Acid Extract of *Galinsoga parviflora* as Corrosion Inhibitor on Mild Steel in 1M Hydrochloric acid Media-Stability and Durability Study

Gowthami T.S.

13PCH005

Thesis submitted to

Avinashilingam Institute for Home science and Higher

Education forWomen, University

Coimbatore – 641 043

In Partial Fulfilment of the Requirements for the

Degree of Master of Science in Chemistry

March, 2015

CERTIFICATE

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GOWTHAMI T.S

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LIST OF ABBREVATIONS

IE	Inhibition Efficiency
CR	Corrosion Rate
GP	*Galinsoga parviflora*
H	Hours
v/v	Volume / Volume
Conc	Concentration
RT	Room Temperature
RFT	Refrigeration Temperature
mpy	miles per year

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INTRODUCTION

1. INTRODUCTION

CORROSION:

Corrosion is a chemical reaction in which molecules break down due to a chemical reaction with its surroundings. Most often, corrosion is the electrochemical oxidation of a metal.

For e.g.;

Iron "corroding" to form iron oxide

Types of corrosion

- **Uniform corrosion:**

  Uniform attack is the most common form of corrosion, it is normally characterized by a chemical or electrochemical reaction that proceeds uniformly over the entire exposed surface. The metal surface becomes thinner and eventually fails.

- **Galvanic corrosion:**

  Galvanic corrosion occurs when two or more dissimilar metal in electrical contact are placed in an electrolyte. This results due to the potential difference between the metals, which causes a flow of current between them.

- **Crevice corrosion:**

  Intense localized corrosive attack usually occurs within a confined space or crevice formed by certain mechanical configurations such as tapped joints, tubular, sleeves, bolts, rivets, etc., and is called Crevice corrosion

- **Pitting corrosion:**

  Pitting corrosion is a form of extremely localized attack, the rate of attack being at some areas. Pitting corrosion results in sudden failure of equipment due to formation of holes.

- **Intergranular corrosion:**

  Localized attack at grain boundaries and adjacent to grain boundaries with relatively little corrosion of the grains is intergranular corrosion. The alloy disintegrates and loses its strength.

- **Selective leaching:**

  Selective leaching is the removal of one element from a solid alloy by corrosion processes. The most common example is the selective removal of zinc in brass alloys (dezincification).

- **Erosion corrosion:**

  Erosion corrosion can be defined as the increase in corrosion rate caused by relative motion between the metal surface and the corrosive environment, which may be liquid or gas.

- **Stress corrosion:**

  The cracking of metal alloy by conjoint action of a tensile stress and a corrosive environment is known as stress corrosion.

- **Waterline corrosion:**

  When water is stored in a steel tank, it is generally found that the maximum amount of corrosion takes place along a line just beneath the level of the water materials. The area above the water line acts a cathode and is completely unaffected by corrosion.

IMPORTANCE OF CORROSION STUDY

- Increasing use of metals in all fields of technology.
- Use of rare and expensive metals whose protection requires special prediction.
- It is economic including objective of reducing losses resulting from corrosion of piping tanks, metal components of machine, ships, ships, bridges and so on.

METHODS TO REDUCE CORROSION

- Design improvement
- Change of metal
- Change of metal electrode potential
- Use of coatings for separating metal from the environment
- Change of environment

Design improvement

Corrosion mitigation can also be accomplished by design considerations. The use of acceptable engineering practices to minimize corrosion is fundamental to corrosion control. One of the most important factors in designing for corrosion control is to avoid crevices where deposits of water-soluble compounds and moisture can accumulate and are not accessible for maintenance. Any region where two surfaces are loosely joined, or come into proximity, also qualifies as a crevice site. Joining geometries also prevent various crevice corrosion problems. Examples include: bolting, back-to-back angles, rough welds, weld spatter, sharp edges, corners, discontinuities, and intermittent welding.

Change of metal

The most important method of preventing or reducing corrosion damage is the selection of the proper metal or alloy or material suitable for a particular corrosive environment. The corrosion resistant materials may be metallic or non-metallic. The corrosion resistance of a metal can be greatly improved by change of composition, for example by refining or alloying or by change of micro structure by heat treatment cold working or by elimination of tensile stresses by annealing treatments. Non-metallic materials have low tensile strength and mainly used in the form of liners, gaskets and coatings.

Cathodic and anodic protection

Cathodic protection-provides corrosion control by making the structure to be protected the cathode of a corrosion cell by bringing the potential of the structure into or near the immunity region of the Pourbaix diagram. There are two types of cathodic protection, the sacrificial anode and the impressed-current method. The sacrificial anode method is the simpler method, and utilizes galvanic corrosion.

The sacrificial anodes are pieces of metal usually electrically connected by a wire or steel strap to the structure to be protected. The metals used must be less noble than steel(the common oil-filled material), such as magnesium, zinc, or aluminum. The sacrificial anodes are preferentially corroded, protecting the (cathodic) steel from corrosion. Magnesium and zinc are usually used in soils, and zinc can be used in brine environments. Sacrificial anodes are most often used when current requirements are relatively low, electric power is not readily available, and when system life is short, which calls for a low capital investment.

In the impressed current method metallic structure is made cathode by connecting the negative terminal of external power supply source to the metallic structure to be protected and positive to inert anode. This method has the advantages of larger flexibility of control, applicability to large objects and uncoated parts. But it involves larger installations and high maintenance cost.

Anodic protection is a new method and based on the formation of productive passive films on metal and alloy surface by external impressed anodic current. Anodic protection makes the structure to be protected an anode and an applied current brings the structure's potential into the passivity region of the Pourbaix diagram. Advantages of this method are that it can be applied in weak to very corrosive conditions and uses very small applied currents. Disadvantages is that it requires complex instrumentation and has high installation cost.

Coatings

The protective coatings applied to prevent corrosion can be metallic, inorganic or organic. Metallic coatings are more durable, more decorative and have better shielding against corrosion. They are further classified as cathodic and anodic coatings. Coating of brass, chromium or gold on steel is examples of cathodic coatings. Coating of zinc or aluminum on steel is an example of anodic coatings. Metallic surface coatings are applied by mechanical (cladding, mechanical), physical methods (hot dip coating, welding, spraying, sputtering) and chemical methods (chemical vapour deposition, electrodes plating, anodizing, electroplating) etc.

Inorganic coatings

The principle inorganic coatings for metals are

- Vitreous enamels
- Portland cement coatings
- Chemical conversion coatings

Glass lined steel vessels are used in chemical industries because of their ease of cleaning and corrosion resistance and smooth durable finish. Ceramic coatings and such as porcelain enamels and glasses are used to protect metal surfaces by providing chemically resistant barriers, usually oxides, which are more stable than metals.

Organic coatings

These include paints, varnishes, lacquers and mainly organic polymeric materials. Organic coatings are thin, tough and durable barriers to protect corrosion. Protective coatings can be used to protect tubing, down whole equipment and various flow lines and pressure vessels. Coatings work by reducing the cathodic area available for corrosion reaction. Coatings are often used in connection with cathodic protection or chemical inhibition. Quality control parameters for coating include surface finish preparation, application techniques, coating thickness, joint condition, and inspection. Coated equipment must be carefully handled after coating to prevent defects in the coat.

Change of environment

Environmental conditions are very important in determining the severity of corrosion. Important methods are lowering of temperature, altering the pH of the corrosive medium, decreasing the velocity of liquid, removing oxygen from the liquid, reducing ionic concentrations and addition of inhibitors to electrolytes. Lowering the temperature generally (except in few cases where there is decrease in oxygen solubility with increase in temperature) reduces corrosion since reaction rates are lower at lower temperature. Reduction in flow velocity reduces erosion corrosion. For metals that passivate, stagnant solutions should be avoided. Except for systems which depend on oxygen for passivation, de-aeration reduces corrosion. Electrolyte pH can be adjusted such that metal attains passivity and does not corrode. Corrosion inhibitors are added to the environment in which a given metal must be used to make the environment less corrosive. The inhibitors act either by adsorbing on metal surfaces by providing barriers to the environment or by keeping the environment from becoming more corrosive by providing a buffering action.

Corrosion Inhibitors

A corrosion inhibitor is a chemical additive, which, when added to a corrosive aqueous environment reduces the rate of metal wastage.

Inhibitors are chemicals that react with a metallic surface, or the environment this surface is exposed to, giving the surface a certain level of protection. This is a wide variety of corrosion inhibitor formulations available that can be selected to handle most environments. Inhibitors often work by adsorbing themselves on the metallic surface, protecting the metallic surface by forming a film. Inhibitors are normally distributed from a solution or dispersion. Some are included in a protective coating formulation. Inhibitors slow corrosion process by either increasing the anodic (or) cathodic polarization behavior (Tafel slopes); or reducing the movement or diffusion of ions to the metallic surface and increasing the electrical resistance of the metallic surface. Considerations of cost, toxicity, availability and environmental friendliness are of considerable importance in choosing the inhibitors. Inhibitors reduce the rate of a corrosion process by influencing the kinetics of the part.

Classification of corrosion inhibitors

- Based on technological field of application as pickling inhibitors, de-scaling inhibitors, and cleaning inhibitors, cooling water system inhibitors, gas phase inhibitors, inhibitors in surface coatings etc
- Based on chemical nature as organic and inorganic inhibitors.
- Based on reaction mechanism as passivating inhibitors, adsorption inhibitors, precipitation a film forming inhibitors, volatile corrosion inhibitors and oxygen scavengers.
- Based on their mode of action and effect on partial electrochemical reactions as anodic inhibitors,cathodic inhibitors and mixed inhibitors.

Role of corrosion inhibitors-Mechanism of action

In acid solutions the anodic process of corrosion is the passage of metal ions from the oxide – free metal surface into the solution, and the principal cathodic process is the discharge of the hydrogen ions to produce hydrogen gas. In air- saturated acid solutions, cathodic reduction of dissolved oxygen also occurs, but for iron the rate does not become significant compared to the rate of hydrogen ion discharge until the pH exceeds a value of 3. An inhibitor may decrease the rate of the anodic process, thecathodic process or both processes. The change in the corrosion potential on addition of the inhibitor is often a useful indication of which process is retarded. Displacement of the corrosion potential in the positive direction indicates mainly retardation of the anodic process (anodic control), whereas displacement in the negative direction indicates mainly retardation of the cathodic process (cathodic control). Little change in the corrosion potential suggests that both anodic and cathodic processes are retarded.

Anodic inhibitors retard anodic reactions, cathodic inhibitors retard cathodic reactions leading to corrosion and mixed inhibitors influence both the anodic as well as cathodic reactions. Anodic inhibitors become dangerous below a certain threshold concentration. Cathodic inhibitors are safe in all cases since any concentration of these will reduce the rate and intensity of corrosion. Mixed inhibitors are less dangerous than pure anodic inhibitors.

