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Corrosion Inhibition Study of Proguanil Hydrochloride for Mild Steel Corrosion in 2.0 m HCl by Weight Loss Method

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Abstract This study considers proguanil hydrochloride for inhibition of mild steel corrosion in 2.0M HCl by weight loss method. Useful parameters like mean Corrosion Rate (XCR), Percentage Inhibition Efficiency (%IE) and degree of Surface Coverage (θ) were evaluated from raw data generated experimentally. Analysis of generated data and available literature show that; XCR decreased in the present of proguanil hydrochloride inhibitor. The decrease in XCR increased with increased in inhibitor concentration but tested non-significant ($P<0.05$) for all inhibitor concentrations while showing continuous appreciation to values approaching significance level at high (5.0×10^{-4}M) inhibitor concentrations and low (303K and 313K) corrodent temperatures. Useful parameters (%IE and θ) increased with increase in inhibitor concentration and decreased with rise in corrodent temperature.

Keywords Corrosion Inhibition, Mild Steel, Proguanil Hydrochloride, Hydrochloric acid, Weight loss.

Introduction

Despite numerous efforts to mitigate against the effects of corrosion on production materials in recent years, corrosion still remains basic challenge facing most construction firms worldover [1-2]. By context of definition, corrosion is known to be an environmentally initiated phenomenon, whose rate of occurrence is influenced by the composition of the environment some of which may naturally abound or come as a result of anthropogenic influences on the environment.

Increased application of acids in industrial operations such as pickling, chemical and electrochemical etching, industrial acid descalling, etc leads to increased abundance of acids in the environment [2]. Thus, distorting its physicochemistry, ecology, and enhancing its metallic corrosion potential. Consequently, the study of metallic corrosion specifically in acidic medium is considered essential.

Among several methods available for control of metallic corrosion, the use of corrosion inhibitors is one of the most practical methods [3]. Most well known inhibitors are organic compounds containing Nitrogen, Sulphur, Oxygen and Phosphorus in their functional groups [4-6]. In view to achieving cost effective and environmentally friendly inhibition of metallic corrosion by the environment, recent studies consider pharmaceutical products rich in Nitrogen, Sulphur and Phosphorus for metallic corrosion inhibition [7-9]. The present study shall consider Proguanil Hydrochloride as inhibitor for mild steel corrosion in 2.0 M HCl.

Materials and Methods

Materials

All the reagents used for this study were of analytical grade and were identified alongside with the mild steel material and supplied by reputable companies as stated below:

- Mild steel material (specimen) – Ken-Johnson Nigeria Ltd

- Acetone – BDH chemicals Ltd; Poole-England
- Calcium Chloride –May and Baker Ltd., Dagenham-England.
- Hydrochloric acid – May and Baker Ltd., Dagenham-England.
- Ethanol - James Burrough Ltd., London.
- Sodium Hydroxide pellets – May and Baker Ltd., Poole–England.
- Zinc dust–BDH chemicals Ltd., Poole – England.
- Proguanil Hydrochloride (the inhibitor) was of Analar grade and was supplied by Healthway Pharmacy, Uyo, Akwa Ibom State, Nigeria.

Preparation of Specimen

The mild steel material was mechanically cut into 2.0 x 1.0 x 0.05 cm coupons. A small hole was drilled out at the centre of each coupon. These coupons were pre-cleaned using three different grades of sand paper (P60X, P220 and P450). Each coupon was washed in distilled water to remove dirt, washed in ethanol to remove grease and thereafter in acetone to remove oil. The cleaned coupons were stored over calcium chloride in a dessicator prior to use.

Preparation of Standard Solution of HCl

The molarity of stock was first obtained using direct formula method as presented below:

$$\text{Molarity} = \frac{\text{\% purity x Specific gravity x 1000cm}}{\text{Molar mass x Volume of Solution}} \quad [1,10]$$

Basic information such as % purity, specific gravity and molar mass of the reagent were obtained from the assay on the stock bottle of concentrated HCl, as given below:

% purity = 33.0
Specific gravity = 1.18g
Molar mass = $36.46gmol^{-1}$

By appropriate substitution of the given values into the above formula, we have that;

$$\text{Molarity of stock HCl} = \frac{33.0 \times 1.18g \times 1000}{36.46gmol^{-1} \times 100} = \mathbf{10.66M}$$

The proposed $1000cm^3$ of 2.0m working solution of HCl was therefore obtained by dilution principle as shown below:

$$M_1V_1 = M_2V_2 \quad , \quad V_2 = \frac{M_1V_1}{M_2} = \frac{2.0M \times 1000cm^3}{10.68} = \mathbf{187.30cm^3}$$

Therefore, $187.30cm^3$ of the concentrated HCl was carefully measured and transferred to a standard flask containing distilled water and the volume made up to $1000cm^3$ mark.

