.4 g/L MPW	2.1747	-2.4195	18.08	8.9E-05	0.9978
0.5 g/L MPW	2.1844	-2.4616	18.16	8.53E-05	0.9996

Table 4: Thermodynamic parameters for the adsorption of various concentration of MPW on aluminium surface

System	Slope	Intercept	$\Delta H_{ads}^0 (\frac{J}{mol})$	$\Delta S_{ads}^0 (\frac{J}{mol})$	R ²
Blank (0.1 M HCl)	1.2222	-10.4930	-10.16	136.41	0.9873
0.1 g/L MPW at 303 K	1.7776	-9.0856	-14.78	148.11	0.9823
0.2 g/L MPW at 303 K	2.0188	-8.4276	-16.78	153.58	0.9672
0.3 g/L MPW at 303 K	1.8776	-8.9399	-15.61	149.32	0.9781
0.4 g/L MPW at 303 K	1.8600	-9.1722	-15.46	147.39	0.9972
0.5 g/L MPW at 303 K	1.8698	-9.2143	-15.55	147.04	0.9995

Gasometric measurement

Fig.2 shows plots for the variation of volume of hydrogen gas evolved during the corrosion of aluminium in 0.1 M HCl, in the absence and presence of various concentrations of EMPW. From the plots, it can be seen that the volume of hydrogen gas evolved for the blank was higher than those evolved by solutions containing EMPW hence EMPW inhibited the corrosion of aluminium in solution of HCl. Inhibition efficiencies calculated for 0.1, 0.2, 0.3, 0.4 and 0.5 g/L of the inhibitor in 0.1 M HCl were 40.65, 60.94, 64.33, 74.40 and 75.33 % respectively. These values are higher than those obtained from weight loss measurement, indicating that the instantaneous inhibition efficiency of EMPW for the corrosion of aluminium in acidic medium is better than its average inhibition efficiency (measured from weight loss experiment). However, it is worth nothing that the two set of data correlated excellently.

Kinetic considerations

The corrosion of aluminium in 0.1 M HCl was found to fit a first order kinetic, which is common to most corrosion reaction (equation 5)[10]:

$$-\log(\text{weight loss}) = \frac{k_1 t}{2.303} \quad 5$$

where t is the period of immersion and k₁ is the first order rate constant, which is related to half life (t_{1/2}) as follows, t_{1/2} = 0.693/k₁). Using equation 5, values of -log(weight loss) were plotted against t as shown in Fig. 3. Values of k₁ and t_{1/2} estimated from the slope of the plots are presented in Table 2. The results obtained revealed that EMPW extended the half life of aluminium in 0.1 M HCl.

Effect of temperature

The effect of temperature on the inhibited and uninhibited corrosion of aluminium in solution of HCl was investigated using the Arrhenius equation, which can be written as follows [11]

$$CR = A \exp\left(\frac{-E_a}{RT}\right) \quad 5$$

where CR is the corrosion rate of mild steel, A is the Arrhenius or pre-exponential constant, E_a is the activation energy, R is the

gas constant and T is the temperature. By taking the natural logarithm of equation 5, equation 6 was obtained:

$$\ln(CR) = \ln A - \frac{E_a}{RT} \quad 6$$

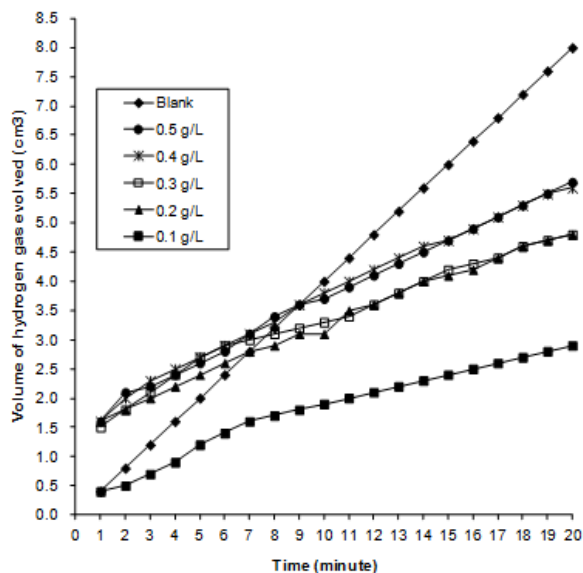


Fig 2 variation of volume of hydrogen gas evolved with time during the inhibition of the corrosion of AL in 0.1 HCL by various concentration of MP at 303K

