Chapter 2

CHAPTER-2

REVIEW OF LITERATURE

A number of benzofused five, six and seven membered heterocyclic compounds have been synthesized and their inhibitive effect on the corrosion of mild steel, copper and aluminium have been reported. A review of the previous work is listed below.

Larabi *et al.,* studied the inhibition property of 2-mercapto-1-methylimidazole for copper corrosion in HCl solution by employing weight loss, DC-polarization and AC-impedance techniques. A significant decrease in corrosion rate was observed in presence of the investigated compound. Adsorption of the inhibitor on the surface of copper was found to obey Langmuir adsorption. Potentiodynamic polarization curves indicated that the compound was mixed inhibitor with a more pronounced anodic effect[1].

Quraishi *et al.,* synthesized 2-pentadecyl-1, 3-imidazoline (PDI), 2-undecyl-1, 3-imidazoline (UDI), 2-heptadecyl-1, 3-imidazoline (HDI), 2-nonyl-1, 3-imidazoline (NI) and investigated their corrosion inhibition properties on aluminium in 1M HCl and 0.5 M H_2SO_4 using weight loss, potentiodynamic polarization, electrochemical impedance and scanning electron microscopic techniques. The inhibition efficiency increases with increase in inhibitor concentration but decreases with increase in time and temperature. The inhibition efficiency was found in the order UDI > NI > PDI > HDI. The adsorption of the inhibitors on the surface of aluminium follows Langmuir adsorption isotherm. Mixed type nature of the inhibitors was shown by the results of potentiodynamic polarization. Electrochemical impedance spectroscopy was used to investigate the mechanism of corrosion inhibition[2].

Khaled *et al.,* examined the corrosion inhibitive effect of three benzotriazole derivatives namely, 1-(phenylsulfonyl)-1H-benzotriazole, 1-(3-pyridinylsulfonyl)-1H-benzotriazole and 1-(2-pyridinylsulfonyl)-1H-benzotriazole using weight loss and electrochemical measurements for copper corrosion in 1M HNO_3 solution. The results indicate that benzotriazole derivatives are good corrosion inhibitors. The adsorption behavior has been studied using molecular dynamics method and density functional theory. Results reveal that the adsorption of the inhibitors on the surface of copper takes place through the benzotriazole ring and heteratoms[3].

Khaled *et al.,* investigated the behavior of three thiazole derivatives namely, 2-amino-4-(p-tolyl) thiazole (APT), 2-methoxy-1, 3-thiazole (MTT) and thiazole-4-carboxaldehyde (TCA) at iron (110) surface dissolved in aqueous solution through molecular dynamics (MD) simulations. Results reveal that the inhibitor APT showed preferred adsorption among the tested thiazoles derivatives. The corrosion inhibitive performance of the three thiazoles on mild steel was studied at room temperature using weight loss, Tafel polarization and electrochemical impedance spectroscopy. Electrochemical frequency modulation (EFM) technique was used to determine the corrosion rates. Polarization studies showed mixed type behavior of the inhibitor. A good agreement of the test results obtained from EFM was found with chemical and electrochemical techniques. Results obtained from chemical and electrochemical techniques were found to be consistent with computational studies showing the effectiveness of the inhibitor APT among the tested thiazoles[4].

Parameswari *et al.,* synthesized heterocyclic compounds such as 4-phenyl-5-acetyl/carbethoxy-3-methyl-6-hydroxy-6-methyl-4, 5, 6, 7-tetrahydro-2, 1-benzisoxazole and benzopyrazole (BIS 1, BP1, BIS2 and BP2) and studied the corrosion inhibition property for mild steel in 1M H_2SO_4 medium. The techniques used for the investigation are weight loss measurements, potentiodynamic polarization and electrochemical impedance (EIS) measurements. Adsorption of the inhibitors on the mild steel surface was found to obey Langmuir adsorption isotherm. From the results it was found that the inhibition efficiency of the inhibitors varies with concentration and temperature. Synergistic study was carried out for all the four compounds using weight loss method by the addition of KI, KBr and KCl. Investigation results reveal that all the four compounds act as excellent corrosion inhibitor for mild steel in 1M H_2SO_4. Polarization studies showed them to be mixed type inhibitors. The surface morphology of the mild steel specimen in presence of the inhibitors was studied through scanning electron microscopy[5].