Preparation of Standard Solution of Proguanil Hydrochloride

1.0M stock solution of Proguanil Hydrochloride was first prepared by carefully measuring the equivalent weight of the compound and dissolving it in 30ml of distilled water in appropriate flask, then making up the volume to $1000cm^3$ with distilled water. The respective concentrations (2.0×10^{-4}M, 1.0×1.0^{-4}M, 5.0×10^{-5}M and 0.5×10^{-5}M) of the working solutions were obtained from the stock solution by dilution principle as shown below:

Concentration of stock Cs x Volume of stock Vs = Conc. Of working Soln C_w x Volume of working soln V_w ; Volume of working solution $V_w = \frac{C_sV_s}{C_w}$

Where $C_s = 1.0M$, $V_s = 1000cm^3$, $C_w = 2.0 \times 10^{-4}M$ and $V_w = ?$

By appropriate substitution, we have that $V_w = \frac{1.0M \times 1000cm^3}{2.0 \times 10^{-4}M} = \mathbf{0.05cm^3}$

Hence, $0.05cm^3$ of stock solution of Proguanil Hydrochloride was carefully measured and transferred into a standard flask and the volume is made up to 1000 cm^3. Other concentrations of the working solution were obtained in the same manner, using similar principle. The equivalent weight of Proguanil Hydrochloride is 252.5g [11].

Weight Loss Analysis

Weight Loss Analysis was conducted on the prepared specimen (mild steel coupons). The coupons were totally immersed by means of glass rod and hook in 100ml of test solutions and blank each maintained at 303K. To determine weight los with time, the coupons were retrieved from the test solutions and blank at two hours interval, immersed in 20% NaOH solution containing $200gL^{-1}$ of Zinc dust, scrubbed with bristle brush, washed in distilled water, dried in acetone and reweighed. The weight loss was to be the difference between the initial and the final weights respectively of the coupon at a given time. The analysis was repeated with temperature of test solution and blank maintained at 313K, 323K and 333K respectively. For each temperature, the corresponding weight loss values were measured and recorded.

From the weight loss values, useful parameters such as corrosion rate (CR), surface coverage (θ) and percentage Inhibition Efficiency (%1E) were evaluated using appropriate equations as shown below;

$$CR = \frac{W_i - W_f}{ST}, \quad \theta = \frac{CR_0 - CR_i}{CR_0} \text{ and } \%IE = \frac{CR_0 - CR_i}{CR_0} \times 100$$

Where; W_i - Initial weight of coupon
W_f - Final weight of coupon
S - Total surface Area of coupon
T - Corrosion Time,
CR - Corrosion Rate
CR_0 - Corrosion Rate of coupon in the absent of inhibitor
CR_i - Corrosion Rate of coupon in the present inhibitor
(θ) - Surface Coverage of inhibitor
%IE - %age Inhibition Efficiency of the inhibitor [10,12-13]

Result and Discussion

Weight Loss Study

Weight loss study of mild steel corrosion in 2.0M HCl and its inhibition by various concentrations of Proguanil Hydrochloride was studied at various temperatures. Results obtained from the study are presented on tables I–IX. Raw data generated from weight loss of mild steel from its corrosion in 2.0M HCl and its inhibition by the various concentrations of Proguanil Hydrochloride at the respective temperatures are presented on tables I, II, III, IV. The corrosion rate (CR) is subsequently evaluated from the weight loss data and presented on tables V, VI, VII and VIII, representing the respective temperatures.

The corrosion rates obtained were statistically analyzed and other useful parameters like Percentage Inhibition Efficiency (%IE) and degree of Surface Coverage (θ) were evaluated and presented on table IX.

Table 1: Weight Loss Experiment for the Corrosion of Mild Steel Coupons in 2.0 M HCl Solution Containing Different Concentrations of Proguanil Hydrochloride at 303K.

