Corrosion Inhibition for Carbon Steel by Levofloxacin Drug in Acidic Medium

A.S Fouda[1], A.M.El-Wakeel[1], K.Shalabi[1] and A.El-Hossiany[2]

[1]Department of Chemistry, Faculty of Science, El-mansoura University, El-Mansoura-35516, Egypt.

[2]First Chemist, Delta Fertilizers Company on Talkha, Egypt.

ABSTRACT

The hindrance corrosion of Carbon steel in one molar Hydrochloric acid by *Levofloxacin* antibiotic was considered utilizing Electrochemical techniques (EIS, EFM, and Tafel plots) and Chemical (WL, HE and thermometric) at 25ºC. The inhibitor was adsorped on metal surface is steady with Langmuir isotherm adsorption. The curves of polarization reveal that the expansions of Levofloxacin movements the cathodic and anodic branches towards lower currents. Such moves demonstrate that Levofloxacin goes about as a mixed inhibitor. The thermodynamic elements of adsorption procedures were ascertained from weight loss at distinctive temperatures information were utilized to analyses the mechanism of drug. The surface morphology of the metal examples was evaluated using (EDX and SEM) analysis.

Introduction

Corrosion is a principal procedure assuming an essential part in economy and wellbeing, especially for metals and alloys [1]. The utilization of inhibitors is a standout amongst the most methods routines for securing materials versus corrosion, especially in acidic solution [2]. Compounds (N- heterocyclic) are study the best inhibitors for corrosion steel in corrosive media [3]. A number of heterocyclic compounds including Nitrogen, Oxygen and Slufer either long carbon chain or aromatic has been accounted to be effective inhibitors [4-7]. These inhibitors have extended π-electron systems and functional groups for example -NH$_2$, -C=C-, -OH, -NR$_2$, -OR and –SR. The functional groups give electrons that the adsorptions facilitate to the drug on the metal surface [8-13]. A few medications, (for example, ampiclox, ampicillin, tetracycline, cloxacillin, penicillin G, azithromycin, orphenadrine, etc) had been discovered great inhibitors for corrosion of metals. Numerous authors for the most part concur that medications are inhibitors that can compete favorably with green inhibition of corrosion and that most medications can be Synthesized from natural products. The select of some medications for inhibition of corrosion is taking into the following: (a) drug molecules contain oxygen, sulphur and nitrogen as active sites, (b) it is reportedly environmentally friendly furthermore vital in organic responses (c) drugs can be easily produced and purified [14-18].

In recent years the drugs use as corrosion inhibitors for different metals result to their non-poison nature, namely Ciprofloxacin, Cefatrexyl, Ofloxacin, Norfloxacin, and Tacrine drugs have paid attention on by some authors [19-21]. The family of Levoflaxcin is fluoroquinolones, broad spectrum antibacterial agents with bactericidal activity. Levofloxacin drugis scond-generation synthetic fluoroquinolone antibacterial agent in having greater activity against Gram-(+) bacteria and anaerobes [22].

In present work, we explore the corrosion inhibition activity of metal in 1M HCl at distinctive temperatures on the presence of Levofloxacin antibiotic using electrochemical and chemical methods. Surface of the metals were analyzed utilizing SEM in the absence and presence Levofloxacin and EDX analysis.

Experimental techniques

Materials

The investigations with C steel (C1018) were performed with following composition:
Rectangular examples on measurements were utilized for weight reduction test. For electrochemical tests, the uncovered surface region of carbon steel was 1 cm^2.

Inhibitors

Pharmaceutical compound has been investigated named **Levofloxacin used in this study are available, soluble in water, has larg molecular weight, contain numerous donating atoms (O, N, P) and easily available as** pharmaceutical drugs manufactured by many pharmaceuticals and non-toxic and their structures are listed below:
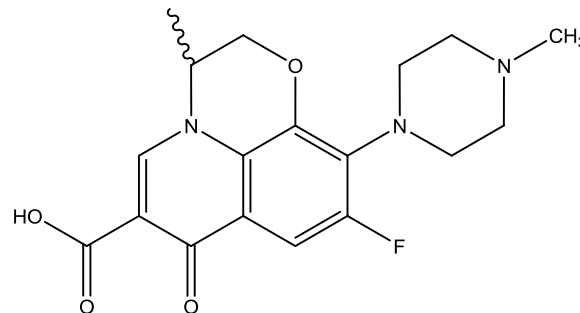
Chemical Formula: C$_{18}$H$_{20}$FN$_3$O
Molecular Weight: 361.37

Figure 1. Molecular structure of Levofloxacin

Solution

The forceful arrangements, 1 M Hydrochloric acid were arranged BDH HCl (37 %) attenuation with bidistilled water. 1 M stock arrangements from the investigated inhibitor were arranged by dissolving the fitting weight of the solid pharmaceutical medication in bidistilled water, alternate

Tele:
E-mail addresses: asfouda@hotmail.com

centralizations of pharmaceutical medication (0.05 – 0.3 M) were arranged by dilution using bidistilled water. All the materials utilized as received and AR grade.

Procedures

Weight loss techniques

Square specimens of size 2 x 2 x 2cm were used. The specimens were abraded with emery papers grit sizes (400, 800, 1200 and 2000), degreased with acetone [23]. The weight reduction estimations were completed in a 100 ml limit glass measuring utensil set in bath water thermostat. The samples were put in the test arrangement with or without Levofloxacin. Triplicate samples were uncovered for every system and losses of weight were calculated.

The % IE and metal areia degree coverage (θ) have been measured using the relations [24]:

%IE=θx100=[1-($\Delta W_{inh}/\Delta W_{free}$)]x100   (1)

Where ΔW_{free} and ΔW_{inh} are the mass losses of C steel / unit area with and without Levofloxacin at specific time.

Thermometric technique

The study was done with test pieces made of sheets measuring 1 x10 x0.2 cm. Before being utilized, these were delicately scraped with emery papers of (400, 800, 1200 and 2000), evaluation then degreased by acetone. Every analysis was completed with another clean example and with 15mL of the forceful solution. The inhibiting efficiency was measured from the % down in (RN) reaction number was determined using the following equations:

IE(%) = [$RN_{free} - RN_{inh.}/RN_{free}$]x100   (2)

Where RN = Reaction Number which calculated:

RN = ($T_m - T_i$) / t = ΔT/ t ^{o}C min^{-1} (3)

$\Delta T = T_m - T_i$

(t = time / minutes to arrive Ti (starting) to Tm (greatest) temperatures separately.

