www.ijecs.in
International Journal Of Engineering And Computer Science ISSN:2319-7242
Volume 2 Issue 8 August, 2013 Page No. 2355-2363

Kinetic And Correlation Studies Between Varying Corrosion Parameters And Corrosion Rate Of N-80 Oil Well Tubular Steel In 15% Hydrochloric Acid Pickling Solution Using *Ficus Abutilifolia* Plant Extract

Abubakar, G*., Ibrahim, H., Mustafa, M., Apugo-Nwosu, T. U., Nwobi, B.E., Ayilara, S. I., Akuso, S. A. and Agboun, D.T

National Research Institute for Chemical Technology, Zaria-Nigeria

Corresponding author E-mail address: emailganiyu@yahoo.com

ABSTRACT
The varying effects of temperature, time and inhibitor concentrations on the corrosion rate of N-80 oil well tubular steel in 15% hydrochloric acid with and without leave extract of Ficus Abutilifolia have been investigated. The time, temperature and concentration of inhibitor were varied in the range 1-2.5 hrs at 0.5 hr interval, 45°C-90°C at 15°C interval and 0.1 – 0.9 v/v% at 0.1v/v% interval respectively. Standard deviation, effect of variables at 95% confidence interval, factorial design, and Arrhenius kinetics approach were used to correlate the corrosion parameters and corrosion rate. The obtained results indicate that temperature increase enhances corrosion rate while increase in inhibitor concentration and time decreases corrosion rate. It was found also that temperature and inhibitor concentration are the most important control parameters for corrosion process. The kinetic and statistical approaches were in good agreement.

Keywords: Corrosion inhibition, *Ficus Abutilifolia*, hydrochloric acid, kinetic and statistical analysis.

1. INTRODUCTION

Corrosion of metals is a major industrial problem that has attracted a lot of investigators in recent years (Liu *et al*, 2001; Ita and Offiong, 1999**;** Ekpe *et al*,1995; Collins *et al*, 1993**).** In industries such as pulp and paper industry, power generation, underground structures, chemical and oil industries, metals are used in over 90% of construction process (Osarolube *et al*., 2004). Iron and steel are the most commonly used materials in the fabrication and manufacturing of oil field operating platforms because of their availability, low cost, ease of fabrication, and high strength (Umezurike, 1998; Nwoko and Umoru, 1998). Most industrial media are usually rich in elemental gases, inorganic salts, and acidic solutions most of which influence corrosion rates, and mechanisms (Owate and Abumere, 2003; Abiola and Oforka, 2005). The highly corrosive nature of aqeous mineral acid used with most engineering materials found in industrial environment requires some degree of restraint to achieve economic maintenance and operation of equipments or materials and maximum safety conditions (Kuznetsov and Yu, 2002). Metals are usually exposed to the action of bases or acids in the industries. The most important industrial fields of application are acid pickling, industrial acid cleaning, acid descaling and oil well acidification (Hosseini *et al*, 2003a; Fan *et al*, 2002; Hosseini *et al*, 2003b).

During pickling, various hot acid solutions are used for removing mill scales (oxide scales) from the metal surface at elevated temperatures, such as 60°C in hydrochloric acid and up to 95°C in sulfuric acid (Sadaf and Quraishi, 2010). Thus in this work maximum temperature of 90°C was used.

Corrosion prevention of metal based on the use of corrosion inhibitors which when present in a system at sufficient concentrations, decrease the corrosion rate without causing considerable changes in the concentration of any corrosion reagent (standart ISO 8044, 1989). Considering that losses from metal corrosion exceed 5% of the gross national product in industrial countries, the development and application of inhibitors, which is one of the main methods of corrosion protection, should be considered as a scientific and engineering task of current interest. Studies have revealed that the existence of various inhibitors namely oxidizing, adsorption, complexation-type and polymeric type (Kuznetsov and Yu, 2002).

The best known oxidizing inhibitors are the salts of chromic acid. However, discharge of chromate has become unacceptable, due to environmental hazards.

The recent trend is towards environment – friendly inhibitors. Most of the natural products are non-toxic, biodegradable and readily available in plenty. Various parts of plants – seeds, fruits, leaves, flowers, etc – have been used as corrosion inhibitors (Rajendran, *et al*, 2005).

