Drugs as Corrosion Inhibitors: A Review

R. K. Pathak¹, Pratiksha Mishra²

¹,² Govt.MLB Girls P.G. College, Indore (M.P), India

Abstract: The inhibiting effect of drugs towards the corrosion of different metals and alloys has been reviewed in this paper. Results of Weight loss method, Potentiodynamic polarization and Electrochemical impedance spectroscopy were investigated. Kinetic and thermodynamic parameters provide valuable information about the mechanism of corrosion inhibition. Different classes of drugs, having hetero-atoms or aromatic ring in their molecular structures were reported in this article.

Keywords: Drugs, corrosion, adsorption isotherms, medium, alloys

1. Introduction

Corrosion is the deterioration of metal by chemical attack or reaction with its environment. It is a constant and continuous problem, often difficult to eliminate completely. Prevention would be more practical and achievable than complete elimination. Corrosion processes develop fast after disruption of the protective barrier and are accompanied by a number of reactions that change the composition and properties of both the metal surface and the local environment, for example, formation of oxides, and diffusion of metal cations into the coating matrix, local pH changes, and electrochemical potential. The use of inhibitors is one of the best options of protecting metals and alloys against corrosion. Several inhibitors in use are either synthesized from cheap raw material or chosen from compounds having hetero atoms in their aromatic or long-chain carbon system. However, most of these inhibitors are toxic to the environment containing heavy metals. This has prompted the search for green corrosion inhibitors [1]. A number of heterocyclic compounds containing N, O and S either in the aromatic or long chain carbon system have been reported to be effective inhibitors [2-5]. These inhibitors have extended π-electron systems and functional groups (such as -C=C-, -OR, -OH, -NR₂, -NH₂ and -SR). The functional groups provide electrons that facilitate the adsorption of the inhibitor on the metal surface [6-11]. Most of organic inhibitors are expensive, toxic and have negative effect on the environment this properties restrict its use to inhibit the metal corrosion. Thus it is important and necessary to develop low cost and environmentally safe corrosion inhibitors [12-13]. In the recent years drugs has been used as corrosion inhibitors. According to Eddy and Odoemelam, the use of drugs for the inhibition of the corrosion of metals has some advantages over the use of some organic/inorganic inhibitors because of their eco-environmental nature [14]. Drugs are nontoxic, cheap, negligible negative effects on environment, so it suggested replacing the traditional toxic corrosion inhibitors [15]. Many authors generally agree that drugs are inhibitors that can compete favorably with green corrosion inhibitors and that most drugs can be synthesized from natural products. The choice of some drugs used as corrosion inhibitors is based on the following: (a) drug molecules contain oxygen, nitrogen and sulphur as active centers, (b) drugs are reportedly environmentally friendly and important in biological reactions and (c) drugs can be easily produced and purified [16-20]. Research efforts have been done recently on the use of antibacterial drugs as corrosion inhibitors for carbon steel and aluminum in acidic and alkaline media [21-23]. GokhanGece (2011) review from literatures the use of many types of drugs as corrosion inhibitors of various metals [24]. Some drugs (such as ampicillin, ampiclox, cloxacillin, tetracycline, methocarbamol, orphenadrine, penicillin G, azithromycin, etc) have been found to be good inhibitors for the corrosion of metals [25]. The inhibitive effect of four antibacterial drugs, namely Ampicillin, Cloxacillin, Flucoxacinil and Amoxicillin towards the corrosion of aluminum was investigated [26]. Cephalosporins are among the oldest and most frequently prescribed naturally occurring antimicrobial agents, among these cephalosporins, only for the present, cefatraxyl, cefazolin and cefalexin are used as corrosion inhibitors of iron in acidic media [28-29]. The use of expired drugs as corrosion inhibitors can be traced back to 2009’s by R. S. Abdel Hameed, where expired ranitidine was used as corrosion inhibitors for Al in HCl corrosive medium [60-61]. The inhibition action of these drugs was attributed to blocking the surface via formation of insoluble complexes on the metal surface. The corrosion inhibitions of various drugs were studied by weight loss technique, potentiodynamic polarization measurements, electrochemical frequency modulation (EFM), electrochemical impedance spectroscopy (EIS), and linear polarization resistance. Kinetic parameters (activation energy, pre-exponential factor) as well as thermodynamic parameters (enthalpy, entropy, free energy of adsorption) were also calculated for some drugs. Some quantum chemical parameters and the Mulliken charge densities for omeprazole were calculated by the semi-empirical AM1 method to provide further insight into the mechanism of inhibition of the corrosion process. Quantum chemical approach was also used to calculate some electronic properties of the molecule in neutral and protonated form in order to find any correlation between the inhibition effect and molecular structure of fluconazole molecule. Quantum chemical studies showed that in adsorption process of fluconazole molecules, nitrogen and oxygen atoms, and benzene ring act as active centres. Thermometric and Gasometric measurements were carried out to find out the reaction number, inhibition efficiency, and degree of surface coverage. Theoretical calculations investigate by studying the relationship between molecular structure and inhibition efficiency by using semi-empirical molecular quantum calculations within the PM3 method as implemented in HyperChem package. Drugs are effectively
used as corrosion inhibitors for mild steel, copper, aluminum, iron and zinc in different acidic and alkaline media in various concentrations.