Gasometric technique

Evolutions of Hydrogen were estimations at room temperature. From the hydrogen volume developed every minute, (%I) and levels of surface scope (q) were ascertained utilizing comparisons (4) and (5), individually:

%I = [(1 − V Ht) ÷ V^0Ht] x 100   (4)

q = %I ÷ 100   (5)

Where V Ht is the hydrogen volume developed for inhibited solution and V^0Ht is the hydrogen volume of advanced at time t for uninhibited solution.

Electrochemical techniques

Electrochemical estimations, including potentiodynamic polarization, EIS and EFM were performed in 3 electrodes at 25°C. The counter electrode is aplatinum, calomel electrode is electrode reference coupled to a fine luggin slim and the working is arranged from metal as a square example fixed with epoxy (PTFE) to give a surface region of 1cm^2.

Electrochemical estimations were performed by utilizing instrument Gamry which incorporates a Gamry frame work taking into account ESA400.

Surface Examinations

The specimens of C-steel used for analysis of morphology surface was prepared in 1 molar hydrochloric acid (blank) and with 300 ppm of Moxifloxacin at room temprature for 2 days. The performed examinations used scanning electron microscope (JEOL JSM-5500, Japan).

Results and Discussion

Chemical Measurements

Weight Loss Measurements

Measurements data of this experimental give % IE from equation (1). All the experiments were performed at 25-45°C. Corrosion rate (CR) Value and %IE of Levofloxacin is outlined in Table (1). The estimation of % IE increments with expanding inhibitor concentration and declines with ascend in temperature. This conduct credited increment of the coverage surface due to Levofloxacin adsorbed on the metal surface. Ideal focus needed accomplish an effectiveness 90.1% was discovered at 300 ppm. The outcomes affirmed great impact of Levofloxacin is the corrosion hindrance of C-steel in acid. Figure (2) demonstrates the weight reduction time bends for the corrosion of carbon steel in acid arrangement on nonappearance and vicinity of Levofloxacin at 25°C.
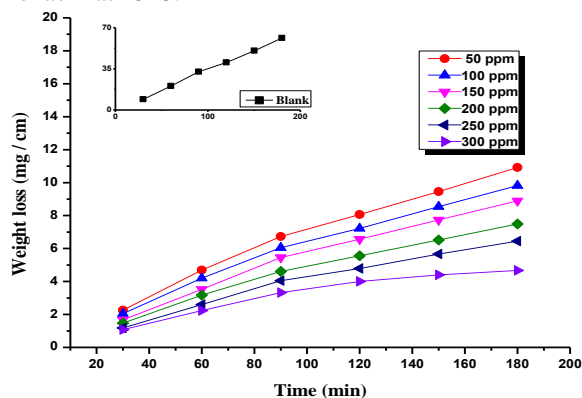

Figure 2. Weight reduction time bends for the metal in solution of 1 molar acid in the nonattendance and vicinity of Levofloxacin at 25°C

Temperature Effect

The temperature effect of on rate of corrosion of carbon steel in acid with various concentrations from Levofloxacin was tried by weight reduction estimations more than a temperature range from 25 to 45°C. The impact of expanding temperature on the consumption rate and IE% got from weight reduction estimations. The data of corrosion rate increments as the temperature builds and reductions with the convergence of Levofloxacin expands Figure (3).

The energy of activation (E_a^*) of the corrosion procedure was computed utilizing Arrhenius comparison:

k =A exp (-E_a^*/ RT)   (6)

k =corrosion rate, A = Arrhenius consistent, R = the gas constant and T = the temperature absolute. Figure (4) present the Arrhenius plot in the vicinity and nonattendance of Levofloxacin. E_a^* qualities decided from the slopes of linear digrams are demonstrated in Table (5) which demonstrated that the estimation of E_a^* for solution inhibited is higher than that for uninhibited solution, proposing that disintegration of C steel is slow in the vicinity of inhibitor and can be deciphered as because of physical adsorption[25]. From equation (6) the higher values of E_a^* lead to the lower corrosion rate, because the arrangement of a film on the C steel surface serving such as energy barrier for metal corrosion [26]. Entropy and enthalpy of initiation (ΔS*, ΔH*) of the corrosion procedure were ascertained from transition state theory Table (5):

kcorr = k'/ Nh e $^{(\Delta S^*/R)}$ e$^{(-\Delta H^*/RT)}$ (7)

h = Planck's constant, k' = Boltzmann constant and N = Avogadro's number.

Draw log (k / T) various 1/ T for carbon steel in acid at diverse focuses of researched Levofloxacin, give straight lines as

indicated in Figure (5). The indications of positive enthalpy mirror nature endothermic of metal in dissolution process. Large and negative entropy lead to (1) preferably the activated complex association as opposed to dissociation step. (2) Suggesting abatement in disordering happens on setting off from reactants to the initiated complex [27].
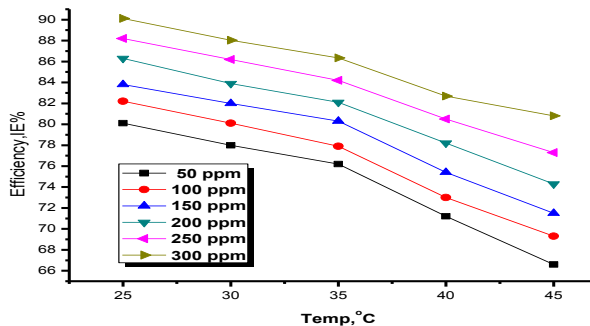

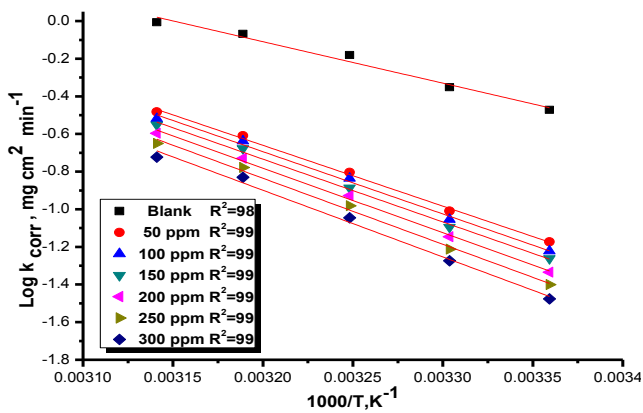**Figure 3. Effect of Levofloxacin concentration on the inhibition efficiency**