Passivatinginhibitors cause a large anodic shift of the corrosion potential, forcing the metallic surface into the passivation range. There are two types of passivation inhibitors viz. oxidizing anions, such as chromate, nitrite and nitrate, that can passive steel in the absence of oxygen and non-oxidizing such as phosphate, tungstate and molybdate that require the presence of oxygen to passivate steel. These inhibitors are the most effective and consequently the most widely used. Chromate based inhibitors are the least expensive inhibitors. It is essential that periodic colorimetric analysis be conducted to prevent acceleration of corrosion.

Cathodic inhibitors either slow the cathodic reaction itself or selectively precipitate on cathodic areas to increase the surface impedance and limit the diffusion of reducible species to these areas. Cathodic inhibitors can provide inhibition by three different mechanisms as cathodic poisons, cathodic precipitates and oxygen scavenger.

Some cathodicinhibitors, such as compounds of arsenic and antimony, work by making the recombination and discharge of hydrogen more difficult. Other cathodic inhibitors, ions such as calcium, zinc or magnesium, may be precipitated as oxide to form a protective layer on the metal. Oxygen scavengers help to inhibit corrosion by preventing the cathodic depolarization caused by oxygen.

Both anodic and cathodic effects are sometimes observed in the presence of organic inhibitors but, as a general rule, organic inhibitors affect the entire surface of a corroding metal when present in sufficient concentration. Organic inhibitors affect the entire surface of designated as film-forming, protect the metal by forming a hydrophobic film on the metal surface.

The effectiveness of the inhibitors depends on the chemical composition, there molecular structure, and their affinities for the metal surface. Because film formation is an adsorption process, the temperature and pressure in the system are important factors.(Rosenfeld, 1981). Organic inhibitors will be adsorbed according to the ionic charge of the inhibitor and the charge on the surface. Cationic inhibitors, such as amines, or anionic inhibitors, such as sulphonates, will be adsorbed preferentially depending on whether the metal is charged negatively or positively. The strength of the adsorption bond is the dominant factor for soluble organic inhibitors. For any specific inhibitor in any given medium there is an optimal concentration. Precipitating inducing inhibitors are film forming compounds that have a general action over the metal surface, blocking both anodic and cathodic sites indirectly. Precipitation inhibitors are compounds that cause the formation of precipitates on the surface of the metal, thereby providing a protective film. Hard water that is high in calcium and magnesium is less corrosive than soft water because of the tendency of the salts in the hard water to precipitate on the surface of the metal and form a protective film. The most common inhibitors of this category are the silicates and phosphates. Sodium silicate, for example, is used in much domestic water softness to prevent the occurrence of rust water. In aerated hot water systems, sodium silicate protects steel, copper and brass. However, protection is not always reliable and depends heavily on pH and a saturation index that depends on water composition and temperature. Phosphates also require oxygen for effective inhibition. Silicates and phosphates do not afford the degree of protection provided by chromates and nitrites, however, they are very useful in situations where non-toxic additives are required.

Volatile corrosion inhibitors (VCI), also called Vapour Phase Inhibitors (VPI), are compounds transported in a closed environment to the site of corrosion by volatilization from a source. In boilers, volatile basic compounds, such as morpholine orhydrazine, are transported with steam to prevent corrosion in condenser tubes by neutralizing acidic carbon dioxide or by shifting surface pH towards less acidic and corrosive values. In closed vapour spaces, such as shipping containers, volatile solids such as salt of dicyclohexylamine, cyclohexylamine and hexamethyelene – amine are used. On contact with the metal surface, the vapor of these salts condenses and hydrolyzed by any moisture to liberate protective ions. It is desirable, for an efficient VCI, to provide inhibition rapidly while lasting for long periods. Both qualities depend on the volatility of these compounds, fast action wanting high volatility while enduring production requires low volatility. All the various inhibitors used to combat corrosion of metals in acids are grouped as inhibitors of acid corrosion.

Pickling

Pickling of metals for the purpose of scale removal is most widely practiced in the metallurgical industry in the manufacture of various semi-finished products like pipes, sheets etc., in power plants for the acid washing of steam boilers and in others power installations in order to clean them of the scale and encrustations that accumulate during assembly and operation. It is the quick and clean process of removing scaling in contrast to scale mechanical scale removal methods like shot blasting, brushing, scraping, grinding etc.

During the hot rolling or heat treatment of steel, oxygen from the atmosphere reacts with iron in the surface of the steel to form a crust that is made up of mixture of iron oxides which is objectionable when steel is subsequently shaped or cold rolled and cooled. Pickling is the treatment of metallic surfaces in order to remove impurities, stains, rust or scale with a solution called pickle liquor, containing strong mineral acids, before subsequent processing, such as extrusion, rolling, painting, galvanizing or plating with tin or chromium. The two acids commonly used are hydrochloric acid and sulfuric acid. Pickling liquor may be a combination of acids and may also contain nitric or hydrofluoric acids.

Pickling lengthens die life, promotes surface smoothness of the finished product, and permits proper alloying or adherence of metallic and non-metallic coatings and paints. Inhibitors are normally added to pickling acid to reduce the unnecessary dissolution of steel, to produce smooth surface of the end product and to reduce fumes and spray by limiting the amount of hydrogen gas produced. Rate of pickling is affected by several variables like base steel constituents, type of adherence of oxides, acid concentration, $FeCl_2$ concentration, temperature and agitation, time of immersion and presence of inhibitor.

Carbon steel is pickled usually by either sulfuric acid or hydrochloric acid. Pickling in HCl medium involves the following reactions

$$FeO + 2HCl \rightarrow Fe\,Cl_2 + H_2O$$

$$Fe_2O_3 + 6\,HCl \rightarrow 2\,Fe\,Cl_3 + 3H_2O$$

$$Fe_3O_4 + 8\,HCl \rightarrow Fe\,Cl_2 + 2\,Fe\,Cl_3 + 4\,H_2O$$

$$Fe + 2\,HCl \rightarrow Fe\,Cl_2 + H_2$$

Interaction of $H_2\,SO_4$ with the iron oxides can be represented as

$$FeO + H2SO_4 \rightarrow Fe\,SO_4 + H_2O$$

$$Fe_2O_3 + 3H_2SO_4 \rightarrow Fe_2\,(SO_4)_3 + 3H_2O$$

$$Fe_3O_4 + 4H_2\,SO_4 \rightarrow Fe\,SO_4 + Fe_2(SO_4)_3 + 4\,H_2O$$

$$Fe + H_2\,SO_4 \rightarrow Fe\,SO_4 + H_2$$

Of the total amount of 10% sulfuric acid expended only 5% goes for the chemical dissolution of scale.

Table 1. Expenditure of acid during pickling of steel

Dissolution of steel	55%
Carry over with parts sent fir washing	25%
Overflow with solutions used	15%
Dissolution of scale	5%

At one time, sulfuric acid was the pickling agent of choice for picklers running integrated steel works. Hydrochloric acid is chosen in more modern lines when bright surfaces, low energy consumption, reduced over pickling and the total recovery of the pickling agent from the waste pickle liquor are desired. Hydrochloric acid is relatively cheaper and offers the advantages of the pickling at lower temperature and needs much less time as compared to those needed in case of sulfuric acid. But in view of its concentration, large corrosion resistant containers are required for its storage and transport.

Some criteria should be considered when making a choice of chemical compounds for inhibition of corrosion. Inhibition of metallic corrosion is mainly an economical process. Pure synthetic chemicals are costly, some of them are not easily biodegradable and their disposal creates pollution problems. Awareness of the environmental ill effects of synthetic corrosion inhibitors like chromates, dyes and other synthetic hetrocyclics , their cost of manufacture and the need for developing green technology in every possible field have necessitated the study of many natural plant extracts as corrosion inhibitors. Plant extracts offer several advantages over traditional inhibitors such as chromates. These green corrosion inhibitors fulfill four of the twelve principles of green chemistry (Paul Anastas, 1998) namely

1. Chemical products should be designed to preserve efficacy of function while reducing toxicity.
2. Whenever practicable, methodologies should be designed to use and generate substances that possess little or no toxicity to human health environment.
3. The use of auxiliary substances (solvents, separating agents etc.) should be made unnecessary whenever possible.
4. Chemical products should be designed so that at the end of their function they do not persist in the environment and instead break down into innocuous degradation products.

OBJECTIVES OF THE CURRENT STUDIES

Most of the natural products studied as inhibitors have been reported to be efficient inhibitors though in very few cases no efficient inhibition or negative inhibition reported.The leaves of *Galinsoga parviflora* has been evaluated as corrosion inhibitor (Divya.P, M.Sc Thesis)for mild steel in acid media by Weight loss method.The present study is carried out to standardize the studied plant extract with the following objectives

- ★ To confirm the inhibiting nature of the *Galinsoga parviflora leaves* to protect the corrosion of mild steel in 1M HCl by Gasometric Method.
- ★ To examine the effect of concentration of inhibitor on inhibitionefficiency by Gasometric method.
- ★ To study stability of the extract as corrosion inhibitor.
- ★ To find out the durability of the extract.
- ★ To compare the inhibition efficiency between Weight loss and Gasometric methods.
- ★ To evolve probable adsorption behavior of the constituents of the *Galinsoga parviflora* extract.

REVIEW OF LITERATURE

2.REVIEW OF LITERATURE

Reviewing a number of literatures will make us to show the originality and relevance of our research problem. The present study on **"Acid extract of *Galinsoga parviflora*as corrosion inhibitor on mild steel in 1 M HCl media – Stability and Durability study"** is reviewed in this chapter:

- *Allium ampeloprasum* extract as corrosion inhibitor for carbon steel was investigated by **Hussein Ibrahim etal, (2015).**Reports showed that the inhibition efficiency was found to increase with increasing concentration of the extract. The adsorption of the inhibitor on mild steel was found to obey Langmuir adsorption isotherm.

- The influence of *Calotropis gigantean* leaves extract on corrosion inhibition of mild steel in 1M HCl has been studied using weight loss method and electrochemical measurements. Inhibition efficiency was found to be 96.1% and the phytoconstituents of the extract found to be adsorbed on the steel surface and obeyed adsorption isotherm.**P.S.Desai (2015)**

- The inhibition effect of *Cissusquadrangularis* extract on mild steel in 1M HCl was investigated by weight loss measurement. The inhibition efficiency increased with temperature. The kinetic and thermodynamic parameters showed that the inhibition was spontaneous ,chemisorption obeying Langmuir isotherm.SEM analysis was also used to analyse the adsorbed surface film.**S.Thirumalaietal.,(2015)**

- *Psidiumguajava* leaf extract as corrosion inhibitor for mild steel in 1M phosphoric acid medium was studied using weight loss, Potentiodynamic polarization and electrochemical impedance techniques. Inhibition efficiency was found to increase with increase in the concentration of the inhibitor. The adsorption obeys both the Langmuir and the Temkin isotherm.

