Gmelina arborea Root Extract as Eco-friendly Inhibitor of Mild Steel Corrosion in Acidic Medium

ABSTRACT

The inhibition of mild steel corrosion in sulphuric acid solution by *Gmelina arborea* root extract has been studied using weight loss and hydrogen evolution methods. The results obtained reveal that the extract appreciably inhibited the corrosion of mild steel in the acid medium. The inhibition efficiency increases with increase in *Gmelina arborea* root extract concentration but decreases with increase in temperature. The highest inhibition efficiency of 78.59% occurs at extract concentration of 2 g/L at 30°C by weight loss measurements. Physical adsorption has been proposed for the adsorption of *Gmelina arborea* root extract onto mild steel surface. The calculated thermodynamic parameters reveal that the adsorption process was endothermic and spontaneous. The phytochemical screening of *Gmelina arborea* root extract reveals the presence of alkaloids, saponins, anthraquinones and terpenes. The adsorption of the root extract on mid steel surface obeys the Langmuir adsorption isotherm.

1. INTRODUCTION

Pure metals and its alloys have gained extensive use in industrial and engineering applications. These metals have been deployed into various service environments which are either acidic or alkaline. Upon exposure to these aggressive environments, the metals experience weakening in their mechanical strength or complete structural failure due to corrosion [1]. Annual economic losses that result from corrosion processes is of global concern. Due to an increasing need for the use of metals for engineering infrastructure, corrosion inhibitors are sought after in order to prolong the service life of metallic components in contact with aggressive environments. Numerous organic compounds have been synthesised to tackle this problem [2-6]. These organic compounds contain nitrogen, oxygen, sulphur and/or phosphorus. Researchers nowadays do extensive work to curb the situation by using green inhibitors because the synthetic organic compounds are toxic, non-biodegradable and environmentally unfriendly [7-10]. Reports have documented the use of extracts from *Diospyros mespiliformis* [11], *Cucurbita maxima* [12], *Piper longum* [13], *Chromolaena odorata* [14], African breadfruit [15] and *Hibiscus sabdariffa* [16] as potential green inhibitors of mild steel corrosion in acidic medium.

Gmelina arborea (Family: Verbenaceae) is a tropical, evergreen perennial deciduous tree that grows to a height of 12 to 30 m. It grows preferably in moist fertile area. It is moderately adaptable and survives well on a wide range of soil types: acid soils, calcareous loams, and lateritic soils [17]. In Nigeria, the stem bark is boiled as a concoction for the treatment of chest and waist pain, lumbago and rheumatism. Extracts of *Gmelina arborea* are used in herbal medicine for its analgesic [18] anti-diabetic [19], antimicrobial [20], antioxidant [21] and wound healing properties [22]. Previous studies [23] revealed that *Gmelina arborea* stem bark extract appreciably inhibited mild steel corrosion in acidic medium. The aim of this work was to study the inhibitory effect of *Gmelina arborea* root extract on mild steel corrosion in H_2SO_4 solution.

2. MATERIALS AND METHODS

2.1 Test Materials

The mild steel sheet was purchased from Kenjohnsons Limited, Uyo, Akwa Ibom State, Nigeria. It had the following chemical composition (wt. %): C (0.12), Mn (0.85), S (0.06), P (0.05), Si (0.09) and Fe (98.83). The sheet was mechanically press - cut into 4.0 cm x 4.0 cm (for weight loss method) and 2.0 cm x 4.0 cm (for hydrogen evolution studies) coupons, respectively. The coupons were abraded with silicon carbide papers to mirror finish, washed in absolute ethanol and acetone, dried in room

46 temperature and stored in moisture-free desiccators before use in corrosion studies. All solutions
47 were prepared using deionized water.
48

49 **2.2 Preparation of *Gmelina arborea* Root Extract**

50 Fresh roots of *Gmelina arborea* were collected from a farm in Urua Ekpa, Akwa Ibom State, Nigeria.
51 They were washed, cut into small pieces and air - dried for seven days. The roots were ground to
52 powder form. The *Gmelina arborea* root extract was obtained following standard procedure reported
53 previously [24]. The root extract was used for the preparation of 0.5 g/L, 1.0 g/L, 1.5 g/L and 2.0 g/L
54 extract concentrations, respectively, in 1 M H_2SO_4 solution.
55

56 **2.3 Phytochemical screening of *Gmelina arborea* Root Extract**

57 Phytochemical analysis of *Gmelina arborea* root extract was done using standard procedures [25 -

58 26].