2. Literature Survey

N.O.Eddy et al (2008) studied inhibition efficiency of Penicillin V Potassium in acidic medium. With the increase in the concentration of drug, rate of corrosion decreases of mild steel in H₂SO₄. Adsorption characteristics of the inhibitor has also been studied and found to be spontaneous and consistent with the mechanism of physical adsorption. S.K.Shukla et al. (2009) reported corrosion inhibition of Streptomyacin against mild steel in 1.0 M HCl. Result obtained from tafel polarization, electrochemical impedance spectroscopy revealed that inhibition occurs through adsorption of the drug on the metal surface without modifying the mechanism of corrosion process. In an another interesting work of I.Naqvi et al. (2011) Cefixime is the choice of drug used against mild steel in 1.0 M HCl solution. Kinetic as well as thermodynamic parameters were calculated. The adsorption of Cefixime takes place according to Langmuir’s adsorption isotherms. R.S.Abdel Hameed (2011) has investigated corrosion inhibition activity of expired Rantidine in 1.0 M HCl using different techniques. Results obtained from polarization and electrochemical impedance spectroscopy is in good agreement with each other. In another publication of S.U.Ofoegbu et al. (2012) Chloroquine diphosphate is used against mild steel in 0.1M HCl solution using weight loss techniques. A.S.Fouda et al.(2013) reported that the Septazole acts as a mixed inhibitor in 0.1 M HCl at different concentration. The adsorption of Septazole on the surface of copper followed by Langmuir’s adsorption isotherms at all concentration and temperature were studied .In another publication of same author (2014) Streptoquin and Septazole were studied as corrosion inhibitors in 0.1 M HCl solution. These drugs act as a mixed type inhibitor suppressing the corrosion reaction by forming a protective adsorption film on copper surface. Abdulrasoul salih mahdi in 2014 studied on the inhibition effect of Amoxicillin on corrosion concrete reinforced steel samples immersed in alkaline solution consisting of 2% KOH and 3% NaCl which is a simulation to the chloride contaminated concrete pore solution using potentiodynamic polarization technique. Inhibition efficiency of various antibiotics drugs in 0.1N, 0.01N & 0.001N (HCl, H₂SO₄, HNO₃) acidic medium has been reported by Suraj.B.Ade et al. (2014). Weight loss technique has been employed for the study corrosion of mild steel in various acidic medium. The work of I.A.Akpan et al.2014 was focused on the antihypertensive drug Amlodipine which significantly increases the resistance of mild steel against corrosion in 0.1 M solution. The adsorption mode of the drug was found to be monolayer chemisorption obeyed Langmuir’s adsorption isotherms. In another publication of same author (2015) Amidoquine is the choice of drug. Similar results were obtained as mentioned as above. Expired Phenyltoin sodium drug is a mixed type of corrosion inhibitor. Thermodynamic parameters revealed that drug decreases corrosion rate (Hussain I.Al-Shafey 2014). Tenormin was investigated as corrosion inhibitor for stainless steel in 2.0 M HCl solution. Potentiodynamic polarization & electrochemical impedance spectroscopy were used to study corrosion efficiency (A.S.Fouda et al 2015). S.karthekeyan et al. (2015) reported corrosion inhibition activity of Vancomycin in 1.0 M H₂SO₄ medium. Polarization studies revealed that inhibitor acted as cathodic inhibitor and follows Langmuir’s adsorption isotherms.