Figure 4. Arrhenius digram for the rate corrosion of C steel in 1M HCl present and disappear Levofloxacin at distinctive temperatures
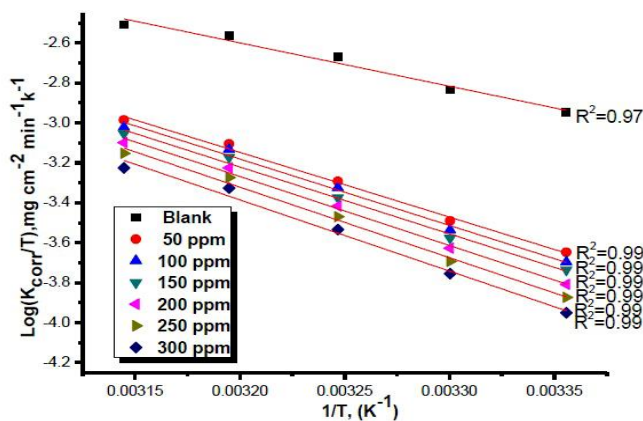

Figure (5). Log (k_{corr}/T) versus 1/T for metal in 1M HCl as blank, with Levofloxacin at different temperatures

Adsorption Isotherms

Accepting that mulled over inhibitor influence the corrosion rate of the transform primarily through variety level of coverage surface (θ). Thus, hindrance Efficiency is role of the surface electrode secured by the inhibitor particles, i.e. θ = I E/100. Attempts were done to relationship fit amidst for θ and the mass inhibitor concentration of utilized at a certain offered temperature to offer a comprehension into the process of adsorption. A few isotherms are generally endeavored to depict execution inhibitor and better fit has obtained utilizing isotherm Langmuir, that expect the surface strong contains a modified

number of adsorption destinations and adsorbed species every site holds one [28] in great concurrence with the accompanying comparison (8):

$$C/\theta = 1/ K_{ads} + C \qquad (8)$$

Wherever Kads = the balance steady of the process adsorption. A plot (C/ θ) versus (C) of Levofloxacin at diverse temperatures is introduced in Figure (6) recommends that no forces repulsion or attraction between the atoms adsorbed, ever after relationship a linear is given with intercept equal to (1÷Kads) and a slope similar to unity, adsorption equilibrium constant being result to the free standard energy of ΔG° adsorption by the relation (9):

$$K_{ads} = (1/55.5) e^{(\Delta G_{oads}/RT)} \qquad (9)$$

The constant 55.5 is concentration water molar in solution in M^{-1}. By applying relation 6, we obtain different values of ΔG°ads for extract as a role of temperature in the range 298–318K were given and are recorded in Table (3). From data Table demonstrate the reliance of ΔG°$_{ads}$ on absolute the temperature (T). Figure (7) demonstrates the connection in the ΔG°$_{ads}$ and T. A linear plot was obtained with high regression constant and a slope equivalent to the entropy (ΔS°$_{ads}$) and intercept equivalent to the enthalpy (ΔH°$_{ads}$), as indicated by mathematical statement (10):

$$\Delta G°_{ads} = \Delta H°_{ads} − T\Delta S°_{ads} \qquad (10)$$

The different thermodynamic role for the process of adsorption (K $_{ads}$, ΔG°$_{ads}$, ΔH°$_{ads}$ and ΔS°$_{ads}$) are given in Table 3. It is for the most part evident that ΔG°$_{ads}$ has progressively negative quality, as increment of % I E, which related to the analyses adsorbed compounds are spontaneously on surface of metal making a relatively stable adsorbed layer.

It realized that estimations of ΔG°$_{ads}$ lower than 20 kJ mol^{-1} characteristic of physical adsorption [29]. The estimation of ΔG°$_{ads}$ is roughly equivalent 23 kJ mol^{-1} show that the mechanism of adsorption of the Levofloxacin on surface of C steel includes adsorption physical. The K$_{ads}$ takes the same pattern as in bigger estimation of K$_{ads}$ means more adsorption effective and subsequently good inhibition efficiency. Negative resulte of ΔH°$_{ads}$ related to adsorption of the inhibitor on C steel surface from 1 M HCl arrangement is an exothermic procedure, which infers that %IE for the drug diminishes with the ascent in temperature. Such conduct was clarified on premise that increase temperature give desorption of some adsorbed concentrate parts particles on the C steel surface and consequently evolution formation of organic surface layer having down protection.
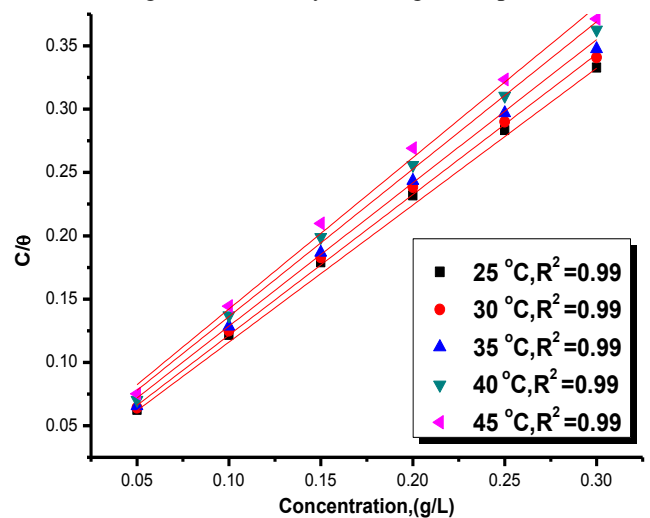