59 **2.4 Weight Loss Method**

60 Weighed mild steel coupons were immersed in 100 ml of 1 M H_2SO_4 solution (blank) in open beakers
61 with the aid of glass rods and hooks. One mild steel coupon per beaker was used. The temperature of
62 the experiments was maintained at 30°C, 40°C, 50°C, and 60°C, respectively, by placing the beakers
63 in a thermostatic water bath. The mild steel coupons were retrieved after 4 hours intervals and
64 washed in running water, rinsed in acetone and allowed to dry at room temperature before
65 reweighing. The experiments were also repeated in 1 M H_2SO_4 solution containing 0.5 g/L, 1.0 g/L,
66 1.5 g/L, and 2.0 g/L *Gmelina arborea* root extract concentrations, respectively.
67 The corrosion rate (CR) was calculated using the formula [9]:

$$CR \ (mg \ cm^{-2} hr^{-1} \ ) = \left(\frac{W}{At}\right) \tag{1}$$

68
69 where W is the weight loss (mg), A is the total surface area (cm^2) while t is the exposure time (hours).

70 The inhibition efficiency I(%) was evaluated through the equation [1]:

$$I(\%) = \left(\frac{W_0 - W_1}{W_0}\right) \ \times 100 \tag{2}$$

71   where

72 W_0 and W_1 are the weight losses of the mild steel coupons in the absence and presence of extract,

73 respectively, in 1 M H_2SO_4 at the same temperature.

74 **2.5 Hydrogen Evolution Method**

75 The hydrogen evolution method (via a gasometric assembly) is a rapid and sensitive technique] used
76 to monitor the rate of corrosion through the rate of hydrogen gas evolved from a metal corroding in
77 aqueous media [27-28]. The reaction vessel and procedure for the corrosion process by this method
78 are as described by other workers [7]. A 100 ml of 1 M H_2SO_4 solution was transferred into the
79 reaction vessel. Mild steel coupons weighing 6 g were dropped into the 1 M H_2SO_4 solution (blank).
80 The volume of H_2 gas evolved from the corrosion reaction was recorded every 60 seconds for 60
81 minutes. The experiment was repeated in the presence of 0.5 g/L – 2.0 g/L *Gmelina arborea* root
82 extract (inhibitor) in 1 M H_2SO_4 solution.
83 The inhibition efficiency I(%) by the gasometric method was calculated using Equation (3) [29]:

$$I(\%) = \left(1 - \frac{R_{H1}}{R_{H0}}\right) \times 100 \qquad\qquad (3)$$

84
85   where R_{H0} and R_{H1} are the H_2 gas evolution rates in the absence and presence of extract,
86   respectively, at a specific time.
87

3. RESULTS AND DISCUSSION

88

3.1 Results of Phytochemical Analysis Of *Gmelina Arborea* Root Extract Ethanol Rind

89

Extract

90

91   The results of the phytochemical anlysis of ethanol *Telfairia occidentalis* rind extract indicate the
92   presence of alkaloids, saponins, anthraquinones and terpenes.
93

3.2 Effect of *Gmelina arborea* Root Extract Concentration on Inhibition Efficiency

94

95   The inhibition efficiency of *Gmelina arborea* root extract on mild steel corrosion in 1 M H_2SO_4 solution
96   increases with increase in the extract concentration (Fig. 1). The highest inhibition efficiency of
97   78.59% was obtained at extract concentration of 2.0 g/L at 30 ℃ by the weight loss method. Fig. 2
98   depicts a drastic reduction in the volume of H_2 gas evolved in mild steel corrosion in 1 M H_2SO_4
99   solution in the presence of *Gmelina arborea* root extract compared to the blank. The reduction in the
100 volume of H_2 gas evolved increased with increase in the root extract concentration, indicating that the
101 extract inhibited the corrosion of mild steel in the medium. The calculated values of inhibition
102 efficiency by the hydrogen evolution measurements (Table 1) reveal that the inhibition efficiency
103 increased with increase in the extract concentration. A similar trend was observed in the inhibition
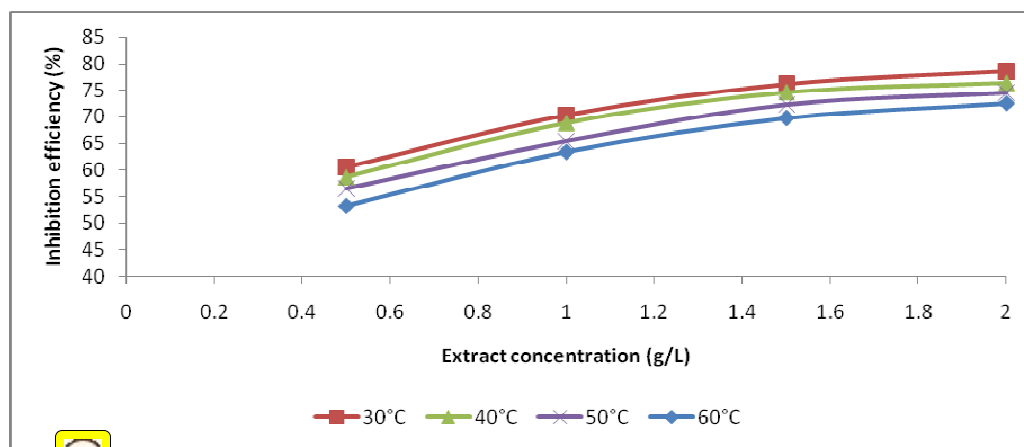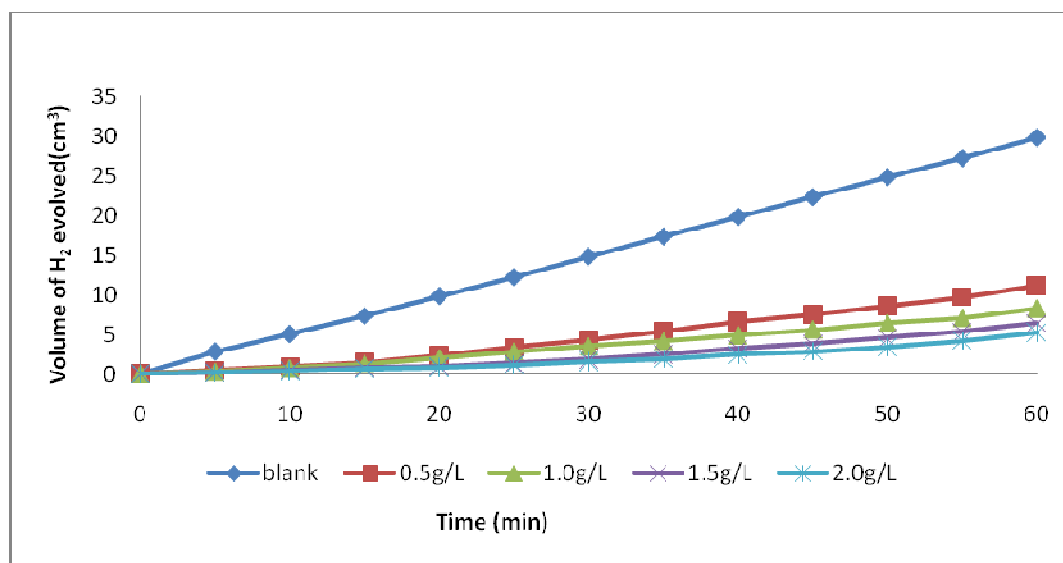104 efficiencies obtained by both the weight loss and hydrogen evolution measurements.
105
106

