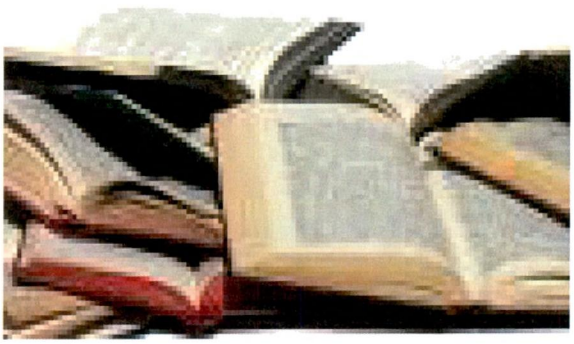

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Review of the past literature is a survey that helps to decide the extent or depth of study in the field of present work. A research work will be perfect only if it is new and different from the previous work. This can be effectively done only with a survey of past literature.

Acid solutions are commonly used in the chemical industry to remove scales from the metallic surfaces. These acids damage the materials under treatment. A useful method to protect metals and alloys in aggressive environments against corrosion is addition of organic or inorganic species to the solution in contact with the surface inorder to inhibit the corrosion reaction and hence reduce the corrosion rate.

The review of the previous studies are discussed under the following headings

2.1. Review of Organic compounds as inhibitors for corrosion of mild steel

2.2. Review of Organic compounds as inhibitors for corrosion of metals and alloys other than mild steel

2.3. Review of Natural products / Plant materials as corrosion inhibitors for mild steel

2.4. Review of Natural products / Plant materials as inhibitors for metals and alloys other than mild steel

2.1. Organic compounds as inhibitors for corrosion of mild steel

Inhibition of corrosion of iron and steel in acids has been the subject of numerous investigations. Organic molecules are known to inhibit corrosion of these materials by adsorption. Organic compounds having hetero atoms are found to have higher basicity and electron density and thus assist in corrosion inhibition. **Putilova *et al.*, (1960)** has documented that organic inhibitors are commonly used to reduce the corrosion attack on metallic materials in acidic media. Many nitrogen containing heterocyclic compounds with polar groups and / or π electrons are good corrosion inhibitors of mild steel in acidic media. These molecules are generally polar and can adsorb on the metal surface because of the electrostatic attraction between molecules

and metal or the interaction with the metal of their π electrons or unshared electron pairs, or a combination of the above.

Jha and Gurmeet singh, (1990) studied the corrosion of mild steel in 1N H_2SO_4 solution containing various concentration of β Alanine by weight loss and polarization methods. The inhibitor was reported to be of mixed type.

Corrosion inhibition parameters such as weight loss, inhibition efficiency and surface coverage has been evaluated for mild steel in presence and in the absence of 1,10 phenanthroline as inhibitor in sulphuric acid medium by **Sethumadhavan *et al.*, (1991)**. The inhibitor was found to adsorb physically on the surface of the steel.

Subramaniam *et al.*, (1993) has studied the effect of substituted arsines, phosphines and stibines on the corrosion of mild steel in HCl medium. A significant decrease in the corrosion rate of mild steel in HCl was observed in the presence of these additives and the compounds acted as both anodic and cathodic inhibitors. The adsorption followed Bokris- Swinkels type of isotherm.

Morretti *et al.*, (1996) worked in finding out the capability of some indole derivatives viz, 5-hydroxy indole and 5- nitro indole as inhibitors for mild steel corrosion in 0.5 M H_2SO_4 and reported in comparison with that of indole. In the temperature range 25 -55°C the inhibiting effect of both the derivatives were more pronounced on the anodic rather than on the cathodic process. The adsorption of 5-nitro indole and indole followed Frumkin's isotherm, while that of 5-hydroxy indole followed Temkin model. The best inhibiting effects were noted at higher concentrations of indole and 5-hydroxy indole while 5-nitro indole did not act significantly as an inhibitor.

The inhibition efficiencies of formaldehyde, propargyl alcohol (**Jayaperumal *et al.*, 1996 and 1997)** and Octyl alcohol and propargyl alcohol at 30 and 150°C **(Jayaperumal, 2010)** in relation to the corrosion of mild steel in 5% hydrochloric acid using potentiostatic and gravimetric methods was studied. The inhibitors worked as a mixed type following Temkin's isotherm.

Chaudhary and Santosh Sharma (1997) have investigated methyl red as inhibitor for corrosion of mild steel in 1.0 M sulphuric acid and perchloric acid solutions. It was reported that methyl red adsorbed physically on the surface of mild steel and it acted as a mixed inhibitor. It followed Langmuir adsorption isotherm.

Mernari *et al.*, (1998) have synthesized 3,5- bis(n-pyridyl)-4-amino- 1,2,4-triazoles and studied its inhibiting action on the corrosion of mild steel in 1M HCl by weight loss and electrochemical impedance spectroscopy. The compounds acted as anodic inhibitor. The adsorption obeyed Langmuir adsorption isotherm.

The corrosion behavior of mild steel in binary acid ($HCl + HNO_3$) mixture was examined using weight loss method and thermometric techniques in presence of aniline and its derivatives. The mode of inhibition was chemisorption. (**Tandel and Oza, 1998).**

Santosh Sharma *et al.*, (1999) has studied the corrosion of mild steel in 1 M H_2SO_4 and 1M HCl solutions in presence of rhodamine B by weight loss, electrochemical, scanning electron microscopy and electron spectroscopy for chemical analysis techniques. It was found that rhodamine B adsorbed physically on the surface of mild steel.

The corrosion inhibition of mild steel in 2M hydrochloric acid solution by tributylamine has been investigated by **Bastidas *et al.*, (2000)** using impedance technique. The inhibition mechanism was found to be selective at active points. The compound adsorbed chemically and the adsorption followed Bockris-Swinkels isotherm.

Abd El Rehim *et al.*, (2001) investigated the corrosion inhibition characteristics of 2-amino thiophenol and 2-cyanomethyl benzothiazole on two types of steel in 1M HCl at different temperatures using gravimetric and galvanostatic polarization techniques. The adsorption obeyed Langmuir isotherm. 2-cyanomethyl benzothiazole was effective than 2-amino thiophenol.

The corrosion behaviour of mild steel in HCl solutions and its inhibition by 4-acetamidoaniline was studied by **Okafor *et al.*, (2003)** using weight loss and hydrogen evolution techniques at 303-323 K. The study revealed that the inhibition efficiency of the inhibitor increased with increase in inhibitor concentration and temperature but decreased with increase in acid concentration. The adsorption of the acetamidoaniline molecules on the surface was reported to be chemisorption.

The influence of dianils (1,4-Di –dimethyl aminobenzyledene aminophenylene, 1,4-Divanilledene aminophenylene, 1,4-Disalicylidene aminophenylene, 1,4-Dibenzyledene aminophenylene and 1,4-Dicinnamyledene aminophenylene) on corrosion of mild steel in 1N hydrochloric acid and 1N sulphuric acid has been investigated by **Quraishi and Danish Jamal (2003).** All the dianil compounds studied showed good inhibition efficiency in both the acids. The efficiency depended on the nature and concentration of the compounds, solution temperature, immersion time and nature of acid solutions. The adsorption of these compounds obeyed Temkin adsorption isotherm. By potentiodynamic polarization studies all the compounds were found to be mixed type inhibitors.

The cationic surfactant cetylpyridinium chloride was investigated as corrosion inhibitor for low carbon steel in 1 M H_2SO_4 by **Atia and Saleh, (2003)** using electrochemical method. It inhibited effectively and the inhibitor shifted the corrosion potential in the cathodic direction. The adsorption followed Bockris – Swinkels isotherm.