4-amino-3-hydrazino-5-mercapto-1, 2, 4-triazole (AHMT) was analyzed as corrosion inhibitor for copper in 2M HNO_3 at 303 K by weight loss, AC-impedance and DC-polarization techniques by **Zarrouk *et al***.. The inhibition efficiency of the inhibitor AHMT increases with increase in inhibitor concentration and attains a maximum of 94.7% at 10^{-2}M. Polarization results concluded mixed type nature of the inhibitor. The influence of

temperature on the inhibitor adsorption process was studied in the temperature range 303K-343K. The adsorption of the inhibitor AHMT on the surface of copper followed Langmuir adsorption isotherm. The kinetic and adsorption parameters in the absence and presence of inhibitor were determined and discussed[6].

The inhibition efficiency of 2-amino-5-mercapto-1, 3, 4-thiadiazole (2A5MT) and 2-mercaptothiazoline (2MT) on mild steel corrosion in 1M H_2SO_4 was studied by **Ali Doner *et al***.. Potentiodynamic polarization, linear polarization resistance and electrochemical impedance spectroscopic techniques indicate that both the inhibitors are good corrosion inhibitors for protection of mild steel. The inhibition efficiency of these inhibitors were attributed to the blocking effect by the phenomenon of adsorption on the steel surface. The corrosion inhibition efficiency of the inhibitor 2A5MT was investigated through theoretical calculations[7].

Xiumei Wang *et al.,* studied the inhibitive effect of 1,4-bis (benzimidazolyl) benzene (BBMB) on the corrosion of mild steel in 0.5 M HCl and 0.25 M H_2SO_4 by using weight loss, electrochemical impedance spectroscopy(EIS) and potentiodynamic polarization methods. The results of the investigations show that BBMB is a good inhibitor in both the acidic media. However a predominant effect was found 0.5 M HCl solutions compared to that of 0.25 M H_2SO_4. The adsorption of the inhibitor BBMB follows Langmuir adsorption isotherm. Results of potentiodynamic polarization techniques reveal that BBMB acts as mixed type inhibitor[8].

The inhibitive action of 2-mercaptobenzimidazole (2MBI) on mild steel corrosion has been investigated at 308 K by **Benabdellah *et al***. using are weight loss measurements, impedance spectroscopy and potentiodynamic polarization. The inhibition efficiency increases with increase in inhibitor concentration and reaches a maximum efficiency of 98% at 10^{-3}M. Polarization studies revealed mixed nature of the inhibitor. EIS measurements showed an increase in charge transfer resistance with inhibitor concentration. The influence of temperature on the corrosion inhibiting behavior of mild steel in 1M HCl in presence and absence of the inhibitor was studied in the temperature range of 308 K to 353 K. Thermodynamic parameters such as heat of adsorption (Q_{ads}), enthalpy of adsorption

(ΔH°_{ads}) and entropy of adsorption (ΔS°_{ads}) and kinetic parameters at different concentration of the inhibitor were determined. The adsorption of the inhibitor on the mild steel surface was found to obey Langmuir adsorption isotherm[9].

The corrosion inhibitive action of 2-mercaptobenzimidazole (MBI) and 2-thiobenzylbenzimidazole (TBBI) on mild steel in 1M HNO_3 medium was studied using weight loss method at a temperature range of 298 K- 338 K and at a concentration range of 10^{-5} to 10^{-3}M. Both the compounds show fairly good corrosion inhibition efficiency of 90% for TBBI and 87.7% for MBI. The adsorption of both the compounds on the mild steel surface was found to obey Langmuir adsorption isotherm. Quantum chemical parameters such as E_{HOMO}, E_{LUMO}, ΔE and dipole moment (μ) were calculated using DFT/B3LYP/6-31G (d, p). Theoretical data was found to be consistent with experimental results[10].

Mistry *et al.,* studied the inhibition effect of 2-(benzothiazol-2-ylsulfanyl)-1-(5-methyl-thiazol-2-ylamino)-ethanol towards mild steel corrosion in 1N HCl solutions using weight loss, potentiodynamic polarization method, linear polarization and electrochemical impedance spectroscopic techniques. From the results it was found that the inhibitor was effective and the efficiency increased with concentration of the inhibitor. Linear polarization resistance revealed a mixed mode of inhibition. Changes in the impedance parameters such as charge transfer resistance and double layer capacitance confirmed the strong adsorption of the inhibitor on to the steel surface. The inhibition action of the inhibitors was assumed to occur via active centers present in the inhibitor molecules[11].