Potentiodynamicpolarization studies showed that the inhibitor acted as a mixed-type .**S.Noyel victoria etal., (2015)**

- Corrosion inhibition of mild steel in 1M H_2SO_4 and 1M HCl solutions using *rice husk* was investigated by **K.K.Alanemeetal., (2015).**The study was carried out using weight loss, Atomic absorption spectroscopy,FT-IR spectroscopy and surface analysis. The studies showed that the inhibition efficiency increased with increase in concentration of the inhibitor. The efficiency of the extract in HCl is found to be 96% and that for H_2SO_4 is 86%.Thermodynamic parameters showed that the adsorption of extract onto the metal surface was spontaneous.FT-IR results showed that the inhibition mechanism was by adsorption ,through the functional groups present in the extract.

- The efficiency of acid extract of leaves of *PterocarpusSoyauxi* as corrosion inhibitor for mild steel in IN HCL medium was investigated. The results showed that The inhibition efficiency increased with an increase in inhibitor concentration but decreased with temperature. The inhibition of corrosion of mild steel obeyed Tempkin and Freundlich adsorption isotherms and fitted into First Order reaction kinetics. **M. Iloamaeke et al., (2012)**

- An aqueous extract of *Aloe vera (L) Burm f. (Liliaceae)* has been used as a corrosion inhibitor in controlling corrosion of carbon steel immersed in sea water. Weight loss method reveals that 4ml of the extract provide 98% inhibition efficiency was investigated by **V. Sribharathyetal.,(2013)**

- The Effect of *MorindaTinctoria* Leaves Extract on the Corrosion Inhibition of Mild Steel in Acid Medium was investigated by K**. Krishnaveni et al.,(2013)** using weight loss method.

- Green Approach to Corrosion Inhibition of Mild Steel Using *Emilia Sonchifolia and VitexDoniana*in 2.5M HCl Medium has been studied by **Iloamaeke I. M et al.,(2013)** using The adsorptions of ES extract on the surface of the mild steel followed Langmuir, Temkin and Freundlich

- The inhibition effect of *Anemone coronaria*Extract on the corrosion of carbon steel in 1.0 M hydrochloric acid has been studied by **M. Belkhaouda1 et al.,(2013)** using the weight loss method, potentiodynamicporarization curve and electrochemical impedance spectroscopy (EIS) measurements.

- The inhibitive action of eco-friendly benign *costusafer*stem extract on the corrosion of mild steel in 5 M HCL solution has been evaluvated by **Ikama E. Uwah et al.,(2013)** using the Langmuir, Temkin, Frumkin and Freundlich isotherms.

- *PartheniumHysterophorus*Plant Extract as an Efficient Green Corrosion Inhibitor for Mild Steel in Acidic Environment has been investigated by **Gopal Ji1 et al., (2011)** using the Weight loss measurements, Tafel polarization and electrochemical impedance spectroscopy techniques.

- Corrosion Inhibition by an aqueous Extract of *PhyllanthusAmarus* has been studied by **M. Sangeetha et al., (2011)** using the weight loss method. Polarization study reveals that this system functions as mixed type of inhibitor controlling the cathodic reaction and anodic reaction to an equal extend.

- *Azwain (TrachyspermumCopticum)* Seed Extract as an Efficient Corrosion Inhibitor for aluminum in NaoH Solution was studied by **Singh Ambrish And Quraishi M.A.,(2012)** using weight loss and electrochemical techniques. The Azwain (Trachyspermumcopticum) seed extract is environmental friendly, biodegradable, nontoxic, cheap and easily available source of material which is used as corrosion inhibitor for aluminium metal in 0.5 M NaOH.

- *Paniala (FlacourtiaJangomas)* Plant Extract as Eco Friendly Inhibitor on the Corrosion of Mild Steel in Acidic Media was investigated by **S. Khalid Hasanand Pinky Sisodia, (2011)**. Inhibition efficiency of Flacourtiajangomasextract increased with increasing extract concentration. Maximum inhibition efficiency 98% for 1M HCl and 95% for 0.5M H2SO4 was reported. The inhibition activity was due to the adsorption ability of the extract which was confirmed by Langmuir and Freundlich adsorption isotherms.

- Effect of Green Inhibitors on Acid Corrosion of Aisi 1022 Steel was investigated by **VivekananthanShanmugaSundaram et al., (2013)**themethanolic extract of the flowers from *Millingtoniahortensis*and*Cleomechelidonii*were studied against the corrosion of mild carbon steel in 1 M HCl by different techniques. Weight loss and electrochemical studies. The extract from Cleome chelidoniiexhibited a maximum inhibition efficiency of 91.5% for 400 ppm concentration at 300 K, whilst the extract from Millingtoniahortensisshowed 83.4% inhibition efficiency for 1000 ppm.

- The Inhibitive Effect Of *Eucalyptus Camaldulenis*LeavesExtract On The Corrosion Of Low Carbon Steel In Hydrochloric Acid has been reported by **Asst. Lecture LubnaGhalibabdulkhaleq,(2013).**The inhibition efficiency increases with increase in the concentration of eucalyptus camaldulenis leaves extract and increase with increase in temperature.

- **C.A. Loto, et al., (2013)**have reported the Inhibition Effect of *VernoniaAmygdalina*Extract on the Corrosion of Mild Steel Reinforcement in Concrete in 3.5m Nacl.Vernoniaamygdalina(bitter leaf) extract performed effectively as an inhibition agent to the corrosion of the embedded steel rebar in concrete at 25%, 50% and 75% concentrations in NaCl test medium.

- **RathigaSenthooranandNamalPriyantha (2012),**haveinvestigated the Inhibition of Corrosion of Copper in HCl by Tea Leaves Extracts. Adsorption of components in the tea leaves extract follows Langmuir adsorption isotherm.

- Corrosion Inhibition of Stainless Steel (316l) Using *Cola Nitida, Cola Acuminata* and *Cola Garcinia* has been in investigated by **Adindu .C. Iyasaraet al.,(2013).** Cola Garcinia proved to be the best inhibitor in the soil and 2M HCl acid environments, while Cola Acuminata showed the best inhibition efficiency in the seawater and 1M HCl acid environments.

- *SolanumTrilobatum*as a Green Inhibitor for Aluminum Corrosion in Alkaline Medium using weight loss, hydrogen evolution, polarisation and electrochemical impedance spectroscopy methods. By **S. Geetha et al., (2013).**

- Corrosion inhibition of commercial aluminium in 1M HCl by leaves *(Calotropisprocera)* extract was investigated using weight loss method, hydrogen evolution method, potentiodynamicpolarisation method and impedance spectroscopy method. Calotropisprocera leave extract was a good corrosion inhibitor for aluminium in hydrochloric acid medium. The inhibition efficiency depends on the concentration of the inhibitor.**K.Bharathi et al., (2013)**

- Aqueous extract of *Propolis*as corrosion inhibitor for carbon steel in aqueous solutions was studied by S. **Fouda and A. HamdyBadr, (2013**). The maximum inhibition efficiency of propolis is found to be 99.03% at 600 ppm of inhibitor from mass loss studies at 30°C. The inhibition efficiency increases with respect to the concentration of the inhibitor and decreases with rise in temperature from 30 to 60°C.

- The effect of alkaloids extracted from *Isertiacoccinea*plant (AEIC) on the corrosion of C38 steel in 1M hydrochloric acid was investigated by electrochemical impedance spectroscopy (EIS) and potentiodynamic polarization techniques. The plant could serve as an effective inhibitor for the corrosion of C38 steel in hydrochloric acid solution **M.Lebriniea al.,(2011).**

- The inhibition performance of extracts of *Ziziphusmauritiana*on mild steel corrosion in 0.5 M H2SO4 and 0.5 M HCl was investigated using gravimetric, electrochemical polarization, electrochemical impedance spectroscopy and scanning electron microscopic studies by **ShivapuraSubbappaShivakumar And KikkeriNarasimhaShettyMohana ,(2012).**

- **T. Y. Soror (2013)** reportedthat the inhibitive nature of alcoholic extract of *Cassia alata*leaves toward the corrosion of aluminum in 1N HCl was investigated by using mass loss measurement with various contact period and temperature. The inhibition efficiency increases with the increase of concentration of inhibitor and temperature.Andalsothe inhibitive effect of aqueous extract of Saffron leaves toward the corrosion of aluminium in 2 M HCl solution has been investigated by weight loss and electrochemical polarization study. The extract functions as a good inhibitor. The inhibition efficiency increased with extract concentrations. The plant extract behaves as cathodic–type inhibitor and the inhibition effect of GymnemaSylvestris (GS) on corrosion of mild steel in hydrochloric acid solutions has been studied. The mass loss and polarization techniques were employed at 302K-333K. The inhibition efficiency increased with increase in concentration of inhibitors and decreased with rise in temperature from 302K to 333K. The inhibition efficiencies 94.44% in 1N HCl have been obtained with small amount of GymnemaSylvestris(0.1%) by mass loss technique at 302K.

- **J. ArockiaSelvi et al, (2009)** reported that the inhibition efficiency (IE) of an aqueous extract of *beet root* (BR) in controlling corrosion of carbon steel in well water in the absence and presence of Zn2+ has been evaluated by mass loss method. The formulation consisting of 4 mL of BR extract and 50 ppm Zn2+ offers 98% inhibition efficiency to carbon steel immersed in well water.

- **Aisha M. Al-Turkustani**carried out a study on Corrosion inhibition of steel in sulphuric acid by aqueous extract of *Ajowan(carom) seeds* has been studied using chemical (HE and ML) and electrochemical (EIS and PDP) measurements at 30^{o}C. The results indicated that Ajowanextract inhibit the corrosion process in 2.0M H2SO4 and the inhibition efficiency increase as concentration increased. Adsorption process of Ajowanmolecules on steel surface is spontaneous and it obeys the Freundlish adsorption isotherm.

- **J. Rosaline Vimala et al , (2011)** have reported as the inhibition efficiency of acid extract of flowers of *Cassia Auriculata* (CAF) plant on the corrosion of mild steel in 1 M HCl was investigated by weight loss measurements and electrochemical studies. The corrosion rate of mild steel and the inhibition efficiencies of the extract were calculated. The results obtained showed that the extract could serve as an effective inhibitor for the corrosion of mild steel in HCl media. Inhibition was found to increase with increasing concentration of the plant extract.

- **M. Lebrini et al,** investigated Alkaloids Extract from *Palicoureaguianensis*Plant as Corrosion Inhibitor for C38 Steel in 1 M Hydrochloric Acid Medium by potentiodynamic polarization and electrochemical impedance spectroscopy. The polarization studies showed that AEPG acts as mixed-type inhibitor. The electrochemical impedance spectroscopy showed that the charge transfer resistance increases and the double layer capacitance decreases on increasing plant extract concentration. The inhibition efficiency of the extract obtained from impedance and polarization measurements was in a good agreement and was found to increase with increasing concentration of the extract. Inhibition efficiency of 89% was achieved with 100 mg L-1 of AEPG at 25 °C.

- **FataiAfolabiAyeni et al (2014)**, reported the aqueous corrosion inhibition of Al-Cu-Mg Alloy in acidic medium using extract of *Sidaacuta(wire weed)* plant as corrosion inhibitor at 10%, 20%, 30% and 40% v/v of the extract. After exposing the alloy to the medium, the results showed that the plant extract inhibited the acid induced corrosion. The presence of Sidaacutaplant extract reduces corrosion rate from 0.0012 to 0.0001 MPY and percentage protection increases from 37.42% to 93.63% within a ten-day period with increase in percentage volume of the extract.