The significant of equation 6 is that a plot of ln(CR) versus 1/T should be linear with slope and intercept equal to E_a/R and lnA respectively. Fig. 4a present the Arrhenius plots for the corrosion of aluminium in solution of HCl containing various concentrations of EMPW while Table 3 present Arrhenius parameters deduced from the plots. From the results obtained, it can be seen that excellent correlations were obtained for all the plots (R² ranged from 0.9749 to 0.9996) indicating that the data fitted the Arrhenius model. The activation energies for the inhibited systems were found to ranged from 17.39 to 19.40 J/mol while that of the blank was 12.78 J/mol. Since E_a value for the blank is lower than those calculated for the inhibited system, it can be stated that EMPW retarded the corrosion of aluminium in solution of HCl.

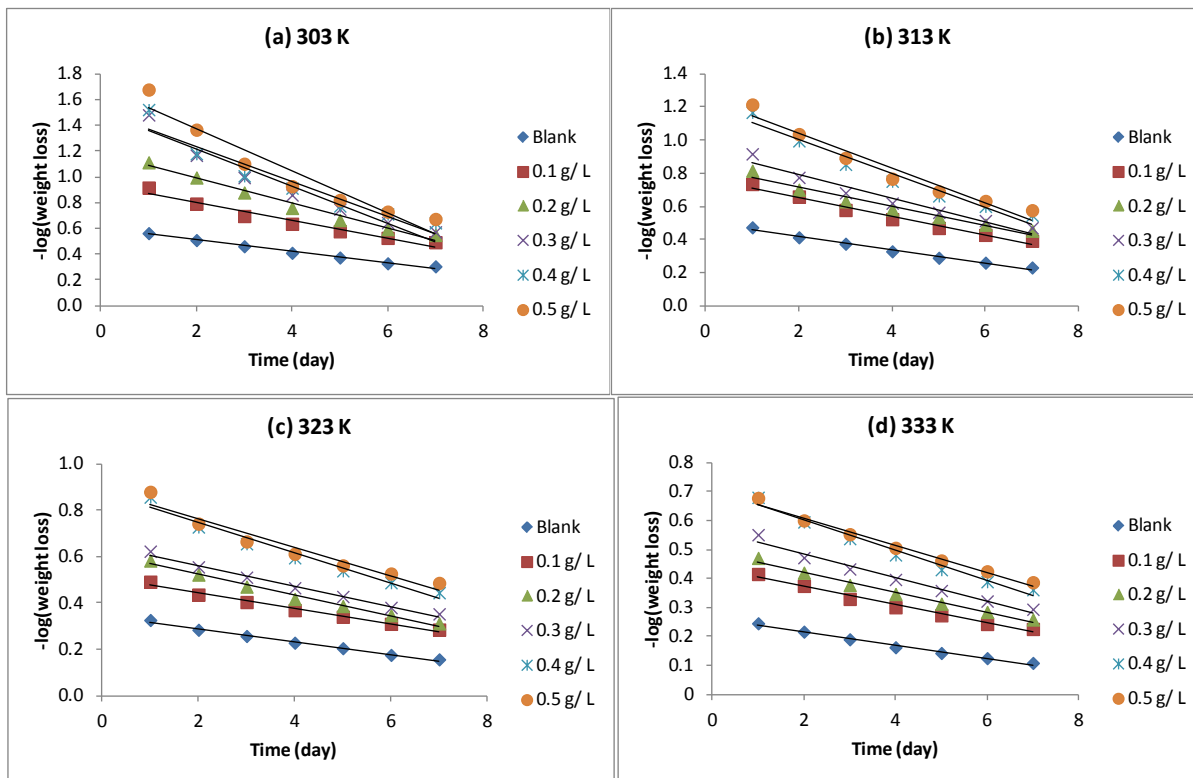


Fig. 3: Variation of $-\log(\text{weight loss})$ with time for the corrosion of aluminium in 0.1 M containing various concentrations of EMPW