107
108
109 **Fig.1.** Effect of *Gmelina arborea* root extract concentration (g/L) on the inhibition efficiency (%)
110 of mild steel corrosion in 1 M H_2SO_4 solution at different temperatures
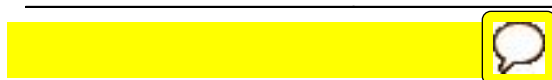111

112

113
114

Fig 2. Variation of volume of H_2 gas evolved (cm^3) with time (min) for mild steel corrosion in 1 M H_2SO_4 in the absence and presence of *Gmelina arborea* root extract at 30°C

Table 1. Effect of *Gmelina arborea* root extract concentration on inhibition efficiency of mild steel in 1 M H_2SO_4 solution at 30 °C (Hydrogen evolution measurements)

Extract Concentration (g/L)	H_2 evolution rate (cm^3 min^{-1})	Inhibition Efficiency (%)
Blank	0.4967	-
0.5	0.1867	62.42
1.0	0.1383	72.15
1.5	0.1067	78.52
2.0	0.0867	82.55

121
122

3.3 Effect of Temperature on Inhibition Efficiency

Table 2 reveals that the inhibition efficiency decreases with increase in temperature, suggesting that increase in temperature increases the degree of inhibitor desorption from the surface of the mild steel especially at high temperatures.

136 **Table 2. Calculated values of corrosion rate and inhibition efficiency for mild steel corrosion in**
137 **1 M H_2SO_4 in the absence and presence of different concentrations of *Gmelina arborea* root**
138 **extract**
139
140

Extract Concentration	Corrosion rate (mg cm^{-2} hr^{-1})				Inhibition efficiency (%)			
	30°C	40°C	50°C	60°C	30°C	40°C	50°C	60°C
Blank	2.554	4.906	7.000	16.141	-	-	-	-
0.5 g/L	1.007	2.023	3.039	7.547	60.55	58.76	56.58	53.24
1.0 g/L	0.757	1.523	2.414	5.906	70.34	68.95	65.51	63.41
1.5 g/L	0.609	1.242	1.937	4.875	76.15	74.68	72.32	69.80
2.0 g/L	0.547	1.156	1.781	4.429	78.59	76.43	74.55	72.56