- **Babatunde et al (2012)** , reported that The inhibitive effect of leaf extract of *Irvingiagabonensis*on the corrosion of aluminum in 1M HCl solution was investigated using chemical method at 30, 35 and 40 oC respectively. The inhibition efficiency for the extract increased with increasing concentration of the extract and decreased with increase in temperature. The adsorption of the inhibitor molecules on aluminium surface was found to obey Langmuir adsorption isotherm.

- **D. Ben Hmamou et al.,*(2012)**, have reported that *Chamomile extract* (CE) was tested as corrosion inhibitor for C38 steel in 1 M HCl using potentiodynamic polarization, electrochemical impedance spectroscopy (EIS) and scanning electron microscope (SEM) studies. The effect of temperature on the corrosion behavior of C38 steel in 1 M HCl with addition of plant extracts was studied in the temperature range of 298–328 K. Inhibition efficiency of 88% was achieved with 7g/L CE at 298 K..

- **M.Sangeetha et al, (2012)**havereported that an aqueous extract of *Banana peel* has been used as a corrosion inhibitor in controlling corrosion of carbon steel. The main constituent of this extract is bananadine [(3Z,7Z,10Z)-1-oxa-6-azacyclododeca-3,7,10-triene]. It has excellent inhibition efficiency (IE) of 98% at Zn2+ (15 ppm) by the weight loss method. The protective film has been analyzed using Atomic Force Microscopic (AFM) and FTIR spectroscopic techniques. Protective film formed on the metal surface is confirmed by using Electro chemical studies such as potentiodynamic polarization and AC impedance techniques. Polarization study reveals that this system functions as mixed type of inhibitor.

- **M. Benahmed, et al,(2012)**, have reported that Inhibition of the corrosion of carbon steel in acid solution by the extract of *Limoniumthouinii*(Plumbaginaceae),The inhibition of the corrosion of C steel in 1 M HCl by *Limoniumthouinii*has been studied by weight loss,potentiodynamic polarization method and electrochemical impedance spectroscopy measurements. Theinhibition efficiency increased with increasing concentration of the inhibitor.

- **SALAMI et al**., concluded that *Musa Sapientumpeels*extractwas used as a corrosion inhibitor on mild steel in concentrated tetraoxosulphate (vi) acid using weight loss method. The results of the study showed that as the concentration of the inhibitor increases, the rate of corrosion decreases and the inhibition efficiency also increases up to a optimum of approximately 71 % for 0.8 g/l extract in 2.0 M H2SO4.

- **C A Loto1 and A P I Popoola (2012)**, have reported the Effects of *tobacco (Nicotiana) and Kola tree (Cola acuminata)* extracts on the corrosion inhibition of an aluminium alloy 2S (1200) grade specimens immersed in 0.5M sulphuric acid, investigation was carried out at ambient temperature by gravimetric and metallographic methods. Extracts of kola plant and tobacco in different concentrations were used as 'green' inhibitors.

- **M. Abdulwahab et al,(2013)**, have been reported that the corrosion inhibition of thermally pre-aged Aluminium-Silicon-Magnesium (Al-Si-Mg) alloy in 3.5 % NaCl solution with natural Avogadro oil of varying concentrations has been studied using linear polarization techniques.

- **Jie Zhang et al,(2013)**, have reported the Investigation of *Diospyros Kaki L.f husk* extracts as corrosion inhibitors and bactericide in oil field by using Weight loss method.

- **Onuegbu T. Uetal., (2013)** have been reported that the leaves of *Eupatorium odoratum*inhibits the corrosion of mild steel in H2SO4 solution to a reasonable extent. The inhibition efficiencies of the plant extracts were found to increase with increase in the concentration of the plant extract and decreases with increase in temperature of the system. The increase in inhibitors efficiency with decrease temperature and ability to fit Langmuir isotherm show that the plant is physically adsorbed on the mild steel coupon.

- The extracts of *Ginkgo biloba*leave have been investigated on the corrosion inhibition of Q235A steel with weight loss and potentio dynamic polarisation techniques. The inhibition efficiency of the extracts varies with extract concentration was studied by **Gang Chen et al., (2013).**

- Corrosion Inhibition of Pulverized *JatrophaCurcas*Leaves on Medium Carbon Steel in 0.5 M H_2SO_4 and NaCl Environments was investigated by

Omotoyinbo, J.Aetal., (). The inhibition efficiency of 92.1 % was obtained from the 1.5 g of the pulverized *Jatrophacurcas*leaves in NaCl solution, while 55.5 % efficiency was obtained from 2.5 g extract in H2SO4 solution.

- **Emeka E. Oguzie et al.**,investigated Characterization and Experimental and Computational Assessment of Kola*nitida* Extract for Corrosion Inhibiting Efficacy. KN extract was seen to affect both the cathodic and the anodic reactions following adsorption of organic species from the extract on the metal/solution interface.

- **AbdellahLaqhaili et al.,(2013)** have investigated Effect of *Lavandulastoechas*oil on welded material corrosion in 5.5M H3PO4 solution.The inhibition efficiency of inhibitor increases with concentration to attain 89 % at 1.2 g.L-1 of [L] in the phosphoric acid (40 wt. %) or 5.5M H_3PO_4 with the addition of chemical impurities (4 wt. % of H2SO4 and 0.04 wt. % of chloride ions used as KCl).

- **Y. Abboud et al,(2013)** have investigated leave of *Punicagranatum* extract (LPGE) as green inhibitor for the corrosion of mild steel in 1M HCl solution, studied using weight-loss and potentiodynamic polarization measurements. The results obtained revealed that LPGE has fairly good inhibiting properties for mild steel corrosion in 1M HCl solution, with efficiency of around 94 % at a concentration of 1 g/l. The inhibition was of a mixed anodic–cathodic nature.

- **MansoorBozorg et al.,(2014)** have investigated that the inhibitive properties of MyrtusCommunis in sulfuric acid solution on the copper surface were examined by weight loss, potentiodynamic polarization, electrochemical impedance spectroscopy, atomic force microscopy, and scanning electron microscopy methods. Weight loss and electrochemical analysis showed that the MyrtusCommunis extract was a highly efficient mixed type inhibitor.

- Alkaloid extracts of leaves (OOL) and bark (OOB) of Ochrosiaoppositifolia, as well as isoreserpiline (ISR), the major alkaloid isolated from OOL and OOB, were investigated**PandianBothi Raja et al.,(2013),**as potential corrosion inhibitors for mild steel (MS) in 1 M HCl medium. The inhibition properties of these phytoconstituents were studied using electrochemical techniques (potentiodynamic polarization measurements and electrochemical impedance spectroscopy, EIS) and scanning electron microscopy (SEM). The results indicated that these green inhibitors effectively reduced the corrosion rate**.**

- **Lebe A. Nnanna et al., (2013)**, have investigated the corrosion inhibition of mild steel in acidic solution of 0.5 M HCl using root extract of *Uvariachamea*by way of gravimetric measurements. It was shown that the presence of *U. chamea*root extract inhibited the corrosion of mild steel in the test solution and the inhibition efficiency depended on the concentration of the plant extract as well as on the time of exposure of the mild steel samples in HCl solutions containing the extract. The experimental data complied to the Langmuir and Temkin adsorption isotherms.

- **N S Patel et al., (2013)** have investigated thatExtract of various plants *(Wrightiatinctoria, Clerodendrumphlomidis, Ipomoeatriloba)* leaves was investigated as corrosion inhibitor of mild steel in 0.5 M H2SO4 using conventional weight loss, electrochemical polarization, electrochemical impedance spectroscopy and scanning electron microscopic studies.

- **Debi Gaius Eyu et al.,(2013)** have investigated the effect of *Vernoniaamygdalina*extractson corrosion inhibition of mild steel immersed in 3.5wt% NaCl solution by weight loss measurement. The study was conducted at temperature range within 28oC to 34.7oC.The results of the study shown that the plant extracts reduced corrosion rate of mild steel in 3.5% NaCl and the inhibition mechanism was by physical adsorption, the adsorbed molecules block the active sites thus prevent the metal from corrosion in the chloride environment.

- **Saedah R. Al-Mhyawi (2014)**have investigated the inhibition of mild steel corrosion using *Juniperus*plants as green inhibitior. The inhibition efficiency increases with increase in inhibitor concentration but decreases with an increase in temperature. The inhibitive effect of the *Juniperus*plant could be attributed to the presence of some compound in the plant which is adsorbed on the surface of the mild steel.

- **P. Muthukrishnanet al., (2014)**, havereported the *Hyptissuaveolens* leaf extract (HSLE) acted as corrosion inhibitor in 1 M H2SO4 was evaluated using mass loss measurement as well as potentiodynamic polarization and electrochemical impedance spectroscopy measurements. The extract was found to efficiently inhibit the corrosion process in 1 M H2SO4 and inhibition efficiency increased with increasing extract concentration.

- **K. Shalabi et al.,(2014)**, have investigated the inhibition efficiency of alcoholic extract of *Phoenix dactylifera* plant on aluminum and aluminum_silicon in 0.5 M hydrochloric acid solution have been evaluated by potentiodynamic polarization, electrochemical impedance spectroscopy (EIS) and electrochemical frequency modulation (EFM). Values of inhibition efficiency obtained are dependent upon the plant extract concentration and temperature.

- **J Buchweishaija,(2009)** have investigated The inhibitive performance of gum exudates from *Acacia drepanolobium* and *Acacia senegal* from Tanzania, towards the corrosion of mild steel in fresh water. The experimental methods include potentiodynamic polarization and electrochemical impedance spectroscopy (EIS) studies.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

Selection of mild steel

Mild steel finds application in many industries due to its easy availability, ease of fabrication, low cost and good tensile strength besides various other desirable properties. Its low carbon content makes it neither brittle nor ductile. It is best used as a structural material. It suffers from severe corrosion when it comes in contact with acid solutions during acid cleaning, transportation of acid, de-scaling, storage of acids and other chemical processes. The heavy loss of metal as a result of its contact with acids can be minimized to a great extent by the use of corrosion inhibitors. Hence in the present work mild steel is selected for corrosion inhibitors studies.

Sample preparation

Rectangular sample of area 1x 5 cm^2 have been cut from a big sheet of mild steel locally bought. The specimens (mild steel coupons) were mechanically polished; a hole drilled at one end for free suspension and numbered by punching. The specimens were degreased with acetone, washed with distilled water, and well-polished with emery paper, cleaned, rinsed and dried and then stored in desiccators, for further study.

Choice of Acid media

Acids commonly used in the pickling process are hydrochloric acid and sulphuric acid. Both these acids have their own advantages and disadvantages. Hydrochloric acid is relatively cheaper; pickling can be done at lower temperature and needs much less time, hence selected for the present study.