The inhibiting effect of N-phenacylpyridinium bromides on the corrosion of carbon steel in 3 M sulphuric acid was studied by **Yurchenko *et al.*, (2004)** and found that these compounds showed inhibition efficiency at higher temperatures too.

The corrosion and inhibition behaviour of mild steel in 1M HCl in the presence of poly (4-vinylpyridine) and Potassium iodide was investigated using weight loss measurements, potentiodynamic polarization studies and impedance measurements. The adsorption of this compound either alone or in combination with iodide ions on the metal surface was found to obey Langmuir's adsorption isotherm. **(Larabi *et al.*, 2004)**

The inhibition of corrosion of mild steel in 0.01-0.1 N HCl solutions by N-cyclohexyl-N'-phenyl thiourea (CPTU) has been studied using potentiodynamic polarization technique. Results indicated that CPTU performs excellently as anodic inhibitor for mild steel in HCl solution. The influence of parameters like temperature, HCl concentration and inhibitor concentration on the corrosion of mild steel has also been reported. (**Divakara Shetty *et al.*, 2005).**

Decanohydrazide, dodecanohydrazide, hexa decanohydrazide and octadecanohydrazide were synthesized by **Quraishi *et al.*, (2005)** and evaluated as corrosion inhibitor for mild steel in hydrochloric acid solutions by weight loss and potentiodynamic polarization methods. The adsorption of all the hydrazides on mild steel surface in the acid solution was found to obey Langmuir's isotherm. The potentiodynamic polarization studies revealed that all the studied compounds acted as mixed inhibitors.

The inhibitive influence of hexamine on the corrosion of commercial mild steel in 1.0M HCl medium has been investigated using weight loss and polarization studies by **Violet Dhayabaran *et al.*, (2005).** The adsorption was found to obey Temkin adsorption isotherm. The polarization studies revealed that the corrosion is predominantly cathodic control.

The influence of thiophene and the derivatives 5-tert-butoxy-thiopene-2-carbaldehyde phenylhydrazone and 5-tert-butoxy-thiopene-2-carboxylic acid on the corrosion inhibition of steel in 0.5M H_2SO_4 solution was studied by **Bouklah *et al.*, (2005)** using weight loss, electro chemical polarization and impedance measurements. 5-tert-but-oxythiophene-2-carbaldehyde phenylhydrazone behaved as best inhibitor. Potentiodynamic polarization studies revealed that it acts as a cathodic inhibitor.

Four Schiff's bases containing pyridyl group {(2-1Z-1-aza-2-(2-pyridyl) vinyl benzene-1-thiol, (1Z)-1-aza-1,2-di(2-pyridyl) ethane, [((1Z)-1-aza-2-(2-pyridyl) vinyl) amino] benzene-1-thione and 2-((1Z)-1-aza-2-(2-pyridyl) vinyl) benzothiazole} were investigated as corrosion inhibitors for low carbon steel in 0.1M hydrochloric acid by potentiodynamic polarization method and impedance measurements. All the bases inhibited the corrosion of low carbon steel and they acted as anodic inhibitors.

The compounds adsorbed on the steel surface obeying Temkin's isotherm. **(Yurt *et al.*, 2005).**

2-(N,N-dimethylamino) benzylidene imino-4-(4-methyl phenyl)-1,3-thiazole, 2-benzylidene imino -4-(4-methyl phenyl)-1,3-thiazole, 2-salicylidene imino- 4-(4-methyl phenyl)-1,3-thiazole and 2-cinnamylidene imino -4-(4-methyl phenyl)-1,3-thiazole were synthesized and their influence on the inhibition of corrosion of mild steel in 20% formic acid and 20% acetic acid was investigated by weight loss method and potentiodynamic polarization techniques. The inhibition efficiency of these compounds was found to vary with their nature and concentration, temperature, immersion time and acid concentration. These compounds adsorbed following Langmuir adsorption isotherm and acted as a mixed inhibitor. **(Quraishi and Sharma, 2005).**

Morad and Kamal El-Dean (2006) synthesized 2,2' – Dithiobis(3-cyano 4,6-dimethyl pyridine) and investigated its inhibiting action on the corrosion of mild steel in 1-5 M H_2SO_4 solutions. The compound showed excellent performance. The compound behaved as anodic inhibitor in 1M H_2SO_4 solution and as mixed type in 3M and 5M solutions. The adsorption followed Temkin's adsorption isotherm.

Bouklah *et al.*, (2006) measured the corrosion rate of steel in the presence of 2,5 – bis (4-methoxyphenyl)- 1,3,4- oxadiazole in 0.5M H_2SO_4 by weight loss method in the range of temperatures from 303-343K. The inhibition was via adsorption and the adsorption followed Langmuir isotherm model.

The corrosion inhibition of mild steel in 3.5 M NaCl and 0.3M Na_2S media using varied concentrations of Potassium chromate and Sodium nitrate was investigated using the weight loss method by **Ayo Samuel Afolabi (2007).**

Morad (2007) has evaluated and reported the corrosion resistance of mild steel in 1M H_2SO_4 solution after addition of Sn^{2+} and Zn^{2+}, N-acetylcystein and S-benzylcystein. The results revealed that all the blends provided good inhibition which increased with rise in temperature.

The effect of succinic acid on the corrosion inhibition of a low carbon steel has been investigated in aerated non-stirred 1.0M HCl solutions in the pH range (2-8) at 25◦C. Weight loss, potentiodynamic polarization and electrochemical impedance spectroscopy techniques were applied to study the metal corrosion behaviour in the absence and presence of different concentrations of succinic acid. The polarization curves showed that it behaved mainly as an anodic-type inhibitor (**Mohammed *et al.*, 2007).**

Adsorption and inhibitive efficiencies of 5 amino- 1- cyclo propyl – 7- [(3R,5S) 3,5- dimethyl piperazin – 1 – yl] -6,8 – difluoro-4-oxo – uinoline -3-carboxylic acid (ACPDQC) have been studied by gasometric and thermometric techniques. Thermodynamic / adsorption considerations revealed that the adsorption of ACPDQC on the surface of mild steel is exothermic, spontaneous and proceeded via physical adsorption.(**Eddy *et al.*, 2008 a**).

Khaled (2008) synthesized N-(5,6 diphenyl 4,5 dihydro- [1,2,4] triazine -3-yl) guanidine and investigated its inhibitive performance towards the corrosion of mild steel in 1M HCl and 0.5M H_2SO_4.

L-Leucine was evaluated as an inhibitor for mild steel in acidic medium by potentiostatic and galvanostatic polarization techniques. The electrochemical polarization results proved L-leucine as an effective inhibitor. The substance acted as a mixed type of inhibitor. (**Puja Singh *et al.*, 2008).**

Kalpana Bhrara *et al.*, (2008) has evaluated butyl triphenyl phosphonium bromide as corrosion inhibitor for mild steel in 0.5M H_2SO_4 using galvanostatic polarization and potentiostatic polarization measurements. The inhibitor acted as mixed type. The adsorption followed Langmuir isotherm.

The effect of Sodium Lauryl Sulphate, a surfactant on corrosion of mild steel in 1M hydrochloric acid has been studied by **Atul kumar (2008)** using weight loss, electrochemical polarization and metallurgical research microscopy. The author has reported Sodium lauryl sulphate as a good inhibitor.

Hexamethylpararosaniline chloride (Crystal violet) was investigated for its corrosion inhibition on mild steel dissolution in 0.5M H_2SO_4 and 1M HCl using gravimetric technique in the temperature range 303-333K. The compound inhibited corrosion in both media and at all temperatures and the efficiency increased with increase in concentration. Adsorption followed Langmuir and Temkin isotherm. The compound was effective in 1M HCl. **(Oguzie *et al.*, 2008).**

Barbituric acid, 5,5-diethylbarbituric acid sodium salt and thiobarbituric acid were investigated as corrosion inhibitors for mild steel in 1M H_3PO_4 solution at 25±1 ◦C using AC impedance spectroscopy, linear polarization resistance measurement and polarization curves measurement techniques (**Muzaffer *et al.*, 2008).**

Xiang-Hong Li (2009) has studied the inhibitive effect of tween -85 on the corrosion of cold rolled steel in 1.0M hydrochloric acid by weight loss and potentiodynamic polarization methods. Tween-85 behaved as a good inhibitor. Its adsorption obeyed Langmuir adsorption isotherm.