Time (hr)	Inhibitor Concentration x 10^{-4}(M)	Initial Mild Steel Coupon (W_1)g	Final wt of mild steel coupon (W_2)g	Weight loss ($\Delta W = W_1 - W_2$)g
	Blank	1.900	1.745	0.155
	0.1	1.990	1.849	0.141
2	0.5	1.885	1.763	0.122
	1.0	1.965	1.871	0.094
	2.0	1.830	1.752	0.078
	5.0	1.955	1.889	0.066
	Blank	1.900	1.732	0.168
	0.0	1.990	1.837	0.153
4	0.5	1.885	1.753	0.132
	1.0	1.965	1.864	0.101
	2.0	1.830	1.746	0.084
	5.0	1.955	1.884	0.071
	Blank	1.900	1.723	0.177
	0.0	1.990	1.829	0.161
	0.5	1.885	1.745	0.140
6	1.0	1.965	1.857	0.108
	2.0	1.830	1.741	0.089
	5.0	1.955	1.879	0.076
	Blank	1.900	1.710	0.190
	0.0	1.990	1.818	0.177
	0.5	1.885	1.735	0.150
8	1.0	1.965	1.850	0.115
	2.0	1.830	1.735	0.095
	5.0	1.955	1.875	0.080
	Blank	1.900	1.705	0.195
	0.0	1.990	1.813	0.177
10	0.5	1.885	1.731	0.154

1.0	1.965	1.846	0.119
2.0	1.830	1.732	0.098
5.0	1.955	1.870	0.085

Table 2: Weight Loss Experiment for the Corrosion of Mild Steel Coupons in 2.0 M HCl Solution Containing Different Concentrations of Proguanil Hydrochloride at 313K.

Time (hr)	Inhibitor Concentration x 10^{-4} (M)	Initial Mild Steel Coupon (W_1)g	Final wt of mild steel coupon (W_2)g	Weight loss ($\Delta W = W_1 - W_2$)g
	Blank	2.040	1.888	0.152
	0.1	1.980	1.839	0.141
2	0.5	1.830	1.705	0.125
	1.0	1.835	1.735	0.100
	2.0	1.905	1.822	0.083
	5.0	1.865	1.796	0.069
	Blank	2.040	1.872	0.168
	0.0	1.980	1.824	0.056
4	0.5	1.830	1.694	0.136
	1.0	1.835	1.725	0.110
	2.0	1.905	1.814	0.091
	5.0	1.865	1.788	0.077
	Blank	2.040	1.864	0.176
	0.0	1.980	1.816	0.164
6	0.5	1.830	1.686	0.144
	1.0	1.835	1.718	0.117
	2.0	1.905	1.808	0.097
	5.0	1.865	1.785	0.080
	Blank	2.040	1.852	0.188
	0.0	1.980	1.806	0.174
8	0.5	1.830	1.679	0.154
	1.0	1.835	1.711	0.124
	2.0	1.905	1.802	0.103
	5.0	1.865	1.779	0.086
	Blank	2.040	1.843	0.197
	0.0	1.980	1.797	0.183
10	0.5	1.830	1.668	0.162
	1.0	1.835	1.705	0.130
	2.0	1.905	1.797	0.108
	5.0	1.865	1.774	0.091

Table 3: Weight Loss Experiment for the Corrosion of Mild Steel Coupons in 2.0 M HCl Solution Containing Different Concentrations of Proguanil Hydrochloride at 323 K.

Time (hr)	Inhibitor Concentration x 10^{-4}(M)	Initial Mild Steel Coupon (W_1)g	Final wt of mild steel coupon (W_2)g	Weight loss ($\Delta W = W_1 - W_2$)g
	Blank	1.820	1.641	0.179
	0.1	1.830	1.170	0.170
2	0.5	1.715	1.559	0.156
	1.0	1.935	1.795	0.140
	2.0	2.025	1.901	0.124
	5.0	2.045	1.942	0.103
	Blank	1.820	1.627	0.193
	0.0	1.830	1.647	0.183
4	0.5	1.715	1.548	0.167
	1.0	1.935	1.784	0.151
	2.0	2.025	1.892	0.133
	5.0	2.045	1.934	0.111

	Blank	1.820	1.615	0.205
	0.0	1.830	1.637	0.193
6	0.5	1.715	1.537	0.178
	1.0	1.935	1.776	0.158
	2.0	2.025	1.884	0.141
	5.0	2.045	1.928	0.117
	Blank	11.820	1.610	0.210
	0.0	1.830	1.631	0.199
8	0.5	1.715	1.532	0.183
	1.0	1.935	1.771	0.164
	2.0	2.025	1.879	0.146
	5.0	2.045	1.923	0.122
	Blank	1.820	1.595	0.255
	0.0	1.830	1.616	0.214
10	0.5	1.715	1.739	0.196
	1.0	1.935	1.759	0.176
	2.0	2.025	1.870	0.155
	5.0	2.045	1.914	0.131

Table 4: Weight Loss Experiment for the Corrosion of Mild Steel Coupons in 2.0 M HCl Solution Containing Different Concentrations of Proguanil Hydrochloride at 333K.