Figure 6. Langmuir adsorption isotherms for Levofloxacin at different temperatures for C steel immersed on 1M HCl
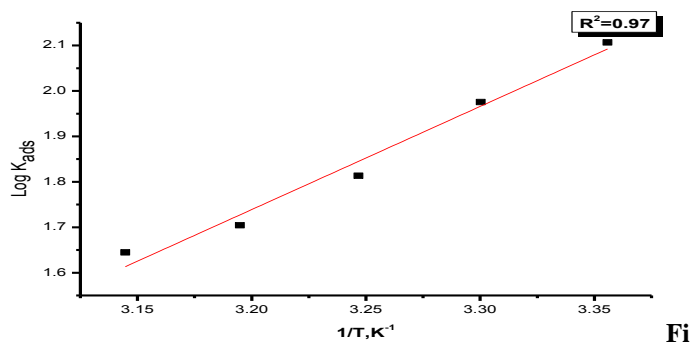
Figure 7. (1000 / T) aganist Log K$_{ads}$ for metal in 1M Hydrochloric acid plus Levofloxacin
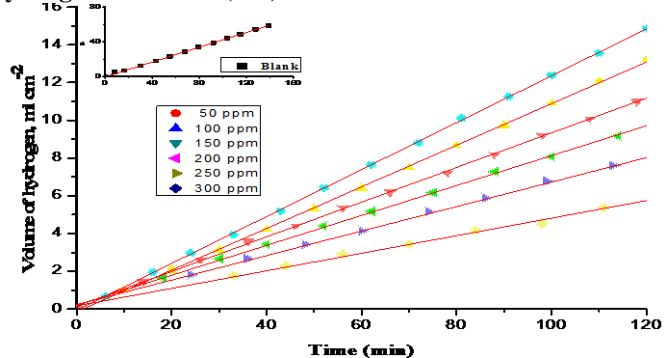
Hydrogen Evolution (HE)

Figure 8. Hydrogen Volume advanced against time arrangements with distinctive centralization of inhibitor at 25°C

Information are draw form volume of hydrogen advanced versus time for 50: 300 ppm of Levofloxacin focuses and exhibited in Figure (8). Inclines of the slope of line evaluated the rates of corrosion response as said some time recently. The great straight lines show vicinity of insoluble film on the metal surface.

The ascertained corrosion rates (CR) acquired from HE individually, against concentrations are classified in Table 1. As watched, corrosion rates diminish with expanding of Levofloxacin concentration, demonstrating decline conduct for the metal disintegration. This outcome is normal on the grounds that with expanding inhibitor fixation, both acidity and Cl$^-$ particle focus are lessening. As indicated by mathematical statement (12) pointed out that Fe disintegration in acid arrangements relies on upon hydrogen ion more than the chloride particle [30]. H$^+$advancement and mass misfortune is delivered by the same response:

$$Fe \text{ (solid)} + 2 H^+ == Fe_2 + + H_2 \text{ (gas)} \qquad (11)$$
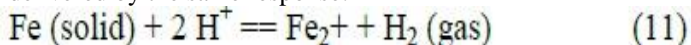
Thermometric Measurements

In this method the temperature change was followed without and with concentrations different of Levofloxacin as inhibitors. Digrams of Figure (9) represent the behaviour delivered the presence of concentrations different of inhibitor. All curves of the tested materials are portrayed by a beginning slow rise (because of the oxide film initially display on the metal surface) [31] followed by a sharp rise and at last by a lessening in temperature in the wake of attaining a maximum value.The plots for put containing systems fall down than the free acid. This explain that the collective behave as inhibitors over the concentration range studied. The percentage reduction in RN of the studied compounds is presented in Table (5). The results compiled in Table (8) relased to efficiency of corrosion inhibition for determined the reduction percentage in RN against concentration of the inhibitor
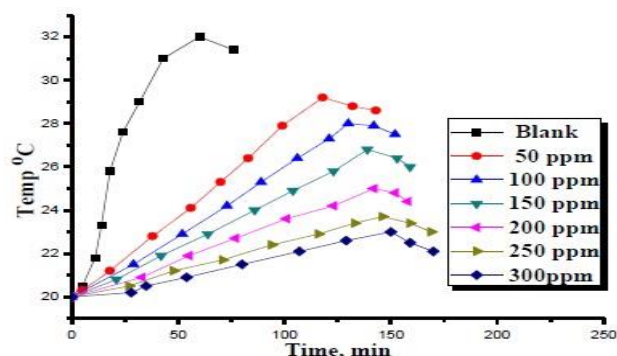

Figure 9. Temperature--time plots obtained without and with different concentrations of druge

Electrochemical measurements

A. Potentiodynamic Polarization caluculation

Figures (10) show ordinary polarization bends for meal in acid medium. The two unmistakable locales that showed up were the dynamic disintegration locale (clear Tafel district) the restricting current area without inhibitor arrangement, the anodic polarization bend of C steel demonstrated a monotonic increment of current with potential until the current came to the most extreme quality. After extreme current thickness esteem, the presents thickness declined quickly with potential expand, framing an anodic current crest. In the vicinity of inhibitor, both the cathodic and anodic current densities were extraordinarily more diminished than a wide potential territory. Different corrosion parameters, for example, corrosion potential, cathodic Tafel inclines (βa, βc), anodic, the corrosion current thickness, the level of surface scope (θ) and the hindrance proficie (%IE) were measured from equation 12:

% IE = Θ x 100 =100 [1 − (i$_{corr(inh)}$/ i$_{corr(free)}$)]   (12)

Where i$_{corr}$ = corrosion current density without inhibitor and the i$_{corr(inh)}$ = current with inhibitor. It can see from the experimental results in all cases addition of this compound induced a significant decrease in cathode and anodic currents. The values of Ecorr were affected and slightly changed by the addition of this compound. This indicates that this inhibitor acts as mixed inhibitor [32]. The slopes of anodic and cathodic (Tafel lines are parallel) on rise the concentration of the compound which related to no change of the inhibition mechanism in the with and without this compound. The order of efficiency inhibition of the tested compound at concentrations different was obtain by measurements polarization which listed in Table (6). The outcomes are in great concurrence with those got from weight reduction estimations.
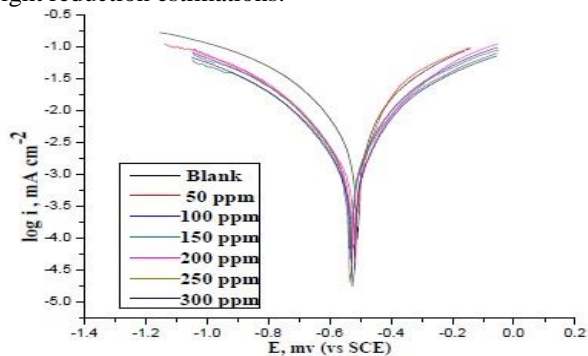

Figure (10). Polarization tafel digram of corrosion C steel without and with different concentrations of Levofloxacin at room temperature.