Xiumei Wang *et al.,* reported the influence of benzimidazole derivative, 1, 8-bis (1-chlorobenzyl-benzimidazolyl)-octane (CBO) on the corrosion behavior of mild steel in different concentration of HCl solution. The inhibition efficiency was evaluated using weight loss, potentiodynamic polarization, electrochemical impedance spectroscopy and SEM. The inhibitor CBO undergoes strong chemical adsorption on to the steel surface suppressing both anodic and cathodic processes in accordance with Langmuir adsorption isotherm. The inhibition efficiency depends on concentrations of the inhibitor and acid. The inhibition mechanism was proposed based on the adsorption of the inhibitor molecules on the surface of the mild steel[12].

Kabanda *et al.,* studied the molecular properties of phenazine, phenothiazine, phenoxazine and 1, 12-phenathroline and correlated with the inhibition efficiencies of the compounds. The interaction between the metal ion and the inhibitors revealed that charge transfer mechanism is responsible for the binding of these compounds on to the metal surface. Experimental results indicated that the inhibition efficiency is maximum for 1, 12-phenathroline. Experimental data obtained fits the Langmuir adsorption isotherm[13].

The inhibition effect of (2-(1,3-dioxoisoindolin-2-yl) acetonitrile (IND), 2-((1H-tetrazol-5-yl)methyl)isoindolin-1,3-dione (IND-TET) and 5-(chloromethyl)-1H-tetrazole (TET) on mild steel in 1M HCl was studied by Polarization and electrochemical impedance spectroscopic techniques. The inhibition efficiency was explained by Langmuir adsorption isotherm model. The influence of molecular structure was discussed and no synergism was observed in IND-TET inhibitor[14].

Trabanelli *et al.,* investigated 5-alkyl derivatives of benzotriazole (BTA) for corrosion of iron at 298 K in sulphuric acid and hydrochloric acid and copper at 303 K in acidic sulphate and saline solutions. The compounds showed better inhibiting properties in copper than in iron. The BTA derivatives act as more efficient inhibitor for the corrosion of iron in hydrochloric acid solution than in sulphuric acid solution. However in the case of copper, they are effective in both acids. This is justified that adsorption of the inhibitor BTA follows chemisorptions instead of physisorption[15].

Musa *et al.,* tested the ability of phthalazine (PT), phthalazone (PTO) and phthalhydrazide (PTD) to inhibit corrosion of mild steel in 1M HCl at 303 K by employing electrochemical impedance spectroscopy (EIS) and potentiodynamic polarization measurements. The results of the investigation showed that the inhibition efficiencies of these derivatives increase with increase in concentration. The inhibition efficiency was found to be in the order PTD < PT< PTD. Electronic structure of the PT was determined using theoretical calculations. Results of experimental studies were consistent with theoretical calculations [16].

Novel benzodiazepine derivatives, 10-benzyl-pyrrolo[2,1-c][1,4]benzodiazepine-5, 11-dione (BZD=2O) and 10-benzyl-pyrrolo[2,1-c][1,4]benzodiazepine-5, 11-dithione (BZD=2S) were examined for their corrosion inhibition performance on mild steel in

1M HCl at 308 K using electrochemical and weight loss measurements. The compounds were found to have good inhibiting properties and their inhibition efficiency increases with increase in concentration of the tested inhibitors. The inhibitor BZD=2S showed better protection property than BZD=2O even at higher temperature. The adsorption of the inhibitor BZD=2S was in accordance with Langmuir adsorption isotherm[17].

Ouici *et al.,* reported the inhibitory effects of 2-mercapto-1-methylimidazole (MMI) towards mild steel corrosion in 50% HCl solution using weight loss measurement, electrochemical techniques and SEM analysis. Polarization curves indicated that the inhibitor acts as cathodic type inhibitor. The inhibition efficiency of the inhibitor is due to the formation of adsorption film on the metal surface which was confirmed by SEM and EDX examinations[18].