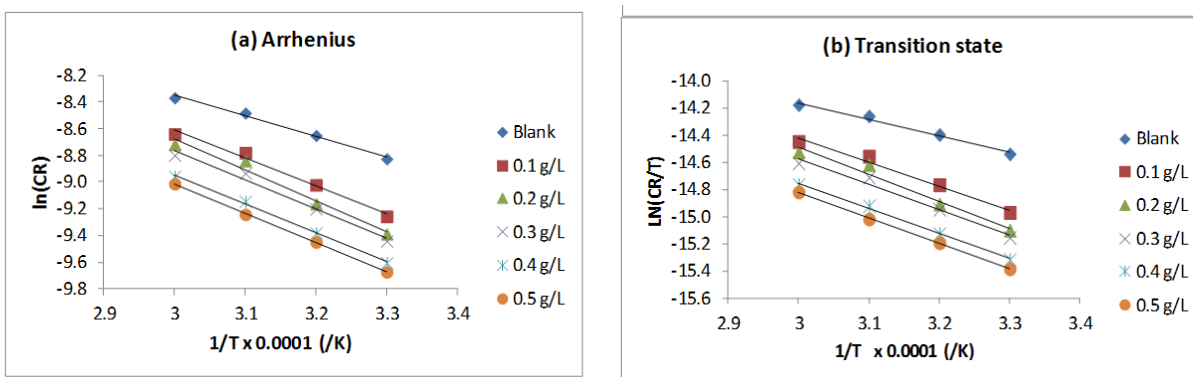


Fig. 4: Arrhenius and Transition state plots for the corrosion of aluminium in 0.1 M HCl containing various concentrations of EMPW

Table 5: Adsorption parameters deduced from Temkin, Freundlich, El awardy et al and Dubinin Raduskevich isotherms

Temkin parameters						
T (K)	Slope	Intercept	a	logb	$\Delta G_{ads}^0 \left(\frac{J}{mol} \right)$	R^2
303	0.3136	0.6533	3.67	0.0890	-10.64	0.9580
313	0.3365	0.6365	3.42	0.0930	-11.01	0.9507
323	0.4009	0.6213	2.87	0.1082	-11.46	0.8798
333	0.3461	0.5600	3.33	0.0842	-11.66	0.9271
Langmuir						
T (K)	$\ln b_{ads}$	slope		$\Delta G_{ads}^0 \left(\frac{J}{mol} \right)$	R^2	
303	0.3623	0.6971		-9.02	0.9957	
313	0.3689	0.6489		-9.34	0.9916	
323	0.356	0.5308		-9.60	0.9418	

333	0.4625	0.5558	-10.19	0.9773	
El awardy et al					
T (K)	slope	intercept	1/y	B	R ²
303	0.3372	0.2718	2.965599	1.235001	0.9620
313	0.6093	0.2474	1.641228	1.415038	0.9579
323	0.757	0.2328	1.321004	1.500588	0.9005
333	0.6778	0.1322	1.475361	1.229196	0.9474
Dubnin Raduskevich					
T (K)	'a'	lnx	x	E (J/mol)	R ²
303	0.0003	-0.4837	0.616498	40.82	0.9332
313	0.0003	-0.5086	0.601337	40.82	0.9337
323	0.0004	-0.5559	0.573556	35.36	0.8380
333	0.0004	-0.6456	0.524348	35.36	0.8990

Generally, values of E_a lower than 80 kJ/mol are associated with the mechanism of physical adsorption while those that range from 80 kJ/mol and above are consistent with the mechanism of chemical adsorption [12]. Therefore, the adsorption of EMPW on the surface of aluminium is consistent with the mechanism of physical adsorption.