The effect of betanin (2,6-pyridinedicarboxylic acid, 4-(2-(2-carboxy-5-(beta-D-glucopyr-anosyloxy) - 2, 3 – dihydro – 6 - hydroxy-1H-indol-1-yl)ethenyl)-2,3-dihydro-(S- (R*,R*))) on the corrosion inhibition of mild steel was investigated in 1 M HCl solution. The results obtained showed that betanin is a good "green" inhibitor for mild steel in 1 M HCl solution. The polarization curves showed that betanin behaves mainly as a mixed-type inhibitor. **(Habib Ashassi-Sorkhabi & Moosa Es'haghi, 2009).**

The inhibition behavior of metol (N-methyl-p-aminophenol sulphate) on mild steel in HCl and H_2SO_4 containing different concentration of metol was investigated by chemical and electrochemical method. It was observed that inhibition efficiencies increased with increase in metol concentration. SEM studies revealed the formation of passive film on the metal surface. **(Praveen and Venkatesha, 2009).**

The inhibition effect of tryptamine on the corrosion of mild steel in 0.5M hydrochloric acid at 30°C was investigated using linear polarization, potentiodynamic

polarization and electrochemical impedance spectroscopy techniques. Adsorption of Tryptamine followed Langmuir adsorption isotherm. (**Pongsak Lowmunkhong *et al.*, 2010).**

2.2 Organic compounds as inhibitors for corrosion of metals and alloys other than mild steel

The inhibitive effects of alkaloids namely brucine, strychnine, narcotine, ephedrine and papavarine on the corrosion of aluminium in 1M hydrochloric acid and 0.1 M sodium hydroxide have been investigated. These compounds were inhibitive in the acid medium but were not effective in alkali to any significant extent. The polarization experiments in HCl revealed that corrosion of Aluminium is under cathodic control (**Subramanyan and Ramakrishnaiah, 1971).**

The effectiveness of papavarine, nicotine, quinine salicylate and quinine sulphate as corrosion inhibitor for Zinc in HCl and H_2SO_4 has been studied by **Jain and Gaur (1978).** Quinine salicylate, nicotine and quinine sulphate show higher inhibition efficiency in H_2SO_4 whereas papavarine showed maximum efficiency in hydrochloric acid.

Some dyes namely Bismarck brown, Naphthol blue black – B, Auromine, Congo red, Brilliant green, Crystal violet, Methyl orange, Safranine T and Indigo carmine were studied as inhibitors for 1100 Al in trichloroacetic acid. Potentiostatic polarization studies showed that the dyes work as mixed type of inhibitors. The inhibition followed Langmuir adsorption isotherm. **(Dubey and Upadhyay, 1994).**

DL-Methionin has been investigated as inhibitor for corrosion of 304 stainless steel in 1.0 M sulphuric acid solution. The inhibition efficiency increased with increase in concentration of the inhibitor and decrease in temperature. The inhibitor adsorbed physically on the surface of steel and acted as a mixed inhibitor. The adsorption followed Langmuir adsorption isotherm. **(Singh and Chaudhary, 1995).**

Bgugaine(Bg) and its derivative, irniine(Ir) have been tested as corrosion inhibitors for iron in 1M HCl by weight loss method. The studies revealed that Bg inhibited well and the adsorption followed Frumkin adsorption isotherm. (**Belkheir Hammouti *et al.*, 1995).**

Agrawal and Namboodhiri (1997) carried out studies to determine the effectiveness of valeronitrile, benzonitrile and derivatives of benzonitrile in suppressing the corrosion rate, cathodic hydrogen evolution reaction and hydrogen embrittlement of HSLA steels in 0.5 M H_2SO_4. Naphthonitrile showed a maximum efficiency and valeronitrile the lowest.

The corrosion behaviour of admiralty brass electrode in 0.1 M H_2SO_4 solution in the presence of amino acid compounds namely, glycine, L-phenylalanine, L-tyrosine and L-histidine has been studied using weight loss and polarization measurements. Among the studied compounds, Histidine was reported to be more efficient **(Abdallah and Atia, 1997).**

The inhibition by aniline and chloro substituted anilines o-chloro aniline, m-chloro aniline and p-chloro aniline on the corrosion of zinc in sulfamic acid solutions has been studied in relation to the concentrations of the acid and inhibitors and the temperature. Galvanostatic polarization showed both anodic and cathodic polarization. (**Vashi and Champaneri, 1997).**

The corrosion inhibition offered by ethanol amines, benzoic acids, acetylinic alcohols for Fe and Ni was investigated by **Jayalakshmi and Muralidharan (1998)**. The molecules adsorbed on the metal surface and offered inhibition.

The inhibition activity of the substituted N-arylpyrroles namely 1-(2-methylphenyl)- 2,5-dimethylpyrrole, 1-(2-fluorophenyl)- 2,5-dimethylpyrrole, 1-(2-chlorophenyl)- 2,5-dimethylpyrrole, 1-(2-iodophenyl)- 2,5-dimethylpyrrole, and 1-(2-fluorophenyl)- 2,5-dimethylpyrrole -3- carbaldehyde, on aluminium corrosion in 0.5M hydrochloric acid was studied using potentiodynamic and impedance spectroscopy techniques. All the investigated compounds acted as cathodic type inhibitors. The inhibition efficiency was attributed to the condensation reaction of inhibitor molecules at the electrode surface. (**Metikos-Hukovic *et al.*, 2002).**

Saratha *et al.*, (2002) have studied the effect of halides (chloride, bromide and iodide) on the corrosion of mild steel in 1M sulphuric acid using weight loss and polarization methods.

Corrosion inhibition of pure iron in 1M HCl solution by stet 5-benzyl-6-methylpyridazin-3-yl thioethanoic, (5-benzyl-6-methyl-3-Oxo pyridazin-3-yl) ethyl thioethanoate and (5-benzyl-6-methylpyridazin-3-yl) ethyl thioethanoate has been studied using weight loss measurements, polarization and impedance spectroscopy methods. The compounds act as cathodic inhibitors. **(Chetouni *et al.*, 2003).**

The inhibiting properties of piperidines and the derivatives 2-methyl piperidine, 3-methyl piperidine, 4-methyl piperidine, cis-2,6-dimethyl piperidine, 3,5-dimethyl piperidine and 4-benzyl piperidine were investigated as corrosion inhibitors for iron in 1 M HCl by potentiodynamic polarization and electrochemical impedance spectroscopy. The compounds were suggested to be mixed type inhibitors. **(Khaled *et al.*, 2004).**

Corrosion of copper in aerated synthetic sea water (3.5% NaCl) solutions and its inhibition by 3-amino-1,2,4-triazole (ATA) have been studied using electrochemical, gravimetric, and pH measurements, along with Raman spectroscopy. Weight loss measurements indicated that the dissolution of copper and the accompanying change of pH decreased to a minimum even after 24 days immersion due to the presence of ATA and the increase of its concentration. **(El-Sayed *et al.*, 2007).**

β-amino alcohols (1,3-bis-dialkyl(C_nH_{2n+1})aminopropan-2-ols where n=2,3 and 4) were tested as volatile corrosion inhibitors for brass in simulated atmospheric water using potentiodynamic, potentiostatic current transient, electrochemical impedance spectroscopy, gravimetric and volatile inhibition ability measurements. The compounds acted as anodic inhibitor. The adsorption of the inhibitor on the brass surface followed Langmuir adsorption isotherm. **(Guo Gao and Chenghao Liang, 2007).**

2.3. Natural products / plant materials as corrosion inhibitors for mild steel

Recent awareness of the corrosion inhibiting abilities of tannins, alkaloids, organic and amino acids has resulted in sustained interest on the inhibiting properties of natural products of plant origin. Usage of natural products is of much importance because in addition to its environment friendliness and ecological acceptability, plant products are inexpensive, readily available and renewable sources of materials. The

natural extracts are found to be effective inhibitors in the acidic media and can be safely used without toxic effects and pollution problems. The use of natural products as corrosion inhibitors have been widely reported by several authors.