EIS Measurements

Figure (11) demonstrates the Nyquist plot for meal in acid the nonattendance and vicinity of distinctive centralizations of Levofloxacin at 25 °C. This graph has a crescent appearance; it demonstrates that the corrosion of Levofloxacin is for the most part controlled by a charge exchange process. The Bode draw for the alloy is shown in Figure (12) while the electrolyte resistance RΩ Corresponds to high frequency limit, the sum of $(R_\Omega + R_p)$ represents to low frequency limit, R_p is the first determined approximation by the electrolytic conductance of the oxide film and polarization resistance of the dissolution and passivation process. Various impedance parameter for example R_{ct} = resistance charge transfer, C_{dl} = capacitance double layer and (% IE) inhibition efficiency were measured and are given in Table (7). The data obtained show that the values of charge transfer resistance (R_{ct}) increase and the data of (C_{dl}) diminish with expanding the concentration of drug which accompanied with increasing (% IE) lead to adsorption of this drug components on the electrode surface due to formation of film on electrode surface. The obtained Nyquist impedance diagram not semicircle because attributed to the dispersion frequency due to the heterogeneity of the surface electrode [33-34]. In presence of acid and various concentration of investigated Levofloxacin the impedance diagram shows the same trend. While the diameters of the capacitive loop increase with increasing concentration of Levofloxacin.
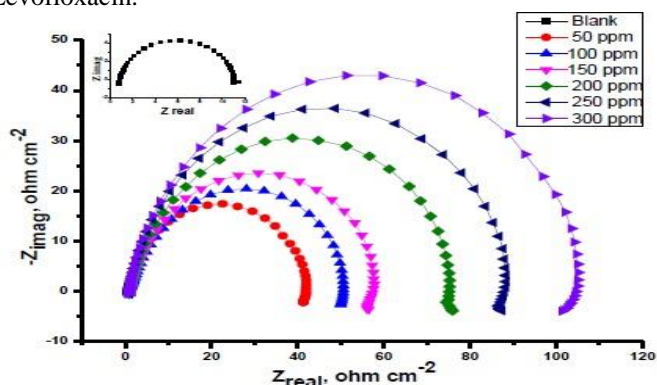

Figure (11). Nyquist plots for the corrosion of C steel in 1 M HCl in the nonappearance and vicinity of changed convergances of Levofloxacin at 25°C
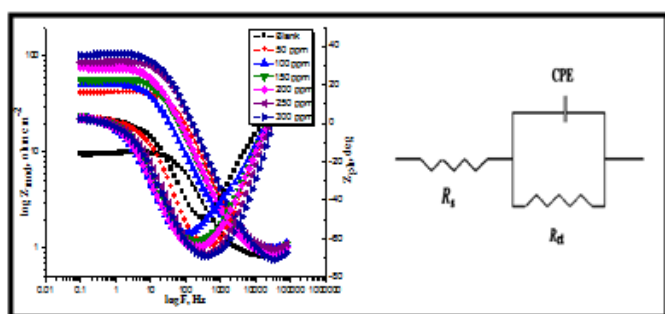

Figure 12. Bode draw for the metal corrosion in 1 molar Hydrochloric acid in nonattendance and vicinity of diverse amassings of Levofloxacin at 25°C and Equivalent model circuit related to the spectra impedance

Electrochemical Frequency Modulation Technique (EFM)

EFM is technique can directly and quickly determine corrosion current data without prior earning of Tafel slopes with a small signal polarizing. These advantages of technique EFM make it a perfect competitor for online corrosion monitoring [35]. The high strength of the EFM related to the causality factors which internal check on the validity of measurement EFM. The causality factors CF-2 and CF-3 are measured from the frequency spectrum of the current responses.

Figure (13) shows EFM (current vs frequency) of steel in acid solution containing different concentrations of Levofloxacin. The harmonic intermodulation peaks are clearly visible which are much larger than the background noise. The experimental EFM data were treated using two different models: complete diffusion control of the cathodic reaction the "activation" model, the latter a set of three non-linear equations had been solved assuming that the corrosion potential does not change due to the polarization of the working electrode [36].The peaks larger were utilized the current corrosion density (icorr), (CF-2 and CF-3)the causality factors and the Tafel slopes (βc and βa).all parameters were listed in Table (11).The data presented in Table (11) the addition of Levofloxacin at a given concentration to the acidic solution down the corrosion density current this lead to these compounds ac as corrosion inhibition of metal in acidic medium through adsorption. The causality factors obtained under different conditions are approximately equal to the values theoretical (2 and 3) demonstrating that the deliberate information are verified agood quality. The inhibition efficiencies %IE EFM increase by increasing the inhibitor concentrations and was measured as from equation 13:

$$\%IE\ EFM = [1-(i_{corr}/i^o_{corr})] \times 100 \qquad (13)$$

Where i^o_{corr} and i_{corr} are corrosion densities current in with and without inhibitor, respectively. Figure (13) shows the EFM Intermodulation spectra of carbon steel in Hydrochloric acid solution containing concentrations different of Levofloxacin. Larger peaks were used to measured (βc and βa), (icorr), and (CF-2 and CF-3) these electrochemical parameters were listed in Table (11). The data presented in Table (11) show the addition of any one of tested compound at a given concentration to the acidic solution decreases the corrosion current density which indicating that compound corrosion inhibition of metal in acid through adsorption.
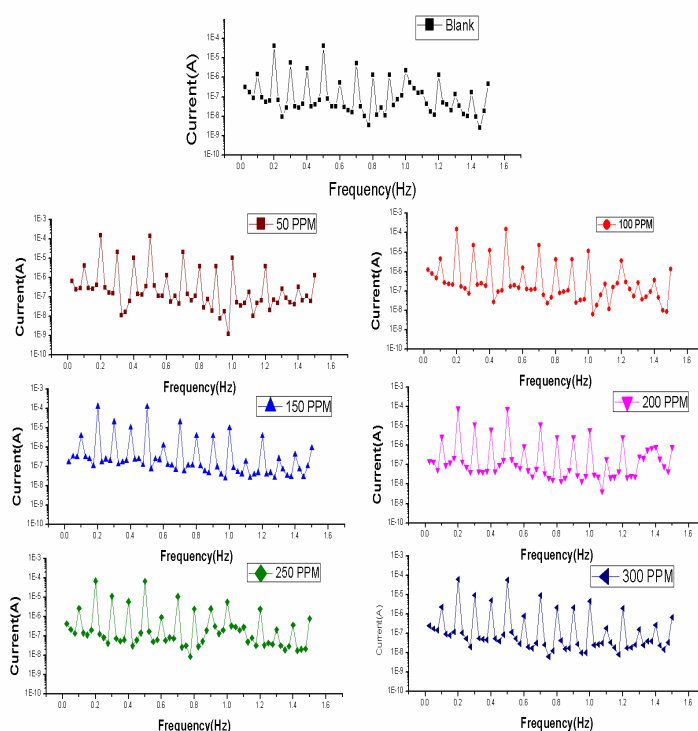