Thermodynamic/adsorption considerations

Thermodynamic parameters for the adsorption of EMPW on aluminium surface were calculated using the Transition state equation (equation 7)[13]

$$CR = \frac{RT}{Nh} \exp\left(\frac{\Delta S_{ads}^0}{R}\right) \exp\left(\frac{-\Delta H_{ads}^0}{RT}\right) \quad 7$$

where CR is the corrosion rate of aluminium in solution of HCl, R is the gas constant, T is the temperature, N is the Avogadro's constant, h is the Planck constant, ΔS_{ads}^0 is the standard entropy of adsorption and ΔH_{ads}^0 is the standard enthalpy of adsorption. From the logarithm of equation 7 and upon rearrangement, equation 8 was obtained.

$$\ln\left(\frac{CR}{T}\right) = \ln\left(\frac{R}{Nh}\right) + \frac{\Delta S_{ads}^0}{R} - \frac{\Delta H_{ads}^0}{RT} \quad 8$$

The significant of equation 8 is that a plot of $\ln(CR/T)$ versus $\frac{\Delta H_{ads}^0}{R}$ should be linear with slope and intercept equal to

and $\ln\left(\frac{R}{Nh}\right) + \frac{\Delta S_{ads}^0}{R}$ respectively. Fig. 4b presents the Transition state plots for the corrosion of aluminium in solution of HCl containing various concentrations of EMPW. Parameters deduced from slopes and intercepts of the plots are presented in Table 4. The results presented, reveal that the adsorption of EMPW proceeded with low and negative values of ΔH_{ads}^0 indicating that the adsorption is exothermic and that it favours physical adsorption. On the other hand, positive values of ΔS_{ads}^0 should normally point toward increasing degree of disorderliness but since other data confirm the ease of adsorption of the inhibitor, it can be stated that the adsorption is probably activation and enthalpy controlled.

Several adsorption models were tested for the fitness of the present data and it was found that Langmuir, Temkin, El awardy et al and Dubinin-Raduskevich isotherms can be used

to explain the adsorption behaviour of EMPW on the surface of aluminium. The Langmuir adsorption model can be represented as follows [14]

$$\log\left(\frac{C}{\theta}\right) = \log C - \log b_{ads} \quad 9$$

where C is the concentration of the inhibitor, θ is the degree of surface coverage and b_{ads} is the adsorption equilibrium constant. Plots of $\log(C/\theta)$ versus $\log C$ (Fig. 5a) gave straight lines with excellent degree of linearity, which indicate that the data fitted the Langmuir adsorption model (Table 5). However, slope values were below unity, as expected from the expression of equation 9. Therefore, there is interaction between the inhibitor and the adsorbent and in order to compensate for this interaction, other isotherms that accounts for molecular interaction were tested and the tests revealed that Temkin isotherm best fitted the adsorption of EMPW on the surface of aluminium. The Temkin adsorption model is given by the following expression [15]

$$\exp(-2a\theta) = b_{ads} C \quad 10$$

where 'a' is the molecular interaction parameter, b_{ads} is the equilibrium constant of adsorption and C is the concentration of the inhibitor in the electrolyte. Taking the natural logarithm of both sides of equation 10 yields equation 11 upon rearrangement:

$$\theta = \frac{-\ln b_{ads}}{2a} - \frac{\ln C}{2a} \quad 11$$

According to Temkin adsorption model, a plot of θ versus $\ln C$ should be linear with slope equal to $-1/2a$ while the intercept should be equal to $-\ln b_{ads}/2a$. Fig. 5b shows Temkin isotherm for the adsorption of EMPW on the surface of aluminium. Adsorption parameters deduced from the plots are also presented in Table 5. The results presented indicated that the molecular interaction parameter at all concentrations are positive, hence there is attractive behaviour of the inhibitor [16].

The significant of the equilibrium constant of adsorption, contained in the Langmuir and Temkin isotherms is that it is related to the standard free energy of adsorption according to equation 11 [17]

$$\Delta G_{ads}^0 = -RT \ln b_{ads} \quad 12$$

Calculated values of the standard free energy are presented in Table 5. The results obtained were in the ranges of -9.02 to -10.19 kJ/mol and -10.64 to -11.66 kJ/mol for the Langmuir

and Temkin models respectively. From the results obtained, the adsorption of the inhibitor is spontaneous and is consistent with the mechanism of physical adsorption.