141
142
143 The activation energy (E_a) for mild steel corrosion in 1 M H_2SO_4 solution in the absence and presence
144 of *Gmelina arborea* root extract was evaluated using the Arrhenius equation [24]:
145

$$\ln CR = \frac{-E_a}{RT} + \ln A \tag{4}$$

146
147 where CR is corrosion rate, R is the universal gas constant, T is the absolute temperature, E_a is
148 activation energy while A is the pre-exponential factor.
149 Fig 3 illustrates linear plot of In CR vs 1/T for the mild steel corrosion in 1 M H_2SO_4 solution in the
150 absence and presence of the extract. The E_a values presented in Table 3 were evaluated from the
151 gradients of the plot. It is observed that the E_a values in H_2SO_4 – *Gmelina arborea* root extract
152 medium were higher than that of the blank (47.36 kJ mol^{-1}). When there is an increase in activation
153 energy (E_a) in the presence of extract compared to the blank, it is an indication of physical
154 adsorption (physisorption) and when there is a decrease in the E_a value in the presence of the extract
155 compared to the blank, chemical adsorption is implied [30 - 31]. In this study, where the E_a values in
156 the presence of the extract is higher than that of the blank. The adsorption of *Gmelina arborea* root
157 extract on mild steel surface is therefore proposed to occur via physisorption mechanism. This
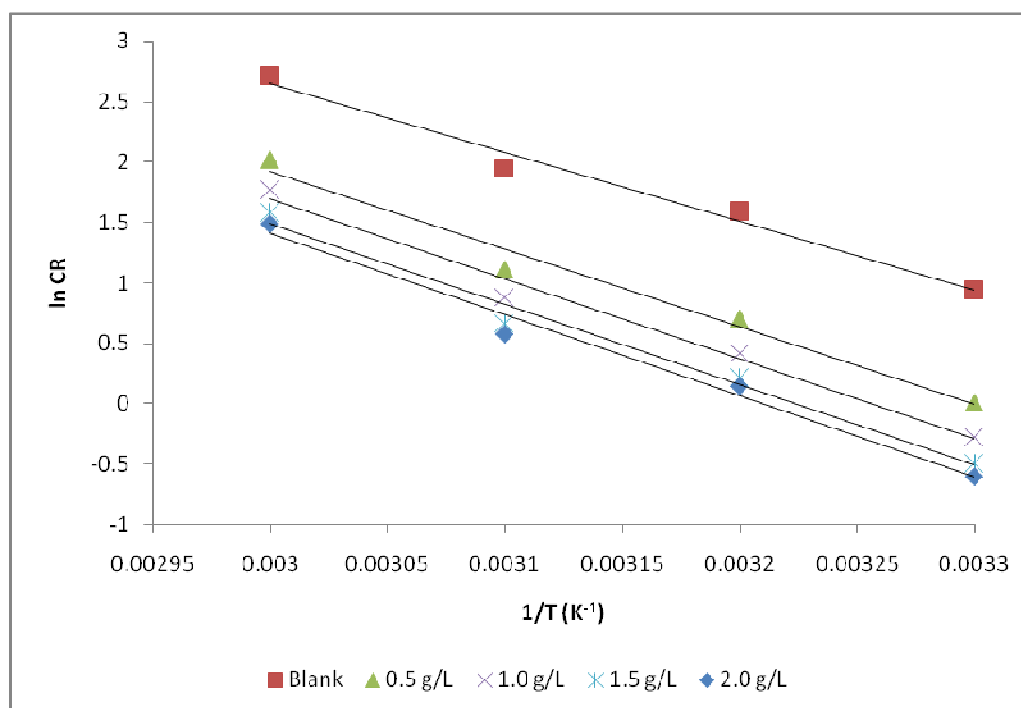158 assertion is further supported by a decrease in inhibition efficiency as temperature increases.
159
160
161
162
163
164
165
166

167
168
169
170 **Fig 3. Arrhenius plot for mild steel corrosion in 1 M H₂SO₄ solution in the presence and**
171 **absence of *Gmelina arborea* root extract, respectively**
172
173
174
175 **Table 3. Calculated values of thermodynamic parameters for mild steel corrosion in 1 M H₂SO₄**
176 **in the absence and presence of *Gmelina arborea* root extract**
177
178

Extract concentration	E_a (kJ mol^{-1})	ΔH^o_{ads} (kJ mol^{-1})	ΔS^o_{ads} (JK^{-1}mol^{-1})
1 M H₂SO₄	47.36	46.29	-84.54
0.5 g/L	53.60	50.96	-76.92
1.0 g/L	55.04	52.40	-74.56
1.5 g/L	55.59	52.92	-74.65
2.0 g/L	55.77	53.13	-74.74

179
180 Values of the enthalpy of entropy of activation (ΔS^o_{ads}) and activation (ΔH^o_{ads}) also presented in Table
181 3 were obtained from the alternative formulation of the transition state equation [10]:
182

$$\ln\left(\frac{CR}{T}\right) = \left[\ln\left(\frac{R}{Nh}\right) + \frac{\Delta S^{\circ}_{ads}}{R}\right] - \frac{\Delta H^{\circ}_{ads}}{RT} \tag{5}$$

