A review on the Enhanced Corrosion Control of Mild Steel in an Acidic Medium using Green Inhibitors

Sheetal S[1], Abhay Prakash[2], Yedhukrishna Raj[3], Manu Harilal[4] and John Felix Kumar[5]*

[1]Sheetal S, Department of Metallurgical and Materials Engineering, Amal Jyothi College of Engineering, Kanjirappally, India
[2]Abhay Prakash, Department of Metallurgical and Materials Engineering, Amal Jyothi College of Engineering, Kanjirappally, India
[3]Yedhukrishna Raj, Department of Metallurgical and Materials Engineering, Amal Jyothi College of Engineering, Kanjirappally, India
[4]Manu Harilal, Assistant Professor, Dept. of Metallurgical and Materials Engineering, Amal Jyothi College of Engineering, Kerala, India
[5]John Felix Kumar, Associate professor & Head, Dept. of Metallurgical and Materials Engineering, Amal Jyothi College of Engineering, Kerala, India

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Abstract - *Mild steel is widely used due to its availability, easiness in fabrication, most importantly its exceptional properties like strength and ductility. The major problem related to this material is its tendency to corrode on exposure to corrosive agents like moisture, acid, and alkali. Corrosion is a destructive process that cannot be eliminated completely but delayed by using suitable methods. The most widely accepted techniques for reducing the rate of corrosion of a material is the use of corrosion inhibitors since they are easily available and cost-effective. There are three types of corrosion inhibitors: organic, inorganic, and mixed, though some issues are associated in the usage of such inhibitors, hence there is a need for finding an eco-friendly inhibitor. The novel and the eco-friendly method to resist corrosion were then found in the use of plant extracts that forms a protective layer on the surface of the metal by adsorption that reduces the corrosion rate and thereby protecting it from destruction. Green inhibitors are becoming popular as it has less adverse effects compared to organic and mixed types.*

***Key Words*: Corrosion; green inhibitor; mild steel; acidic medium.**

1. INTRODUCTION

Mild steel is low carbon steel with a maximum of 0.35% carbon in it and is the most commonly used carbon steels due to its remarkable properties. The presence of a high proportion of iron and ferrite makes it magnetic in nature. As the carbon content is low, it possesses good ductility, machinability, and weldability compared to other carbon steels and has several applications in automobile, marine, and various other sectors. Storage tanks for acids like HCl and sulphuric acids are made of mild steel. The most common problem faced by the material is corrosion when exposed to corrosive mediums like alkali and acid, which ultimately leads to the destruction of that structure causing fatal injuries. So it becomes a very important requirement to find methods to resist corrosion. Nowadays various methods are used for controlling the corrosion of mild steel [1, 2].

Corrosion is nothing but the deterioration of material on exposure to corrosive environments like moisture or other chemicals. Ultimately it leads to the failure of that material. Corrosion is a problem that can never be avoided but can be controlled to a greater extent. Due to this destructive phenomenon, there have been various accidents reported to date. Therefore, preventing corrosion has been a very important economical need. Chuka et al. [3] has studied the corrosion behavior of mild steel in five different mediums like atmosphere, acid, underground water, freshwater, and brine solution. In this, the material was exposed to all such conditions for a period of five weeks. In the presence of some ions it was observed that Corrosion proceeded at a faster rate, and in the absence pollutants in the atmosphere, corrosion proceeded at a controllable rate. Whereas, in swampy areas, Micro-organisms by their metabolic activities provided corrosion stimulating ions and corrosion rate was increased. Further, in an acid, corrosion was proved to be detrimental for a short period, but, Corrosion rate in the acidic medium was faster than in any other mediums. It was also noted that, the rate of corrosion is proportional to the time of exposure. The corrosion rate of MS in various corrosive media decreased in the following order: 0.1M Hydrochloric acid > underground (soil) > saltwater > freshwater > atmosphere.

Corrosion mainly occurs in eight forms: Uniform Attack, Galvanic or Two-Metal Corrosion, Crevice Corrosion, Pitting, Intergranular Corrosion, Selective leaching, Erosion Corrosion, and Stress-corrosion cracking. From all of these kinds, the recurrent form of corrosion occurring to mild steel is uniform attack. Corrosion is normally controlled by methods like: Cathodic and anodic protection, Protective Coatings, Environmental Measures, Sacrificial Coatings, Corrosion Inhibitors, and Design-Modifications. The worldwide accepted technique both in terms of economy and sustainability is the use of inhibitor [4].