The cost of using green inhibitors is less when compared to that of organic inhibitors which takes lot of chemicals and also time for its preparation (Sharmila *et al*, 2010).

Thermodynamic and kinetic parameters are used for analyzing systems undergoing chemical reactivity. However, corroding systems are not in equilibrium and therefore thermodynamic calculation cannot be applied. Hence from the engineering point of view, the major study of interest is the kinetic rate of corrosion. Despite their abundance in our environment no previous work has been undertaken on the corrosion inhibition properties of *Ficus Abutilifolia*. Therefore, investigation into its corrosion inhibition properties will provide pioneering knowledge on the use of its leave extract as inhibitors and therefore add to the growing list of relatively cheap, environmentally friendly and non-toxic corrosion inhibitors. Hence in the present work, the extract of *Ficus Abutilifolia* leaves is evaluated for its corrosion inhibition performance by varying its corrosion parameters using Weight loss method.

2. Materials and Methods

2.1. Materials

The experimental materials used in this study are: Plant extract, Hydrochloric Acid (Analar Grade), Ammonium Acetate (Analar Grade), Distilled Water, Emery papers (220-800 grades), 250ml beakers, retort stand, N-80 steel coupons.

Table 1 The high strength low alloy steel is a commercial micro alloyed steel (in hot-rolled condition) with the following percentage alloy

Element	C	Mn	Si	P	S	Mo	V	Ti	Al	Fe	Total
Composition,%	0.22	1.2	0.25	0.025	0.025	0.001	0.004	0.002	0.051	98.22	100

2.2. Equipment

The equipments used in this study are as follows: thermostated water bath, analytical balance.

2.3. Determination of corrosion rate

The as – received steel (6cm x 5cm x 1.5cm) bars were sectioned into coupon of sizes 2cm x 1cm x 0.75cm and polished with emery papers (220-800 grades).

The specimens were the washed with distilled water followed by degreasing in absolute ethanol, dried in acetone, weighed in an analytical balance and stored in a moisture free desiccators prior to use [16]. Corrosion tests were carried out in freely aerated freshly prepared 15% hydrochloric solution. This was prepared from AR grade 36% HCl and distilled water. Freshly prepared extract of *Ficus Abutilifolia* were added at concentrations of 0.1 v/v%, 0.3 v/v%, 0.5 v/v%, 0.7 v/v% and 0.9 v/v%. All the experiments were conducted at 45^{o}C, 60^{o}C, 75^{o}C and 90^{o}C. The total immersion time was 150 minutes while the corrosion rate was examined every 30minutes, to ascertain the effect of time on the corrosion rate.

3. Results and discussion

3.1. Results

3.1.1. Gravimetric test

To compare the factors that influence corrosion rate of the N-80 Alloy steel, the corrosion rates of the experimental specimens immersed in the corrodent with and without inhibitor at varied temperature and time were determined using the standard expression for measurement of Corrosion rate in mils per year (mpy) which is expressed in the equation.

$r = 534W/\rho At$ --1

where r is the corrosion rate, W is the weight loss (mg), ρ is the density of the material (g/cm^3), t is the time of exposure (hrs) and A is the total surface area (in^2). The results obtained are shown in Figures 1-5.

3.1.2. Kinetic analysis

Kinetic models are a useful tool to explain the mechanism of corrosion inhibition processes. Arrhenius equation was used to determine the corrosion kinetic using the expression (Oloche *et al*, 2009).

$r = B_o e^{-Ea/RT}$ --2

The natural logarithm of the corrosion rate, r, could be represented as a straight line function of 1/T of steel in acid medium (Tang *et al*, 2003; Bouklah et al, 2005).

$\ln r = E_a / RT + \ln B_o$ ---3

Where E_a represents the activation energy, R is the universal gas constant, T is the absolute temperature and B_o is the pre-exponential factor. A plot of ln r against $1/T$ for a range of temperatures gives a linear graph with slope $-E_a/R$. Hence the apparent activation energy Ea was calculated and tabulated in Table A.1. Figures 6 and 7 show the linear regression of ln r and $1/T$ from blank (0 v/v%) to 0.9 v/v% concentration of the inhibitor. Figures 8 and 9 show the plots of apparent activation energy as a function of concentration and time.