The extracts from the leaves, barks, seeds, fruits and roots of plants comprise of mixtures of organic compounds containing nitrogen, sulphur and oxygen atoms and some have been reported to function as effective inhibitors of metal and alloy corrosion in different aggressive environments.

Saleh *et al.*, (1982) has investigated the inhibitive effects of aqueous extracts of *Opuntia ficus indica* and *Aloe eru* leaves and Orange, Mango and Pomegranate fruit peels on the corrosion of mild steel, aluminium, zinc and copper in HCl and H_2SO_4 solutions by weight loss and polarization measurements.

Saleh *et al.*, (1983) have investigated the aqueous and alcoholic extracts of Aloe species namely *Aloe eru*, *Aloe arborescence*, *Aloe vera*, *Aloe formis*, *Aloe grandidentate*, *Aloe spinosissima* and *Aloe ciliaris* as corrosion inhibitors for mild steel in 5 % HCl using weight loss technique.

Garlic was found to be a very good inhibitor for mild steel in nitric acid at conditions such as exposure time, inhibitor concentration and temperature and upto 4N acid strength. Adsorption studies showed that the adsorption of garlic obeyed Freundlich adsorption isotherm. **(Poonam Srivastava and Kumkum Srivastava, 1983)**

Fabrizio Zucchi and Ibrahim Hashi Omar, (1985) has studied the effect of *Papaia, Poinciana pulcherrima, Cassia occidentalis* and *Datura stramonium seeds* and *Papaia, Calotropis procera B, Azydracta indica* and *Auforpio turkiale* sap on the dissolution of mild steel in 1N and 2N HCl solutions.

The inhibitive effects of aqueous extracts of eucalyptus leaves on the corrosion of mild steel and copper in 1N HCl solutions have been studied by weight loss, galvanostatic polarization measurement and surface characteristization. The extract has shown to increase the polarization of the cathodic and anodic reactions of

mild steel, whereas in copper, it increased the cathodic reaction only. The additive acted as a mixed inhibitor, but the cathodic process control was predominant. **(Praveen kar *et al.*, 1993).**

Smita Varma and Mehta have studied the performance of *Lawsonia inermis* extract(**1997 a**) as inhibitor for the corrosion of mild steel in 0.1N HCl and H_2SO_4 solutions and extract of *Eugenia jambolans* **(1997 b)** and acid extracts of *Calotropis giganta* **(1998)** latex for mild steel in 0.1N HCl by linear polarization resistance and Tafel intercept methods.

The extracts of fruits of *Embilica officianalis, Terminalia chebula* and *Terminalia bellirica* in 5% commercial HCl were evaluated as inhibitors for mild steel at 328K by weight loss and polarization techniques **(Sanghvi *et al.*, 1997).**

Corrosion inhibition of mild steel by the extracts of *Pongamia glabra* and *Annona squamosa* in HCl and H_2SO_4 media were reported as safe inhibitors by **Sakthivel *et al.*, (1999).** Weight loss, Polarization, hydrogen permeation and impedance studies have been carried out. The extracts were found to be effective inhibitors in the acidic media.

The inhibitive effects of aqueous extracts of Eucalyptus (leaves), Hibiscus (flower) and Agaricus on the corrosion of mild steel for cooling water systems using tap water have been investigated by weight loss and polarization methods. Agaricus behaved predominantly as a cathodic inhibitor; Eucalyptus and Hibiscus were found to be mixed type inhibitors. **(Minhaj *et al.*, 1999).**

Farooqi *et al.*, investigated the inhibitive effects of aqueous extracts of *Jasminum auriculatum* leaves and *Cordia latifolia* fruits **(1999 a)** on the corrosion of mild steel in 3 % NaCl water and aqueous extracts of *Cordia latifolia* and curcumin **(1999b)** for mild steel in cooling systems by weight loss, electrochemical polarization and impedance measurements. Potentiodynamic measurements showed that extract of *Jasminum auriculatum* was anodic and that of *Cordia latifolia* was cathodic.

The inhibitive action of natural honey on the corrosion of C-steel in high saline water has been evaluated by **El-Etre and Abdallah, (2000)** using weight loss and potentiostatic measurements.

An evaluation of the effective performance of juices extracted from *Anacardium occidentale* (cashew) on the corrosion inhibition of mild steel in 0.1 M HCl was made by **Lotto and Mohammed (2000)**. The juice extracts were obtained from the bark, nuts and apples of the tree. The bark juice extract provided no inhibition for the corrosion of the steel specimen, while the nut juice accelerated the corrosion rate.

The acid extract of *Andrographis paniculata* has been investigated towards corrosion inhibition by **Ramesh *et al.*, (2001).** The inhibitive action has been evaluated using mass loss method, Tafel polarization method and impedance techniques. The extract showed a good inhibition effect.

Sethuraman *et al.*, (2001) investigated tea wastes as corrosion inhibitor for mild steel in acid medium by electrochemical methods such as impedance spectroscopy, tafel polarization plots and weight loss method. The inhibitor acted through mixed mode predominantly by inhibition of cathodic reaction.

Martinez and Stern (2001) have investigated mimosa tannin as inhibitor for low carbon steel in sulphuric acid solutions of pH 1, 2 and 3. At pH 1 and 2, the adsorption followed Temkin and Frumkin isotherms and at pH 3 it followed Freundlich isotherm.

The corrosion inhibition of mild steel in 1M HCl by the extract of flowers and leaves of *Thespesia populnea* has been evaluated by **Maheswari *et al.*, (2001)** using weight loss method.

Saratha *et al.*, (2003) have investigated the inhibitive effect of *Michelia champaca* leaves on the corrosion of mild steel in 0.5M H_2SO_4 and 1M H_2SO_4 by weight loss and potentiodynamic polarization methods.

The effect of *Foenum graecum* as an inhibitor for mild steel corrosion in 5% HCl has been studied using DC electrochemical techniques **(Kalpana and Mehta, 2003).** The inhibitor acted as mixed type.

Tobacco plant extracts were tested for the corrosion inhibition for steel and aluminium in saline environment by weight loss method. The extract was reported to be biodegradable and environmentally benign **(Guy D. Davis and Anthony Von Fraunhofer, 2003).**

The inhibition of the corrosion of mild steel in hydrochloric acid solutions by the extract of the leaves of *Nypa fruticans Wurmb* has been evaluated using weight loss and hydrogen evolution techniques. A first order kinetics was deduced and the adsorption followed physisorption. The results showed that the leaves of *N.fruticans* could serve as an effective inhibitor for the corrosion of mild steel in HCl medium. **(Orubite and Oforka, 2004).**

The study of corrosion inhibition of mild steel in 5% HCl has been carried out using three naturally occurring substances like onion (*Allium cepa*), Garlic (*Allium sativum*) and Bitter gourd (*Momordica charantia*) by **Parikh and Joshi (2004)** using classical weight loss method, Tafel extrapolation and Resistance polarization methods.