Application of inhibitors for corrosion control has now become very common as it is cost-effective, easily available, and less time-consuming. It is reported that the usage of inhibitors reduced the rate of corrosion of MS in corrosive media like H_2SO_4 and HCl. Gulsen Avci [5], used N, N'-Methylenediacrylamide as an organic inhibitor for controlling corrosion of mild steel in 0.5M HCl. According to the results obtained by various techniques like EIS, PDP, and polarization resistance, it was concluded that the inhibition efficiency increased with increasing inhibitor concentration. The metal surface was protected by a layer of inhibitor on the surface which occurred due to the process of adsorption. But the usage of organic inhibitor is limited due to some of its limitations like: a.)They may decompose to give out toxic and sometimes corrosive gases, b.)It may become flammable, thereby reducing the properties of the metal. Hence it became necessary that environment-friendly and non-hazardous inhibitors have to be used for corrosion control.

Therefore, various green inhibitors were developed and tested in acidic medium and were confirmed to be compatible. Green inhibitors are inhibitors derived from plant extracts, seed extracts, and essential oils. They also possess heteroatoms and pi electrons that gives them the ability to behave as a corrosion inhibitor. Green inhibitors cover the disadvantages of conventional inhibitors as they are environment friendly and causes no harm. These inhibitors form a protective layer on the surface by adsorption thereby preventing degradation of that material. Some of the examples of green inhibitors are: Irvingia gabonensis [7], Bark extract of Lantana Camara [9], Chitosan / TiO_2 nanocomposite coating[10], Musa sapientum (Banana) peel extract [11], Prunus dulcis (almond) peel extract [13], Lychee fruit peel and seed extract [14], Saraca Ashoka seed extract, Lemon balm extract[16], Coconut water [19], Paniala leaves extract [36], etc. So this review article focuses on the application of the green inhibitor for controlling corrosion rate of MS.

2. REVIEW ON CORROSION CONTROL OF MILD STEEL USING GREEN INHIBITORS

Asha et al. [6] used garcinia fruit extract to control the corrosion of MS in 0.5M and 1M HCl medium. The inhibition efficiency of the extract was determined using weight loss and other electrochemical methods. The maximum efficiency of 93% was observed in 0.5M HCl while the maximum efficiency for 1M HCl was 87% at 60℃. It was also noted that with an increase in temperature the efficiency of extract was decreased from 87% to 80% for 1M HCl. The extract acted as a mixed type inhibitor and formed a protective layer on the surface due to adsorption by following the Langmuir adsorption isotherm.

Cynthia et al. [7] used Irvingia gabonenis extract on MS to investigate the inhibition efficiency of the extract in 1.5M HCl. The extracts were added in various concentrations of 0.2, 0.5, and 1 g/L and immersion time was maintained as 2, 4, 6, 8, 10 and 12 hours at temperature between 25℃-30℃. In the weight loss technique, it was noted that, in presence of extract the rate of corrosion decreased with an increase in the immersion time but increased with a rise in temperature. The highest efficiency obtained in this study was of 93.33% at 1 g/L addition with an immersion time of 12 hours and at a temperature of 26℃.

From Fig.1 it is noted that the corrosion rate of mild steel in 1.5M HCl drastically reduced in the presence of Irvingia Gabonensis extract. It is also observed that even with increasing temperature the inhibitor inhibits the corrosion rate of the mild steel sample in 1.5M HCl.

Devikala et al. [8] have studied the inhibition efficiency of Allium sativum extract in water, 1M HCl, 3.5% NaCl and 1M H_2SO_4. Nowadays various plant extracts have been used for controlling the corrosion mild steel in different mediums. The presence of protective layer by the extract was confirmed by various techniques like FTIR, SEM etc. The inhibition efficiency of the garlic extract was determined using electrochemical and PDP technique. The maximum efficiency obtained was 92% in the presence of 10ml of extract solution.

Prem et al. [9] studied the inhibition efficiency of bark extract from Lantana camara on MS in 1M HCl.