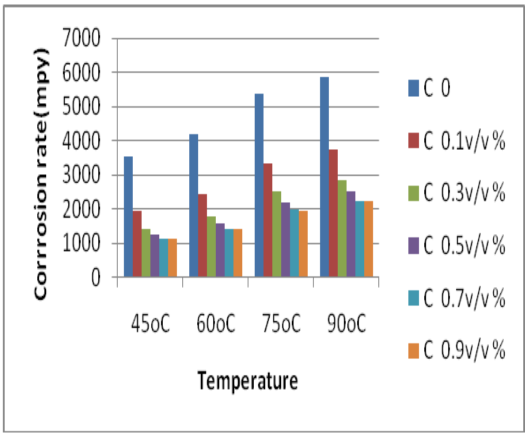

Fig. 1: Variation of corrosion rate with temperature after 0.5 hr exposure time

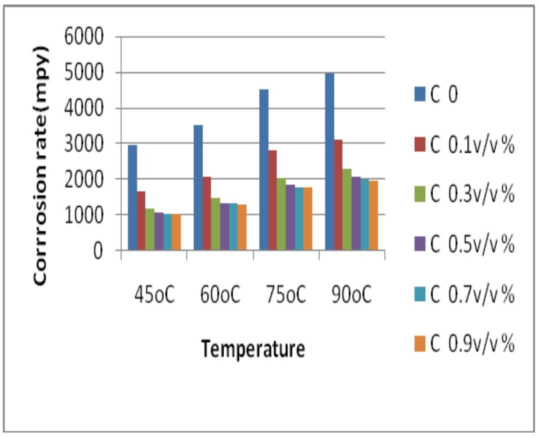

Fig. 2: Variation of corrosion rate with temperature after 1 hr exposure time

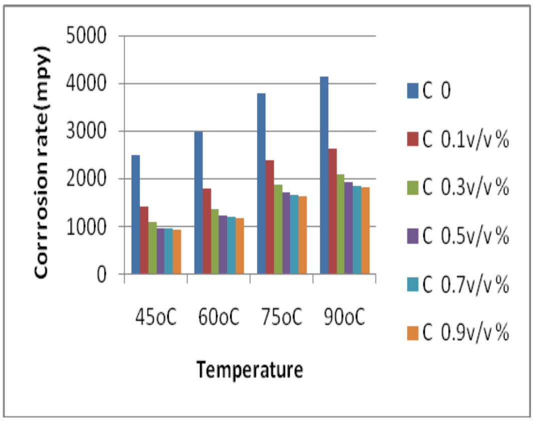

Fig. 3: Variation of corrosion rate with temperature after 1.5 hr exposure time

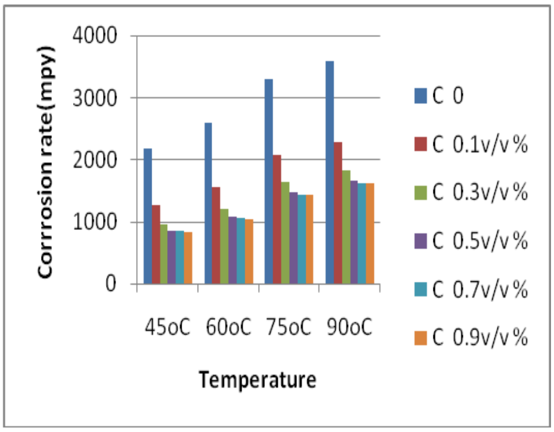

Fig. 4: Variation of corrosion rate with temperature after 2 hrs exposure time

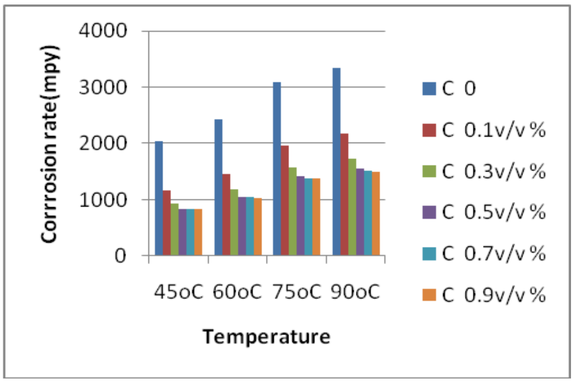

Fig. 5: Variation of corrosion rate with temperature after 2.5 hrs

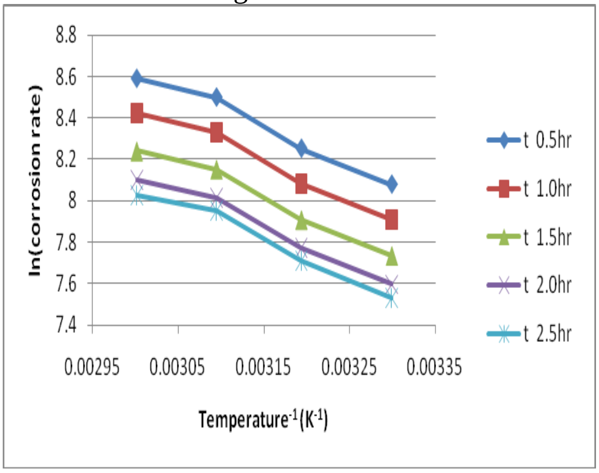

Fig. 6: Variation of ln(corrosion rate) with absolute temperature in HCl with FA extract

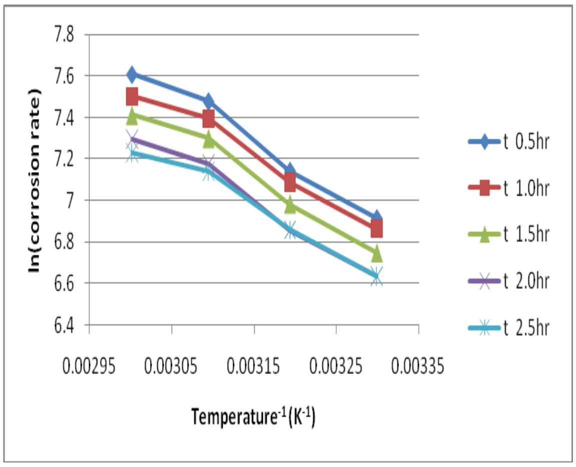