Time (hr)	**Inhibitor Concentration x 10^{-4}(M)**	**Initial Mild Steel Coupon (W_1)g**	**Final wt of mild steel coupon (W_2)g**	**Weight loss ($\Delta W = W_1 - W_2$)g**
	Blank	1.930	1.686	0.244
	0.1	1.865	1.628	0.237
2	0.5	1.810	1.590	0.220
	1.0	1.790	1.590	0.200
	2.0	1.825	1.644	0.181
	5.0	1.845	1.694	0.151
	Blank	1.930	1.668	0.262
	0.0	1.865	1.611	0.254
4	0.5	1.810	1.574	0.236
	1.0	1.790	1.576	0.214
	2.0	1.825	1.1632	0.193
	5.0	1.845	1.683	0.162
	Blank	1.930	1.654	0.276
	0.0	1.865	1.585	0.267
6	0.5	1.810	1.553	0.248
	1.0	1.790	1.564	0.226
	2.0	1.825	1.621	0.204
	5.0	1.845	1.674	0.171
	Blank	1.930	1.641	0.289
	0.0	1.865	1.585	0.280
8	0.5	1.810	1.550	0.260
	1.0	1.790	1.553	0.237
	2.0	1.825	1.611	0.214
	5.0	1.845	1.666	0.179
	Blank	1.930	1.628	0.302
	0.0	1.865	1.572	0.293
10	0.5	1.810	1.538	0.272
	1.0	1.790	1.542	0.248
	2.0	1.825	1.602	0.223
	5.0	1.845	1.658	0.187

Table 5: Evaluation of Corrosion Rate of Mild Steel in 2.0M HCl and its inhibition by various Concentrations of Proguanil Hydrochloride at 303K.

Inhibitor Concentration x 10^{-4} (M)	CR x 10^{-3} ($Mgcm^{-2}h^{-1}$)	$\bar{X}CR \times 10^{-3}$	SD x 10^{-3}	Difference in $\bar{X}CR$ $x\,10^{-3}$	$SEMD$ $x\,10^{-3}$	STATISTICAL TEST VALUES			
						df	$T_{cal.}$	T_{tab} (p<0.05)	TEST Significance (p<0.05)
Blank	18.02 9.77 6.86 5.52 4.53	8.94	4.87	-	-				
0.1	16.39 8.90 6.24 5.15 4.12	8.16	4.41	0.78	2.94	8	0.27	2.31	NS
0.5	14.19 7.67 5.43 4.36 3.58	6.33	3.89	2.61	2.79	8	0.94	2.31	NS
1.0	10.93 5.87 4.19 3.34 2.77	5.42	2.95	3.52	2.25	8	1.38	2.31	NS
2.0	9.07 4.88 3.45 2.76 2.28	4.49	2.45	4.45	2.44	8	1.82	2.31	NS
5.0	7.67 4.13 2.95 2.33 1.98	3.81	2.06	5.13	2.36	8	2.17	2.31	NS

Table 6: Evaluation of Corrosion Rate of Mild Steel in 2.0M HCl and its inhibition by various Concentrations of Proguanil Hydrochloride at 313K.

Inhibitor Concentration x 10^{-4} (M)	CR x 10^{-3} ($Mgcm^{-2}h^{-1}$)	$\bar{X}CR \times 10^{-3}$	SD x 10^{-3}	Difference in $\bar{X}CR$ $x\,10^{-3}$	$SEMD$ $x\,10^{-3}$	STATISTICAL TEST VALUES			
						df	$T_{cal.}$	T_{tab} (p<0.05)	TEST Significance (p<0.05)
Blank	17.67 9.77 6.82 5.47 4.58	8.86	4.84	-	-				
0.1	16.40 9.07 6.36 5.06 4.26	8.23	4.40	0.63	2.93	8	0.22	2.31	NS
	14.53								

0.5	7.91 5.58 4.48 3.77	7.25	3.90	1.61	2.78	8	0.58	2.31	NS
1.0	11.63 6.40 4.53 3.60 3.02	5.84	3.11	3.02	2.57	8	1.18	2.31	NS
2.0	9.65 5.29 3.76 2.99 2.51	4.84	2.58	4.02	2.45	8	1.64	2.31	NS
5.0	8.02 4.48 3.10 2.50 2.12	4.04	2.14	4.82	2.37	8	2.03	2.31	NS

Table 7: Evaluation of Corrosion Rate of Mild Steel in 2.0M HCl and its inhibition by various Concentrations of Proguanil Hydrochloride at 323K.