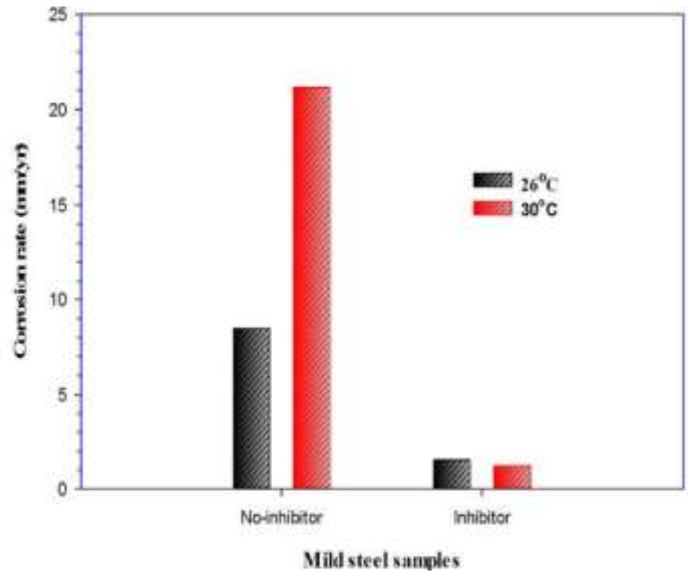

Fig-1: Effect of lantana camara extract on corrosion rate of mild steel (Chinyere et al., 2019)

Methanolic extract of bark of lantana camara was found to be more effective in reducing corrosion rate of MS sample. It was found that the inhibition efficiency was increased with increase in concentration level of inhibitor. From Potentio-dynamic polarization technique the maximum efficiency was found to be 97.33% and 89.93% in 1000 ppm and 200 ppm respectively.

Sam et al. [10] studied the inhibition efficiency of chitosan/ TiO_2 nanocomposite coatings on MS in 0.1M HCl. The corrosion behavior was studied or evaluated by the electrochemical process. Chitosan/ TiO_2 films were coated on MS by Sol-gel and dip-coating technique. In this, the measured efficiency was 84.69% and the efficiency of chitosan/ TiO_2 nanocomposite coatings was studied using EIS (Electrochemical Impedance Spectroscopy), LPR (Linear Polarization studies), and Potentio-dynamic polarization techniques.

In the figure 2.a, the semicircle represents the interaction of metal suface with corrosive media. It is also observed that with increase in the concentration of inhibitor the size of the semicircle also increases depicting the charge transfer process. It was aslo noticed that the chitosan/ TiO_2 added at metal-acid interface blocks further corrosive attack of specimen.

Rosli et al. [11] studied the inhibition efficiency of Musa sapientum (Banana) peel extract for MS. It was tested in different concentrations of extract at different temperatures in 1M HCl. From weight loss method it is showed that inhibition efficiency increased from 86.9% to 89% as the concentration of extract increased from 300 ppm to 500 ppm. It is also observed that efficiency decreases as the temperature was raised from 25°C to 60°C.

The following equations were used to determine the corrosion rate of the sample and the inhibition efficiency of the musa sapientum extract [11]:

$$\text{Corrosion rate} = (K \times W) / (A \times T \times D) \quad (1)$$

K = constant, T = time of exposure in hours, A = area in cm^2, W = mass loss in grams, and D = density in g/cm^3

$$\text{Inhibitor efficiency} = ((w_o - w_i) / w_o) \times 100\% \quad (2)$$

w_o = weight loss of steel without inhibitor

w_i = weight loss of steel with inhibitor

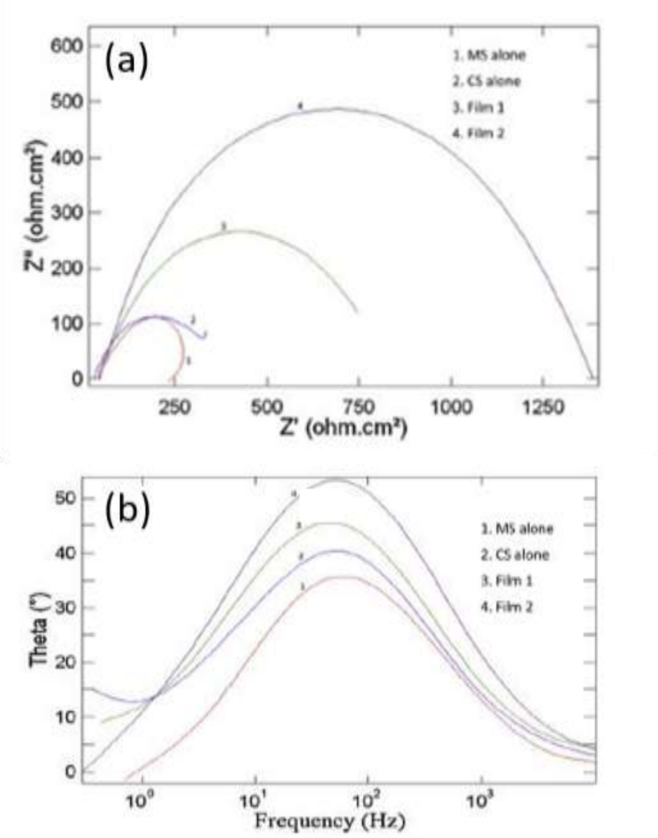

Fig-2.a: Nyquist Plot, **Fig-2.b:** Bode phase angle plot (Sam John et al., 2019)