Table 1: List of drugs used as corrosion inhibitors in different media

| S.No | Metal/alloy | Medium | Inhibitor (drug) | Class of drug | Author/Year |
|------|------------|--------|-----------------|---------------|-------------|
| 1.   | Mild steel | 1M,1.5M,2M,2.5M H₂SO₄ acid solution | PenicillinV potassium | Antibiotic drug | N.O. Eddy et al.2008 |
| 2.   | Mild steel | 1M HCl acid solution | Streptomyacin | Antibiotic drug | S.K. Shukla et al.2009 |
| 3.   | Aluminium | 0.1M HCl acid solution | Fluconazole &Clotrimazole | Antifungal drug | J.B. Obot et al.2009 |
| 4.   | Mild steel | 1M HCl acid solution | Cefixime | Antibiotic drug | Imran Naqvi et al.2011 |
| 5.   | Carbon steel | 1 mol L⁻¹ HCl acid solution | Sulfathiazole | Antibacterial drug | A. Samide et al.2011 |
| 6.   | Aluminium 6063 | 2M sodium hydroxide solution | Omeprozole | Anti-inflammatory drug | Haidar A. Abood 2011 |
| 7.   | Mild steel | 1M HCl acid solution | Cefacetrile | Antibiotic drug | Ashish Kumar Singh et al.2011 |
| 8.   | Mild steel | 1M HCl acid solution | Rantidine | Histamine-2 blocker agent | R.S. Abdel Hameed et al.2011 |
| 9.   | Mild steel | 1 M HCl solution | Tindazole | Antiprotozoal & Antibacterial agent | I.Reza et al.2011 |
| 10.  | Mild steel | 0.1M HCl acid solution | Chloroquine diphosphate | Anti-malarial | S. U. Ofoegbu et al.2012 |
| 11.  | Carbon steel | 0.5M H₂SO₄ acid solution | Cefazolin & Cefotaxime | Antibacterial drug | A.Nazer et al.2012 |
| 12.  | Carbon steel | 0.1mol L⁻¹ H₂SO₄ acid solution & 0.25 mol L⁻¹ acetic acid + 0.25 mol L⁻¹ sodium acetate buffer solution | Paracetamol & Carbamazepine | Analgesic- Antipyretic & Anticonvulsant drug respectively | N. Vaszilcsin et al.2012 |
| 13.  | Copper | 0.1M HCl acid solutions | Sepattazol | Antibacterial drug | A. S. Fouda et al.2013 |
| 14.  | Mild steel | 1M HCl acid solution | Diclofenac sodium | Anti-inflammatory & Analgesic | K.R. Ansari et al.2013 |
| 15.  | Carbon steel | 1M H₂SO₄ acid solution | Lornoxicam & Tenoxicam | NSAID | A. S. Fouda et al.2013 |
| 16.  | Mild steel | 1M HCl acid solution | Trazodone | Anti-depressant drug | S. Mani megalai et al.2013 |
| 17.  | Mild steel | 1M HCl acid solution | Meclizine | Antihistamine drug | J. Ishwara Bhat et al.2013 |
| 18.  | Copper | 0.1M HCl acid solution solutions | Streptoquin and Septazole | Antibiotic drug | A. S. Fouda et al.2014 |
| 19.  | Mild steel | 0.1M HCl acid solutions | Amlodipine | Anti-hypertensive drug | I. A. Akpan et al.2014 |
| 20.  | Steel | Alkaline solution consisting of 2%KOH & 2%NaCl which is a simulation to chloride concrete pore | Amoxicillin | Anti-bacterial drug | Abdulrasoul Salih Mahdi 2014 |
3. Proposed Methodology

Different methods have been used to determine the inhibition efficiency of different drugs by Weight loss technique [36-44,25,22-23] [30-32]. Potentiodynamic polarization measurements [47-48] [25,23] [39,22] [36,32,30,15]. Electrochemical frequency modulation [EFM] [47-48] [25,32], Electrochemical impedance spectroscopy [EIS] [47-48] [25,23] [39,22] [36,32,30], linear polarization resistance [45-46] [41,39,22,33].

3.1 Weight Loss Measurements

Weight of metal wire pieces before and after dipping in corrosion solution, loss in weight, % loss weight was calculated by usual method. The % inhibition efficiency was calculated by using following formula.

\[ I.E = \frac{W_u - W_i}{W_u} \times 100 \]

Where, \( I.E \) = Inhibition efficiency

\( W_i \) = Loss is weight in inhibitor solution,

\( W_u \) = Weight loss in control solution

Table 2: For the various pharmaceutical drugs the values of corrosion potential (\( E_{corr} \)), corrosion current densities (\( I_{corr} \)), anodic Tafel slope (\( \beta_a \)), cathodic Tafel slope (\( \beta_c \)), inhibition efficiency (IE%), charge transfer resistance (\( R_{ct} \)) and double layer capacitance (\( C_d \)) were calculated.