The effect of rosemary oil on the corrosion of steel in 3M HCl has been studied using weight loss and electrochemical polarization methods by **Chaieb *et al.*, (2004).** The adsorption followed Frumkin adsorption isotherm.

The inhibitive effect of *Zenthoxylum alatum* extract on the corrosion of mild steel in different concentrations of aqueous orthophosphoric acid by weight loss and electrochemical impedance spectroscopy has been studied by **Gunasekaran and Chauhan, (2004).**

The influence of L-ascorbic acid on mild steel corrosion in pH 2-6 solutions has been investigated by **Ferreira *et al.*, (2004)** using weight loss and electrochemical methods.

The dual function of leaf extract of Fig (*Ficus carica L.*) as antiscalant and corrosion inhibitor for steel was studied. The obtained results showed that the plant extract inhibits the corrosion of steel under the tested conditions. The extract of Fig leaf acted as an anodic inhibitor, reducing metal dissolution. (**Abdel-Gaber *et al.*, 2005).**

The efficacy of *Telfaria occidentalis* extract as a corrosion inhibitor for mild steel in 2 M HCl and 1 M H_2SO_4 solutions was investigated by **Oguzie (2005)**. The corrosion rate was calculated from the hydrogen evolution. It was reported that protonated species in the extract composition played a vital role in the inhibiting action.

Extracts of *Ricinus communis* leaves were tested for the corrosion inhibitory effect of mild steel in 100 ppm sodium chloride solution. The anti corrosion effects were studied by means of weight loss, electrochemical polarization and impedance measurements. The studies revealed it as an efficient inhibitor. The polarization measurements indicated that the plant extract acted as an anodic inhibitor. (**Ananda Louise Sathiyanathan *et al.*, 2005).**

Berberine extracted from *Coptis chinensis* was evaluated for the inhibition efficiency on corrosion of mild steel in 1M H_2SO_4 through weight loss experiment, electrochemical techniques and scanning electronic microscope with energy disperse spectrometer. The data showed a good fit to Flory-Huggins isotherm **(Yan Li *et al.*, 2005).**

Quinine, a natural product was investigated as a corrosion inhibitor for low carbon steel in 1M HCl solution using electrochemical impedance spectroscopy and potentiodynamic polarization methods. The results revealed that Quinine acts as an efficient inhibitor for low carbon steel. Electrochemical impedance spectroscopy measurements showed that the corrosion of iron was controlled by charge transfer process (**Mohamed Ismail Awad, 2006).**

Rosemary oil was tried as green corrosion inhibitor for steel in phosphoric acid at various temperatures and by polarization measurements. The oil was found to

be rich in 1, 8-cineole. Polarization measurements showed that rosemary oil acted essentially as a cathodic inhibitor. **(Bendahou *et al.*, 2006).**

Natural oil extracted from Pennyroyal mint (*Mentha pulegium*,) was evaluated as corrosion inhibitor of steel in molar hydrochloric acid using weight loss measurements, electrochemical polarization and impedance methods. The natural oil was found to retard the corrosion rate of steel. **(Bouyanzer *et al.*, 2006).**

The effect of extracts of Chamomile (*Chamaemelum mixtum L.*), Halfabar(*Cymbopogon proximus*), Black cumin (*Nigella sativa L.*) and Kidney bean (*Phaseolus vulgaris L.*) plants on the corrosion of steel in aqueous 1M sulphuric acid were investigated by **Abdel-Gaber *et al.*, (2006)** using electrochemical impedance spectroscopy (EIS) and potentiodynamic polarization techniques. EIS techniques showed that the dissolution process of steel occurs under activation control.

The *Azadirachta indica* extract was tested for its inhibitive action for steel in the acid media. The extract functioned as a mixed type, depending on its concentration. At lower concentration the inhibition was by physical adsorption and at higher concentration the adsorption was noted to be chemisorption. **(Oguzie, 2006).**

Okafor *et al.*, (2006) investigated the extracts of *Allium sativa* and *Allium cepa* as corrosion inhibitors of mild steel in hydrochloric acid using gravimetric and gasometric techniques. The adsorption followed Langmuir isotherm. Kinetic treatment showed first order type of mechanism.

The inhibitive effect of cocoa (*Theobroma Cacao*) and kolanut (*Cola Acuminata*) extracts on the corrosion of mild steel in seawater at room temperature has been investigated by **Umoru *et al.*, (2006)**. The results showed kola and cocoa leaves extracts as potential inhibitors of mild steel corrosion in sea water and marine environment.

The corrosion inhibition effect of naturally occurring extract of *artemisia* on steel in 0.5M H_2SO_4 in the temperature range 298 - 353 K was studied by weight loss method and electrochemical polarization methods. The study revealed that the

presence of natural artemisia does not change the mechanism of hydrogen evolution reaction and acted as a mixed type inhibitor **(Bouklah and Hammouti, 2006).**

The inhibition effect of the extract of *Ficus nitida* leaves on the general and pitting corrosion of C-steel, nickel and zinc in acidic, neutral and alkaline media was studied by **El-Etre and El-Tantawy, (2006).**

The adsorption of the phytochemical components was reported to be spontaneous and followed Langmuir adsorption isotherm.

Prunus cerasus juice was investigated for its inhibition effects on the corrosion of steel in HCl solution using polarization and electrochemical impedance techniques by **Ashassi-Sorkhabi and Seifzadeh, (2006).**

El-Etre (2006) investigated the inhibitive effect of khillah (*Ammi visnaga*) seeds extract for the corrosion of SX 316 steel in HCl solution by weight loss and potentiostatic technique. The inhibition was reported to be due to the presence of khellin.

The inhibitive effect of ethanol extracts of *Garcinia kola* for the corrosion of mild steel in H_2SO_4 solutions was investigated by **Okafor *et al.*, (2007).** The inhibition efficiency has been evaluated using the hydrogen evolution technique at 30 - 60° C. The experimental data obeyed the Langmuir adsorption isotherm as well as the El-Awady et al thermodynamic –kinetic model. The activation energy calculated for the process suggested that the molecules are physically adsorbed on the metal surface.

The extract of *Datura stramonium* (**Bothi Raja** and **Sethuraman, 2007)** has been studied as a possible source of green inhibitor for corrosion of mild steel in HCl and H_2SO_4 media by conventional weight loss studies, electrochemical studies namely; Tafel polarization, ac impedance and SEM studies. The studies revealed that the plant extract acted as good inhibitor in both the acid media and better in H_2SO_4 medium.

The inhibition effect of *Zenthoxylum alatum* plant extract on the corrosion of mild steel in 5 % and 15% aqueous hydrochloric acid solution has been evaluated by weight loss and electrochemical impedance spectroscopy by **Chauhan and Gunasekaran (2007)**. The extract inhibited more effectively in 5% HCl than in 15% HCl. The adsorption was found to obey Langmuir adsorption isotherm.

Acid extracts of the different parts of *Carica papaya* were used as inhibitors in various corrosion tests like gravimetric and gasometric techniques. The extracts were found to inhibit mild steel corrosion in H_2SO_4. The experimental data fitted well into the Langmuir and Temkin adsorption isotherms. **(Okafor and Ebenso, 2007).**

The inhibitive action of the aqueous extract of olive (*Olea europaea* L.) leaves toward the corrosion of C-steel in 2 M HCl solution was investigated using weight loss measurements, Tafel polarization, and cyclic voltammetry. The extract acted as a good corrosion inhibitor for the tested system. **(El-Etre, 2007).**

Ehteram A. Noor (2007) has studied the temperature effects on mild steel corrosion in 2M HCl and H_2SO_4 using the aqueous extract of fenugreek leaves by gravimetric method. The adsorption was spontaneous and followed Langmuir isotherm in HCl and Temkin isotherm in H_2SO_4.