Figure 13. EFM for meal in 1 M Hydrochloric acid unlucky deficiency and vicinity of distinctive convergances of Levofloxacin

Table 1. Weight % of the C1018

Constituent	Carbon	P	Si	Mn	Iron
Composition%	0.2	0.04	0.003	0.6	Rest

Table 2. Impact of Levofloxacin fixations on corrosion rate (kcorr, mg cm^{-2} min^{-1}) and restraint effectiveness (% IE) at 25-45°C and 120 min submersion

Conc, (ppm)	25		30		35		40		45	
	k_{corr}	% IE	k_{corr}	% IE	k_{corr}	% IE	k_{corr}	% IE	k_{corr}	% IE
50	0.067	80.1	0.44	78	0.659	76.2	0.854	71.2	0.986	66.6
100	0.06	82.2	0.098	80.1	0.157	77.9	0.246	73	0.329	69.3
150	0.055	83.8	0.088	82	0.146	80.3	0.231	75.4	0.303	71.5
200	0.046	86.3	0.080	83.9	0.13	82.1	0.21	78.2	0.281	74.3
250	0.04	88.2	0.071	86.2	0.118	84.2	0.186	80.5	0.253	77.3
300	0.033	90.12	0.061	88.03	0.104	86.34	0.167	82.7	0.223	80.8

Table 3. C steel Activation parameters for corrosion various concentrations of Levofloxacin

Conc, (ppm)	Activation parameters		
	E_a^* K J /mol	ΔH^* K J /mol	$-\Delta S^*$ J /mol K
HCl	42.2	41.6	114.3
50	61.9	62.1	59.1
100	63.4	63.6	54.7
150	63.9	64.2	53.8
200	65.8	66.1	48.3
250	67.2	67.6	44.6
300	67.8	68.3	43.8

Table 4. Corrosion parameters for Kinetic of metal in 1M Hydrochloric acid at different temperatures

Temp ^{o}C	K_{ads}, M^{-1}	$-\Delta G^o_{ads}$, kJ /mol	ΔH^o_{ads} kJ /mol	ΔS^o_{ads} Jmol^{-1} K^{-1}
25	127.9	22		73.6
30	94.5	21.6		71.1
35	65.1	21	43.5	68.0
40	50.6	20.7		65.9
45	44.2	20.6		64.8

Table 5. Corrosion rates for metal at concentrations of Levofloxacin at room temperature

Conc., ppm	Corrosion Rate ml cm^{-1} min^{-1}	θ	% IE
50	0.1244	0.703	70.3
100	0.1102	0.737	73.7
150	0.0918	0.781	78.1
200	0.0792	0.811	81.1
250	0.0649	0.845	84.5
300	0.0465	0.889	88.9

Table 6. Inhibitor Efficiencies of Levofloxacin

Con, M/L	R.N C/min	θ	% red in R.N
Blank	0.2	--	--
0.05	0.078	0.610	61.0
0.1	0.062	0.692	69.2
0.15	0.049	0.755	75.5
0.2	0.035	0.824	82.4
0.25	0.026	0.871	87.1
0.3	0.020	0.900	90.0

Table 7. Parameters of corrosion in the vicinity, nonattendance of Levofloxacin got from polarization estimation

Conc, ppm	$i_{corr.}$ mA /cm	$-E_{corr.}$ mV vs SCE	b_a mV dec^{-1}	b_c mV dec^{-1}	CR mpy	θ	% IE
50	3.071	455	309	383	3.4	0.722	72
100	2.636	465	290	365	3.9	0.76.3	76
150	2.306	469	300	347	4.5	0.791	79
200	2.197	457	261	314	5.2	0.804	80
250	1.537	459	268	295	5.8	0.861	86
300	1.090	472	249	287	6.1	0.901	90

Table 8. EIS information of Levofloxacin in 1 M HCl in the unlucky deficiency and vicinity of distinctive convergances of at 25°C

Conc, ppm	R_p, Ω cm^2	C_{dl}, μF cm^{-2}	θ	% IE
0.0	12.31	220	-	-
50	53.75	177	0.771	77.1
100	62.17	163	0.802	80.2
150	78.41	156	0.843	84.3
200	84.89	135	0.855	85.5
250	96.92	111	0.873	87.3
300	124.34	85	0.901	90.1

Table 9. Electrochemical dynamic parameters got by EFM method for meal in the unlucky deficiency and vicinity of different amassings of Levofloxacin in 1M hydrochloric acid at 25°C

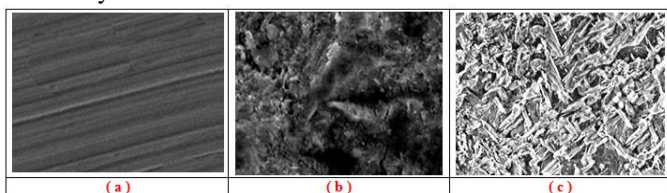| Conc, ppm	$i_{corr.}$ μA cm^{-1}	β_a mVdec^{-1}	β_c mVdec^{-1}	CF (2)	CF (3)	CR MPY	θ	% IE
0.0	625	87	153	1.98	3.10	285	-	-
50	194	62	134	2.02	3.04	89	0.690	69.0
100	148	58	130	2.01	3.01	68	0.763	76.3
150	90	56	112	2.04	3.04	41	0.856	85.6
200	75	52	107	2.01	2.97	35	0.880	88.0
250	65	52	106	1.98	3.00	29	0.896	89.6
300	62	51	98	2.01	2.91	20	0.900	90.0

Table 10. Surface creation (wt %) of meal previously, then after the fact submersion in 1 M Hydrochloric acid without and with 300 ppm of Levofloxacin at at room temperature

Mass %	Fe	Mn	P	O	N	C	Cl
Free	98.28	0.82	0.03	-	-	0.78	-
HCl	71.98	0.64	0.04	25.5	-	1.13	0.7
Inhibitor	60.12	0.54	0.01	14.3	10.2	15.1	0.13

| Methods	Chemical			Electrochemical		
	Wt. loss	Therm.	H E	EFM	EIS	POT
% IE	90.1	90	88.9	90	90.1	90

SEM-EDX Measurement

As indicated by Figure (14a) spectroscopy EDX for surface of meal donates the picture of surface. Figure (14a, c) yield to aloof film shaped on the steel after inundation in the destructive in nonappearance and vicinity of the drug for around 2 days. Figure (14a) the outcomes showed that thick permeable corrosion layer of item (oxide film) cover all anode surface; the surface was unequivocally harmed, so the terminal surface can't be seen, while Figure (14c) present the picture of the surface cathode in vicinity of 300 ppm Levofloxacin, the picture demonstrate the surface is free from harms and it is smooth, this shows a decent defensive film exhibit on the carbon steel surface, furthermore affirm the most astounding hindrance proficiency of Levofloxacin.