Devikala et al. [12] has studied the inhibition efficiency of asafoetida extract in 3.5% NaCl using PDP and EIS. A protective layer was formed during the process which was confirmed by SEM, FTIR, and XRD. The maximum efficiency obtained was 90% in 10 ml of extract solution. From the corrosion study, it was revealed that this extract acts as a mixed type inhibitor, and also it was noted that the formation of a protective layer occurred as a result of adsorption.

Shweta et al. [13] studied the inhibition efficiency of Prunus Dulcis (Almond) peel extract in 0.1M HCl for MS. The result was obtained using electrochemical methods. In this they studied the efficiency of inhibition in Methanolic almond peel extract (MAPE) and aqueous almond peel extract (AAPE) separately. The obtained result shows an inhibition efficiency of 93% of methanolic and 85% of aqueous extracts.

Liu et al. [14] studied the inhibition efficiency of extract from lychee fruit peels and seeds in 0.5M HCl. In this, the best inhibition efficiency obtained was at 600 ppm concentration. The result was obtained by using the weight loss method and electrochemical method. The main contribution to inhibition was from ethanol present in the extract. The theoretical illustrations proved the adsorption properties of the extract onto the specimen surface. The extract of peels and seeds was considered to be efficient due to the presence of hydroxyl groups and phenol rings.

Saxena et al. [15] studied the inhibition efficiency of Saraca Ashoka seed extract on MS in 0.5M H_2SO_4. The process used to determine the result was weight loss measurement, Potentio-dynamic polarization, and EIS. The best inhibition efficiency was found at 100 ppm and due to the presence of hetero-atoms in the extract. Here an efficiency of 95.48% was obtained.

Asadi et al. [16] studied the efficiency of lemon balm on MS in 1M HCl. The maximum efficiency obtained was 95% in the concentration of 800 ppm. The surface of the steel sample was studied by using AFM (Atomic Force Microscopy), contact angle measurement and SEM analysis (Scanning Electron Microscope). The damage to the surface of the steel sample was found to be decreasing with the addition of 800ppm concentration of extract.

Tafel plots (Fig. 3) were obtained for the mild steel samples immersed in 1M HCl solution containing different concentrations of Lemon balm extract after 48 h immersion time. These results confirmed that the lemon balm extract acts as a mixed type inhibitor due its activity. With increasing extract concentrations the anodic and cathodic current densities were observed to be decreasing.

From Fig. 4 the SEM images show that the extract is adsorbed on to the surface thereby producing a protective film. It is clearly observed that surface of the mild steel sample exposed to the acidic medium without inhibitor underwent severe surface damage while the surface of the samples exposed in the presence of inhibitor are almost less attacked due to corrosion.

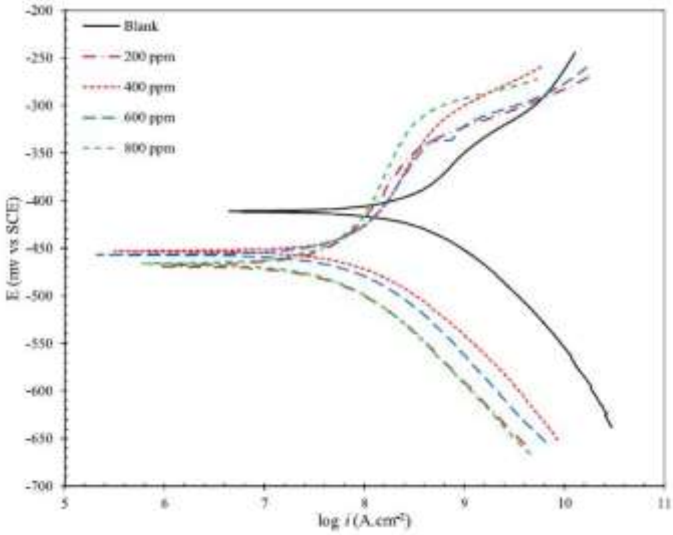

Fig-3: Potentio dynamic polarization plot for mild steel sample in 1M HCl with and without lemon balm extract (Asadi et al., 2018)