Inhibitor Concentration x 10^{-4} (M)	**CR x 10^{-3} ($Mgcm^{-2}h^{-1}$)**	**$\bar{X}CR \times 10^{-3}$**	**SD x 10^{-3}**	**Difference in $\bar{X}CR$ $x\ 10^{-3}$**	**$SEMD$ $x\ 10^{-3}$**	**df**	**STATISTICAL TEST** **TEST Significance** **$T_{cal.}$**	**T_{tab} (p<0.05)**	**VALUES (p<0.05)**
Blank	20.81 11.22 7.95 6.10 5.93	10.26	5.65	-	-				
0.1	19.77 10.64 7.48 5.78 4.98	9.73	5.46	0.53	3.51	8	0.15	2.31	NS
0.5	18.14 9.71 6.70 5.32 4.56	8.93	4.99	1.33	3.37	8	0.39	2.31	NS
1.0	16.28 8.78 6.12 4.77 4.09	8.01	4.44	2.25	3.21	8	0.70	2.31	NS
2.0	14.42 7.73 5.47 2.24 3.60	7.09	3.93	3.17	3.08	8	1.03	2.31	NS
5.0	11.98 6.45 4.53 3.55	5.91	3.25	4.35	2.91	8	1.47	2.31	NS

	3.05

Table 8: Evaluation of Corrosion Rate of Mild Steel in 2.0M HCl and its inhibition by various Concentrations of Proguanil Hydrochloride at 333K.

Inhibitor Concentration x 10^{-4} (M)	**CR x 10^{-3} ($Mgcm^{-2}h^{-1}$)**	**$\bar{X}CR$ x 10^{-3}**	**SD x 10^{-3}**	**Difference in $\bar{X}CR$ $x\ 10^{-3}$**	**$SEMD$ $x\ 10^{-3}$**	**df**	**STATISTICAL TEST: TEST Significance $T_{cal.}$**	**T_{tab} (p<0.05)**	**STATISTICAL TEST VALUES (p<0.05)**
Blank	28.37 15.23 10.70 8.40 7.02	13.94	7.73	-	-				
0.1	27.56 14.77 10.35 8.14 6.81	13.53	7.52	0.41	4.83	8	0.08	2.31	NS
0.5	25.58 13.72 9.61 7.56 6.33	12.56	6.98	1.38	4.66	8	0.30	2.31	NS
1.0	23.26 12.44 8.76 6.89 5.77	11.42	6.33	2.52	4.47	8	0.56	2.31	NS
2.0	21.05 11.22 7.91 6.22 5.19	10.32	5.74	3.62	4.31	8	0.84	2.31	NS
5.0	17.56 9.42 6.63 5.20 4.35	8.63	4.78	5.31	4.07	8	1.30	2.31	NS

From tables V, VI, VII, and VII, data on corrosion rate show that XCR of mild steel in 2.0M HCl reduces in the present of proguanil Hydrochloride Inhibitor. It was also observed that the reduction in XCR of the mild steel in the test solution increased with increase in inhibitor concentration. XCR was also observed to increase with rise in corrodent temperature even in the present of inhibitor. The increase in successive reduction in XCR with corresponding increase in inhibitor concentration tested non-significant (P<0.05) for all concentrations of proguanil Hydrochloride inhibitor. Statistical test also reveals that the tested significance (P<0.05) gradually appreciated to values approaching significant levels at higher concentrations (5.0 x 10^{-4}M) of inhibitor and lower temperatures (303K and 313K).

Table 9: Summary of analyzed data of Corrosion Rate (CR) and evaluation of relevant parameters (Surface Coverage, θ and Percentage Inhibition Efficiency, %IE) at various Temperatures and respective inhibitor concentrations.

	303K			**313K**			**323K**			**333K**		
Inhibitor Concentration x 10^{-4} (M)	**CR x 10^{-3} ($Mgcm^{-2}h^{-1}$) $\bar{x}\ \pm SD$**	**%IE**	**θ**	**CR ($Mgcm^{-2}h^{-1}$)**	**% IE**	**θ**	**CR ($Mgcm^{-2}h^{-1}$)**	**% IE**	**θ**	**CR ($Mgcm^{-2}h^{-1}$)**	**%IE**	**θ**
Blank	8.94 ± 4.87			8.86 ± 4.84			10.26 ± 5.65			13.94 ± 7.73		
0.1	8.16 ± 4.41	9	0.09	8.23 ± 4.40	7	0.07	9.73 ± 5.46	5	0.05	13.53 ± 7.52	3	0.03