Figure (15) the EDX of meal analysis in 1M Hydrochloric acid only and in the addition of 300 ppmof pharmaceutical compound. The spectra show demonstrating the precence of Carbon. These data shows that the C and O materials covered the sample surface this layer was totally inferable from the inhibitor in light of the fact that the carbon & Oxygen signs are nonattendant on the example surface presented to uninhibited acid. Not with standing O, S, and C were available in the spectra. An equivalent essential dispersion is indicated in Table (12).

Figure 14 (a, b and c). SEM micrographs of meal surface (a) preceding of submersion in 1M Hydrochloric acid (b) following 2 days of drenching in acid and (c) following 2 days of inundation in acid + 300 ppm of Levofloxacin at room temperature
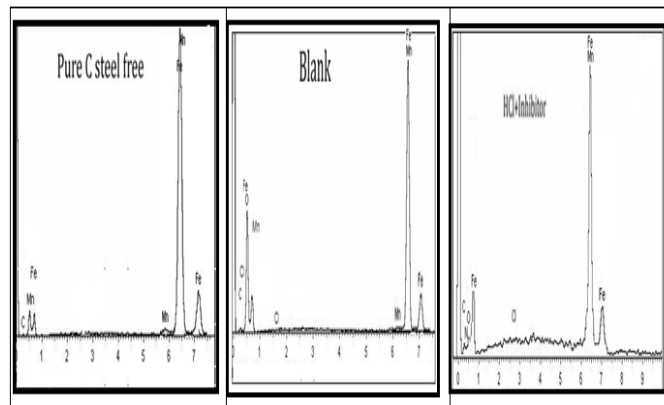
Figure 15. EDX C steel analysis with and without antibiotic compound for 2 days immersion

Corrosion inhibition Mechanism

The adsorption of medication particles can be ascribed to the presence of polar unit having iotas of nitrogen and oxygen and fragrant/heterocyclic rings. In this way, the conceivable response focuses are unshared pair of electron hetero-atom and л-electrons of sweet-smelling ring [37]. The adsorption and hindrance impact of medication particles in 1 M HCl arrangement can be clarified as takes after: In fluid acidic arrangements drug atoms exist either as unbiased particles or as protonated particles and may adsorb on the metal in corrosive arrangement interface by one and a greater amount of the accompanying ways: (i) electrostatic collaboration of protonated particles with effectively adsorbed chloride particles, (ii) communication between unshared electron sets of hetero-iotas and empty d-orbital of iron surface molecules. The conceivable clarification of the hindrance is because of adsorption procedure which is considered as the key of the instrument of restraint activity. It may be recommended that the medication particles stick to the steel surface. This prompts a reduction of the surface zone at which cathodic and anodic responses occur. Restraint productivity of the medication particles relies on upon numerous factors[38], which incorporate the quantity of adsorption dynamic focuses in the atom and their charge thickness, atomic size, and method of cooperation with metal surface[39- 40]. The transition of metal in solution interface with a state of active dissolution to the passive state of great interest. The inhibition effect is attributed to the adsorption of the inhibitor molecules via their functional group onto the metal surface, so drug can be adsorbed in the form of negatively charged species on the metal surface which can interact electrostatically with positively charged metal surface given increase the surface coverage and consequently protect efficiency controlling the anodic metal dissolution and cathodic evolution hydrogen. The adsorption rate is usually rapid due to the reactive metal is shielded from the aggressive environment.

Conclusions

The result shows that Levofloxacin is agood corrosion inhibitor of metal in 1 M Hydrochloric acid. The hindrance is because of adsorption of the medication atoms on the C-steel surface by hindering its dynamic locales. Adsorption of medication fits Langmuir isotherm. Likewise the outcomes demonstrate by expanding inhibitor focus the restraint effectiveness expanded. Polarization information demonstrated that the utilized inhibitor go about as blended sort inhibitor in 1 M Hydrochloric acid. Results acquired from weight reduction, hydrogen advancement, thermometric, AC impedance, DC polarization and EFM procedures are sensibly in great assention as demonstrated as follows.

Rreferences

[1] F. Bentiss, M. Traisnel, M. Lagrenee, The substituted 1, 3, 4-oxadiazoles: a new class of corrosion inhibitors of mild steel in acidic media, Corros. Sci., 42, 127–146, (2000).

[2] G. Trabanelli, Inhibitors an old remedy for a new challenge, Corrosion, 47, 410–419, (1991).

[3] F. Bentiss, M. Traisnel, L. Gengembre, M. Lagrenee, Inhibition of acidic corrosion of mild steel by 3,5 diphenyl-4H-1,2,4-triazole,Appl. Surf. Sci., 161, 194–202, (2000).

[4] N.O. Eddy and S.A. Odoemelam, Corrosion Inhibition and Adsorption Properties of Ethanol Extract of Vernonia Amygdalina for the Corrosion of Mild Steel in H_2SO_4, Adv. Nat. & Appl. Sci., 2(1), 35, (2008).

[5] I.B. Obot, N. O. Obi-Egbedi, S.A. Umoren, Adsorption characteristics and corrosion inhibitive properties of clotrimazole for aluminium corrosion in hydrochloric acid, Int. J. Electrochem. Sci., 4863, (2009).

[6] E.E. Ebenso, H. Alemu, S.A. Umoren, I.B.Obot, Inhibition of mild steel corrosion in sulphuric acid using alizarin yellow GG dye and synergistic iodide additive, Int. J. Electrochem. Sci., 3, 1325, (2008).

[7] S.A. Umoren, I.B. Obot, E.E. Ebenso, N. O. Obi-Egbedi, Synergistic inhibition between naturally occurring exudate gum and halide ions on the corrosion of mild steel in acidic medium,Int. J. Electrochem. Sci., 3, 1029, (2008).

[8] M. Abdallah, Guar Gum as Corrosion Inhibitor for Carbon Steel in Sulfuric Acid Solutions, Portugaliae Electrochimica. Acta, 22, 161, (2004).