| Drug                  | Inhibitor Conc. | \(-E_{corr} \) [mv vs SCE] | \( I_{corr} \) [A cm\(^{-2}\)] | \( \beta_a \) [mV dec\(^{-1}\)] | \( \beta_c \) [mV dec\(^{-1}\)] | IE [%] | \( R_{ct} \) [\( \Omega \) cm\(^2\)] | \( C_d \) [F cm\(^{-2}\)] | IE [%] |
|-----------------------|-----------------|----------------------------|-----------------------------|-----------------------------|-----------------------------|--------|-----------------------------|-----------------------------|--------|
| Septazole             | blank           | 94                         | 284.10 µ                    | 351                         | 670                         | ---    | 172                         | 2640 µ                       | ---    |
| 900 ppm               | 212             | 43.18 µ                    | 233                         | 501                         | 84.8                         | 980.7  | 1542 µ                      | 82.4                         | ---    |
| Streptokin and        | blank           | 144                        | 284.10 µ                    | 351                         | 670                         | ---    | ---                         | ---                          | ---    |
| Septazole             | 900 ppm         | 212                        | 47.93 µ                     | 233                         | 501                         | 83.1   | ---                         | ---                          | ---    |
| 900 ppm               | 197             | 24.66 µ                    | 225                         | 566                         | 91.3                         | ---    | ---                         | ---                          | ---    |
| Tenomol               | blank           | 372                        | 598 µ                       | 64                          | 135                         | ---    | 62.4                        | 22.99x10\(^{5}\) µ            | ---    |
| 300 ppm               | 375             | 149 µ                      | 39                          | 110                         | 75.1                         | 1147.0 | 12.97x10\(^{5}\) µ          | 94.6                         | ---    |
| Lornoxicam            | blank           | 458                        | 99.1x10\(^{-3}\) m          | 348                         | 479                         | ---    | 4.99                        | 20.19x10\(^{-3}\) m           | ---    |
| 50 ppm                | 482             | 2.61x10\(^{-3}\) m         | 275                         | 188                         | 97.3                         | 171.9  | 59x10\(^{-5}\) m            | 97.1                         | ---    |
| Tenoxicam             | 50 ppm          | 456                        | 6.67x10\(^{-3}\) m          | 306                         | 236                         | 93.3   | 23.40                       | 4.33x10\(^{-2}\) m            | 78.7   |
| Cefacetile            | blank           | 469                        | 730 µ                       | 73                          | 127                         | ---    | 17.3                       | 1006 µ                       | ---    |
| 100 ppm               | 460             | 49.7 µ                     | 65                          | 193                         | 93.7                         | 371.2  | 73 µ                        | 95.3                         | ---    |
| Cefixime              | blank           | 487                        | 896.1 µ                     | 180                         | 222                         | ---    | ---                        | ---                          | ---    |
| 600 ppm               | 460             | 118.2 µ                    | 134                         | 177                         | 86.8                         | ---    | ---                        | ---                          | ---    |
| Diclofenac sodium     | blank           | 444                        | 892µ µ                      | 61                          | -81                         | ---    | 13.56                      | 137.95 µ                     | ---    |
| 100mg/L               | 505             | 25.5 µ                     | 69.1                         | -138.2                      | 97.1                         | 321.6  | 15.3 µ                      | 98.0                         | ---    |
| Cefixime              | blank           | 472                        | 1370 µ                      | 93.5                         | 101.2                       | ---    | 16.8                       | 646 µ                        | ---    |
| 8.8x10\(^{-4}\) µ     | 495             | 114 µ                      | 96.3                         | 108.1                       | 91.6                         | 208.5  | 96 µ                        | 91.8                         | ---    |
| Vancomycin            | blank           | 390.18                     | 545.14 µ                    | 82.5                         | 132.0                       | ---    | ---                        | ---                          | ---    |
| 75x10\(^{-4}\) µ      | 314.42          | 16.35 µ                    | 51.6                         | 82.0                        | 97                           | ---    | ---                        | ---                          | ---    |
3.2 Electrochemical Studies

Polarization experiments were carried out in a conventional three electrode cell-counter electrode, reference electrode & working electrode. By changing the electrode potential around the open circuit potential, potentiodynamic polarization curves were conducted. From tafel plot corrosion parameters such as $E_{corr}$, $I_{corr}$, $\beta_a$ and $\beta_c$ were recorded.

3.3 Electrochemical frequency modulation

Impedance measurements were carried out in frequency range from 100 kHz to 0.1Hz with amplitude of 5 mV peak to peak using Ac signals at open circuit potential. The experimental impedance was analyzed and interpreted based on the equivalent circuit. The main parameters deduced from the analysis of Nyquist diagram are the charge transfer resistance $R_{ct}$ (diameter of high-frequency loop) and the double layer capacity $C_{dl}$.

The charge transfer resistance ($R_{ct}$) values were calculated (table 2) from the difference in the Nyquist plots at low and high frequencies. Therefore, the inhibition efficiency, (IE %) and the degree of surface coverage (0) can be calculated from the charge-transfer resistance according to equation (1) [52]

$$IE\% = \theta \times 100 = \frac{R_{ct} - R_{ct}^{ads}}{R_{ct}} \times 100$$  (1)

Where,

- $R_{ct}^{ads}$ = The charge-transfer resistances for uninhibited solution.
- $R_{ct}$ = The charge-transfer resistances for inhibited solution.
- $C_{dl}$ = double layer capacitance obtained from the Nyquist plots and the calculated inhibition efficiency values

4. Results and Discussion

4.1 Weight Loss Measurements

Corrosion rate and inhibition efficiency of reported drugs (table1) in different concentration and in different media were studied. Result obtained through weight loss technique reveals that the corrosion rate values decrease as the concentration of inhibitor increases. Consequently, percent inhibition efficiency values increase with the increase in the concentration. This behavior could be attributed to the strong interaction of compound with the metal surface that results in the adsorption of inhibitor molecules [27].

4.2 Electrochemical Studies

It is clear from the potentiodynamic results reported in (table2) that the presence of drug, in different media, decreases the corrosion rate. The decrease in $I_{corr}$ value is due to the adsorption of the inhibitor molecules. The values of $\beta_a$ and $\beta_c$ changed slightly with increasing inhibitor concentration indicated the influence of these compounds on the kinetics of metal dissolution and of hydrogen evolution. Due to the presence of some active sites, such as aromatic rings, hetero-atoms in the studied compound for making adsorption, they may act as adsorption inhibitors. According to Ferreira and others [51], if the displacement in corrosion potential is more than 85mV with respect to corrosion potential of the blank solution, the inhibitor can be seen as a cathodic or anodic type.