183
184 where T is the absolute temperature, CR is the corrosion rate , h is the Planck's constant, and N is the
185 Avogadro's number and R is the universal gas constant. The plots of ln (CR/T) against (1/T) is shown
186 in Fig 4. This plot has gradient of ($-\Delta H^o_{ads}/R$) and intercept of [ln(R/Nh) + (ΔS^o_{ads} /R)] where the
187 values of ΔS^o_{ads} and ΔH^o_{ads} were obtained. Positive values of ΔH^o_{ads} reveal that the adsorption of
188 *Gmelina arborea* root extract onto mild steel surface was an endothermic process.
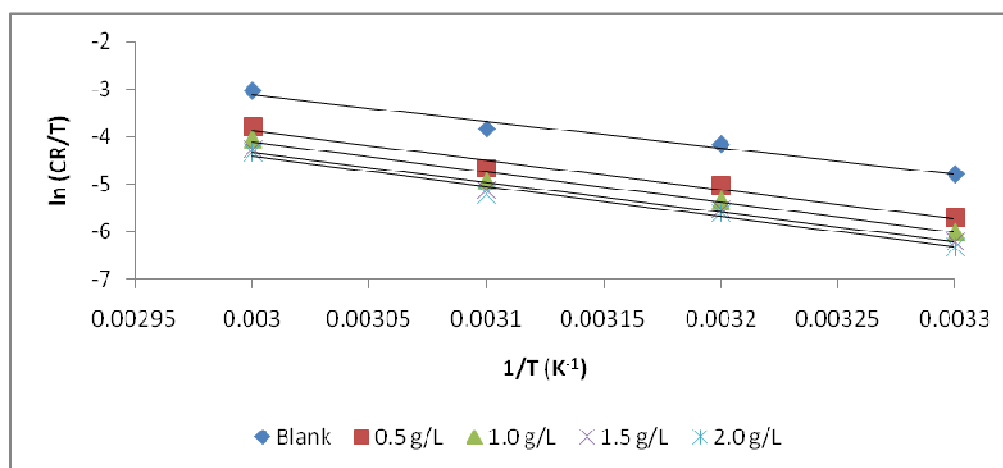189
190

Fig 4.Transition state plot for mild steel corrosion in 1 M H_2SO_4 solution in the presence and absence of *Gmelina arborea* root extract

3.4 Adsorption Studies

The Langmuir adsorption isotherm proposes that adsorption happens on specific homogenous sites on the metal surface and is used successfully in many monolayer adsorption process [7]. The modified Langmuir isotherm was used to investigate the mechanism of adsorption, which is expressed as [32]:

$$\frac{C}{\theta} = \frac{n}{K_{ads}} + nC \tag{6}$$

where θ is the degree of surface coverage, C is the inhibition concentration, K_{ads} is the equilibrium adsorption constant. The plot of C/ θ against C (Fig 5) depict a straight line graph supporting that the adsorption of *Gmelina arborea* root extract on mild steel in 1 M H_2SO_4 obeyed the Langmuir adsorption isotherm. The values of K_{ads} which indicate the adsorption strength of the inhibitor onto the metal surface [7], was evaluated from the intercept of the graph. The standard free energy of adsorption ΔG°_{ads} is determined from the equation [29]:

$$\Delta G^{\circ}_{ads} = -RT \ln(55.5 K_{ads}) \tag{7}$$

where K_{ads} is the equilibrium adsorption constant, ΔG°_{ads} is the standard free energy of adsorption and the value 55.5 is the molar concentration of water in solution expressed in mol/dm^3

216
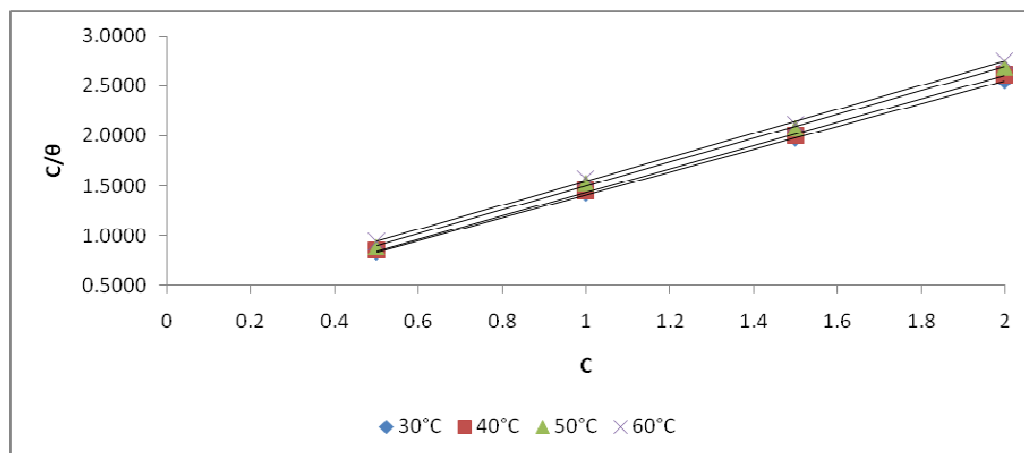
217
218
219 **Fig 5. Langmuir isotherm plot for mild steel corosion in 1 M H_2SO_4 solution containing *Gmelina***
220 ***arborea* root extract at 30 ℃ – 60 ℃**
221