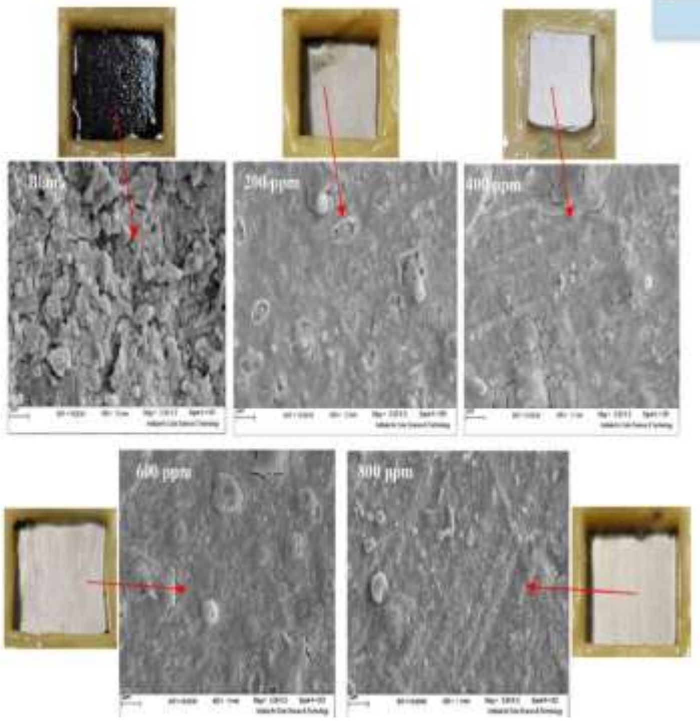

Fig-4: SEM images of mild steel samples with and without inhibitor (Asadi et al., 2018)

Khalil et al. [17] studied the Gum Acacia extract as the inhibitor for controlling the corrosion rate of Mild steel in 1M HCl. Weight loss measurement and electrochemical methodologies were used to get the appropriate results. The specimen was immersed in the acid solution for 6 hours and the temperature maintained was 303K. The maximum efficiency obtained was 97% at 1001 ppm of extract concentration.

Saxena et al. [18] studied the corrosion inhibition effect of Sida cordifolia extract on mild steel in 0.5M H_2SO_4 by using weight loss measurements, potentiodynamic polarization measurements, and electrochemical impedance spectroscopy techniques. The results proved that the presence of this Vasicinone, Vasicine, and Vasicinol containing extract decreases the corrosion rate of mild steel in acidic solution. The best inhibition effect of Sida cordifolia extract for mild steel in 0.5M H_2SO_4 was obtained at 500 mg/L. The adsorption of Sida cordifolia extract on the surface of mild steel has been confirmed by AFM, SEM, and absorption spectroscopic techniques. The presence of heteroatoms in the extract is considered to be a good inhibitor.

Adzor et al. [19] studied the corrosion inhibition efficiency of coconut water for MS in 0.5M H_2SO_4. It was evaluated by using the weight loss method as it is a more informative and simple technique. The amount of coconut water ranges from 30-110 ml at a time interval of 24-190 hrs. In 90 ml the efficiency obtained was 89.07% and in 110 ml there was a decrease in the efficiency to 81.57% for 24 hrs and 48 hrs respectively. This is a case in which the inhibition efficiency of the extract was increasing only up to a particular concentration and further increase in the concentration of extract showed a decrease in its inhibition efficiency.

Senani et al. [20] studied the inhibition efficiency of coriandrum sativum leaves extract as an eco-friendly green inhibitor for corrosion of carbon steel in 1M HCl and 0.5M H_2SO_4 solutions using the potentio-dynamic polarization, electrochemical impedance spectroscopy, weight loss technique and scanning electron microscopy. The inhibition efficiency increased with the addition of the concentration of the extract and decreased with the increase in temperature. The results showed that the extract inhibited the corrosion process by a physical adsorption mechanism that followed the Langmuir adsorption isotherm model. The results were analyzed by comparing the adsorption thermodynamic parameters that were calculated. The results pointed out that the adsorption process was spontaneous and exothermic. All the results show that the extract can act as an inhibitor for the corrosion of carbon steel in the acidic medium.