4.3 Electrochemical Frequency Modulation

It is apparent from (table 2) that the value of $R_{ct}$ increased with increasing concentration of inhibitors. The increase in $R_{ct}$ values is attributed to the formation of an insulating protective film at the metal or solution interface so that the (IEEIS %) inhibition efficiency increased. On the contrary, the value of $C_{dl}$ decreased upon the addition of the inhibitor, suggesting, a decrease in the local dielectric constant and/or an increase in the thickness of the electrical double layer, indicating the inhibitor molecules function by the formation of the protective layer at the metal surface [56].

4.4 Thermodynamic Parameters

The values of thermodynamic parameters can provide valuable information about the mechanism of corrosion inhibition. Some thermodynamic adsorption parameters were ($\Delta G_{ads}$, $\Delta H_{ads}$, $\Delta S_{ads}$) calculated from the estimated value of $K_{ads}$ using adsorption isotherms at different temperatures. The Langmuir’s isotherm for the adsorbed layers is given by the equation.

$$C_{inh}/0 = 1/K_{ads} + C_{inh}$$  (3)

Where $K_{ads}$ is the equilibrium constant of the adsorption/desorption process. Adsorption equilibrium constant [$K_{ads}$] and free energy of adsorption [$\Delta G_{ads}$] were calculated using the equation

$$K_{ads} = C_{inh}^{0}/0 \times 0/1 - 0$$  (4)

$$\Delta G_{ads} = -2.303RT \log [55.5K_{ads}]$$  (5)

It is well known that $K_{ads}$ represents the strength between adsorbate and adsorbent. Large values of $K_{ads}$ mean better inhibition efficiency of the inhibitors, i.e. strong electrical interaction between the double-layer existing at the phase boundary and the adsorbing inhibitor molecules. Small values of $K_{ads}$ however, reveal that such interactions between adsorbing inhibitor molecules and the metal surface are weaker, indicating that the inhibitor molecules are easily removable by the solvent molecules from the metal surface [54]. The negative values of $\Delta G_{ads}$ ensure the spontaneity of the adsorption process and stability of the adsorbed layer on the steel surface. Generally, values of $\Delta G_{ads}$ around -20 kJ mol$^{-1}$ or lower are consistent with the electrostatic interaction between the charged molecules and charge metal, such as physisorption. When it is around -40 kJ mol$^{-1}$ and higher values it involve charge sharing or charge transfer from organic molecules to the metal surface to form a coordinate type of bond that is chemisorption [49-50]. Attempts were made to fit various values to the Freundlich, Temkin, Langmuir, and Flory-Huggins isotherms, and the correlation coefficient ($R^2$) values were used to determine the best fit isotherm [39]
4.5. Kinetics Parameter

Temperature has a great effect on the rate of metal electrochemical corrosion as it is the accelerating factor in most of chemical reactions. It increases the energy of the reacted species, as a result, chemical reaction get much faster. The dependence of corrosion rate (k) on the temperature can be expressed by Arrhenius equation

\[ k = A e^{\left(-\frac{E_a}{RT}\right)} \]  

Where, \(E_a\) is the apparent activation energy, \(A\) is the pre-exponential factor and \(k\) is the corrosion rate.

Enthalpy and entropy of activation (\(\Delta H^*\), \(\Delta S^*\)) of the corrosion process were calculated from the transition state theory as given from eq. 7

\[ \Delta H^* = -RT \ln \left(\frac{k}{A} \right) + E_a \] \[ \Delta S^* = \frac{\Delta H^* - \Delta G^*}{T} \]  

Where, \(h\) is Plank’s constant, \(N\) is Avogadro’s number, \(\Delta S^*\) is the entropy of activation and \(\Delta H^*\) is the enthalpy of activation.

The entropy of activation (\(\Delta S^*\)) in the absence and presence of inhibitor has large and negative values, this indicates that the activated complex in the rate determining step represents an association rather than dissociation, meaning that, a decrease in disordering takes place on going from reactants to the activated complex[55].

5. Conclusions

Corrosion inhibition study on the different class of drugs has been review in different media. Effectiveness of corrosion inhibition depends on their chemical composition, molecular structure and their affinities for metal surface. The most effective corrosion inhibitors are those compounds containing hetero atom like nitrogen, oxygen, and phosphorous as well as aromatic rings. Result obtained from the electrochemical techniques show that all the reported inhibitors of zinc in sulphuric acid have large and negative values, this indicates that the activated complex in the rate determining step represents an association rather than dissociation, meaning that, a decrease in disordering takes place on going from reactants to the activated complex[55].