Bentiss *et al.,* studied the effect of 3, 6-bis (3-pyridyl) pyridazine on the corrosion inhibition of carbon steel in HCl solution by weight loss, polarization and electrochemical impedance spectroscopy. The inhibition efficiency was found to increase with increase in inhibitor concentration. The inhibitor was found to behave as mixed type following Tempkin isotherm. The mechanism of corrosion inhibition of carbon steel in 1M HCl in presence of the inhibitor was analyzed through quantum chemical calculation and X-ray photoelectron spectroscopy[19].

The inhibition effect of 2-(4-pyridyl)-benzimidazole (PBI) against corrosion of mild steel in 1M HCl was investigated using weight loss and electrochemical measurements by **Zhang *et al***. The inhibition efficiency increased with increase in inhibitor concentration but decreased with increase in temperature and concentration of the acid. The theoretical calculations done using DFT and MD simulations revealed that the adsorption of PBI depends on the formation of coordination bonds between the inhibitor molecules and the metal surface [20].

Parameswari *et al.,* investigated the influence of benzothiazole derivatives on the corrosion of mild steel in 1M H_2SO_4 using weight loss, potentiodynamic polarization and AC-impedance techniques. The synergistic effect was also studied by the addition of halide ions. From the results it was seen that the inhibition efficiency increased with increase in inhibitor concentration, but decreased with increase in temperature. Polarization

studies indicated that the inhibitors behaved as cathodic type in 1M H_2SO_4. Change in charge transfer resistance and double layer capacitance observed in impedance measurements showed the adsorption of benzothiazole derivatives on the surface of mild steel[21].

Abboud *et al.,* synthesized 2-(o-hydroxyphenyl) benzimidazole (HPB) and tested its inhibitive performance on the corrosion of mild steel in 1M HCl solution using weight loss, spectrophotometric and potentiodynamic polarization measurements. The inhibition efficiency was tested in the absence and presence of different concentrations of the inhibitor. Results revealed that the compound has fairly good inhibiting properties for mild steel corrosion in 1M HCl solution. The inhibition was found to be mixed anodic-cathodic nature with predominance of anodic character. The adsorption film formed on the surface of the metal was analyzed by FT-IR spectroscopy[22].

Shuangqing Sun *et al.,* investigated the adsorption of imidazole, benzimidazole and 2-mercaptobenzimidazole as corrosion inhibitors on the copper surface in both neutral and dehydrogenated forms using density functional theory. Results indicated that the neutral molecules are weekly chemisorbed perpendicularly on the copper surface through N-Cu or S-Cu bond and X-H metal hydrogen bond. Neutral benzimidazole and 2-mercaptobenzimidazole physisorb parallel to the copper surface. It was found that the dehydrogenated molecules are strongly chemisorbed on the surface with both perpendicular and tilt adsorption configurations. The calculated chemisorption strength is consistent with experimentally determined inhibition efficiency[23].

The inhibitive effect of 3-(4-chlorophenyl)-2-methylquinazolin-4(3H)-one (CMQ) and 2-methyl-3-(4-nitrophenyl)quinazolin-4(3H)-one (MNQ) for corrosion of carbon steel in 2M HCl solution was analyzed by weight loss and polarization techniques at 303 K. Electrochemical results showed that the inhibitors are efficient showing 93.8% at the highest concentration tested and the adsorption on the carbon steel surface follows Langmuir adsorption isotherm. Polarization curves indicated that the inhibitors are mixed type[24].

Sudheer and Quraishi studied the inhibition efficiency of three triazoles derivatives namely, 4-amino- 4H-1, 2, 4-triazole-3-thiol (ATT), 4-amino-5-methyl-4H-1, 2, 4-triazole-3-thiol (AMTT) and 4-amino-5-ethyl-4H-1, 2, 4-triazole-3-thiol (AETT) on copper in 0.5M HCl solution. The techniques used for the analysis were potentiodynamic

polarization method, electrochemical impedance, weight loss methods and quantum chemical studies. Results of potentiodynamic polarization studies showed that the examined compounds are mixed type. (AETT) was found to be the best inhibitor. Adsorption of the inhibitor on the mild steel surface followed Langmuir adsorption isotherm. Experimental results corroborated well with quantum chemical calculation[25].