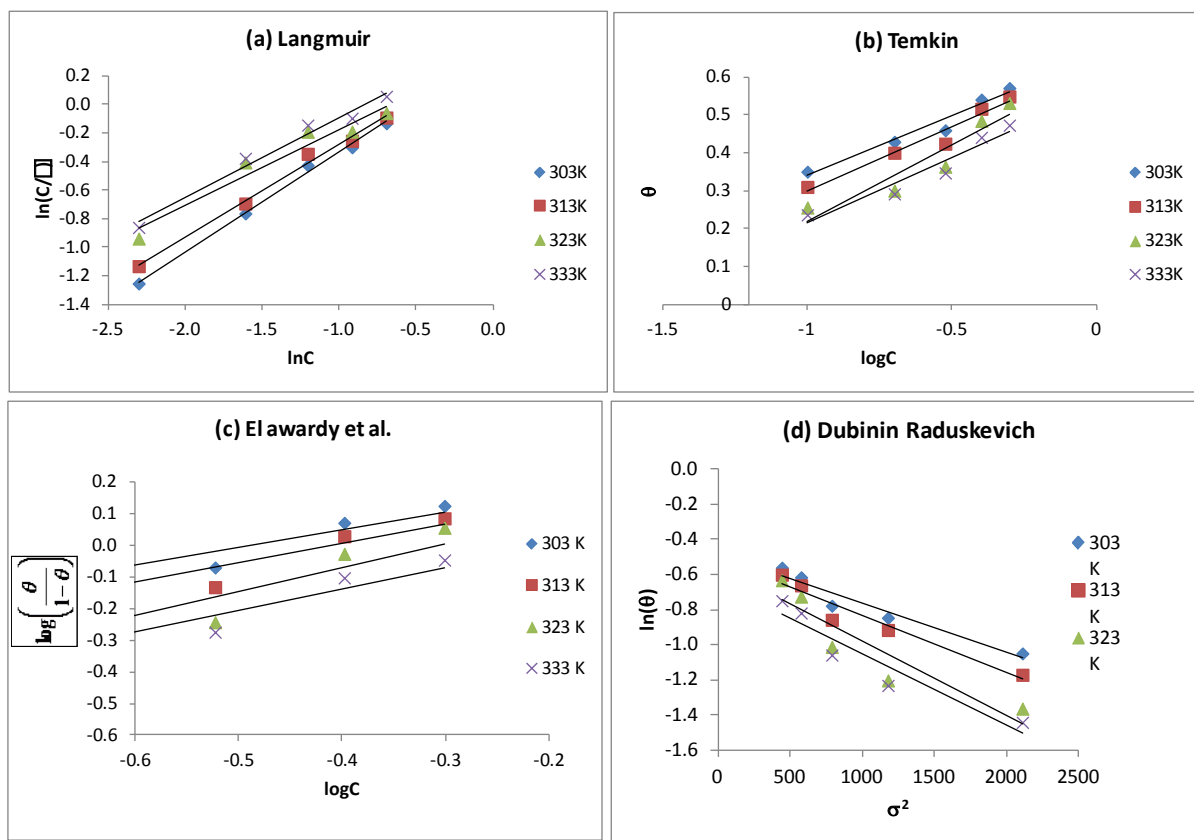


Fig. 5: Various isotherms ((a) Langmuir (b) Temkin (c) El awardy et al. (d) Dubinin Raduskevich)) for the adsorption of EMPW on the surface of aluminium

Table 6: Frequencies and intensity of IR absorption by MPW for various assigned functional groups

Frequency (cm ⁻¹)	Intensity	Functional group
531.41	46.806502	C-X stretch
602.77	46.757903	C-X stretch
1037.74	30.051427	C-H wag
1246.06	46.414943	C-O stretch
1364.68	44.679529	C-H rock
1423.51	44.562837	C-C stretch
1644.37	38.921846	-C=C- stretch
2922.25	32.823036	C-H stretch
3380.36	22.485641	NH stretch
3495.13	24.87124	OH stretch