References

[1] B.E.A. Rani & B.B.J. Basu, “Green inhibitors for corrosion protection of metals and alloys: An overview”, International Journal of Corrosion, 2012, 1-15, 2012.
[2] N.O. Eddy & S.A. Odoemelum, Adv. Nat.& Appl.Sci. 2, 35-42, 2008.
[3] I.B. Obot, N.O. Obi-Egbedi, S.A. Umorden, “Adsorption characteristics and corrosion inhibitive properties of clotrimazole for aluminium corrosion in hydrochloric acid”, International Journal of Electrochemical Science, 4,863-877, 2009.
[4] E.E. Ebenso, H. Alemu, S.A. Umorden, & I.B. Obot, “Inhibition of mild steel corrosion in sulphuric acid using alizarin yellow GG dye and synergistic iodide additive”, International Journal of Electrochemical Science, 8,1325-1339,2008.
[5] S.A. Umorden, I.B. Obot, E.E. Ebenso, & N. O. Obi-Egbedi, “Synergistic inhibition between naturally occurring exudates gum and halide ions on the corrosion of mild steel in acidic medium”, International Journal of Electrochemical Science, 3, 1029-1043, 2008.
[6] M. Abdallah, “Guar Gum as corrosion inhibitor for carbon steel in sulfuric acid solution” Portugaliae Electrochimica Acta, 22,161-175, 2004.
[7] M. Abdallah, “Antibacterial drugs as corrosion inhibitors for corrosion of aluminum in hydrochloric solution”, Corrosion Science, 46,1981-1996, 2004.
[8] M. Abdallah, “Rhodamine azosulpha drugs as corrosion inhibitors for corrosion of 304 stainless steel in hydrochloric acid solution”, Corrosion Science, 44,717-728, 2002.
[9] Y.K. Agrawal, J.D. Talati, M.D. Shah, M.N. Desai & N.K. Shah, “Schiff base of ethylene diamine as corrosion inhibitors of Zinc in sulphuric acid”, Corrosion Science, 46,633-651, 2003.
[10] H.Ashassi-Sorkhabi, B.Shaabani and D. Seifzadeh, “Effect of Some pyrimidinic Schiff bases on the corrosion of mild...
E.E. Ebenso, N.O. Eddy & A.O. Odiongenyi, "Amoxicillin as green corrosion inhibitor for pure Aluminium in acid media. Electrochemical and thermodynamic investigation of an antibacterial agent on the corrosion of mild steel in 1M H2SO4", Journal of Chemical and Pharmaceutical Research, 7,906-912,2015.

S.Manimal, R.Ramesh & P.Manjula, "Inhibition of corrosion mild steel in acid media by Trazodone drug", Research desk, 2, 326-333, 2013.

A.S. Fouda, A.M. El-Defrawy, & M.W. El-Sherbeni, "Cefalexin drug as a new and efficient corrosion inhibitors for mild steel in hydrochloric acid solution", Der Pharma Chemica, 7,22-33, 2015.

J.A. Akpan & N.O. Offiong, "Electrochemical study of corrosion inhibition action of sulphadoxine and pyrimethamine on mild steel in acidic medium", International Journal of Chemical and Process Engineering Research, 1, 10-18, 2014.

N.O. Eddy & S.A. Odoemelam, "Inhibition of thiourea and thiadiazole derivatives: a review", Journal of Materials and Environmental science, 4, 87-96, 2008.

S. Karthikeyan, P. S.Kumaresan, "Experimental studies of an antibacterial agent on the corrosion of mild steel in 1M H2SO4", Journal of Chemical and Pharmaceutical Research, 4, 701-708,2013.

R.T.Loto, C.A. Loto & A.P.I. A.S. Mahdi, "Effect of halide ions on the corrosion inhibition of thiourea and thiadiazole derivatives: a review", Journal of Materials and Environmental science,3,885-894,2012.

S.K. Shukla & M.A. Quraishi, "Cefalexin drug: A new and efficient corrosion inhibitors for mild steel in hydrochloric acid solution", Materials Chemistry and Physics, 120,142-147, 2010.

R. Kushwah & R.K. Pathak, "Inhibition of mild steel corrosion in 0.5 M sulphuric acid solution by Aspirin drug", International Journal of Emerging Technology and Advanced Engineering, 4,880-884, 2014.

K.Z.Mohammed, A.Hamdy & M.Abbas, "A Pharmacically active compound as corrosion inhibitor for carbon steel in acidic medium: Electrochemical and Thermodynamic studies" Research Journal of Pharmaceutical, Biological and Chemical Sciences, 3,912-928, 2012.

A.K. Singh & M.A. Quraishi, "Effect of Cefazolin on the corrosion of mild steel in Hydrochloric acid solution", Corrosion Science, 52,152-160, 2010.

I.A. Akpan & N.O. Offiong, "Electrochemical study of corrosion inhibition of mild steel in hydrochloric acid solution by using Guaifenesin drug as an inhibitor and theoretical calculations", Journal of Al-Nahrain University,18,60-65,2015.