The influence of benzimidazole on corrosion inhibition of mild steel in 0.5 M HCl was investigated by **Xiumei *et al***. using weight loss, electrochemical techniques and atomic force microscopic studies. It was found to perform mixed mode of inhibition. The adsorption of the inhibitor on the mild steel surface was found to obey Langmuir adsorption isotherm. The inhibition performance of the inhibitor correlated with quantum chemical parameters[26].

Nada Abdulwali *et al.,* examined the corrosion behavior of mild steel in 1M H_2SO_4 in the absence and presence of different concentrations of N-alkyl benzimidazolium bromide using potentiodynamic polarization, electrochemical impedance spectroscopy (EIS) and scanning electronic microscopic analysis. The results of the various techniques showed that the inhibitor 1, 3-Dioctylbenzimidazolium bromide was most efficient inhibitors showing an efficiency of more than 96% at a concentration of 10^{-3} M. Potentiodynamic polarization studies showed that the addition of the inhibitors retards both anodic and cathodic corrosion reactions. Thermodynamic parameters were calculated and discussed. The results of polarization studies were in good agreement with electrochemical impedance spectroscopic studies[27].

Sumit Kumar *et al*., studied the inhibition efficiency of 2,4-bis(phenyl)-1H-benzodiazepine (BPBD) and 2,4-bis (methoxyphenyl)-1*H*-benzodiazepine (BMBD) on N80 steel corrosion in 15% HCl solution. The inhibition efficiency increased with increase in inhibitor concentration but decreases with increase in temperature. The inhibitor BMBD and BPBD showed a maximum efficiency of 95.6% and 93.4% respectively at 303 K. Potentiodynamic polarization results conclude mixed type nature of the inhibitor. The adsorption of the inhibitors on the mild steel surface was found to obey Langmuir adsorption isotherm. The mechanism of the inhibition was discussed based on the chemical

structure and quantum chemical calculations of the studied inhibitors. The surface morphology of the specimens in presence and absence of the inhibitors was characterized by SEM[28].

Markhali *et al.,* studied the corrosion inhibition property of two azole derivatives, benzotriazole (BTR) and benzothiazole (BNS) on stainless steel in 1M HCl using electrochemical techniques. The effectiveness of the inhibitor was further confirmed by electrochemical current noise transient analysis, noise resistance and characteristic charge from shot noise theory. The surface morphology of the mild steel specimen was confirmed through SEM in the presence of BNS[29].

Touir *et al.,* investigated the corrosion behavior of three benzimidazole derivatives namely, 5-chloro-benzimidazol-2-one (B1), 5-methyl-benzimidazol-2-one (B2) and benzimidazole-2-one (B3) on mild steel in 1M HCl at different concentrations using weight loss measurements, potentiodynamic polarization curves and electrochemical impedance spectroscopy (EIS) methods. The inhibition efficiency of the investigated compounds was found to depend on inhibitor concentration and their structures. Results of potentiodynamic polarization studies clearly revealed that B1 acts as mixed inhibitor. The inhibition efficiency increases with increase in immersion time and concentration. The results of EIS showed the formation of protective film on the surface of the mild steel. The adsorption of the inhibitor B1 on the mild steel surface was found to obey Langmuir adsorption isotherm[30].

The corrosion inhibitive property of Indoloimidazole derivative namely, (3, 4-dihydro-2-(phenyl) imidazo [4, 5-b] indole) (DPI) was using weight loss, potentiodynamic polarization, electrochemical impedance and quantum chemical studies. Results reveal that an increase in inhibition efficiency was found with increase in concentration of the inhibitor. Influence of temperature on the corrosion inhibition efficiency was studied in the temperature range of 303K-333K. Potentiodynamic polarization studies reveal mixed type nature of the inhibitor in 0.5M H_2SO_4. Adsorption of the inhibitor on the surface of mild steel follows Temkin and Langmuir adsorption isotherm at a temperature of 303 K. Molecular modeling studies were found to correlate with the experimentally determined quantum chemical calculations[31].

Yadav *et al.,* synthesized three benzimidazole derivatives and tested their inhibitive performance on the corrosion of mild steel in 15% HCl solution by using weight loss, electrochemical polarization and impedance spectroscopy (EIS) techniques. Results showed that the inhibition efficiency increased with increase in concentration. The influence of temperature on the corrosion rate was investigated and the thermodynamic parameters were calculated. Polarization studies revealed the mixed nature of inhibition. The adsorption of the inhibitors on the metal surface was found to obey Langmuir adsorption isotherm. The enhancement in the corrosion resistance of the inhibitors was further proved by surface morphological studies. The experimental results were found to be consistent with theoretical calculations obtained using semi empirical AM1 method[32].