Plant materials

With increasing concern about the toxicity, biodegradability and bioaccumulation of inhibitors discharged into the environment leading to its harmful degradation, so natural product inhibitors are very important. There is growing need for green corrosion inhibitors which are biodegradable, environment friendly and have no toxicity. The plant materials chosen for the present study is *Galinsoga parviflora*. It is easily available.

4. PLANT PROFILE

Image 1, ***(Galinsoga parviflora leaves)***

Scientific name	**Galinsoga parviflora**
Common Names	**Quick Weed, gallant – soldiers**
Tamil Name	**Mookuthi Poo**
Origin	**South America**
Family	**Asteraceae**
Habit	**A soft erect annual branched herb up to 60cm high**

Extract preparation

Green leaves of the *Galinsoga parviflora*were collected from the nearby Kodumudi, Erode, Tamil nadu, washed and shade dried. 50 gms of dried powder of leaves were refluxed in 1000ml 1M HCl with reflux condenser for three hours and kept overnight. Next day it was filtered and the filtrate volume was made up of 1000ml using 1M HCl. The extract so prepared was taken as stock solution and from this other concentrations were prepared.

Techniques adopted

- Weight loss method
- Gasometric method

Weight loss method

Mild steel specimens were weighed accurately in electronic balance. Weighed coupons (in triplicate) were fully immersed, by using glass hooks, in beakers containing 100 ml of 1N HCl in the absence and presence of different concentrations (2.5 ,3,3.5, 4,4.5, 5,5.5,6 and 1% v/v) of the inhibitors and for 3 hours immersion period. After the specified period of immersion, the specimens were removed, dipped in sodium bicarbonate for neutralization of residual acid on the surface of the specimen, washed, dried, and re-weighed. The loss in weight was determined and the results were averaged. The study was carried up to one month at week intervals of time.

Image 2, **Weight loss method**

Determination of corrosion rate

i) Corrosion rate (CR)

The rate of dissolution of metal is calculated in terms of corrosion rate using the expression,

$$CR(mpy) = \frac{(534 \times W)}{DAT}$$

Where

W = loss in weight in milligrams

D = density in g/cm^3 (7.9 g/cm^3 for mild steel)

A= area of specimen in square inch

T= immersion time in hours

ii) Inhibition efficiency , (IE)

The percentage inhibition efficiency is found by

$$IE\,\% = \frac{(R_0 - R_i)}{R_0} \times 100$$

Where,

I.E (%) = Inhibition efficiency

R_0= Corrosion rate in the absence of inhibitor.

R_i= Corrosion rate in the presence of inhibitor.

Gasometric method

The gasometric assembly measures the volume of hydrogen gas evolution from the reaction system.

A two necked flask was connected via a delivery tube to a graduated gas collector (a reservoir of water). 100ml of the test solution was then introduced into the flask and the initial volumein the graduated gas collector was set to zero reading. There after one mild steel coupon was dropped into the test solution and the reaction vessel immediately closed. The volume of the hydrogen gas evolved by the corrosion reaction was estimated from the volume change in the level of the water in the gas collector, each experiment was conducted on a fresh specimen of metal coupon.

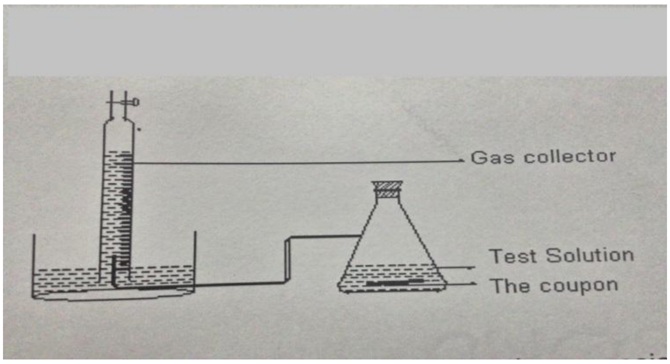


Image 3, Gasometric method

Gasometric methods were carried out at room temperature. From the volume of hydrogen evolved per minute, inhibition efficiency (% IE) and degree of surface coverage (θ) were calculated using equations (a) and (b) respectively.

$$\% IE = [1- V'Ht/ V^0Ht] \times 100 \quad \rightarrow \quad (a)$$

$$\theta = 1- V'Ht/ V^0Ht \quad \rightarrow \quad (b)$$

Where V'H - Volume of hydrogen gas evolved at time t for inhibited solution.

V^0Ht- Volume of hydrogen gas evolved at time t for uninhibited solution.

The volume of hydrogen gas evolved per minute was recorded until there was no evolution of gas anymore.

Phytochemical Constituents Present in Galinsoga parviflora plant

- ❖ Carbohydrates
- ❖ Alkaloids
- ❖ Flavanoids
- ❖ Saponins
- ❖ Fumaric acid
- ❖ Tannins
- ❖ Phytosterol

Stability and Durability Study

The stability and durability of the plant extract was investigated by weight loss determinations. The inhibitor material was stored separately at room temperature and in the refrigerator the refrigerated extract was brought to the room temperature at the time of test. The loss in weight of the metal was determined with the extracts stored at room temperature and in the refrigerator for different inhibitor concentrations and 3 hours immersion period.

RESULT SAND DISCUSSION

RESULTS AND DISCUSSION

The inhibition efficiency of environment friendly plant material for mild steel in acid medium was evaluated through various techniques. *Galinsoga parviflora* has been evaluated as probable acid corrosion inhibitor and the confirmation of *Galinsoga parviflora* as acid corrosion inhibitors has been carried out by Gasometric method in the present study. The investigations were carried out and the results of the experimental study on the corrosion of mild steel in 1M HCl media under various operating conditions are given and discussed in this chapter.

GASOMETRIC TECHNIQUE

Gasometric technique for the measurement of hydrogen evolution from the corrosion of mild steel in absence and presence of various concentrations of the *Galinsoga Parviflora* extract were carried out in 1M HCl medium. The hydrogen evolved displaces the water in the gasometric setup which is read directly (cm^3).

Table 2. Volume of hydrogen gas evolved at different concentrations

Time(mins)	Volume of hydrogen gas (ml)				
	Blank (v/v)	conc 3 (v/v)	conc 4 (v/v)	conc 5 (v/v)	conc 6 (v/v)
5	0.5	0.5	0.4	0.5	0.4
10	0.8	0.5	0.7	1	1
15	1.4	0.9	1	1.4	1.5
20	1.8	1.3	1.4	2	2
25	2.4	1.7	1.6	2.5	2.5
30	2.8	2.1	1.9	3	3
35	2.4	2.5	2.2	3.5	3.5
40	3.6	2.9	2.5	4	4
45	4.2	3.3	2.8	4.5	4.4
50	4.6	3.7	3.1	5	4.9
55	5	4.1	3.4	5.5	5.5
60	5.4	4.5	3.7	6.1	5.9
65	5.8	4.9	4	6.5	6.4
70	6.4	5.3	4.3	7	7
75	6.4	5.7	4.7	7.5	7.5
80	6.4	6.2	5	8	8
85	6.4	6.5	5.3	8.5	8.5
90	6.4	6.9	5.6	9	9
95	6.4	7.3	5.9	9.5	9.5

100	6.4	7.7	6.1	10	10
105	6.4	8.1	6.4	10.5	10.5
110	6.4	8.4	6.7	11	11
115	6.4	8.6	6.9	11.4	11.5
120	6.4	8.8	7.3	11.9	12
125	6.4	10	7.5	12.5	12.4
130	6.4	10.7	7.7	13	12.9
135	6.4	10.7	8	13.5	13.4
140	6.4	10.7	9	14	13.8
145	6.4	10.7	9.5	14.5	14.5
150	6.4	10.7	10	15	15
155	6.4	10.7	10.3	15.5	15.6
160	6.4	10.7	12.5	16	16
165	6.4	10.7	12.8	16.5	16.5
170	6.4	10.7	13.1	17	17
175	6.4	10.7	13.1	17.5	17.5
180	6.4	10.7	13.1	18	18
185	6.4	10.7	13.1	18	18.5
190	6.4	10.7	13.1	18	19
195	6.4	10.7	13.1	18	19.4
200	6.4	10.7	13.1	18	19.4
205	6.4	10.7	13.1	18	19.4
210	6.4	10.7	13.1	18	19.4

Volume of hydrogen gas evolved with time for the corrosion of mild steel in Blank

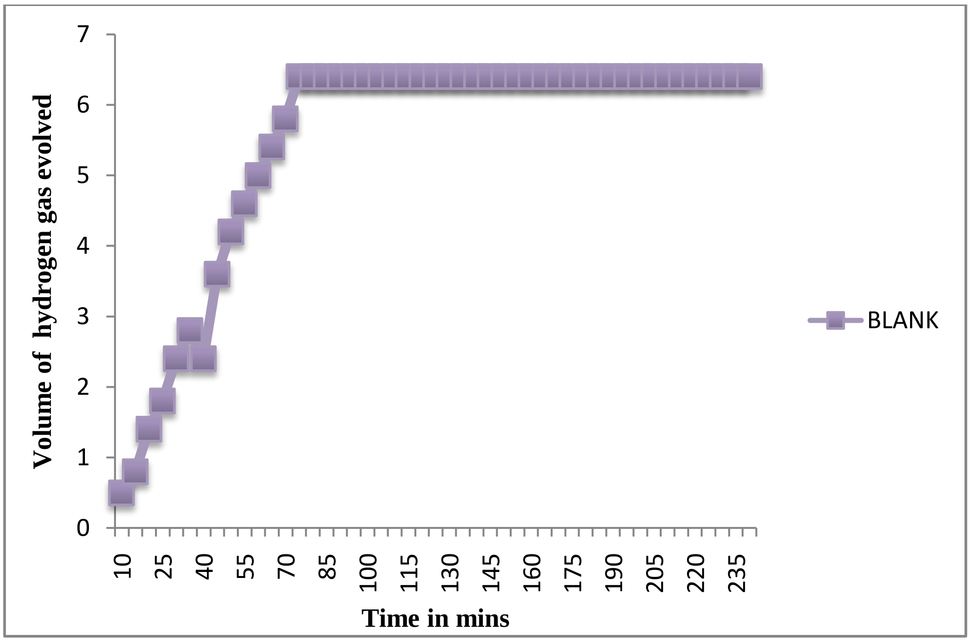


Figure 1

Volume of hydrogen gas evolved with time for the corrosion of mild steel in *Galinsoga parviflora extract* at concentration 3(v/v).