[9] M. Abdallah, Antibacterial drugs as corrosion inhibitors for corrosion of aluminium in hydrochloric solution, Corros. Sci., 46, 1981, (2004).

[10] M. Abdallah, Rhodanine azosulpha drugs as corrosion inhibitors for corrosion of 304 stainless steel in hydrochloric acid solution, Corros. Sci., 44, 717, (2002).

[11] Y. K. Agrawal, J. D. Talati, M. D. Shah, M. N. Desai and N. K. Shah, The atmospheric corrosion of copper at two sites in Portugal: a comparative study, Corros. Sci., 46, 633, (2003).

[12] H. Ashassi-Sorkhabi, B. Shaabani and D. Seifzadeh, Effect of some pyrimidinic Shciff bases on the corrosion of mild steel in hydrochloric acid solution, Electrochimica Acta, 50, 3446, (2005).

[13] E. E. Ebenso, Synergistic Influence of Gum Arabic and Iodide Ion on the Corrosion Inhibition of Aluminium in Alkaline Medium, Bull. Of Electrochem. 19(5), 209, (2003).

[14] E. E. Ebenso, N. O. Eddy and A. O. Odiongenyi, Inhibition of the corrosion of mild steel by Methocarbamol, Portugaliae Electrochimica. Acta. 27(1), 13, (2009).

[15] N.O. Eddy, E.E. Ebenso, corrosion of mild steel in acidic medium, Int. J. Electrochem. Sci., 5, 731, (2010).

[16] N.O. Eddy , 'Inhibition of corrosion of mild steel by some antibiotics' PhD Thesis,University of Calabar, Nigeria, (2008).

[17] N.O. Eddy, S.A. Odoemelam and A.J. Mbaba, Inhibition of the corrosion of mild steel in HCl by sparfloxacin, Afri. J. Pure & Appl. Chem., 2 (12), 132, (2008).

[18] N. O. Eddy, E. E. Ebenso and U. J. Ibok, Corrosion inhibition and adsorption properties of ethanol extract of Gongronema latifolium on mild steel in H_2SO_4, J. Appl. Electrochem 40(2), 445, (2010).

[19] E. E. Oguzie, Corrosion inhibition of mild steel in hydrochloric acid solution by methylene blue dye, Mater. Letters, Mater. Letters, 59, 1076, (2005).

[20] F. Z. Mylius, Condition of the metal surface, the mode of adsorption, the chemical and elchetrochemical between the inhibitor and the metal surface, Metall., 14, 233, (1922).

[21] M.S. Morad, The corrosion inhibition properties of cefotetan (CFT) for mild steel in acidic solution, Corros. Sci., 50, 448, (2008).

[22] S.C.Lafredo, B.D. Foleno, K.P. Fu, Induction of resistance of Streptococcus pneumoniae to quinolones in vitro, Chemotherapy 39 (1), 36–9, (1993). .

[23] R. Narayan, An Introduction to Metallic Corrosion and its Prevention, Oxford and IBH publishing Co. Pvt. Ltd., (1998).

[24] G.N. Mu, T.P. Zhao, M. Liu, T. Gu, Effect of Metallic Cations on Corrosion Inhibition of an Anionic Surfactant for Mild Steel, Corrosion. 52, 853, (1996).

[25] J., Lipkowski, P.N., Ross (Eds.), Adsorption of Molecules at Metal Electrodes, VCH, New York, (1992).

[26] S. L. F. A., Da Costa and S. M. L., Agostinho, Electrochemical Studies of Cu-Al Alloys in Sulphate - SciELO, Corrosion, 45, 472-477 ,(1989).

[27] E.F., El-Sherbiny. Effect of some ethoxylated fatty acids on the corrosion behavior of mild steel in sulphuric acid solution, Mater. Chem. Phys., 60, 286–290, (1999).

[28] E.E. Oguzie, Inhibition of acid corrosion of mild steel by Telfaria occidentalis extract, Pigm. Resin Technol., 34, 321, (2005).

[29] E.E. Oguzie, Studies on the Inhibitive Effect of Occimum viridis Extract on the Acid Corrosion of Mild Steel, Mater Chem. Phys., 99, 441, (2006).

[30] P.C. Okafor, E.E.Ebenso, Inhibitive action of Carica papaya extracts on the corrosion of mild steel in acidic medium, Pigm. Resin Technol., 36, 134, (2007).

[31] A.G. Gad Allah, N. Nassif and T. Mikhail, Effect of temperature on the corrosion behavior of helwan steel in acid chloride solutions, Annali di Chimica, 82, 49, (1992).

[32] A. S. Fouda,M. M. Gouda, and S. I. Abd EL-Rahman, Benzaldehyde, 2-Hydroxybenzoyl Hydrazone Derivatives as Inhibitors of the Corrosion of Aluminium in Hydrochloric Acid, Chem. Pharm. Bull., 48(5) 636—640 (2000).

[33]S.P. Ramesh, K.P.Vinod Kumar and M.G. Sethuraman, Electrochemical parameters were evaluated through the potentiodynamic Tafel polarization and impedance spectral studies, bull. Electrochem, 17, 141, (2001).

[34] H.H. Rehan, Corrosion control by water-soluble extracts from leaves of economic plants, Material wissenschaft Werksofftechnik, 34, 232, (2003).

[35] M.G.Sethuran; P.B.Raja, Corrosion inhibition of mild steel by Datura metel in acidic medium, Pigm. Resin Technol., 34, 327, (2005).

[36] E. Kus, F. Mansfeld., an Evaluation of the Electrochemical Frequency Modulation (EFM) Technique, Corros. Sci., 48, 965, (2006).

[37] G. A.Caigman, S. K. Metcalf, E. M. Holt, Thiophene substituted dihydropyridines, J.Chem. Cryst. 30, 415, (2000).

[38] A. K. Singh, M.A., Effect of Cefazolin on the corrosion of mild steel in HCl solution, Corros. Sci., 52, 1529, (2010).

[39] G. Avci, Corrosion inhibition of indole-3-acetic acid on mild steel in 0.5 M HCl, Colloid Surf., A., 317, 730, (2008).

[40] A.S. Fouda, M. Abdallah, I. S. Ahmed, M. Eissa Corrosion Inhibition of Aluminum in NaOH Solutions using some Bidentate Azo Dyes Compounds and Synergistic Action with some Metal Ions, , Int. J. Electrochem. Sci., 9, 4747, (2014).