Moradi and Attar investigated the inhibitive performance of 2-methylbenzimidazole (2-MBI), 2-methyl benzothiazole (2-MBT) and 2-mercapto benzothiazole (2-SHBT) in 1M HCl solution by gravimetric analysis and electrochemical impedance spectroscopy (EIS). The MBI and MBT were found to obey Langmuir adsorption isotherm, whereas the inhibitor 2-SHBT was found to obey Flory Huggins isotherm. Surface morphological study was done using Atomic force microscopic studies. Quantum chemical parameters - E_{HOMO}, E_{LUMO}, energy gap (ΔE), dipole moment (μ), hardness (η), softness (σ), electro negativity index (χ), fraction of electron transferred (ΔN) were calculated using DFT/B3LYP and HF methods with 6-31G(d, p) basis set[33].

Niouri *et al.,* investigated the inhibitive performance of 2,3- dihydro-1H-pyrrolo[2, 1c][1, 4]benzodiazepine-5, 11(10H, 11aH)- dione (BZD1), 2,3- dihydro-1H-pyrrolo[2, 1c][1, 4]benzodiazepine-5, 11(10H, 11aH)- dithione (BZD2) and 3-phenyl-1,2,4-triazolo[3, 4-c]pyrrolo[1, 2a][1, 4]benzodiazepine- 9-thione (BZD3) on the corrosion of mild steel in 1M HCl medium at 308 K using electrochemical and chemical methods. EIS measurements reveal that with increase in inhibitor concentration, the charge transfer resistance increased and double layer capacitance decreased. BZD3 was found to be efficient among the studied inhibitors following Langmuir adsorption isotherm[34].

Patel *et al.,* investigated the inhibition effect of benzimidazole derivatives on the corrosion of mild steel by weight loss and polarization techniques. Corrosion rate was found to increase with increase in concentration of the acid mixture and decreased with

increase in concentration of the benzimidazoles. The inhibition efficiency depends on the chemical structure, concentration of the inhibitor, and concentration of the corrosive medium. Thermodynamic parameters such as energy of activation (E_a), free energy change (ΔG°_{ads}), heat of adsorption (Q_{ads}), enthalpy change of adsorption (ΔH°_{ads}) and entropy of adsorption (ΔS°_{ads}) were determined. Corrosion rate was found to increase while inhibition efficiency decreased with increase in temperature[35].

Hazazi *et al.*, studied the synergistic effect of 4-amino-5-methyl-4H-1,2,4-triazole-3-thiol (AMTT) and halides on the corrosion inhibition of mild steel in 0.5 M H_2SO_4 at 293 K. The investigation was done using potentiodynamic polarization and electrochemical impedance spectroscopy (EIS). The inhibition efficiency and the surface coverage were found to increase with increase in AMTT concentration. The synergistic effect of halides on the inhibition efficiency followed the order $Cl^- < Br^- < I^-$ which showed the prominent role of radii and electro negativity of the halide ions in the process of adsorption. Adsorption of the inhibitor AMTT followed Temkin isotherm. Thermodynamic and kinetic parameters have been calculated and discussed[36].

Ziyi Cao investigated the adsorption behavior and inhibition mechanism of 2-aminomethylbenzimidazole (ABI), bis (2-benzimidazolylmethyl) amine (BBIA) and tri-(2- benzimidazolylmethyl) amine (TBIA) on mild steel corrosion by quantum chemical calculation and molecular dynamics (MD) simulations. From the investigations it was found that all the three inhibitors have the same ability to donate electrons but they differ in their inhibition efficiency. This may be attributed to the difference in their tendency to accept electrons. MD simulation studies showed that the steric effect between the benzimidazole segments affects the adsorptive configurations of the molecules on the iron surface[37].