Fig. 7: Variation of ln(corrosion rate) with reciprocal of absolute temperature in HCl without inhibitor

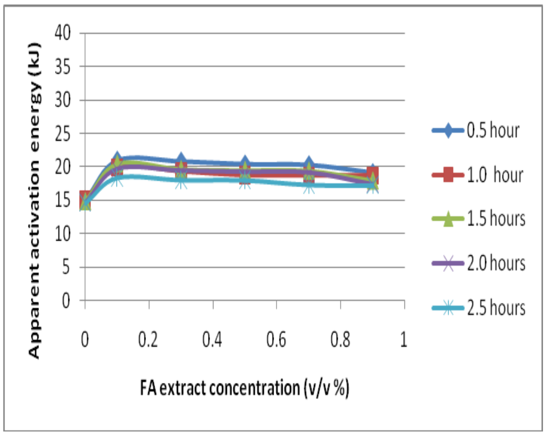

Fig. 8: Variation of apparent activation energy (Ea) with concentration of FA extract (v/v %)

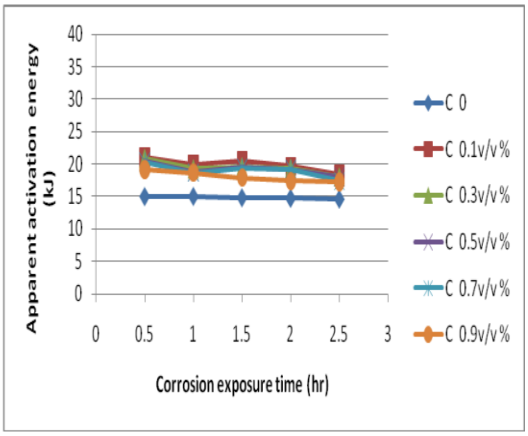

Fig. 9: Variation of apparent activation energy (E_a) with corrosion exposure time (hr)

3.1.3. Statistical analysis of corrosion inhibition process

Two levels, three factors factorial design were used for the statistical analysis (Miller and Freund, 1987, Duncan and Irwin, 1965). The levels for the three factors are entered in Table A2 and the treat ment for the two levels and these three factors are tabulated on Table A3.
The significant factors (main and the interactions) were identified by Yates analysis (Miller and Freund, 1987).