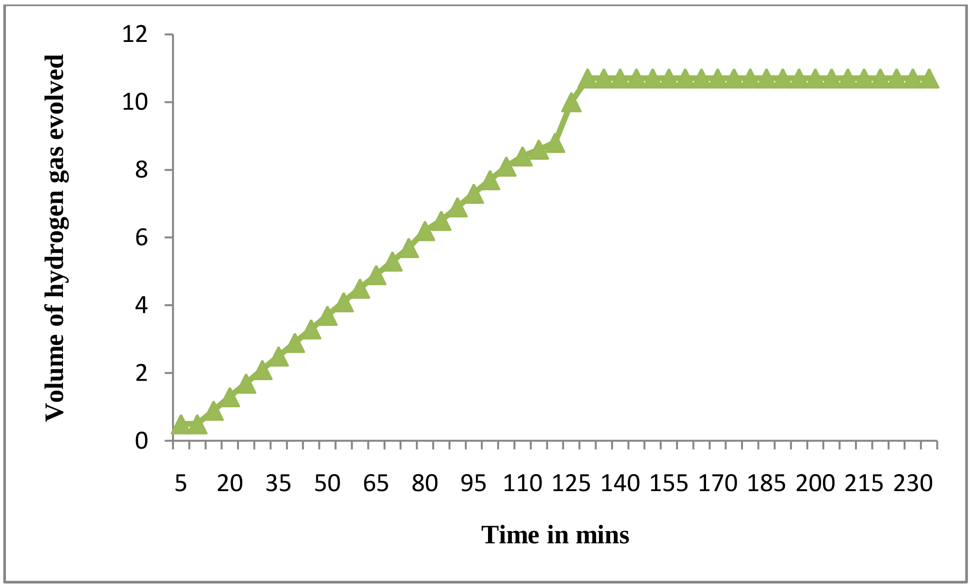


Figure 2

Volume of hydrogen gas evolved with time for the corrosion of mild steel in *Galinsoga parviflora extract* at concentration 4(v/v).

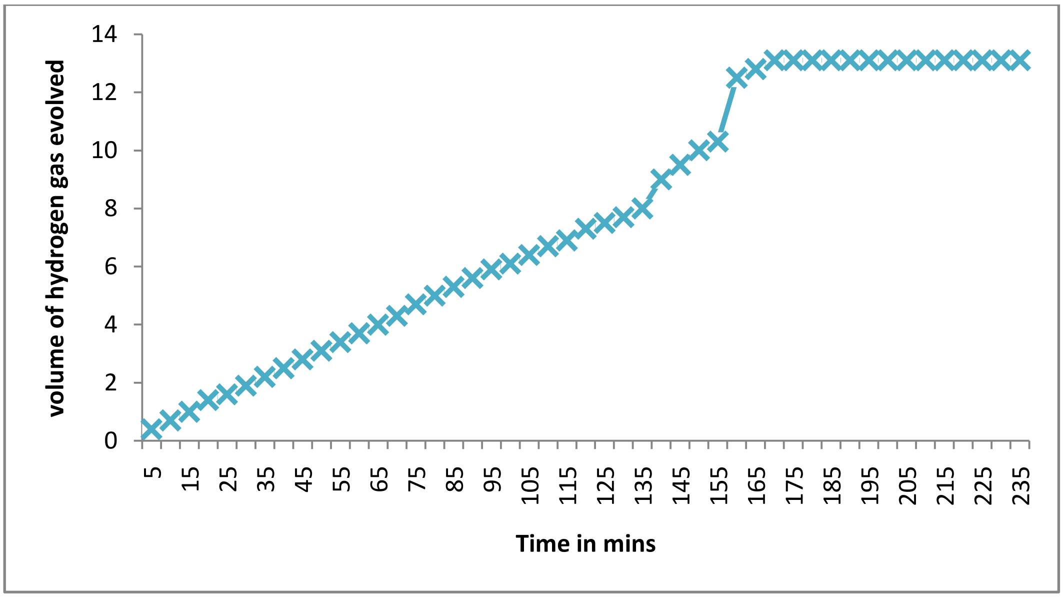


Figure 3

Volume of hydrogen gas evolved with time for the corrosion of mild steel in *Galinsoga parviflora extract* at concentration 5(v/v).

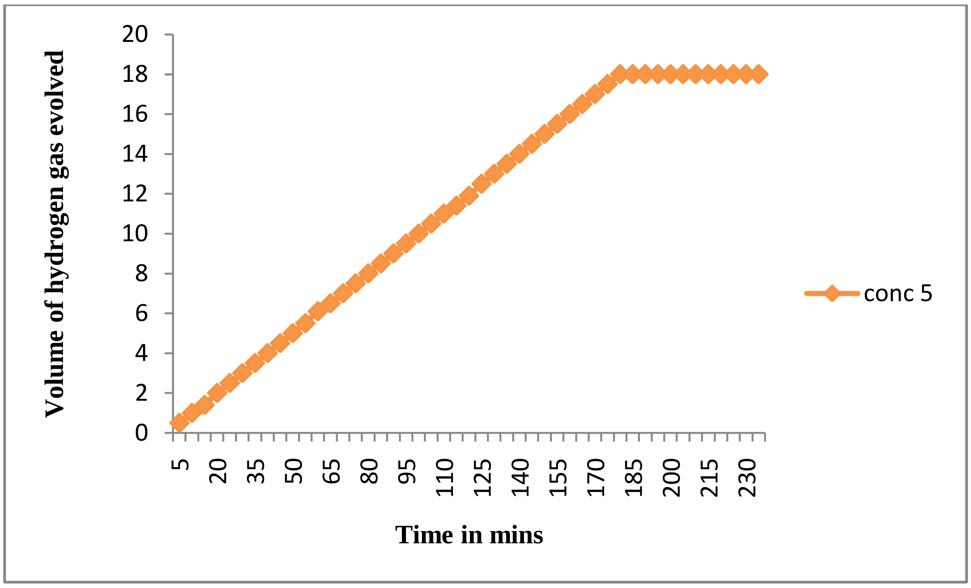


Figure 4

Volume of hydrogen gas evolved with time for the corrosion of mild steel in *Galinsoga parviflora extract* at concentration 6 (v/v).

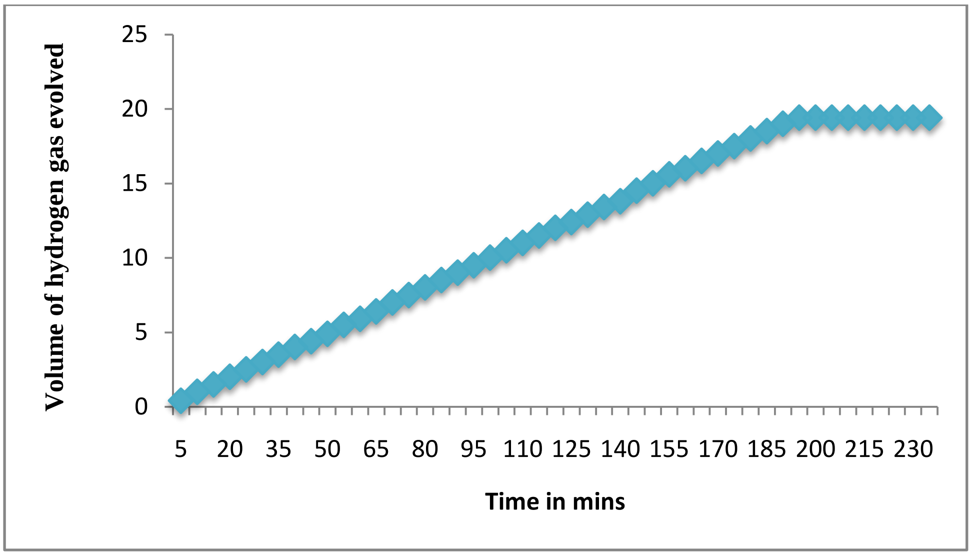


Figure 5

Figure (1-5) shows the plot of the volume of hydrogen gas evolved with time during the inhibition of the corrosion of mild steel in 1M HCl at various concentrations of GP extract. The volume of hydrogen gas evolved per minute was recorded until there was no evolution of gas.

Volume of hydrogen gas evolved with time for the corrosion of mild steel in *Galinsoga parviflora extract*in presence and absence of the inhibitor.

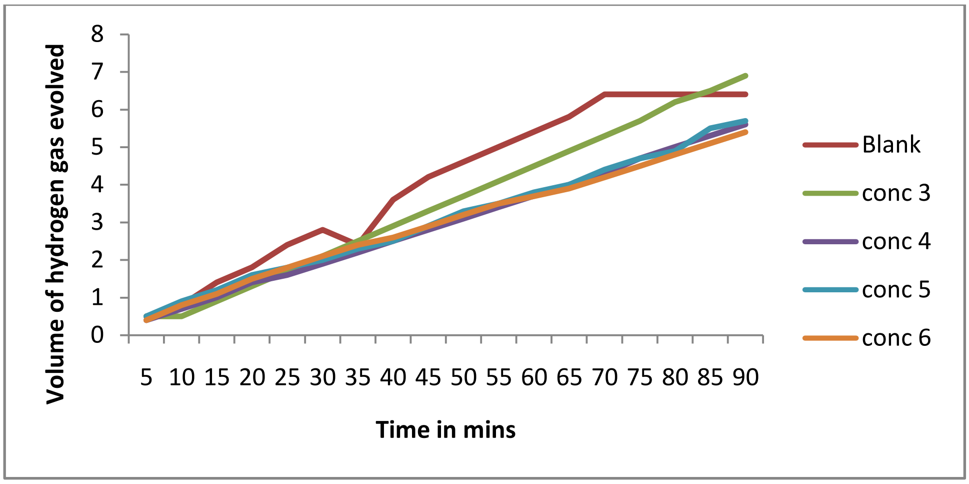


Figure 6

From the figure (6), it is seen that the volume of hydrogen gas evolved is found to decrease on addition of different concentrations of the GP extract.

The corrosion rate was determined from the slope of each line of volume of hydrogen gas evolved against time. Addition of increasing concentration of the inhibitor retards the corrosion rate of mild steel in the solutions.

Table 3. Slope of hydrogen gas evolution against time

Conc	blank	3	4	5	6
Slope	0.077	0.068	0.06	0.059	0.056

This is clearly seen, from the decrease in volume of hydrogen evolved corresponding to decrease in the slope of each line with increase in inhibitor concentration. There by increasing the inhibition efficiency with increase in concentration of the inhibitor. This is in agreement with the previous study (Divya , 2014).

WEIGHT LOSS METHOD

A new plant material being studied needs to be standardized before introduced as an inhibitor in industries , with a view to standardize the selected plant material, its stability and durability at normal temperature and in refrigerationtemperature,hence the influence on inhibition performance was studied.

The durability of the plant extracts as inhibitor i.e. how long the extract could be used under room temperature was studied by testing their inhibition efficiency at various storage periods such as after 7 days, 14days, 21days and 28 days. The results of weight loss method at various storage periods of the extract and at 3 hours immersion period are given table. (4)

Table4: The inhibition efficiency of GP extract in 1M HCl at Room temperature and Refrigeration temperature with different storage period of the extract.