Desai and Indorwala investigated the inhibitive action of benzotriazole and benzylbenzotriazole on the corrosion of mild steel in hydrochloric acid solution. The inhibitor shows highest inhibition efficiency of 98% at the highest concentration of 25 mM and 85% at the lowest concentration of 5 mM. The inhibition efficiency was found to decrease with rise in temperature due to decreased surface coverage of the metal

by the inhibitor. Adsorption of the inhibitor on the mild steel surface takes place according to Langmuir adsorption isotherm model. Polarization studies revealed that the two triazoles functioned as slightly anodic but significantly cathodic inhibitors[38].

Sikine *et al.,* studied the inhibitive influence of 1H-benzo[b][1,4]diazepine-2,4(3H, 5H)-dione towards mild steel in 1M hydrochloric acid medium by electrochemical and chemical methods at room temperature. From the results it was seen that the inhibition efficiency increases with increase in inhibitor concentration. The inhibition efficiency of the inhibitor was discussed on the basis of quantum chemical parameters obtained using DFT [39].

Laabaissi *et al.,* studied the corrosion inhibition performance of 4-acetylmethylene-1, 5-benzodiazepin-2-one (AMBz) on carbon steel in 2M phosphoric acid through potentiodynamic polarization and electrochemical impedance spectroscopic techniques. The inhibition efficiency was found to increase with increase in AMBz concentration. However a decrease in inhibition efficiency was found with increase in temperature. Potentiodynamic polarization studies revealed that the inhibitor behaved as mixed type. The inhibition mechanism of the inhibitor was discussed based on its electrode blocking effect through adsorption process. Thermodynamic parameters were calculated and discussed. Results obtained through all the techniques were in good agreement[40].

Essaghouani *et al.,* studied the adsorption and corrosion inhibition properties of 1-ethyl-4-phenyl-2, 3-dihydro-1H-1, 5-benzodiazepin-2-one (P1) on mild steel surface in 1M HCl solution. The corrosion inhibition properties were studied using weight loss measurements, polarization and electrochemical impedance spectroscopy (EIS) and quantum chemical calculations. Potentiodynamic polarization measurements showed mixed type behavior of the inhibitor. The degree of surface coverage was determined from weight loss measurements. Adsorption of the inhibitor on the mild steel surface obeyed Langmuir adsorption isotherm[41].

References

1. Larabi L , Benali O, Mekelleche S, Harek Y, *App. Surf. Sci*., **253** (2006) 1371.
2. Quraishi M A, Rafiquee M ZA, Khan S, Saxena N, *J. Appl. Electrochem*., **37** (2007) 1153.
3. Khaled K F, Adl-AllahSagar A, Hammouti B, *Mater. Chem. Phys*., **117** (2009) 148.
4. Khaled K F, Amin M A, *Corros. Sci*., **51** (2009) 1964.
5. Parameswari K, Rekha S, Chitra S, Kayalvizhy E, *Port. Electrochim. Acta*., **28** (2010) 189.
6. Zarrouk H, Oudda H, Zarrouk A, Salghi R, Hammouti B, Bouachrine M, *Der Pharma Chemica*, **3** (2011) 576.
7. Doner A, Solmaz R, Ozcan M, Kardas G, *Corros.Sci*., **53** (2011) 2902.
8. Wang X, Yang H, Wang F, *Corros. Sci*., **53** (2011) 113.
9. Benabdellah M, Tounsi A, Khaled K F, Hammouti B, *Arabian J. Chem*., **4** (2011) 17.
10. Niamein P M, Essy F K, Trokourey A, Sissouma D, Diabate D, *Afr. J. Environ. Sci. Technol*., **5** (2011) 641.
11. Mistry B M, Patel N S, Jauhari, *Arch. Appl. Sci. Res*., **3** (2011) 300.
12. Wang X, Wan Y, Zeng Y, Gu Y, *Int. J. Electrochem. Sci*., **7** (2012) 2403.
13. Kabanda M M, Murulana LC, Ebenso E E, *Int. J. Electrochem. Sci*., **7** (2012) 7179.
14. Aouine Y, Sfaira M, Ebn. Touhami M, Alami A, Hammouti B, Elbakri M, El Hallaoui A, Touir R, *Int. J. Electrochem. Sci*., **7** (2012) 5400.
15. Trabanelli G, Frifnani A, Monticelli C, Zucchi F, *Int. J. Corros. Scale Inhib*., **4** (2015) 96.
16. Musa A Y, Jalgham R T T, Mohamad A B, *Corros. Sci*., **56** (2012) 176.
17. Niouri W, Zerga B, Sfaira M, Taleb M, Hammouti B, Touhami E, Al-Deyab S Benzeid H, Essassi El M, *Int. J. Electrochem. Sci*., **7** (2012) 10190.