The Yates analysis computation for the effects is shown in Table A5. The standard deviation of the effects was also calculated. The results are shown in Table A6. The 95% confidence interval for the estimated effect is given as (Oloche *et al*, 2009).

$E \pm \left(t_{\infty,} 0.05\right) \times$ (standard deviation of the estimated effect) -------------------------4

Where $\left(t_{\infty,}0.05\right)$ is 2.31. The results of the estimated effect at 95% confidence interval are shown in Table A7.

3.2. Discussion

Figures 1-5 indicate that the corrosion rate increases with temperature and decreases with inhibitor concentration. The figures show a change in corrosion rate of 2350 mpy, 1987 mpy, 1643 mpy, 1419 mpy and 1313 mpy of the specimen immersed in the absence of inhibitor when the process experimental temperature was raised from 45 ^{o}C to 90^{o}C at an exposure time of 0.5, 1.0, 1.5, 2.0 and 2.5 hours respectively. The figures also show a change in corrosion rate of 831 mpy, 610 mpy, 491 mpy, 428 mpy and 329 mpy at an experimental temperature of 45^{o}C when the inhibitor concentration was increased from 0.1 v/v% to 0.9 v/v% at an exposure time of 0.5, 1.0, 1.5, 2.0 and 2.5 hrs respectively.

However, at all combinations of temperature and inhibitor concentration, the corrosion rates decrease with increase in exposure time. Hence, temperature and inhibitor concentration are the most significant parameters for corrosion rate control.

Figures 6 and 7 represent the linear regression of ln r and 1/T for the specimen immersed in 15% HCl with and without corrosion inhibitor. Some studies (Zhao and Mu, 1999; Khamis, 1990) show that compared with the apparent activation energy in the absence of inhibitor, higher values of E_a were found in the presence of inhibitors. This suggests existence of higher energy barrier for the corrosion process in the inhibited solutions associated with physical adsorption or weak chemical bonding between the inhibitor species and the steel surface (Li and Mu, 2005). Other studies show that in the presence of inhibitors, the apparent activation energy was lower than that in the absence of inhibitor (Banerjee and Misra, 1989; Cai *et al*, 1993). It could be found from Figure 8 that the apparent activation energy for the entire specimen exposed to 15% HCl solution was higher than that without inhibitors (Figure 7), which suggests that *Ficus Abutilifolia* extract is an active inhibitor of the steel corrosion. Similar observation has been reported (Oloche *et al*, 2009).

Activation energy was however greatest with inhibitor addition of 0.1 v/v% at all the test durations. However, E_a values decreases as concentration is increased beyond 0.1 v/v%. The decrease in the E_a value as observed for the inhibitors at higher inhibitor concentration has been reported in the literature (Li, X and Mu, G, 2005; Tang et al, 2006; Tang et al, 2003; Obot and Obi-Egbedi 2009; Ebenso et al, 2009). Riggs and Hurd (1967) explained this observation by stating that at higher levels of inhibition the net corrosion reaction shifts from that on the uncovered part of the metal surface to the covered one. This trend also suggests that FA is an active inhibitor on steel in 15% HCl solution (Oloche et al, 2009 and Ebenso, 2003). The increase in value of activation energy in the presence of FA signify physical adsorption. The values of E_a obtained for all the inhibitors indicated that the whole process is controlled by surface reaction, since the activation energies of the corrosion process is over 20 kJ/mol (Al-Neami et al, 1995). A comparison of Figures 8 and 9 shows a steeper slope in Figure 8 (E_a against concentration of corrosion inhibitor), than the almost horizontal lines of Figure 9 (E_a against time). This observation indicates that change in inhibitor concentration has more effect on the corrosion rate than exposure time. Hence, temperature and inhibitor concentration are the most important kinetic parameters in the corrosion inhibition of steel in 15% HCl with FA as corrosion inhibitor.

From the results of the factorial design for FA (Table A6), the experimental temperature appears to be the most important variable with main effect of 1047.3 mpy followed by concentration with -767.3 mpy and time -748.8 mpy. The analysis shows that raising the temperature from 45^{o}C to 90^{o}C would result in increase in corrosion rate by 1047.3 mpy. Increasing concentration from 0.1 v/v% to 0.9 v/v% would decrease corrosion rate by 767.3 mpy while increasing time from 0.5 to 2.5hrs would decrease the corrosion rate by 748.8 mpy.