P.M. Nouri & M.M.Attar, "Experimental and quantum chemical studies on corrosion inhibition performance of Fluconazole in hydrochloric acid solution", Bulletin of Materials Science, 38, 499–509, 2015.

K.R. Ansari, M.A. Quraishi, Prashant & E.E. Ebenso, "Electrochemical and thermodynamic investigation of Diclofenac sodium drug as a potential corrosion inhibitor for mild steel in hydrochloric acid", International Journal of Electrochemical Science,8,12860-12873,2013.

S.U.Ofoegbu & P.U. Ofoegbu, "Corrosion Inhibition of mild steel in 0.1M hydrochloric acid media by Chloroquine diphosphate", ARPN Journal of Engineering and Applied Sciences,7,272-276,2012.

D.G. Ladha,U.J. Naik & N.K. R.T.Loto, C.A. Loto & A.P.I. A.S. Mahdi, "Effect of halide ions on the corrosion inhibition of thiourea and thiadiazole derivatives: a review", Journal of Materials and Environmental science,3,885-894,2012.

GokhanGece, "Drugs: A review of promising novel antibiotics" Ph.D. Thesis, University of Calabar, 2008.

M. Abdallah, "Antibacterial drug as corrosion inhibitors for corrosion of Aluminum in hydrochloric acid solution", Corrosion Science, 46, 1981-1996, 2004.

H.A. Abood, "The study of the inhibitory properties of Omeprazole on the corrosion of Aluminum 6063 in alkaline media", Basrah Journal of Science,28, 74-93, 2011.

A. Jeeva & K. Raja, "Experimental gravimetric studies of the corrosion inhibition of mild steel by some antibiotics" Ph.D. Thesis, University of Calabar, 2008.

A.S. Fouda, S.M. Rashwan, M.M. Kamel & A. Ibrahim, "Tenormin drug as save corrosion inhibitor for 304 stainless steel in hydrochloric acid solutions", Der Pharma Chemica,7, 22-33, 2015.

A.S. Fouda, A.M. El-Defrawy, & M.W. El-Sherbeni, "Cefalexin & Tenoxicam drug as stable corrosion inhibitors for carbon steel in hydrochloric acid solutions", Der Pharma Chemica,7, 22-33, 2015.

A.S. Fouda, A.M. El-Defrawy, & M.W. El-Sherbeni, "Cefalexin drug as stable corrosion inhibitors for carbon steel in hydrochloric acid solutions", Der Pharma Chemica,7, 22-33, 2015.

A.S. Fouda, A.M. El-Defrawy, & M.W. El-Sherbeni, "Cefalexin drug as stable corrosion inhibitors for carbon steel in hydrochloric acid solutions", Der Pharma Chemica,7, 22-33, 2015.

S.U.Ofoegbu & P.U. Ofoegbu, "Corrosion Inhibition of mild steel in 0.1M hydrochloric acid media by Chloroquine diphosphate", ARPN Journal of Engineering and Applied Sciences,7,272-276,2012.

I.A. Akpan & N.O. Offiong, "Electrochemical study of corrosion inhibition action of sulphadoxine and pyrimethamine on mild steel in acidic medium", International Journal of Chemical and Process Engineering Research, 1, 10-18, 2014.

N.O. Eddy & S.A. Odoemelam, "Inhibition of the corrosion of mild steel in acidic medium by Penicilllin V Potassium". Advances in Natural and Applied Sciences, 2, 225-232, 2008.

H.A. Abood, "The study of the inhibitory properties of Omeprazole on the corrosion of Aluminum 6063 in alkaline media", Basrah Journal of Science (C), 28, 74-93, 2011.

A.S. Fouda, A.M. El-Defrawy, & M.W. El-Sherbeni, "Lornoxicam & Tenoxicam drugs as green corrosion inhibitors for carbon steel in 1 M H2SO4 solution",Journal of Electrochemical Science and Technology 4, 47-56,2013.

H. Adil, "Corrosion inhibition of zinc metal in 2M hydrochloric acid solution by using Guaiifenesin drug as an inhibitor and theoretical calculations", Journal of Al-Nahrain University,18,60-65,2015.
A. Yurt, A. Balaban, S. U. Kandemir, G. Bereket & B. Erk, S.K.Shukla, A.K.Singh, I.Ahamad & M.A.Quraishi, A.A. Nazeer, H.M. El-Abbasy & A.S. Fouda, F.Bentiss, C.Jama, B.Mernari, H.E. Attari, L.El.Kadi, P.Geethamani, P.K. Kasthuri & M.R. St John Foreman, R.W.Bosch, Hubrecht, W.F.Bogaerts & B.C.Syrett, A.S. Fouda, G.Y. Elewady, A. El-Askalani & K. Shalabi, H.M.N. El-Haddad, "Chitosan as a green inhibitor for copper inhibitors for carbon steel", Materials Chemistry and Engineering, 14, 21-36, 2014.