Mayakrishnan et al. [21] studied the corrosion inhibition effect of Tragia plukeneti plant extract for MS in 1M HCl medium. The maximum efficiency obtained was 88% at 500 ppm. Another observation was that the inhibition efficiency increased with an increase in inhibitor concentration. The results showed by Tafel polarization reveals that the extract could act as a good mixed-type inhibitor. Adsorption onto the MS surface followed Langmuir adsorption isotherm. The EIS measurements showed that due to the adsorption process, corrosion inhibition has occurred.

Habib et al. [22] studied the inhibition effect of pomegranate peel extract on the corrosion of mild steel in HCl solution. The polarization method, weight-loss method, and electrochemical impendence techniques were used to evaluate the corrosion inhibition review of the pomegranate peel extract. The results revealed that pomegranate peel extract behaved as a corrosion inhibitor in the HCl solution. The inhibition efficiency increased with the addition of extract concentration. The inhibition action was associated with the adsorption of the chemical compounds present in the extract solution on the mild steel surface.

Rodriguez et al. [23] took the extract of Allium sativum (garlic) as a corrosion inhibitor for carbon steel in 0.5M H_2SO_4. The results were carried out by using potentio-dynamic polarization curves, electrochemical impedance spectroscopy, and weight loss measurements. Inhibitor concentrations included 0, 100, 200, 400, 600 and 800 ppm at 25, 40 and 600°C. Allium sativum has been proved to be an immeasurable inhibitor as the results meant its highest efficiency as 96%. This reduction in the corrosion rate was due to the formation of an external layer formed by S-containing film present in the extract which was adsorbed physically on the steel surface. Allium sativum acted as a mixed type of inhibitor.

Kanchan et al. [24] chose lemon peel and Fenugreek leaves extract for corrosion in mild steel in a 1M HCl. The study was being carried out by weight loss method and electrochemical methods. The electrochemical and non- electrochemical methods showed that these were good inhibitors and had good inhibition properties. Results from the electrochemical method proved that it was a mixed inhibitor. The adsorption onto MS surface by Fenugreek leaves and Lemon peel extract followed by Langmuir adsorption isotherm. The maximum efficiency obtained was 87.49% at 5% v/V for Fenugreek leaves and 85.19% at 5% v/V for Lemon peel.

Punita et al. [25] used marigold flower which has a scientific name as Tagetes Erecta along with its extract (TEE) to test it, as a corrosion inhibitor for MS in a concentration of 0.5M H_2SO_4 solution. This extract along with concentration had undergone several processes like gravimetric, potentiodynamic polarization, and electrochemical impedance spectroscopic measurement. The Tafel study which was of major importance gave details about the TEE as a mixed-type inhibitor. Surface analysis was performed using Scanning Electron Microscopy (SEM). Another observation was that the inhibition efficiency increased with an increase in marigold extract concentration. The PDP was done to know the fact that the inhibitor could affect both anodic and cathodic reactions. This adsorption process directs to Langmuir adsorption isotherm at every required temperature.

Ramananda et al. [26] concentrated on preparing an inhibitor using litchi peel (Litchi chinensis). In this study, it was also conveyed that this extract behaves as a mixed type inhibitor. The damage to the surface of metal due to acid was observed to be decreasing with increasing concentration. The inhibition mechanism of the extract was adsorption. Considering the gravimetric readings alone the maximum efficiency observed was 97.8% in the presence of 3000 ppm concentration of extract.

Y. Abboud et al. [27] selected the leaf of Punica granatum extract (LPGE) as a green inhibitor and was practiced for corrosion of mild steel in 1M HCl solution. The maximum efficiency was around 94% at a concentration of 1 g/L. These results showed that LPGE had good inhibiting properties. The inhibition efficiency was determined by weight loss measurement and Tafel polarization.

From the table-1, it is clearly observed that the rate of corrosion decreased with increasing concentration of the LPGE extract and material loss was also found to be reduced with the addition of the extract.

Saedah et al. [28] analyzed the corrosion inhibition ability of Juniperus plant extract on mild steel in 2M H_2SO_4 solution at a temperature range of 30 to 60°C. They considered using chemical and electrochemical methods. The Juniperus plant behaved as an inhibitor in the acid environment. The inhibition efficiency improved as the inhibitor concentration increased and qualified with an increase in temperature. The inhibitive effect of the Juniperus plant could be connected to the presence of some compound in the plant which is adsorbed on the surface of the mild steel that made the inhibition. The Juniperus plant was found to adapt to the Frumkin adsorption isotherm and Temkin adsorption isotherm at all the concentration levels and temperature studied. The phenomenon of physical adsorption is introduced from the activation parameters obtained. Thermodynamic parameters exhibited that the adsorption process is spontaneous.