222 The values of K_{ads} and ΔG^o_{ads} are represented in Table 4. Values of ΔG^o_{ads} less negative than -20 kJ
223 mol^{-1} reveal electrostatic interaction between charged organic molecules and the charged metal
224 surface (physisorption) while values of ΔG^o_{ads} more negative than -40 kJ mol^{-1} reveal charge sharing
225 or transfer from the organic molecules to the metal surface to form a coordinate bond (chemisorption)
226 [33]. The negative values of ΔG^o_{ads} indicate that the spontaneity of adsorption of *Gmelina arborea*
227 root extract onto the mild steel surface.
228

229 **Table 4. Some parameters of the linear regression of Langmuir adsorption isotherm for mild**
230 **steel corrosion in 1 M H_2S0_4 solution containing *Gmelina arborea* root extract**
231

Temperature	R^2	n	$1/K_{ads}$ (g/L)	K_{ads} (L/g)	ΔG^o_{ads} (kJ mol^{-1})
303K	0.9998	1.14	0.2643	3.7835	-13.469
313K	0.9997	1.17	0.2678	3.7341	-13.880
323K	0.9992	1.19	0.3027	3.3036	-13.994
333K	0.9996	1.20	0.3494	2.8620	-14.030

232
233 **3.5 Surface Morphology Analysis**

234 Scanning electron microscope (SEM) images were taken in order to study the surface morphology of
235 mild steel in the absence and presence of Gmelina arborea root extract, respectively. SEM
236 micrograph of the surface of mild steel after 4 hrs immersion in 1 M H_2SO_4 solution in the absence of
237 *Gmelina arborea* extract (Fig. 6) reveals that the mild steel surface was severely corroded. Cracks
238 could be seen on the mild steel surface. On the contrary, SEM micrograph of mild steel in the
239 presence of 2.0 g/L *Gmelina arborea root* extract (Fig. 7) reveals a smoother surface. This may be
240 attributed to the formation of an adsorbed film of *Gmelina arborea* molecules on mild steel surface,
241 which inhibit the corrosion of mild steel in 1 M H_2SO_4 solution.
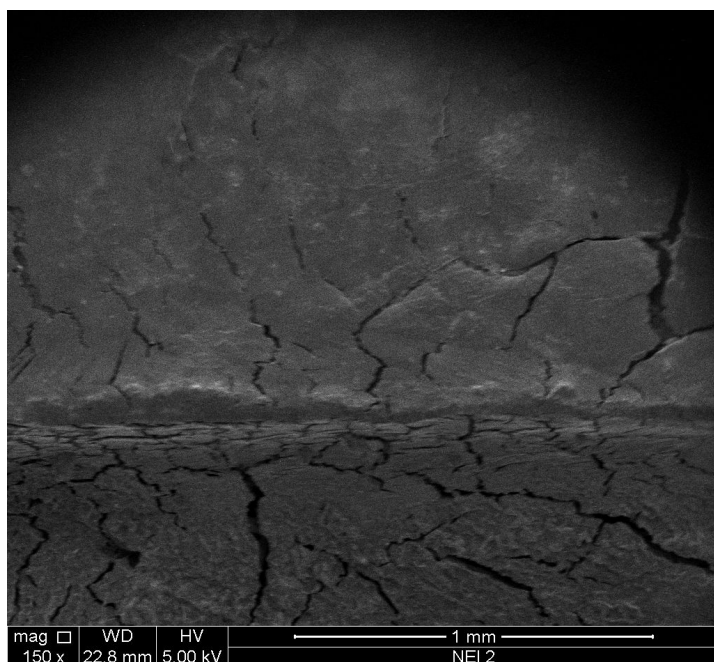
Fig 6. SEM micrograph of mild steel specimens after 4 hours of immersion in 1 H_2SO_4 solution without *Gmelina arborea* extract
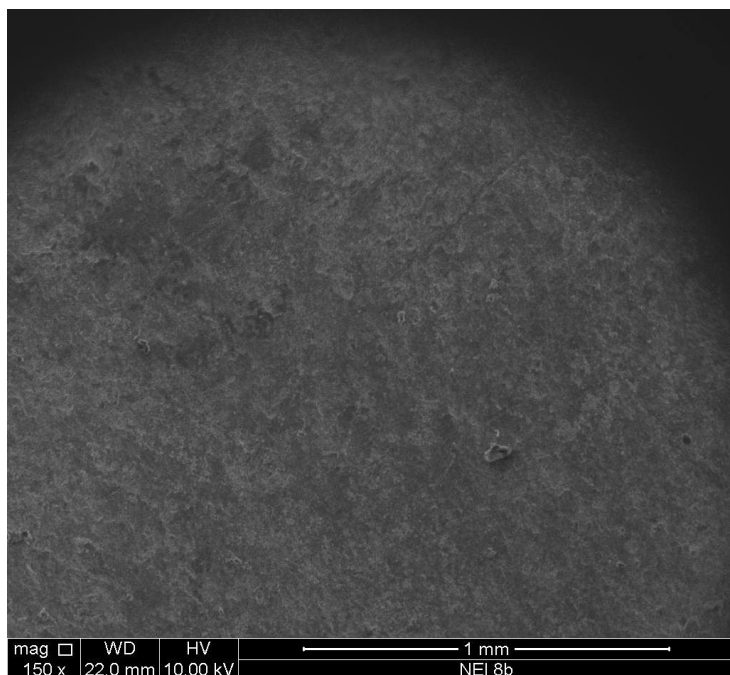