0.5	6.33 ± 3.89	21	0.21	7.25 ± 3.90	18	0.18	8.93 ± 4.99	13	0.13	12.56 ± 6.98	10	0.10
1.0	5.42 ± 2.95	39	0.39	5.84 ± 3.11	34	0.34	8.01 ± 4.44	22	0.22	11.42 ± 6.33	18	0.18
2.0	4.49 ± 2.45	50	0.5	4.84 ± 2.58	45	0.45	7.09 ± 3.93	31	0.31	10.32 ± 5.74	26	0.26
5.0	3.81 ± 2.06	56	0.56	4.04 ± 2.14	54	0.54	5.91 ± 3.25	42	0.42	8.63 ± 4.78	38	0.38

Data on table IX shows that %IE of Proguanil Hydrochloride for mild steel corrosion in 2.0M HCl increases with increase in inhibitor concentration and decreases with rise in corrodent temperature. Similarly, θ increases with increase inhibitor concentration and decreases with rise in corrodent temperature. Variations in the above parameters are shown in the plots below.

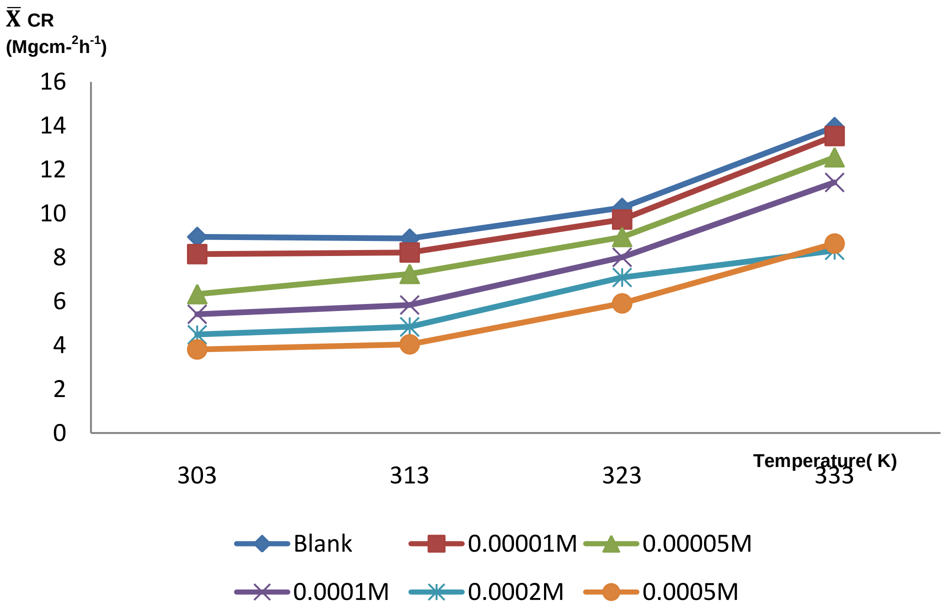


Figure 1: Plot of Mean Corrosion Rate ($\bar{X}$CR) against Inhibitor Corrodent Temperature at Various Inhibitor Concentrations

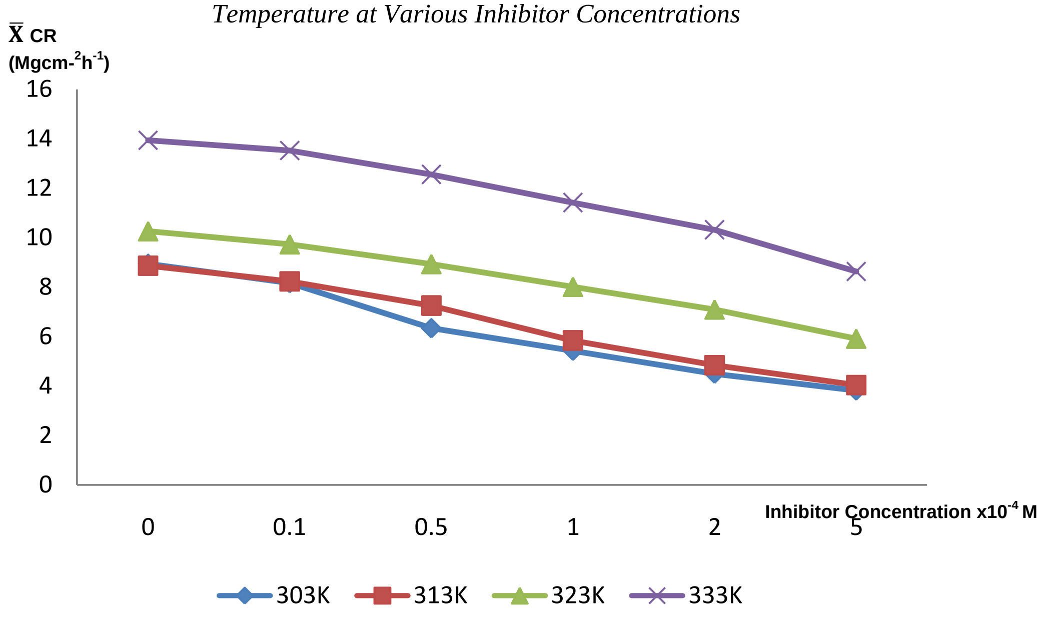


Figure 1: Plot of Mean Corrosion Rate ($\bar{X}$CR) against Inhibitor Concentrations at Various Corrodent Temperature