The corrosion inhibition of mild steel by ethanol extract of *Piper guinensis* has been studied using gravimetric, gasometric and thermometric methods. **(Ebenso *et al.*, 2008).**

Corrosion inhibition of mild steel in 2 M HCl and 1 M H_2SO_4 by the leaf extracts of *Occimum viridis, Telferia occidentalis, Azadirachta indica and Hibiscus sabdariffa* as well as extracts from the seeds of *Garcinia kola* was investigated using a gasometric technique at temperatures 30 and 60 °C. Synergistic effects increased the inhibition efficiency in the presence of halide additives. Comparative analysis of the inhibitor adsorption behaviour in 2 M HCl and 1 M H_2SO_4 as well as the effects of temperature and halide additives suggested that both protonated and molecular species as responsible for the inhibiting action of the extracts **(Emeka. E Oguzie, 2008 a & b).**

The effectiveness of the ethanol extract of *Musa sapientum* peels as corrosion inhibitor for mild steel in H_2SO_4 was investigated by gasometric and thermometric methods **(Eddy and Ebenso, 2008).** The adsorption occurred according to Langmuir and Frumkin isotherm.

The inhibitive action of leaves, seeds and a combination of leaves and seeds extracts of *Phyllanthus amarus* on mild steel corrosion in HCl and H_2SO_4 solutions was studied using weight loss and gasometric techniques. The results indicated that the extracts functioned as a good inhibitor in both environments **(Okafor *et al.*, 2008).**

Exudate gum from *Raphia hookeri* was tested as corrosion inhibitor for mild steel in H_2SO_4 using weight loss and hydrogen evolution techniques at 30-60° C. Results revealed that *Raphia hookeri* extract act as corrosion inhibitor for mild steel. The adsorption of the exudate gum onto the steel surface was found to follow the Langmuir adsorption isotherm **(Umoren *et al.*, 2008).**

Saratha and Vasudha (2008) have investigated the efficiency of *Nyctanthes arbotristis* (Night jasmine, Coral jasmine) leaves as corrosion inhibitor for mild steel in 1N H_2SO_4 by weight loss and polarization studies. The extract was effective and behaved as a mixed type inhibitor.

The alcoholic extracts of stem bark, leaves and fruits of *Proscopis cineraria* were tested by weight loss method for the effectiveness to combat corrosion of mild steel in HCl, H_2SO_4 and in acid mixture (HCl and H_2SO_4). The extracts provided a good protection to mild steel with fruit extract showing better efficiency in the acid mixture than other extracts **(Sharma *et al.*, 2008).**

The inhibitive effect of the gum exudate from *Acacia seyal* var. *seyal* on the corrosion of mild steel in drinking water was investigated by **Buchweishaija and Mhinzi, (2008)** using electrochemical techniques. The study revealed that the gum acted predominantly as an anodic inhibitor.

The inhibitive action of the aqueous extract of the root of shirsh el zallouh (*Ferula harmonis*) on the corrosion of C-steel in 2M HCl solution was investigated by **El-Etre (2008)** using weight loss and potentiostatic polarization techniques. The electrochemical behaviour was studied using cyclic voltammetry.

Eddy *et al.*, (2008 b) studied the corrosion inhibition ability of *Musa acuminate* peel for mild steel using hydrogen evolution and thermometric methods. The adsorption followed Langmuir and Frumkin isotherm.

The effect of concentration of H_2SO_4 on the inhibitive properties of *Aloe vera* for mild steel corrosion was investigated by gasometric and thermometric methods. The ethanol extract was found to be a good inhibitor for mild steel corrosion. The inhibitor acted by chemical adsorption. **(Eddy and Odoemelam, 2009).**

The ethanol extract of *Ocimum gratissimum* was tested for its potential as corrosion inhibitor for mild steel in H_2SO_4 using gasometric, gravimetric and thermometric methods. The adsorption was reported as exothermic, spontaneous and best described by Langmuir adsorption isotherm **(Nnabuk O.Eddy *et al.*, 2010).**

The stability, durability and efficiency of the acid extracts of the leaves of *Emblica officinalis* and *Nyctanthes arbortristis* has been studied as mild steel corrosion inhibitors in acid medium by weight loss method. The extracts acted as effective inhibitors for mild steel in acid medium in room temperature and were comparable with the efficiency of commercial inhibitor VpCI 429. The extract was stable for a period of 8 months. **(Saratha and Vasudha, 2009).**

The corrosion inhibition of mild steel in hydrochloric acid by black pepper extract (*Piper nigrum fem.* Piperacaea) was studied by mass loss measurements, potentiodynamic polarization, linear polarization resistance and electrochemical impedance spectroscopy. The Black pepper extract that contains alkaloid Piperine served as an excellent green inhibitor for corrosion of mild steel in acid solutions. **(Quraishi *et al.*, 2009).**

The inhibition efficiency of the extracts of *Strychnos nux-vomica, Calotropis procera* for the corrosion of mild steel in 1M sulphuric acid and alkaloid extract of *Rauvolfia serpentina* for mild steel in 1M HCl and H_2SO_4 was investigated using weight loss method, electrochemical measurement and scanning electron microscope. All the three materials acted as good inhibitors for corrosion of steel in 1M H_2SO_4 even at elevated temperature. *Rauvolfia serpentina* followed chemisorption mechanism for adsorption. **(Bothi Raja and Sethuraman, 2009 a, b and c).**

The acid extract of Black pepper, *Solanum tuberosum* was tested for its corrosion inhibition on mild steel in 1M HCl and H_2SO_4 using weight loss, electrochemical measurement methods and SEM technique **(Pandian Bothi Raja and Mathur Gopalakrishnan Sethuraman, 2008, 2009).** The adsorption followed Temkin isotherm.

Eddy *et al.*, investigated and reported the inhibitive and adsorption properties of penicillin G **(2009 a)** ethanol extracts of *Terminalia catappa* **(2009 b)**, *Gnetum Africana* **(2009 c)**, *Lasianthera africana* **(2009 d)**, *Gongronema latifolium* **(Eddy and Ebenso, 2010)** and *Heinsia crinata* **(Eddy and Odiongenyi, 2010)** for the inhibition of corrosion of mild steel in H_2SO_4.

The inhibitive action of henna extract (*Lawsonia inermis*) and its main constituents (lawsone, gallic acid, α-d-Glucose and tannic acid) on corrosion of mild steel in 1 M HCl solution was investigated through electrochemical techniques and surface analysis (SEM/EDS). All the examined compounds acted as mixed inhibitor and inhibition efficiency increased with inhibitor concentration. **(Ostovari *et al.*, 2009).**

Patel *et al.*, (2009) used the extract of *Bauhinia purpurea* leaves as corrosion inhibitor for mild steel in 1N H_2SO_4. The weight loss results showed the extract of *Bauhinia purpurea* leaves as an excellent corrosion inhibitor.

The inhibition effect of *Parthenium hystophrous L* extract on the corrosion of mild steel in 1N sulphuric acid was studied by **Muhamath *et al.*, (2009)** by mass loss studies, Tafel polarization and electrochemical impedance spectroscopy between 308 and 338 K.