Fig 7. SEM micrograph of mild steel specimens after 4 hours of immersion in 1 M H_2SO_4 solution containing 2.0 g/L *Gmelina arborea* root extract at 30 °C

4. CONCLUSION

Based on the results obtained in this study, the following conclusions could be made: *Gmelina arborea root* extract exhibits good inhibitive action against the corrosion of mild steel in 1 M

257 H_2SO_4. Inhibition efficiency increases with increase in the root extract concentration but decreases
258 with increase in temperature. Physical adsorption of the extract onto mild steel surface has been
259 proposed based on a decrease in inhibition efficiency with increase in temperature, a higher E_a value
260 in the extract compared to the blank in addition to the ΔG_{ads} of the adsorption process being less
261 negative than -20 kJ/mol. The adsorption of *Gmelina arborea root extract on* mild steel surface in 1 M
262 H_2SO_4 obeys the Langmuir adsorption isotherm.
263
264

265 **REFERENCES**

266
267

268 1. Abakedi OU, Ekpo VF, John EE. Corrosion inhibition of mild steel by *Stachytarpheta indica*
269   leaf extract in acid medium. Pharma. Chem. J. 2016;3(1):165 - 171.
270
271 2. Popova A, Christov M, Deligeorigiev T. Influence of the molecular structure on the inhibitor
272   properties of benzimidazole derivatives on mild steel corrosion in 1 M hydrochloric acid.
273   Corros. 2003;59:756 - 764.
274
275 3. Popova A, Christov M, Raicheva S, Sokolova E. Adsorption and inhibitive properties of
276   benzimidazole derivatives in acid mild steel corrosion. Corros. Sci. 2004; 46:1333 – 1350.
277
278 4. Li X, Deng S, Fu H, Mu G. Inhibition effect of benzylaminopurine on the corrosion of cold
279   rolled steel in H_2SO_4 solution. Corros. Sci. 2009;51(3):620 - 634.
280
281 5. Popova A, Christov M, Zwetanova A .Effect of the molecular structure on the inhibitor
282   properties of azoles on mild steel corrosion in 1M hydrochloric acid. Corros. Sci.
283   2007;49(5):2131 - 2143.
284
285 6. Lece HD, Emregul KC, Atakol O. Difference in the inhibitive effect of some Schiff base
286   compounds containing oxygen, nitrogen and sulphur donors. Corros. Sci. 2008; 50(5):1460-
287   1468.
288
289 7. Obot IB, Obi-Egbedi NO. An interesting and efficient green corrosion inhibitor for aluminium
290   from extracts of *Chlomolaena odorata* L. in acidic solution. J Appl. Electrochem.
291   2010;40:1977–1984.
292
293 8. Umoren SA, Edouk UM, Israel A., Obot IB, Solomon MM. Coconut coir dust extract: a novel
294   eco-friendly corrosion inhibitor for Al in HCl solutions. Green Chem. Letters Rev.
295   2012;5(3):303-313.
296
297 9. Abakedi OU, Asuquo JE, James MA, Ituen NE. Comparative study on the corrosion of mild
298   steel by *Maeseobatrya barteri* leaf and root extracts in acidic medium. J. Sci. Eng. Res.
299   2016;3(5):153 - 160.
300
301 10. Abakedi OU, Asuquo JE. Corrosion Inhibition of Mild Steel in 1 M H_2SO_4 Solution by
302   *Microdesmis puberula* Leaf Extract. Am. Chem. Sci. J. 2016;16(1): 1 - 8.
303
304 11. Oguike RS, Kolo AM, Ayuk AA., Eze FC, Oguzie EE. Electrochemical and Adsorption
305   Behaviour of *Diospyros mespiliormis* on Annealed Carbon steel Corrosion in Hydrochloric
306   acid. Am. Chem. Sci. J. 2015;16(1): 1 – 12.
307
308 12. Anbarasi K, Vasudha VD. Mild Steel Corrosion Inhibition by *Cucurbita maxima* Plant Extract
309   in Hydrochloric Acid Solution J. Environ. Nanotechnol.2014;3(1):16-22.
310
311 13. Ambrish S., Ishtiaque A, Quraishi MA. *Piper longum* extract as green corrosion inhibitor for
312   aluminium in NaOH solution. Arabian J. Chem. 2012;9(2):1584-1589.
313
314 14. Nwosua FO, Muzakirb MM. Thermodynamic and Adsorption Studies of Corrosion Inhibition
315   of Mild Steel Using Lignin from Siam Weed (*Chromolaena odorata*) in Acid Medium. J. Mater.
316   Environ. Sci. 2016;7(5): 1663 - 1673.