The estimated interactions between temperature and concentration, temperature and time, concentration and time and then between all three factors temperature, concentration and time are -235.2 mpy, -273.2 mpy, 308.6 mpy and 77.9 mpy respectively. Of all the interactions, concentration and time is most significant. Raising the two at the same time leads to increase in corrosion rate by 308.6 mpy while raising temperature and time would result in decrease in corrosion rate by 273.2 mpy. Similarly, increasing temperature and concentration would result in increase in corrosion rate by 235.2 mpy while increasing all three factors simultaneously increases corrosion rate by 77.9 mpy. The result in Table A7 shows values for all the main effects of the factors with temperature being the highest with a value of 4.32 times the standard deviation value. This again shows that temperature is the most significant parameter in tubular steel corrosion control using extract of FA as inhibitor. From the results of Table A8, temperature and inhibitor concentration are the most significant parameters in corrosion inhibition of tubular steel at 95% confidence level. The results therefore implies that the results of the statistical analysis comprising Yates factorial design, standard deviation and effect of variables at 95% confidence level, confirm kinetic (activation energy) result that temperature and inhibitor concentration are the most important parameters in the inhibition of tubular steel.

4. Conclusions

1. Extract of *Ficus Abutilifolia* significantly reduced the corrosion rate of tubular steel in 15% HCl solution.
2. the corrosion rate increases with temperature and decreases with inhibitor concentration
3. Maximum corrosion inhibition was observed at inhibitor concentration of 0.9 v/v%.
4. The values E_a for all the inhibitors studied were all less 80KJ/mol indicating physical adsorption mechanism.
5. Yates factorial design, standard deviation and effect of variables at 95% confidence level, confirm that temperature and inhibitor concentration are the most important parameters in the inhibition of tubular steel.
6. Kinetic and statistical analysis are in agreement, confirming that temperature and concentration are the most important corrosion inhibition parameters.

Table A1 Results of apparent activation energy with and without inhibitor at different exposure time

Inhibitor concentration(v/v%)	Apparent activation energy (kJ/mol) at different times (hr)				
	0.5 hr	1.0 hr	1.5 hr	2.0 hr	2.5 hr
0	15.02	15.02	14.84	14.75	14.61
0.1	21.01	19.89	20.46	19.66	18.42
0.3	20.85	19.28	19.60	19.39	18.08
0.5	20.43	18.69	19.47	19.22	18.04
0.7	20.33	18.68	19.38	19.13	17.36
0.9	19.16	18.66	17.91	17.39	17.25

Table A2: Factorial design of the corrosion rate

Factor	Low level	High level
Temperature, T (^oC)	45	90
Concentration, C (v/v%)	0.1	0.9
Time, t (hr)	0.5	2.5

Table A3: Factorial design of the corrosion process showing the treatment combination

Exp.number	Temperature level	Concentration level	Time level
1	-1	-1	-1
T	+1	-1	-1
C	-1	+1	-1
TC	+1	+1	-1
t	-1	-1	+1
Tt	+1	-1	+1
Ct	-1	+1	+1
TCt	+1	+1	+1

Coded: -1(low level),+1(high level)

Table A4: Experimental Condition and Corrosion Rate for Each Condition for FA

Experimental combination	Temp(^oC)	Conc(v/v%)
1	45	0.1
T	90	0.1
C	45	0.9
TC	90	0.9
T	45	0.1
Tt	90	0.1
Ct	45	0.9
TCt	90	0.9

Table A5: Yates Analysis

T.combn	CR	Col 3	Col 4	Col 5	ME
1	1768.76	5171.19	8190.5	13385.7	3346.43
T	3402.436	3019.30	5195.2	4189.10	1047.27
C	1005.9	3056.35	2640.9	-3069.3	-767.34
TC	2013.31	2138.87	1548.1	-940.8	-235.22
t	1062.51	1633.6	-2151	-2995.2	-748.81
Tt	1993.84	1007.3	-917.4	-1092.8	-273.21
Ct	761.042	931.32	-626.3	1234.4	308.60
TCt	1377.83	616.78	-314.5	311.81	77.95