Method of Statistical Analysis

Raw data generated from experimental work was statistically analyzed and changes in parameters of interest were tested using appropriate statistical method (t-test) and their significance measured at appropriate significance level ($p<0.05$). The following statistical instruments were involved in the entire work;

Mean, $\overline{X} = \frac{\sum fx}{\sum f}$ or $\overline{X} = \frac{\sum fx}{N}$

Where $\sum fx$ = Summation f of x and f = Frequency

$\sum f$ = Summation f = N. x = observation

$$SD = \sqrt{\frac{\sum f(x-\overline{x})^2}{\sum f}}$$

Where SD = Standard Deviation

f = Frequency

$\overline{X}$ = Mean

x = Observation

$$SEMD = \sqrt{\frac{S_1^2}{N_1} + \frac{S_2^2}{N_2}}$$

Where SEMD - Standard Error of Mean Deviation

S_1 – Standard Deviation of the first group

S_2 – Standard Deviation of the second group

N_1 – Number of Observations of the first group

N_2 – Number of Observations of the second group

$$t = \frac{\overline{X}_1 - \overline{X}_2}{SEMD}$$

Where t = t-test

$\overline{X}_1$ - mean of the first group

$\overline{X}_2$ - mean of the second group

SEMD - Standard Error of Mean Deviation [14-15]

Occurrence and Mechanism of Corrosion

Corrosion occurs by electrochemical process involving an electrolyte (where there is ionic transfer), anodic and cathodic reactions respectively and electrical currents to initiate its actions. It involves the formation of a chemical cell, in which a potential difference is set up between the points on the surface involved. The electrolytic reactions are as shown below:

$M_s \longrightarrow M^{++}_{(aq)}\ \ 2e^-$ Anadic reaction

$2H^+ + 2e^- \longrightarrow H_{2(g)}$ Cathodic reaction

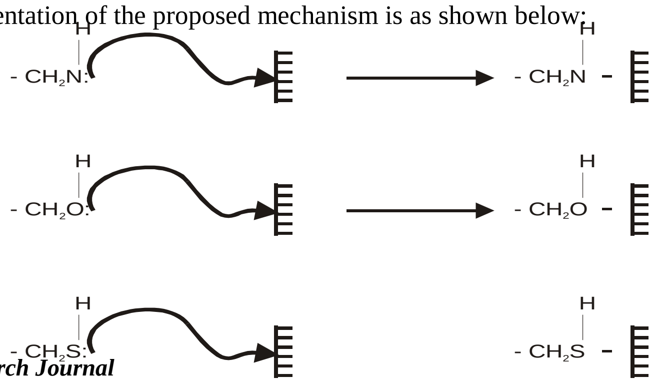
The reaction is characterized by the formation of reddish brown colouration of Fe^{3+} as the corrosion product also known as RUST and the process as RUSTING [16-17].

Proposed Mechanism of Corrosion Inhibition

Most inhibitors are organic compound and Thiourea derivatives containing Nitrogen (N), Oxygen (O) and Sulphur (S) in their molecules which are all electron rich atoms [12]. The compounds are hydrolysable and can easily adsorbed on the metal surface via the lone pair of electrons carried by their respective N, O and S atoms [4,5,18].

The bulky group that carries the functional groups containing the reacting atoms, covers the surface of the metal preventing further interaction of the metal with the corrosion environment and perhaps subsequent characteristic ionic transfer, as such preventing corrosion occurrence. The thin layer coverage formed, essentially blocks the discharge of H^+ and dissolution of metal ions, producing an electrostatic system where the protonated constituents molecules are adsorbed by process of physisorption, producing inhibition effect of very high efficiency [5, 19].