Corrosion inhibition effect of *Justicia gendarussa* extract on mild steel in 1M HCl medium has been investigated by weight loss and electrochemical techniques. The polarization studies showed that the *Justicia gendarussa* extract acted as a mixed –type inhibitor. The adsorption obeyed Langmuir adsorption isotherm. **(Satapathy *et al.*, 2009).**

The corrosion inhibition effect of aqueous extract of *Eclipta alba* in 1 N hydrochloric acid has been investigated by weight loss, potentiodynamic polarization and impedance methods. The inhibition action was attributed to the presence of the Wedelactone and also the alkaloid Ecliptine present in the leaves of *Eclipta alba*. **(Shyamala and Arulanantham, 2009).**

The effectiveness of *Pisum sativum* stem and pod as inhibitor for the corrosion of mild steel in 1M HCl was studied by mass loss, electrochemical method and surface analysis. Both stem and pod had good inhibiting effect. The extracts acted as mixed inhibitors. **(Saratha *et al.*, 2009).**

The inhibiting effect of the naturally occurring biological molecule caffeic acid on the corrosion of mild steel in 0.1 M H_2SO_4 was investigated by **de Souza and Spinelli (2009)** Caffeic acid acted by decreasing the available cathodic reaction area and modifying the activation energy of the anodic reaction.

The corrosion of X52 mild steel in 1M sulphuric acid in the presence of aqueous extract of *Zygophyllum album* was studied by weight loss and electrochemical measurements. The extract behaved as a mixed type inhibitor **(Noureddine Gherraf *et al.*, 2009).**

The alcoholic extracts of leaves, latex and fruits of *Calotropis procera* and *Calotropis giganta* were tested for the corrosion inhibition of mild steel in basic solution using mass loss and thermometric methods **(Sudesh Kumar *et al.*, 2009).**

The inhibition efficiency of aqueous extract of beet root on the corrosion of carbon steel in well water in the absence and presence of Zn^{2+} has been evaluated by mass loss method and polarization technique **(Arockia Selvi *et al.*, 2009).**

Lavender oil extracted from lavender herb was tested as corrosion inhibitor for mild steel in 1M HCl by weight loss measurements and electrochemical methods. The adsorption of lavender oil on mild steel followed Langmuir isotherm **(Zerga *et al.*, 2009).**

The inhibition of the corrosion of mild steel in aqueous solutions by ethyl acetate extract of *Uncaria gambir* containing catechin has been studied using weight loss, potentiodynamic polarisation measurements, electrochemical impedance spectroscopy and scanning electron microscope technology with energy dispersive X-ray spectroscopy. Inhibition was found to be highest at a pH of 5. (**Mohd. Hazwan Hussin and Mohd. Jain Kassim, 2010).**

Methanolic extract of *Artemisia pallens* was tested as corrosion inhibitor for mild steel in 4N HCl and concentrated HCl. Weight loss and polarization techniques were used for evaluating corrosion inhibition in 4N HCl, whilst weight loss, SEM and FT-IR studies were carried out in concentrated HCl. The adsorption followed Langmuir's isotherm. (**Patchaiah Kalaiselvi *et al.*, 2010).**

The efficacy of the acid extract of leaves of *Sida rhombifolia* L as corrosion inhibitor for mild steel in 1M phosphoric acid medium was investigated. The results showed variation in inhibition performance of the inhibitor with varying concentration, immersion time and temperature. The inhibitor acted as a mixed type of inhibitor. (**Saratha and Meenakshi, 2010).**

The efficiency of *Tectona grandis* leaves extract on the corrosion of mild steel in 0.5M H_2SO_4 was studied by **Kasthuri *et al.*, (2010)** using weight loss method and polarization studies. The extract served as an effective inhibitor. Polarization studies showed the inhibitor as mixed type inhibitor.

The aqueous extracts of fruit peels of mango, orange, passion fruit and cashew have been tested for their inhibition efficiency for the corrosion of carbon steel in 1M HCl. The adsorption of the extracts followed Langmuir isotherm **(Janaina Cardozo da Rocha *et al.*, 2010).**

Priya and Saratha (2010) has investigated the corrosion inhibition of mild steel in 1M HCl in presence of *Crossandra infundibuliformis* leaves extract by weight

loss and electrochemical studies. The extract served as an effective inhibitor and the efficiency increased with concentration of the extract. The extract acted as mixed type inhibitor.

Niketan Patel *et al.*, (2010) has investigated the extract of *Bridelia retusa* leaves as corrosion inhibitor for mild steel in 1N H_2SO_4 using weight loss, electrochemical impedance spectroscopy and scanning electron microscopy. The extract provided mixed mode of inhibition.

The corrosion inhibition of *Azadirachta indica* mature leaves extract on the mild steel corrosion in HNO_3 has been evaluated by gravimetric method at 30 and 60°C. The adsorption was exothermic and best described by Frumkin isotherm **(Sanjay Sharma *et al.*, 2010).**

Vijayalakshmi *et al.*, (2010) has investigated the inhibitive effect of palmyra palm (*Borassus flabellier* Linn.) extract obtained by destructive distillation using weight loss and electrochemical methods. The extract showed mixed mode of inhibition. The effectiveness of the extract has been tested in industrial processes.

Ambrish singh *et al.*, have studied the inhibition of mild steel corrosion in hydrochloric acid by the fruit extracts of Shahjan (*Moringa oleifera*), Pipali (*Piper longum*) and Orange (*Citrus aurantium*) **(2010 a)**, seed extract of Karanj (*Pongamia pinnata*) **(2010 b)** and leaves extract of Kalmegh (*Andrographis paniculata*) **(2010 c)** using weight loss, electrochemical impedance spectroscopy, potentiodynamic polarization and linear polarization techniques. The extracts acted as effective inhibitors by mixed mode of inhibition.

Xiang-Hong Li *et al.*, (2010) investigated the inhibition effect of *Jasmimum nudiflorum* Lindl. leaves extract for the corrosion of CR steel in 1M HCl by weight loss, potentiodynamic polarization and Electrochemical impedance spectroscopy methods. The adsorption obeyed Langmuir isotherm. The electrochemical studies showed that the inhibitor acted as mixed type.

The corrosion inhibition of mild steel in 1M HCl by the pineapple leaves extract was investigated using weight loss and hydrogen evolution methods at 30-

60°C by **Ekanem *et al.*, (2010).** The adsorption obeyed Langmuir isotherm. The chemical adsorption was suggested from the temperature studies.

Pyridine based alkaloids namely ricinine, N-dimethylricinine and 4-methoxy pyridine-3-carboxylic acid were isolated from methanolic extract of *Riccinus communis* leaves and tested their corrosion inhibition effect on mild steel in 0.5M HCl using weight loss and electrochemical techniques **(Rinki Goel *et al.*, 2010).**

Sivaraju and Kannan, (2010) has studied the inhibition effect of alcoholic extract *Acalypha indica* L. for mild steel in 1N phosphoric acid by mass loss and polarization techniques between 303 and 333 K. The adsorption of the inhibitor on mild steel obeyed Temkin's adsorption isotherm. The extract acted as mixed type inhibitor.

Al-Turkustani *et al.*, (2011) evaluated the water and alcoholic extracts of *Medicago sative* on the corrosion of steel in 2M H_2SO_4 containing 10% ethanol using weight loss, hydrogen evolution and electrochemical techniques.

The effect of aqueous extract of spent coffee grounds on the corrosion of carbon steel in 1M HCl was examined by **Vanessa *et al.*, (2011).** The extract acted as mixed type with cathodic predominance and the adsorption obeyed Langmuir isotherm.

Corrosion inhibition of mild steel in 0.5M H_2SO_4 by *Tecoma stans* leaves has been investigated by **Saratha *et al.*, (2011)** using weight loss, gasometric and polarization methods. The extract acted as a potent inhibitor. The inhibitor behaved as mixed type.

The inhibition efficiency of the aqueous extract of *Allamanda blanchetii* (purple) for the corrosion of mild steel has been evaluated by the weight loss method. It was found that the extract had better efficiency in sulphuric acid than in citric acid **(Anand and Balasubramanian, 2011).**

El bribri *et al*, (2011) used gravimetric method to study the effect of temperature on carbon steel corrosion in molar HCl in presence of the methanolic

extract of *Euphorbia falcate* L. The adsorption of the extract was spontaneous following Langmuir isotherm.