El awardy et al adsorption model is informative because it can be used to investigate the strength of adsorption and the possibility of formation of multiloecular layer of adsorption [18]. The model relates the degree of surface coverage with concentration according to equation 12

$$\log\left(\frac{\theta}{1-\theta}\right) = \log b' + y \log C \quad 13$$

where y is the number of inhibitor molecules occupying one active site and 1/y represents the number of active sites on the surface occupied by one molecule of the inhibitor. 'y' is related

to the binding constant, B through $B = b' \left(\frac{1}{y}\right)$. The major significant of this model is that if the value of 1/y is greater than unity, then the existence of multimolecular layer of adsorption is upheld. On the other hand, the higher the value of B, the better the strength of adsorption. Fig. 5c presents El awardy *et al.* isotherm for the adsorption of EMPW on the surface of aluminium while values of B, R² and 1/y calculated from slopes and intercepts of the plots are presented in Table 5. From the results obtained, there is no doubt that the adsorption data for

EMPW fitted the El awardy *et al* isotherm excellently and that existence of multimolecular layer of adsorption is confirmed. Also, the adsorption strength seems to increase with increase in temperature.

Finally, we applied Dubinin-R1 nadushkevich (D-RIM) model to confirm the mechanism of adsorption of the inhibitor. The model is best written in the form expressed by equation 13 [19]

$$\ln\theta = \ln\theta_{\max} - a\sigma^2 \quad 14$$

where θ_{\max} is the maximum surface coverage and σ is the polanyi potential and can be estimated from the following equation,

$$\sigma = RT\ln\left(1 + \frac{1}{C}\right) \quad 15$$

It follows from equation 13 that a plot of $\ln\theta$ versus σ^2 should give a straight line with slope equals to a constant, 'a'. This constant, 'a' is defined as half the square of the reciprocal of the mean adsorption energy (i.e. $a = \frac{1}{2} (1/E)^2$). It has been found that E value less than 8 kJ/mol supports the mechanism of physical adsorption but E values greater than 8 kJ/mol are consistent with the mechanism of chemisorption. Fig. 5d presents D-RIM isotherm for the adsorption EMPW on the surface of aluminium. D-RIM adsorption parameters are presented in Table 5. From the results obtained, the adsorption of EMPW on the surface of aluminium favours the mechanism of physical adsorption because values of E are less than the threshold value of 8 kJ/mol.

FTIR study

Corrosion inhibition is a process that depends on the chemical structure of the inhibitor. It has been found that most inhibitors have suitable functional groups and possess hetero atoms. Thus, FTIR analysis can be used to partially assess the suitability of a given compound as an inhibitor. In this study, we carried out FTIR analysis of EMPW and the data obtained from the spectrum are presented in Table 5.

The results obtained indicated the presence of OH stretch at 3495 cm^{-1} , NH stretch at 3380 cm^{-1} , CH stretch at 2922 cm^{-1} , C=C stretch at 1644 cm^{-1} , C-C stretch at 1423 cm^{-1} , CH rock at 1365 cm^{-1} , C-O stretch at 1246 cm^{-1} , CH wag at 1038 cm^{-1} , CX stretch at 603 and at 531 cm^{-1} . Therefore, EMPW has suitable functional groups that can enable it to act as a corrosion inhibitor.