15. Ejikeme PM, Umana SG, Menkiti MC, Onukwuli OD. Inhibition of mild steel and Aluminium corrosion in 1M H_2SO_4 by leaves extract of African breadfruit. Int. J. Mater. Chem. 2015;5(1):14 - 23.

16. Molina-Ocampo LB, Valladares-Cisnero MG, Gonzalez-Rodriguez JG. Using *Hibiscus sabdariffa* as corrosion inhibitor in 0.5 M H_2SO_4. Int. J. Electrochem. Sci. 2015;10: 388 - 403.

17. Kijkar S. *Gmelina arborea* Roxb. In: Vozzo, J. A. Tropical tree seed manual - Part II, Species Descriptions G, Agriculture Handbook, U.S. Dept. of Agriculture, Forest Service. 2002;476-478.

18. Nayak BS, Dinda SC, Ellaiah P. Opioid and Non-opioid Analgesic Activity of *Gmelina arborea* Roxb. Fruit Extracts. Int. J. Pharm. Sci. 2013;5: 263-266.

19. Nayak, BS, Ellaiah P, Dinda SC. Antibacterial, Antioxidant And Anti-Diabetic Activities of *Gmelina Arborea* Roxb Fruit Extracts. Int. J. Green Pharm. 2012;6: 224 – 230.

20. El-Mahmood A.M, Doughari JH, Kiman HS. *In Vitro* Antimicrobial Activity of Crude Leaf And Stem Bark Extracts of *Gmelina Arborea* (Roxb) Against Some Pathogenic Species of Entero bacteriaceae. African J. Pharm. Pharmacol. 2010;4: 355-361.

21. Patil SM, Kadam VJ, Ghosh R. *In Vitro* Antioxidant Activity of Methanolic Extract of Stem Bark of *Gmelina arborea* Roxb. (Verbenaceae). Int. J. Pharm. Technol. Res. 2009;4: 1480 - 1484.

22. Shirwaikar A, Ghosh S, Padma G, Rao M. Effect of *Gmelina arborea* Roxb. Leaves on Wound Healing in Rats. J. Nat. Rem. 2003;3(1): 45 - 48.

23. Nnanna LA, Uchendu KO, Nwosu FO, Ihekoronye U, Eti EP. *Gmelina arborea* bark extracts as a corrosion inhibitor for mild steel in acidic environment. Int. J. Mater. Chem. 4(2); 34 – 39.

24. Abakedi OU, Moses IE. Aluminium corrosion inhibition by *Maesobatrya barteri* root extract in hydrochloric acid solution. Am. Chem. Sci. J. 2016;10(3):1-10.

25. Oguzie EE. Corrosion Inhibition of Aluminium in Acidic and Alkaline by *Sansevieriatri fasciata* extract. Corros. Sci. 2007;49:1527-1539.

26. Abakedi OU, Moses IE, Asuquo JE. Adsorption and Inhibition Effect of *Maesobatrya barteri* Leaf Extract on Aluminium Corrosion in Hydrochloric Acid Solution. J. Sci. Eng. Res. 2016;3(1): 138 – 144.

27. Ebenso EE, Oguzie EE. Corrosion inhibition of mild steel in acidic media by some organic dyes. Mater. Letters. 2005;59(17): 2163 - 2165.

28. Oguzie EE. Corrosion inhibitive effect and adsorption behaviour of *Hisbiscus sabdariffa* extract on mild steel in acidic media. Portugalie Electrochem. Acta 2008;26: 303 - 314.

29. Abakedi OU, Asuquo JE. Mild steel corrosion inhibition by *Eremomastax polysperma* leaf extract in acidic medium. Asian J. Chem.. Sci. 2016;1(1): 1 - 9.

30. Ita BI, Abakedi OU, Osabor VN. Inhibition of mild steel corrosion in hydrochloric acid by 2-acetylpyridine and 2-acetylpyridine phosphate. Glo. Adv. Res. J. Eng. Technol Inno. 2013;2(3): 84 - 89.

31. Bentiss F, Bouanis M, Mernari B, Trainei M, Ezin H, Lagrenee M. Understanding the adsorption of 4H-1,2,4-triazole derivatives on moild steel surface in Molar hydrochloric acid. Appl. Surf. Sci. 2007;253: 3696 - 3704.

32. Villami RFV, Corio P, Rubim JC, Agostinho SML. Effect of sodium dodecylsulfate on copper corrosion in sulfuric acid media in the absence and presence of benzotriazole. J. Electroanal. Chem.1999;472(2): 112–119.

33. Obot IB, Obi-Egbedi NO. Adsorption properties and inhibition of mild steel corrosion in sulphuric acid solution by ketoconazole: experimental and theoretical investigation. Corros. Sci. 2010;52(1): 198 - 204.