Oluseyi O. Ajayi *et al*, (2011) investigated the degradation of mild steel in 2M H_2SO_4 in the presence of *Vernonia amydalina* extract by using gasometric technique. The adsorption mechanism was explained by Freundlich isotherm.

Mobin *et al.*, (2011) studied the corrosion inhibition of mild steel in 0.1M H_2SO_4 in presence of starch and the surfactants sodium dodecyl sulfate and cetyl trimethyl ammonium bromide as additives using weight loss and potentiodynamic polarization measurements in the temperature range 30-60°C. Starch alone and in combination with the surfactants obeyed Langmuir isotherm.

The essential oil from ariel parts of *Mentha spicata* L. obtained by hydrodistillation was evaluated as inhibitor for the corrosion of steel in 1M hydrochloric acid using weight loss and electrochemical polarization measurements. The oil acted as mixed inhibitor **(Znini *et al.*, 2011).**

2.4. Natural products / plant materials as corrosion inhibitors for metals and alloys other than mild steel

Saleh *et al.*, (1984) reported the effect of aqueous of Fenugreek and Lupine seeds, doum, beet and *Solanum melongena* fruits on the corrosion of mild steel, Aluminium, Zinc and Copper in HCl and H_2SO_4. The extracts retarded the dissolution of the metal to an extent depending on the metal, concentration of the additive and the type and temperature of the attacking acid.

The action of *Vernonia amygdalina* (bitter leaf) on the acidic corrosion of 2S and 3RS alloys of aluminium was studied using weight loss method. The inhibitor was effective in 0.1M HCl. **(Gregory O. Avwiri and Igho, 2003).**

El-Etre, (2003) studied the inhibitive action of the mucilage extracted from the modified stems of prickly pears on the corrosion of aluminium in 2M HCl using weight loss, thermometry, hydrogen evolution and polarization techniques. It was reported that the adsorption was spontaneous and followed Langmuir isotherm.

The corrosion inhibition of aluminium in HCl in presence of *Carica papaya* and *Azhadirachta indica* was investigated using weight loss, thermometric and hydrogen evolution techniques. The adsorption of the inhibitor obeyed Freundlich, Temkin and Flory-Huggins isotherms **(Ebenso *et al.*, 2004). Valek and Martinez, (2007)** investigated *Azadirachta indica* leaves extract as copper corrosion inhibitor in 0.5M sulphuric acid. The adsorption followed Frumkin isotherm.

The aqueous extract of the leaves of henna (*lawsonia*) was tested as corrosion inhibitor of C-steel, nickel and zinc in acidic, neutral and alkaline solutions, using the polarization technique. The extract acted as a good inhibitor and the degree of inhibition depended on the nature of metal and the type of the medium. The extract acted as a mixed inhibitor. **(El-Etre *et al.*, 2005).**

The corrosion inhibition properties of *Ocimum tenuiflorum* (Tulsi) leaves extract as a potential green inhibitor of zinc corrosion in H_2SO_4 have been investigated employing gravimetric and thermometric techniques. The results showed that different concentrations of the *Ocimum tenuiflorum* extract have inhibited zinc corrosion and the inhibition efficiency varied with the concentration of extract and temperature of experimental corrosion half-cell. **(Sanjay K. Sharma *et al.*, 2007).**

The ethanolic extract of different parts of *Capparis decidua* was investigated for its corrosion inhibition for aluminium in 0.5N, 1N and 2N HCl and H_2SO_4 by mass loss and thermometric methods **(Arora *et al*, 2007).**

Oguzie, (2007) has reported the inhibitive action of leaf extracts of *Sansevieria trifisciata* on the aluminium corrosion in 2M HCl and 2M KOH solutions.The adsorption characteristics was approximated by Freundlich isotherm.

Umoren *et al.*, have evaluated exudate gums from *Pachylobus edulis, Raphia hookeri* **(2008 a)** and *Dacrodyes edulis* **(2008 b)** as corrosion inhibitors for aluminium in HCl using weight loss and thermometric methods at 30-60°C. The adsorption followed Temkin isotherm. The exudate gum of *Raphia hookeri* was reported to be a better inhibitor than that of *Pachylobus edulis*. Physical adsorption mechanism was proposed for *Dacrodyes edulis*.

The effect of *Raphia hookeri* exudate gum and halide ions on the corrosion inhibition of aluminium in HCl solutions at 30-60°C was studied using gravimetric, gasometric and thermometric techniques. The adsorption obeyed Freundlich, Langmuir and Temkin adsorption isotherms. The addition of halide ions enhanced the inhibition efficiency by synergistic effect **(Umoren and Ebenso, 2008).**

The influence of natural honey (chestnut and acacia) and natural honey with black radish juice, on corrosion of tin in aqueous and sodium chloride solutions was studied using weight loss and polarization techniques. The inhibition efficiency of acacia honey was lower than that of chestnut honey, while the addition of black radish juice increased the inhibition efficiency of both honey varieties. The process of inhibition was attributed to the formation of multilayer adsorbed film on the tin surface. (**Radojcic *et al.*, 2008).**

The effect of liquid and dry extracts of rice, buckwheat and sunflower husks on the corrosion of St.3 steel in water – salt and acid media was studied by gravimetric and potentiodynamic methods. The action of the extracts on the surface was examined by electron microscopy and electron microprobe analysis. (**Karchenko *et al.*, 2008).**

Abdel Gaber *et al.*, (2008) investigated the inhibition of aluminium corrosion in 2M sodium hydroxide solution in the absence and presence of 0.5M NaCl using damsissa (*Ambrosia maritime* L.) extract employing gasometric and potentiodynamic polarization techniques.The extract was more effective in presence of chloride ions. The extract behaved as mixed type inhibitor.

James and Akaranta, (2009) has investigated the acetone extract of red onion skin for its inhibition efficiency on aluminium in 2M HCl by weight loss method. The mechanism of adsorption was reported to be Physical adsorption and it obeyed Langmuir isotherm. The compound responsible for the inhibitory action was found to be Quercetin.

Corrosion inhibition of aluminium alloy (AA3003) in 0.5 M HCl by extracts of *Euphorbia hirta* and *Dialum guineense* was investigated by **Nnanna *et al.*, (2010)**

using gravimetric technique at 30 and 60°C. The results indicated that the extracts inhibited the corrosion process in the medium by virtue of adsorption.

The leaf extract of *Chromolaena odorata* L. has been tested as green inhibitor for the corrosion of Aluminium in 2M HCl by gasometric and thermometric techniques. **(Obot and Obi-Egbedi, 2010)** It was reported that the extract has the potential to be a cost effective alternative to the commercial inhibitors.

The effect of *Solanum melongena* L. leaf extract on the corrosion of Aluminium in 0.5M H_2SO_4 was investigated by **Ihebrodike Maurice Meheja *et al.*, (2010)** using gravimetric technique. The extract adsorbed spontaneously following Langmuir adsorption isotherm.

The influence of caffeine on the electrochemical behaviour of aluminium alloy AA2024 in aqueous solutions was studied by **Rondon Sabino *et al.*, (2010).** The protective action improved with time due to the sealing process that enhanced the film stability.

The inhibitive action of leaf extracts of *Anthocleista vogelii* on the aluminium corrosion in water-ethanol mixture has been studied by **Adeyemi and Olubomehin, (2010)** using gravimetric techniques. The mechanism of adsorption was proposed to be physical.

The corrosion inhibition effects of *Aningeria robusta* extract for aluminium in 2M HCl and the influence of KI as additive has been evaluated using hydrogen evolution method at 30 and 60°C by **Obot *et al.*, (2011).** The mechanism of adsorption was chemical for the *Aningeria robusta* extract and physical for the extract – iodide mixture. The adsorption followed Langmuir adsorption isotherm.