Ananth et al. [29] selected Asparagus racemosus stem extract for corrosion inhibition on a Mild Steel plate subjected under corrosion in 0.5M H_2SO_4. The

Table-1: Corrosion Parameters obtained in the Gravimetric Analysis in1M HCl (Abboud et al., 2013)

Inhibitor Concentration (g/L)	Weight Loss (mg)	Corrosion Rate (mg/cm^2)	Inhibition Efficiency (E) %
Blank	7.75	1.938	
0.2	2.86	0.71	63.36
0.4	2.22	0.55	71.62
0.6	1.61	0.40	79.36
0.8	1.16	0.29	85.03
1	0.46	0.12	93.80

observations were contributed by the Weight loss method. Potentio-dynamic polarization and Electrochemical Impedance Spectroscopy. Based on the Observations from the different processes and comparing the results the addition of the extract increased the inhibitor content to attain around 91.66% efficiency. The results indicated that the Asparagus racemosus acts as a mixed-type inhibitor and impedance results showed that the corrosion of mild steel is mainly controlled by a charge transfer process and the presence of the extract.

Ben et al. [30] analyzed the corrosion inhibition efficiency of Prickly Peer Seed Oil extract for MS in 1M HCl. The key processes used for the corrosion test in PPSO were weight loss measurement, potentiodynamic polarization, and electrochemical impedance spectroscopy. These were the general corrosion techniques used for processing green leaves for corrosion-related applications. The major findings during the process were that the inhibition rate increased with an increase in the concentration of extract. The maximum efficiency shown was 90% at 5000 ppm of PPSO. The different tests proved that PPSO is a type of mixed inhibitor. Another property regarding the inhibitor was its adsorption onto the steel surface which follows Langmuir adsorption isotherm.

Ambrish et al. [31] studied the inhibition activity of Kalmegh leaves on mild steel in hydrochloric acid using different processes like EIS, linear polarization, PDP. The major observation during the process was that the inhibition rate increased with increase in the rate of concentration of extract. Along with these, the temperature, immersion time, and concentration of acid were also evaluated. The adsorption mechanism obeys Langmuir adsorption isotherm. The protective film was formed on the metal surface and analyzed by FTIR spectroscopy.

Gopal Ji et al. [32] selected the leaf of Parthenium hysterophorus plant leaves extract as a green inhibitor and was practiced for corrosion inhibition for mild steel in 1M HCl solution. The maximum potential of the extract was obtained at 1100 mgL^{-1} with 84% efficiency. It was found that the adsorption of Parthenium hysterophorus extract follows Langmuir isotherm. The inhibition efficiency was determined by weight loss measurement and Tafel polarization.

Kamal et al. [33] analyzed the inhibition efficiency of spirulina plantesis on mild steel in 1M HCl and 1M H_2SO_4 at different temperature 30°C, 40°Cand 50°C. The corrosion inhibition was inferred using several methods like EIS, weight loss, PDP, and presence of the protective layer was substantiated using SEM analysis. In this work, greater inhibition efficiency was observed in H_2SO_4 than in HCl. The maximum efficiency obtained from the EIS test was at 500 ppm of extract solution which was 80.2% in H_2SO_4 and 75.2% in HCl. It was also noted that efficiency increased with increasing extract concentration.

Avci Gulsen [34] studied the corrosion inhibition efficiency of Laures nobiles leaves extract for MS on 1M H_2SO_4 solution. These results proved that Laures nobiles leaves were a good inhibitor for corrosion control for M.S. The potentio-dynamic polarization measurement provided information about the inhibition efficiency behavior of Lauresnobiles leaves extract. The efficiency of inhibitor increased with an increase in the rate of concentration. The maximum efficiency obtained was about 91% for 20 gL^{-1} Laures nobiles extract. The adsorption mechanism onto the mild steel surfaces was followed by Langmuir adsorption isotherm. An addition of film-coated on MS surfaces by L.Nobiles extract and that coating furnished excellent corrosion resistance for a steel surface for a long time.

Beenakumari et al. [35] took the inhibitive effect of the Murraya koenigii (curry leaf) leaf extract on the corrosion of Mild steel in 1M HCl. The study was undertaken by the weight-loss method, open circuit potential measurements, potentio-dynamic polarization techniques, and impedance analysis. The results show that Murraya koenigii extract is an effective corrosion inhibitor for protecting the corrosion of mild steel in 1M HCl medium even at stimulated conditions. The study indicated that the inhibition efficiency increased with increasing the concentration of the inhibitor in the medium. The percentage inhibitor efficiency under stagnant condition calculated based on the weight loss method is found to be above 94.5% when the medium contains 1000 ppm of the inhibitor.