Conc of the extract (v/v)	Storage periods in days / Inhibition efficiency (%)								
	1	7		14		21		28	
	RT	RT	RFT	RT	RFT	RT	RFT	RT	RFT
2.5	78	79	79	80	79	76	86	84	86
3	79	79	81	81	82	85	86	84	86
3.5	80	79	82	83	82	86	88	88	86
4	81	79	82	84	83	88	88	88	87
4.5	81	79	83	85	85	88	88	88	88
5	83	79	84	85	86	89	89	90	89
5.5	85	82	85	85	86	90	90	90	90
6	86	84	86	86	89	91	92	91	93

Plant extract was stored separately at room temperature and in the refrigerator. After a period of the specified days the inhibition performance of the plant extract stored under different storage conditions were studied. The results are given in the table (4) and are shown in the figures (6- 9)

Inhibition efficiency of *Galinsoga parviflora* extract at room temperature and refrigeration temperature on 7th day.

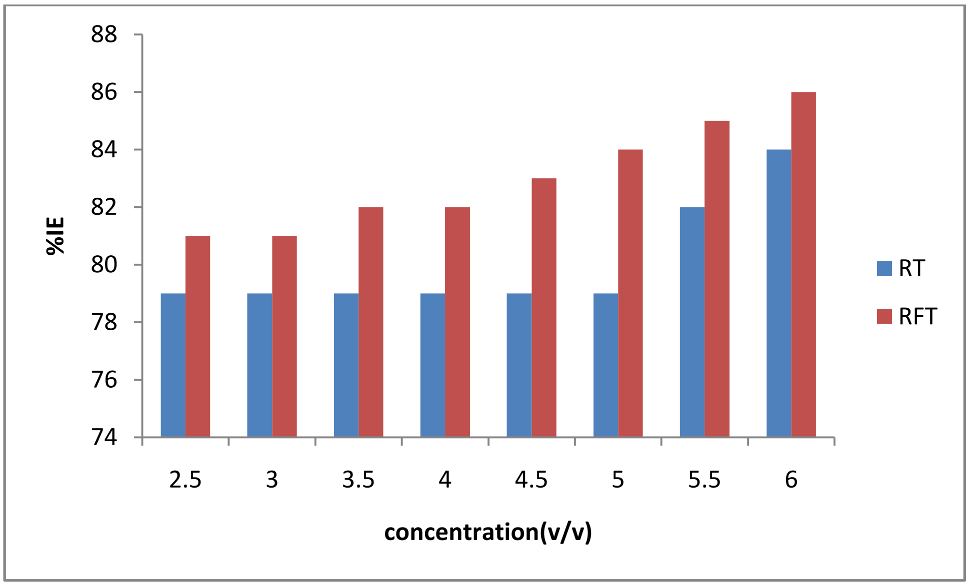


Figure 7

Inhibition efficiency of *Galinsoga parviflora* extract at room temperature and refrigeration temperature on 14th day.

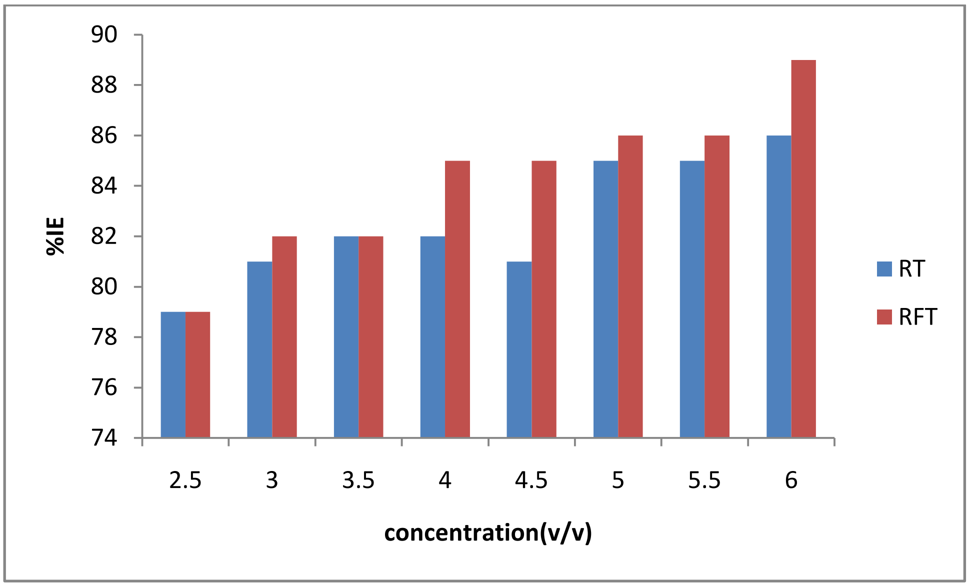


Figure 8

Inhibition efficiency of *Galinsoga parviflora* extract at room temperature and refrigeration temperature on 21st day.

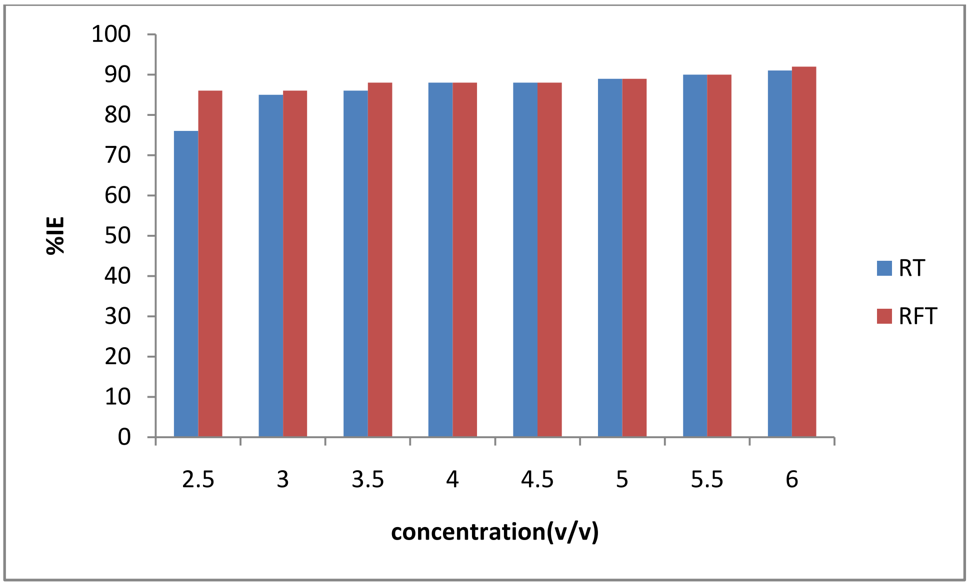


Figure 9

Inhibition efficiency of *Galinsoga parviflora* extract at room temperature and refrigeration temperature on 28th day.

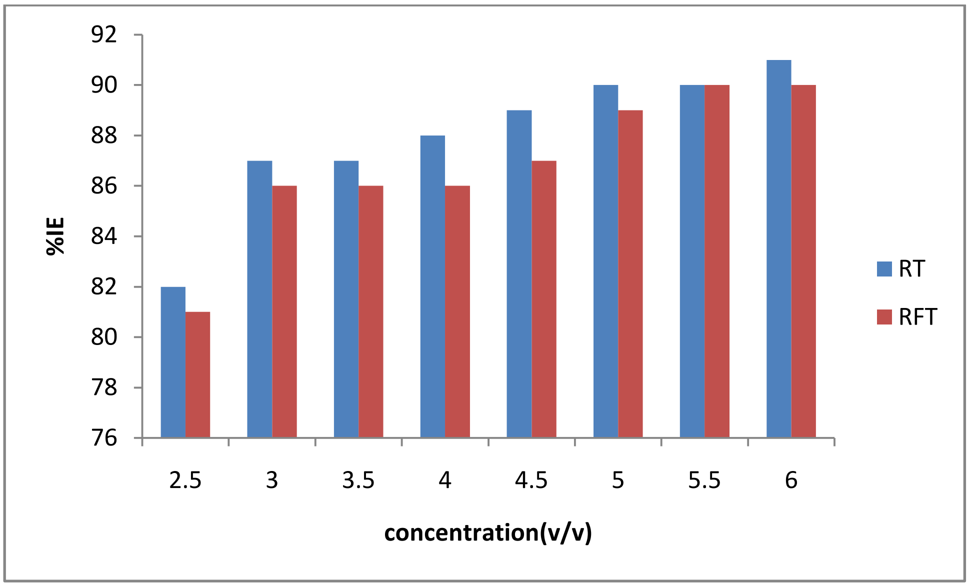


Figure 10

It is found that the inhibition efficiencies are found to increase with increasing extract concentration at all storage periods (Figure 11).

Inhibition efficiency of *Galinsoga parviflora*extractwith various storage periods.

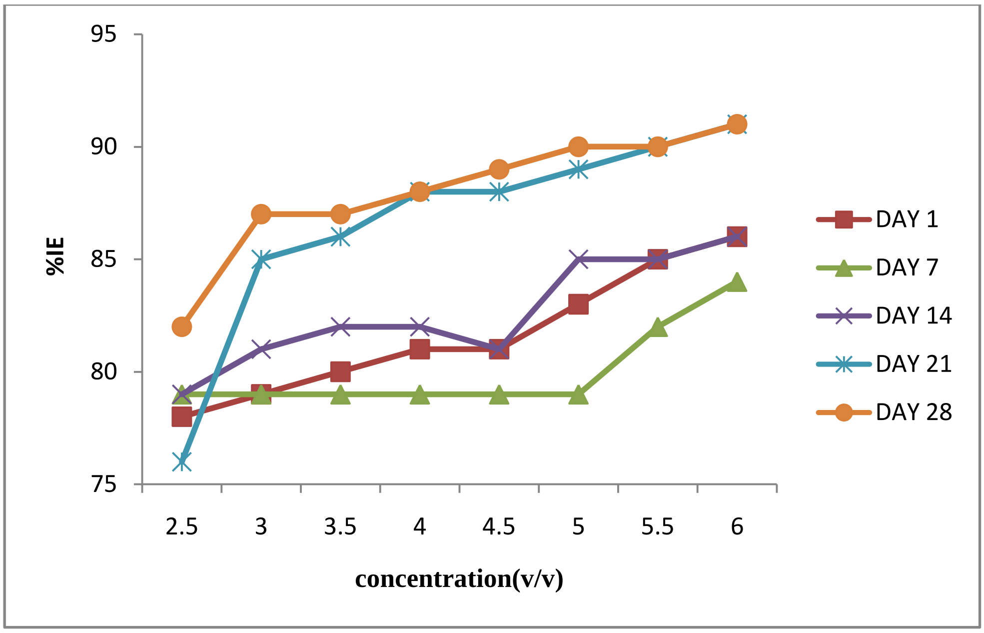


Figure 11

The inhibition efficiency of the extract stored at refrigeration condition is found to have more inhibition efficiency than that stored at room temperature. This observation was noted up to 14days of the storage, during 21st day there is no significant variation in the inhibition efficiency of the extract between two storage conditions.

During 28th day study,it was observed that the inhibition efficiency of the extract stored at refrigeration condition is found to be less than that stored at room temperature. This may be due to sedimentation of some of the phytoconstituents present in the extract at refrigeration temperature. Hence it is evident that the plant material is stable and effective as inhibitor at room temperature and could be used effectively up to 28 days.