18. Ouici H B, Benali O, Harek Y, Al-Deyab S S, Larabi L, Hammouti B, *Int. J. Electrochem. Sci*., **7** (2012) 2304.

19. Bentiss F, Outirite M, Traisnel M, Lezin H, Lagrenee M, Hammouti B, Al-Deyab S S, Jama C, *Int. J. Electrochem. Sci*., **7** (2012) 1699.

20. Zhang F, Tang Y, Cao Z, Jing W, Wu Z, Chen Y, *Corros. Sci*., **61** (2012) 1.

21. Parameswari K, Chitra S, Selvaraj A, Brindha S, Menaga M, *Port. Electrochim. Acta*., **30** (2012) 89.

22. Abboud Y, Hammouti B, Abourriche A, Ihssane B, Bennamara A, Charrouf, Al-Deyab S S, *Int. J. Electrochem. Sci*., **7** (2012) 2543.

23. Sun S, Geng Y, Tian L, Chen S, Yan Y, Hu S, *Corros.Sci*., **63** (2012) 140.

24. Fouda A S, Elewady G Y, Mostafa H A and Habbouba S, *Afr. J. Pure Appl. Chem*., **7** (2013) 198.

25. Sudheer M A, Quraishi, *Corros. Sci*., **70** (2013) 161.

26. Wang X, Wan Y, Wang Q, Ma Y, *Int. J. Electrochem. Sci*., **8** (2013) 4086.

27. Abdulwali N, Ennajih H, Guenbour A, AbdelkbirBellaouchou, Al Subari R, Jose Garcia Anton, El Mokhtar Essassi, *Aust. J. Basic & Appl. Sci*., **7** (2013) 1.

28. Kumar S, Sharma D, Yadav P, Yadav M, *Ind. Eng. Chem. Res*., **52** (2013) 14019

29. Markhali B P, Naderi R, Mahdavian M, Sayebani M, Arman S Y, *Corros. Sci*., **75** (2013) 269.

30. Touir R, Belakhmima R A, Ebn Touhami M, Lakhrissi L, El-Fayed, Lakhrissi B, Essassi E M. *J. Mater. Environ. Sci*., **4** (2013) 921.

31. Nalini D, Sudha D, *Int. J. Scientific and Engg Res*, **4** (2013) 1161.

32. Yadav M, Bahera D, Kumar S, Sinha R R, *Ind. Eng. Chem.. Res*., **52** (2013) 6318.

33. Moradi Z, Attar M M, *App. Surf. Sci*., **317** (2014) 657.

34. Niouri W, Zerga V, Sfaira M, Taleb M, Ebn Touhami M, Hammouti B, Mcharfi M, Al-Deyab S S, Benzeid H, Essassi E M, *Int. J. Electrochem. Sci*., **9** (2014) 8283.

35. Patel H K, Kadiya R T, Vashi, *Der Pharma Chem.*, **6** (2014) 45.

36. Hazazi O A, Fawzy A, Awad M, *Int. J. Electrochem. Sci*., **9** (2014) 4086.

37. Cao Z, Tang Y, Cang H, Xu J, Lu G, Jing W, *Corros. Sci*., **83** (2014) 292.

38. Desai P S, Indorwala N S, *Int. J of Curr Microbiol App Sci*., **4** (2015) 928.

39. Sikine M, Rodi K Y, Elmsellem H, Krim O, Ouzidan Y, Kandri Rodi A, Ouazzani Chahdi F, Sebbar N K, Essassi E M, *J. Mater. Environ. Sci*., **7** (2016) 1386.

40. Laabaissi T, Bouassiria M, Oudda H, Zarrok H, Zarrouk A, Elmidaoui A, Lakhirissi L, Lakhrissi B, Essassi E M, Touir R, *J. Mater. Environ. Sci*., **7** (2016) 1538.

41. Essaghouani A L, Elmsellem H, Ellouz M, El Hafi M, Boulhaoua M, Sebbar N K, Essassi E M, Bouabdellaoui M, Aouniti A, Hammouti B, *Der Pharma Chem.*, **8** (2016) 297.