A.S. Fouda, M.N. EL-Haddad & Y.M.Abdallah, I.A. Akpan & N.O. Offiong, "Inhibition of Aluminum corrosion in hydrochloric acid solution", Journal of Electrochemical Society, 107, 259-263, 1960.

A.S.Fouda & H.E.Gadow, "Streptomycin and Septazole: Antibacterial drugs as corrosion inhibitors for copper in acidic solutions", Global Journal of Researches in Chemical and Pharmaceutical Research, 3, 343-356, 2011.

A.S. Fouda, Yurt, A. Balaban, S. U. Kandemir, G. Bereket & B. Erk, "Investigation on some Schiff base as HCl Corrosion inhibitors for carbon steel", Materials Chemistry and Physics, 85, 420-426, 2004.

A.K. Singh & M. A. Qurashi, "The effect of some bisthiadiazole derivatives on the corrosion of mild steel in hydrochloric acid", Corrosion Science, 52, 1373-1385, 2010.

Bentiss, C.Jama, B.Mernari, H.E. Attari, L.El.Kadi, M.Lebrini, M.Traisnel & M.Lagrenee, "Corrosion control of mild steel 3,5-bis(4-methoxyphenyl)-4-amino-1,2,4 triazole in normal hydrochloric acid medium "Corrosion Science,51,1628-1635, 2009.

I.Ahamad, R.Prasad, & M.A.Quraishi, "Adsorption and inhibitive properties of some new manic bases of isatin derivatives on corrosion of mild steel in acidic media", Corrosion Science, 52, 1472-1481, 2010.

M.N. El-Haddad, "Chitosan as a green inhibitor for copper corrosion in acidic medium", International Journal of Biological Macromolecules, 55, 142–149, 2013.

H.F. Finely & N. Hackerman, "Effect of adsorption of polar organic compounds on the reactivity of steel!", Journal of Electrochemical Society, 107,259-263, 1960.

A.S. Fouda, G.Y. Elewady, A. El-Askalani & K. Shalabi, "Inhibition of aluminum corrosion in hydrochloric acid media by three Schiff base compound", Zastita Materijala, 51,205-219,2009.

R.W.Bosch, Hubrecht, W.F.Bogaerts & B.C.Syrett, "Electrochemical frequency modulation: A new electrochemical technique for online corrosion monitoring", Corrosion,57,60-70,2001.

A.A. Nazeer, H.M. El-Abbasy & A.S. Fouda, "Antibacterial drugs as environmentally-friendly corrosion inhibitors for carbon steel in acid medium", Research on Chemical intermediates, 39,921-939, 2013.

P.Geethamani, P.K. Kasthuri & M.R. St John Foreman, "Adsorption and corrosion inhibition of mild steel in acidic media by expired pharmaceutical drug", Cogent Chemistry, 1, 2015.

S.K.Shukla, A.K.Singh, I.Ahamad & M.A.Quraishi, "Streptomycin: A commercially available drug as corrosion inhibitor for mild steel in hydrochloric acid solution", Materials Letters, 63,819-822, 2009.

R.S.A.Hameed, "Ranitidine drugs as non-toxic corrosion inhibitors for mild steel in hydrochloric acid medium", Portuguese Electrochemistry Acta, 29, 2011.

N.Vaszilexin, V.Ordadi & A.Borza, "Corrosion inhibitors from expired drugs", International Journal of Pharmaceutics, 15, 2012.

I.B.Obot, N.O.Obi-Egbedi & S.Umoren, "Drugs as corrosion inhibitors for aluminium in 0.1 M HCl", Corrosion Science,51,1868-1875,2009.

I.Reza, A.Saleemi & S.Naveed, "Corrosion inhibition of mild steel in HCl solution by Tinidazole", Polish Journal of Chemical Technology, 13, 67-71, 2011.

A.S.Fouda, S.H.Etaiw & A.Wahba, “Effect of Acetazolamide drug as corrosion inhibitor for carbon steel in hydrochloric acid solution", Nature and Science, 13, 1-8, 2015.

J.I.Bhat & V.D.P.Alva, “ Melcizidine hydrochloride as a potential non-toxic corrosion inhibitor for mild steel in hydrochloric acid medium", Archives of applied Science Research,3,343-356,2011.

A. Samide, B. Tutunaru & C. Negriela, "Corrosion Inhibition of Carbon Steel in Hydrochloric Acid Solution Using a Sulfa Drug", Chemical and Biochemical Engineering,25,299-308,2011.

H.I.AI-Shafey,R.S.A.Hameed,F.A.Ali,A.el-Aleem S.Aboul-Magd & M.Salah, “Effect of Expired Drugs as Corrosion Inhibitors for Carbon Steel in 1M HCl Solution”, International Journal of Pharmaceutical Sciences Review and Research,27,146-152,2014.

Authors Profile

Dr. R.K.Pathak is Professor & Head of the Department of Chemistry in Govt.MLB Girls P.G. College, Indore, MP. He is working in the area of Electrochemistry.

Ms.Pratiksha Mishra is Assistant Professor in Govt.MJB Girls P.G. College, Indore, MP.