Comparison between Weight loss and Gasometric methods

Values of inhibition efficiency obtained from weight loss and Gasometric methods are given in table (5)

Table 5: Inhibition Efficiency Obtained from Weight loss and Gasometric Method.

Conc of the extract (v/v)	**Inhibition Efficiency (%)**	
	Weight loss method* (Divya.P, 2014)	**Gasometric Method**
3	38	79
4	51	81
5	56	83
6	78	86

Values of inhibition efficiency of GP extract obtained from gasometric measurements are significantly higher than values obtained from weight loss measurements. The difference confirms that gasometric method measures instantaneous rate of corrosion, while weight loss measurements measures average rate of corrosion.

ADSORPTION ISOTHERM

The values of degree of surface coverage calculated from weight loss measurements at room temperature have been used to study the adsorption characteristics of GP extract on the surface of mild steel and to predict the adsorption isotherm. Adsorption isotherm provides information about the nature of interaction between the metal surface and inhibitor, ie, to describe the adsorption characteristics of the extracts.

There are many isotherm models to describe the inhibitor/ metal interaction like Langmuir, Temkin, Frumkin, Freundlich etc. but in the present study Langmuir, Temkin, Freundlich isotherms found to provide the best description of the adsorption behavior with the regression coefficient of $R^2$0.9974,0.9167,0.9321respectively.

In the presence of inhibitor, water soluble organic compounds dissolved in the solution interacted with the negatively charged mild steel surface which caused adsorption of inhibitor molecules at metal / solution interface.

The phytoconstituents present in GP plant extract have strong affinity towards metal surface and in acidic environment, protonation of organic moieties showed better adsorption over the metal surface protonated species adsorption on the cathodic sites mild steel is shown by decreased hydrogen evolution.

Langmuir adsorption isotherm

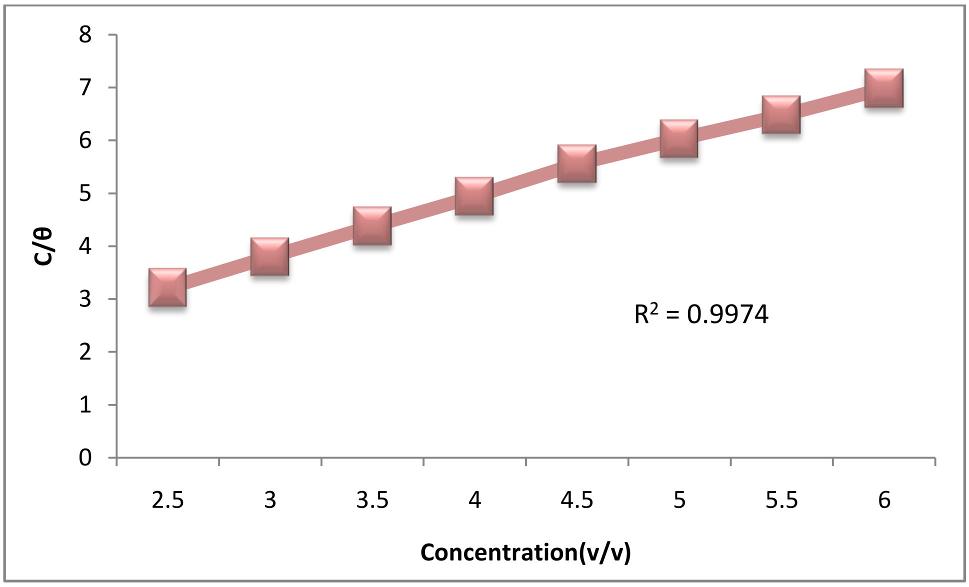


Figure 12

Temkin isotherm

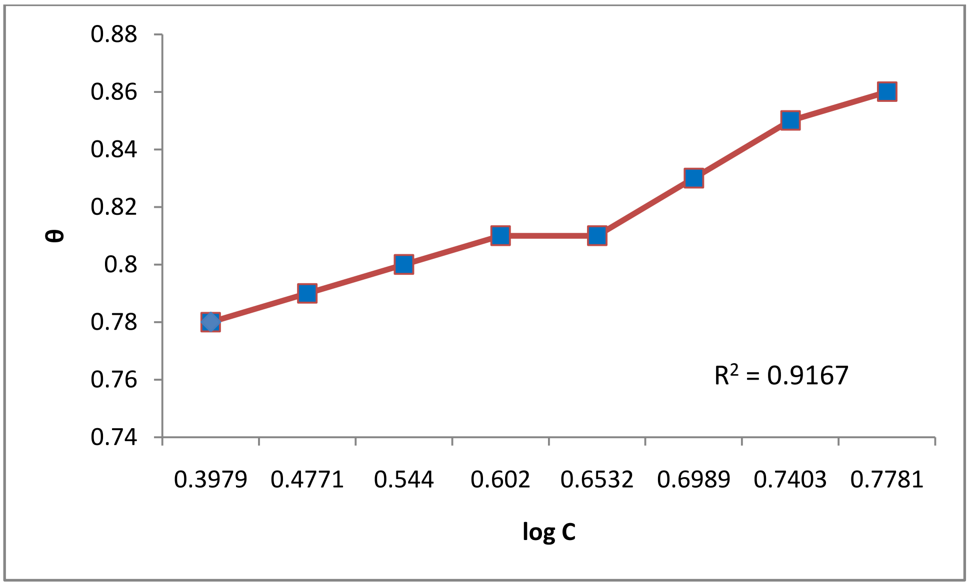


Figure 13

Frendulich isotherm

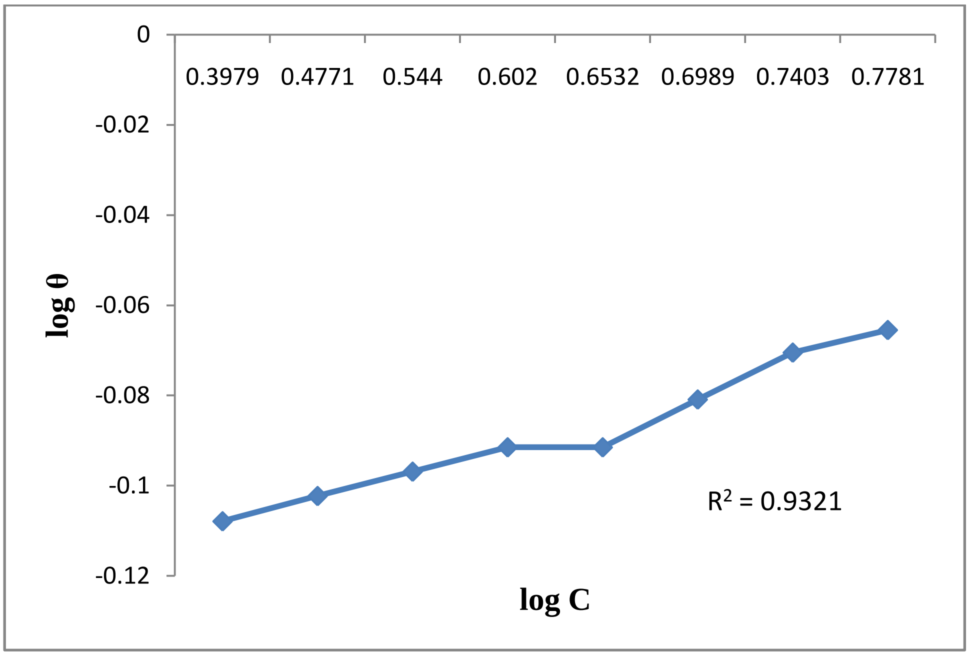


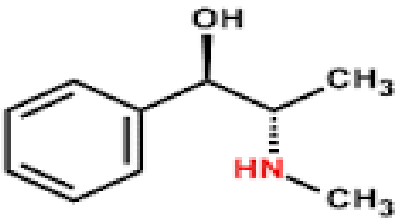
Figure 14

Linear plot was obtained by plotting C/θ vs C confirming the applicability of Langmuir adsorption isotherm to the adsorption of *Galinsoga parviflora* extract on the surface of mild steel at room temperature. Therefore there is no interaction between the adsorbed species.

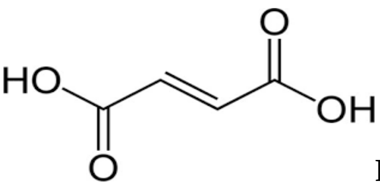
Probable mechanism of inhibitor

The selected plant for the present study is found to contain phytoconstituents such as alkaloids, flavonoids, tannins etc,(https://www.google.co.in/imghp)

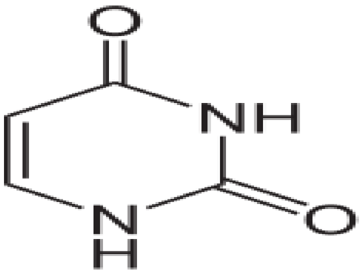
Structures of Phytoconstituents present in Galingsoga parviflora



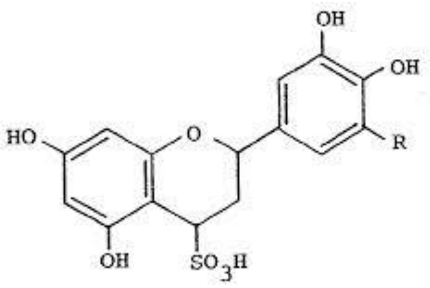
Alkaloids



Fumaric acid



Uracil



Tannins

The constituent contains heteroatoms (N, O) which satisfy the basic requirement for a substance to act as a corrosion inhibitor. In the present study, the inhibition of corrosion may be due to the adsorption of one or more molecules of the phytoconstituents present in GP extracts on to the metal surface, there by forming a layer, which protect the metal surface from the corrosive environment. The adsorption behavior is confirmed through the adsorption isotherms.

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

Findings of the present investigation entitled "**Acid Extract of *Galinsoga parviflora* as Corrosion Inhibitor on Mild Steel in 1M Hydrochloric acid Media-Stability and Durability Study"** are summarized in this section.

- The tested acid extract of *Galinsoga parviflora* acts as a potent inhibitor for corrosion of mild steel in 1M HCl medium was supported by Gasometric studies.
- The volume of hydrogen evolved decreased with increase in inhibitor concentration showing decrease in corrosion rate and increase in inhibition efficiency.
- There is no significant variation in the inhibition efficiency of the extract stored at different storage conditions *viz* room temperature and refrigerated condition indicating stability of the extracts as inhibitors at room temperature.
- The plant extract could be stored up to one month.
- The inhibition efficiency obtained from Gasometric method measurements are found to be higher than that obtained from weight loss measurements.
- The inhibition of corrosion of mild steel in acid medium may be due to the adsorption of one or more molecules of the phytochemical constituents present in the extract to more than one active site in the metal surface, which is proved through the adsorption isotherms.

SUGGESTIONS

- The study may be carried out in other acid and metals to find its applicability in industries.
- Field test may be carried out to find its utility in the industries.
- To find out its cost effectiveness, a comparative study may be carried out with commercially available inhibitor.

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