The schematic representation of the proposed mechanism is as shown below:



$4H^{+}_{(aq)} + O_{2(g)} \longrightarrow 2H_2O_{(1)}$ In acidic medium

$2H_2O_{(1)} + O_2 + 4e^{-} \longrightarrow 4OH^{-}$ In basic medium

The reaction mechanism of corrosion follows the 'absolute reaction rates theory' also known as "transition state theory", which states that; 'molecules before undergoing reaction must form an activated complex in equilibrium with the reactants, and that the rate of any reaction is given by the rate of decomposition of the complex to form the reaction products [3,13]. Generally, for a reaction between a molecule of A and B, the postulated steps can be represented schematically as below:

$A + B \longleftrightarrow [AB]^* \xrightarrow{K}$ Products

Reactant Activated Complex

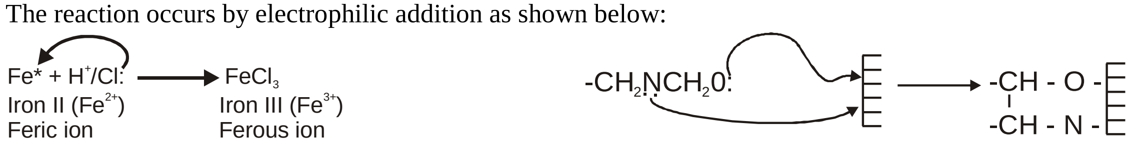
The activated complex has certain properties of an ordinary molecule and possess temporary stability [13]

Similarly, corrosion of mild steel in HCl solution follows a reaction mechanism as presented below:

$Fe_{(s)} + HCl_{(aq)} \longleftrightarrow [Fe(H_2O)]\,Cl_{3(aq)} \xrightarrow{K} FeO_3.xH_20_{(aq)} + FeCl_{3(s)}$

The above reaction illustrates an oxidation of Fe from oxidation state of +2 to +3 by a lone pair of election from chlorine (Cl^-) [20-21.

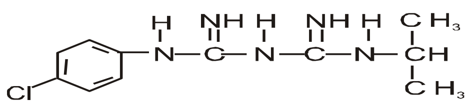
The reaction occurs by electrophilic addition as shown below:



From the above mechanism, corrosion inhibition can be explained on the basis of the concept of adsorption of inhibitors on the corroding metal surface. The inhibitive actions of these compounds have been attributed to the strong adsorption of these molecules on the positive metal surface, using the lone pairs of election available on their hetero atoms [5,13,22].

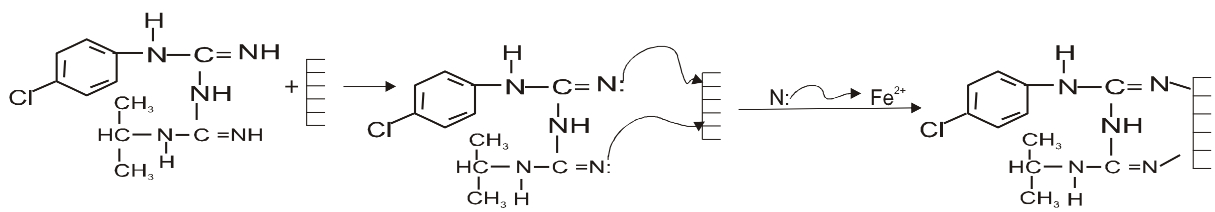
Proguanil Hydrochloride as Corrosion Inhibitor

Proguanil Hydrochloride is an organic compound with equivalent weight of 252.5g. It is rich in Nitrogen and has a chemical structure as presented below.



Proguanil Hydrochloride

It is readily available as a pharmaceutical with high potency for microbial infections [11]. As corrosion inhibitor, proguanil hydrochloride is proposed to operate with the mechanism below.



Proguanil hydrochloride like other nitrogeneous inhibitors shows sufficient evidence of inhibition of mild steel corrosion in 2.0M HCl with non-significant ($P<0.05$), efficiency at its lower concentrations ($\leq 5.0 \times 10^{-4}$M). It corrosion inhibition property is accounted for by strong adsorption of its molecules on the positive metal surface using the lone pairs of electron from its nitrogen. The bulky functional group spread on the metal surface preventing its further interactions with the corroding environment [6,7,22].

Conclusion

XCR of mild steel in 2.0M HCl decrease in the present of proguanil hydrochloride inhibitor. The successive decrease in the XCR increased with corresponding increase in inhibitor concentration. XCR increases with rise in corrodent temperature with or without inhibitor. Useful parameters like %IE and θ both increased with increase in inhibitor concentration and decreased with rise in corrodent temperature. Reduction in XCR tested non-significant ($P<0.05$) for all inhibitor concentrations, but showing gradual appreciation to values approaching significant level at higher (5.0×10^{-4}M) inhibitor concentration and lower (303K and 313K) temperatures. Thus, making proguanil hydrochloride better inhibitor for mild steel corrosion in 2.0M HCl at high ($5.0x10^{-4}$M) inhibitor concentrations and low (T≤ 313K) corrodent temperatures.

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