Khalid et al. [36] studied the inhibition efficiency of Paniala extract on MS in 1M HCl and 0.5M H_2SO_4 acid solutions at 30°C. The result was obtained by the weight loss method. The efficiency was 98% in HCl and 95% in H_2SO_4. Here it was observed that at lower concentrations of inhibitor, the efficiency was more in 1M HCl than in 0.5M H_2SO_4. The decrease in corrosion rate on mild steel sample was due to the adsorption of the extract onto the surface proved by Langmuir and Freundlich adsorption isotherms. The adsorption property of paniala was due to the chemical composition present in the extract. Flavonoids, steroids, tannins, and phenolic compounds were present in the paniala extract.

Khamis et al. [37] took six different herbal plants and studied the corrosion inhibition of steel by AC and DC electrochemical techniques. The main compounds were thyne, coriander, hibiscus, anise, black cumin, and Garden cress. The performance of these compounds was studied by electrochemical impedance spectroscopy. The protection on the steel surface was provided by Thymol which had an active antiseptic ingredient. The inhibition efficiency obtained was the highest for thyme, followed by hibiscus, coriander, anise, black cumin, and least for garden cress.

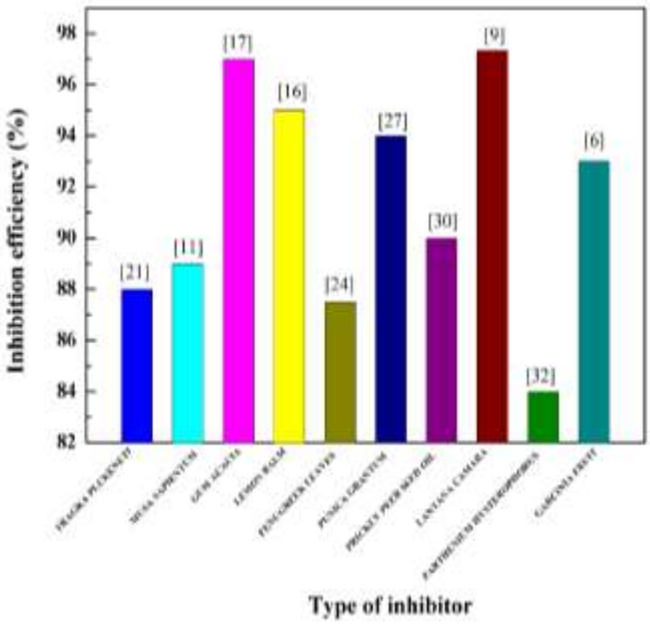

Fig-5: Inhibition efficiencies of various green inhibitors for mild steel in 1M HCl.

Based on the literature, Fig-5 shows the comparison of various green inhibitors and their corresponding inhibition efficiency in 1M HCl. Among the various green inhibitors mentioned below, the maximum efficiency is attained by Lantana Camara with inhibition efficiency of 97.33%.

Thus, it can be seen that addition of green inhibitors helps to improve the corrosion protection efficiency of mild steel in acidic media.

3. CONCLUSIONS

Green inhibitors have been widely used to control the corrosion rate of MS in various acidic environment due to their availability, applicability, eco-friendly, cost-effective, non-hazardous, nature. The inhibition efficiency of the green inhibitors used was determined using various techniques like Electrochemical Impedance Spectroscopy (EIS), Potentio-Dynamic Polarization (PDP), Weight loss, etc. The effect of inhibitors on morphological characteristics of the mild steel under corrosion was extensively studied using optical microscope and SEM. Based on the various research studies reported elsewhere it could be concluded that the addition of the green inhibitors brings about the following advantages from corrosion point of view:

•Corrosion rate can be significantly reduced by the application of using green inhibitors.
•The inhibition efficiency increases with an increase in the concentration of inhibitor.
•With increasing temperature and decreasing inhibitor concentration, the inhibition efficiency also decreases.
•Adsorption of inhibitor onto the surface of the MS sample follows Langmuir adsorption isotherm.
•There is a formation of a protective layer on the surface of the mild steel due to the adsorption of extract.
•The damage occurring to the metal sample when exposed to the acidic medium is reduced in the presence of inhibitor.

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