T.combn=treatment combination
ME=Mean effect

Table A6: Calculation of the Standard deviation of the effects

Y	Y-S	[Y-S]^2
1768.763	-95.547	9129.229
3402.436	-1729.22	2990202
1005.993	667.223	445186.5
2013.31	-340.094	115663.9
1062.514	610.702	372956.9
1993.843	-320.627	102801.7
761.0422	912.1738	832061
1377.83	295.386	87252.89
$\frac{\sum Y}{N} = \frac{13385.7}{8} = 1673.2$	$S = \frac{\sum [Y-S]^2}{N} = \sqrt{\frac{4955254}{8}} = 787.02$	

S = Standard deviation, Y=Effect, N=Number of effects

Table A7: Effects of variables at 95% Confidence level

Main effect	Effect±($t_{\infty,0.05}$)*S	95% Confidence interval
T	1047.28±1818.03	-770.75+2865.31
C	-767.35±1818.03	-2585.38+1050.68
T	-748.82±1818.03	-2566.85+1069.21
Two-factor interaction		
TC	-235.22±1818.03	-2053.25+1582.81
Tt	-273.22±1818.03	-2091.25+1544.81
Ct	308.60±1818.03	-1509.43+2126.63
Three-factor interaction		
TCt	77.95±1818.03	-1740.08+1895.98

Panda BB,Gaur K , Kori ML, Tyagi LK, Nema RK, Sharma CS et al . Anti-Inflammatory and analgesic activity of Jatropha gossypifolia in experimental animal models. Global Journal of Pharmacology 2009; 3(1):1-5.

References

Abiola, O.K., and Oforka, N.C. Organic Corrosion Inhibitors for steel and aluminium in acid systems. J. Corr. Sci. Tech. 2005; 3: 113-117.

Al-Neami, K.K., Mohamed, A.K., Kenawy, I.M., Fouda, A.S. Inhibition of the corrosion of iron by oxygen and nitrogen containing compounds Monatsh. Chem. 1995; 26: 369.

Banerjee, N.S and Misra, S. 1,10,-Phenanthroline as Corrosion Inhibitor for Mild Steel in Sulfuric Acid Solution. Corrosion Corrosion 1989; 45: 780.

Bouklah, M., B. Hammouti and M. Benkaddour. Corrosion inhibition of steel in HCl acid solution by new bipyrazole derivatives, Pigment and resin Technology 2005; 197-202.

Cai, H.Q., B. Shan, H. Lu and , X. Yuan. Inhibitive Behavior of Cadmium Sulfate on Corrosion of Aluminum in Hydrochloric Acid. Corrosion 1993;49: 486-490.

Collins, W.D., Weyes, R.E and Al-Qadi, I. L. Corrosion National Association of Corrosion Engineers 1993; 47.

Duncan, A.J., D. Richards and I. Miller. Quality Control and Industrial Statistics, 3rd Ed., Inclusive Publishers, USA, 1965,772-801.

Ebenso, E.E. Synergistic effect of halide ions on the corrosion inhibition of aluminium in H_2SO_4 using 2-acetylphenothiazine. Materials Chem. & Phys.2003; 79: 58-70.

Ebenso, E.E., N.O. Eddy and A.O. Odiongenyi. Corrosion Inhibition and Adsorption Properties of Methocarbamol on Mild Steel in Acidic Medium Portugaliae Electrochimica Acta 2009; 27(1): 13-22.

Ekpe, O.J., Ibok, V.J., Ita, B.T. Offing, O.E and Ebenso, E.E. Inhibitory action of methyl and phenyl thiosemicarbazone derivatives on the corrosion of mild steel in hydrochloric acid. Mater. Chem, Phys. 1995; 40: 87.

Fan, H.B., Fu, C.Y., Wang, H.L., Guo, X.P., Zheng, J.S. Inhibition of corrosion of mild steel by sodium N,N-diethyl dithiocarbonate in hydrochloric acid solution. Br Corros J. 2002; 37:122–125

Hosseini, M.G., S.F.L. Mertens, M. Ghorbani and M.R. Arshadi. Asymmetrical Schiff bases as inhibitors of mild steel corrosion in sulphuric acid media. Mater. Chem. Phys.2003a; 78: 800.