REFERENCES

- [M. Ismail, A. S. Abdulrahman and M. S. Hussain. Solid waste as environmental benign corrosion inhibitors in acid medium. *Int J Eng Sci Tech* 3(2011) 1742-1748
- L. Salami, T. O. Y. Wewe, O. P. Akinyemi, and R. J. Patinvoh. A study of the corrosion inhibitor of mild steel in sulphuric acid using *Musa musa sapientum* peels extract. *Global Engineers and Technologist Review* 2(12)(2012) 1-6.
- N. O. Eddy, and E. E. Ebenso, E. E. Adsorption and inhibitive properties of ethanol extract of *Musa sapientum* peels as a green corrosion inhibitor for mild steel in H_2SO_4 . *African Journal of Pure and Applied Chemistry* 2(6)(2008) 1-9.
- M. Sangeetha, S. Rajendran, J. Sathiyabama, and P. Prabhakar, P. Eco-friendly extract of Banana peel as corrosion inhibitor for carbon steel in sea water. *J. Nat. Prod. Plant Resour.* 2(5)(2012) 601-610
- S. A. Mangai and S. Ravi. Comparative Corrosion Inhibition Effect of Imidazole Compounds and of *Trichodesma indicum* (Linn) R. Br. on C38 Steel in 1 M HCl Medium. *Journal of Chemistry* (2013) 1-4
- N. O. Eddy and B. I. Ita. Theoretical and experimental studies on the inhibition potentials of aromatic oxaldehydes for the corrosion of mild steel in 0.1 M HCl. *Journal of Molecular Modeling* 17(2001) 633-647.
- N. O. Eddy, U. J. Ibok, P. O. Ameh, N. O. Alobi and M. M. Sambo. Adsorption and quantum chemical studies on the inhibition of the corrosion of aluminum in HCl by *Gloriosa superba* (GS) gum. *Chemical Engineering Communications*, 201(10)(2014) 1360-1383.
- X. Li, S. Deng, H. Fu and X. Xie, X. Synergistic inhibition effects of bamboo leaf extract/major components and iodide ion on the corrosion of steel in H_3PO_4 solution. *Corrosion Science* 78 (2014) 29-42
- P. O. Ameh and N. O. Eddy. *Commiphora pedunculata* gum as a green inhibitor for the corrosion of aluminium alloy in 0.1 M HCl. *Research in Chemical Intermediates* 40(8)(2014) 2641-2649
- A. S. Fouda, and B. A. Hamdy. Aqueous extract of propolis as corrosion inhibitor for carbon steel in aqueous solutions. *African Journal of Pure and Applied Chemistry* 7(10)(2013) 350-359.
- P. B. Raja, A. A. Rahim, H. Osman and K. Awang. Inhibitive effect of *Xylopi ferruginea* extract on the corrosion of mild steel in 1M HCl medium. *International Journal of Minerals, metallurgy and materials.* 4(2011) 413-418.
- A. Hamdy and N. S. El-Gendy. Thermodynamic, adsorption and electrochemical studies for corrosion inhibition of carbon steel by henna extract in acid medium. *Egyptian Journal of Petroleum* 22 (2013) 17-25.
- E. E. Ebenso, I. B. Obot and L. C. Murulana. Quinoline and its derivatives as effective corrosion inhibitors for mild steel in acidic medium. *International Journal of Electrochemical Science* 5(2010) 1574-1586.
- R. Herle, P. Shetty, S. D. Shetty and U. A. Kin. Corrosion inhibition of 304 SS in hydrochloric acid solution by N - Furfuryl N'- Phenyl Thiourea. *Portugaliae Electrochimica Acta* 29(2 (2011), 69-78.
- S. A. Umoren, I. B. Obot, E. E. Ebenso and N. Obi-Egbedi. Studies on the inhibitive effect of exudate gum from *Dacroydes edulis* on the acid corrosion of aluminium. *Portugaliae Electrochimica Acta* 26 (2008) 199-209.
- A. S. Fouda, A. A. Nazeer, A. Y. El Khateeb and M. Fakihs, M. Cinnamon plant extract as corrosion inhibitor for steel used in waste water treatment plants and its biological effect on *Escherichia coli*. *Journal of Korean Chemical Society* 54(4)(2014) 350-364.
- N. O. Eddy, H. Momoh-Yahaya and E. E. Oguzie. Theoretical and experimental studies on the corrosion inhibition potentials of some purines for aluminum in

0.1 M HCl. Journal of Advanced Research (2014)
DOI:10.1215-14-00237-0

18. E. A. Noor. Potential of aqueous extract of Hibiscus sabdariffa leaves for inhibiting the corrosion of aluminum

in alkaline solutions. *Journal of Applied Electrochemistry*, 39(2009) 1465-1475.

Citation: Nnabuk Okon Eddy, et al.. (2014) Inhibition of the Corrosion of Aluminium in 0.1 M HCl by Ethanol Extract of Mango Peel Waste (EMPW) . J. of Bioprocessing and Chemical Engineering. V2I2. DOI: 10.15297/JBCE.V2I2.03

Copyright: © 2014 Nnabuk Okon Eddy . This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.