Hosseini, M.G., S.F.L. Mertens and M.R. Arshadi. Synergism and antagonism in mild steel corrosion inhibition by sodium dodecylbenzenesulphonate and hexamethylenetetramine Corros. Sci. 2003b; 45: 1473.

Ita, B.I., and O.E. Offiong.. Adsorption Studies on the Corrosion Inhibition Properties of 2-acetylpyrole and 2-acetylpyrole-(2-acetylthiosemicarbazone) on Mild Steel in Hydrochloric Acid Medium. Global J. Pure and App. Sci.1999; 5(4): 497-501.

Khamis, E. The effect of temperature on the acidic dissolution of steel in the presence of inhibitors Corrosion 1990;46: 476-484.

Yu. I. Kuznetsov, “State-of-the-art of the theory of inhibition of corrosion in metals,” Zashch. Met.2002; 38(2): 122–131.

Li X. and G. Mu, 2005. Tween-40 as corrosion inhibitor for cold rolled steel in sulphuric acid: Weight loss study, electrochemical characterization, and AFM. Appl. Surf. Sci.2005; 252: 1254.

Liu G. Q., Zhu Z. Y., Ke W., Han C. I., Zeng C. L., Corrosion, National Association of Corrosion Engineers 2001; 57(8): 730.

Miller, I., and J.E. Freund. Probability and Statistics for Engineers, Prentice Hall India Ltd., India, 1987. 1-157.

Nwoko, V.O., and L.E. Umoru. Corrosion of Mild Steel in some Environments. J. Corr. Sci.1998 (NICA): 61-65.

Obot, I.B., and N.O. Obi-Egbedi. Ginseng Root: A new Efficient and Effective Eco-Friendly Corrosion Inhibitor for Aluminium Alloy of type AA 1060 in Hydrochloric Acid Solution , Int. J. Electrochem. Sci. 2009; 4(39): 1277 – 1288.

Oloche, O.B., S.A. Yaro and E.G. Okafor. Analytical correlation between varying corrosion parameters and corrosion rate of Al-4.5Cu/10%ZrSiO4 composite in hydrochloric acid by rare earth chloride. Journal of Alloys and compounds 2009; 472:178-185.

Osarolube, E., I.O. Owate and N.C. Oforka. The Influence of Acidic Concentrations on Corrosion of Copper and Zinc. J. Corr. Sci. Tech. 2004; 66-69.

Owate, I.O., O.E. Abumere and K.B. Okeoma, 2003. Changes in Varistor Properties under Harsh Environment. J. Corr. Sci. Tech. 2003; 2: 171-181.

Rajendran S, Ganga SV, Arockiaselvi J, Amalraj AJ, Corrosion inhibition by plant extracts- An overview. Bull. Electrochem., 2005; 21:367-377

Riggs Jr. O.L., and Hurd, R. M..Temperature Coefficient of corrosion inhibition. Corrosion 1967; 23: 252.

Sadaf, K., and M. A. Quraishi, Synergistic effect of potassium iodide on Inhibitive performance of thiadiazoles During corrosion of mild steel in 20% Sulfuric acid. The Arabian Journal for Science and Engineering 2010; 35(1A).

Sharmila, A. A. P. and Sahayaraj, P. A., Influence of murraya koenigii (curry leaves) Extract on the corrosion inhibition of carbon Steel in HCl solution, 2010, Rasayan J. Chem. 2010; 3(1): 74-81.

Standart ISO 1989, 8044.

Tang, L., G. Mu and G. Liu, The effect of neutral red on the corrosion inhibition of cold rolled steel in 1.0 M hydrochloric acid. Corrosion science 2003; 45: 2251-2262.

Tang, L., X. Liu, Y. Si, G. Mu and G. Liu, The Synergistic Inhibition between 8-hydroxyquinoline and chloride ion for the corrosion of cold-rolled steel in 0.5M sulphuric acid. Materials Chemistry and Physics 2006; 95:29-38.

Umezurike, C., The Corrosion of some Oil Field Equipment, J. Corr. Sci.1998;73-78.

Zhao, T and Mu, G. The adsorption and corrosion inhibition of anion surfactants on aluminium surface in hydrochloric acid. Corrosion Sci. 1999;41: 1937-1944.