

EVALUATION OF MECHANICAL AND CORROSION PROPERTIES OF MILD STEEL
IN SOME ENVIRONMENTS INHIBITED BY AFRICAN LOCUST BEANS TREE
(*Parkia biglobosa*) EXTRACTS

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ZARIA, NIGERIA

APRIL, 2016

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BY

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MSc/Eng/5195/2011-2012

A DISSERTATION SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES

AHMADU BELLO UNIVERSITY, ZARIA

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD

OF A

MASTER OF SCIENCE DEGREE IN MECHANICAL ENGINEERING

DEPARTMENT OF MECHANICAL ENGINEERING

FACULTY OF ENGINEERING

AHMADU BELLO UNIVERSITY,
ZARIA, NIGERIA

APRIL, 2016

CERTIFICATION

This dissertation entitled EVALUATION OF MECHANICAL AND CORROSION PROPERTIES OF MILD STEEL IN SOME ENVIRONMENTS INHIBITED BY AFRICAN LOCUST BEANS TREE (*Parkia biglobosa*) EXTRACTS by SALISU USMAN meets the regulations governing the award of the degree of Masters of science (MSc) degree in Mechanical Engineering (Production Studies) of the Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

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ACKNOWLEDGEMENTS

My gratitude goes to my mother, my greatest pillar of support and to all my brothers and sisters that help me throughout this programme.

Prof. D.S. Yawas and Dr M. Dauda my supervisors, I am indeed thankful for your guidance in producing this work and Mr. Ochibo a technician in post-graduate chemistry laboratory of A B U Zaria whose help and expert advice is deeply appreciated.

DEDICATION

This research is dedicated to almighty Allah (S.W.T), to my late father Mallam Usman Dakyes, may Allah grant him Aljannah firdaus amin and my mother Hajiya Habiba Ibrahim Dakwang.

ABSTRACT

Corrosion of mild steel is a big problem in most of our industries causing huge losses of millions of dollars in maintenance. Synthetic corrosion inhibitors are carcinogenic and not biodegradable hence the urgent need for organic inhibitors. Shaded leaves and pods from African locust beans tree (*Parkia biglobosa*) constitute agricultural waste which dirty our environment. In investigating ways to tackle these problems, four extracts (from pods, leaves, stem bark and root) of African locust beans tree (*Parkia biglobosa*) were used as corrosion inhibitors on mild steel immersed in 0.5M H₂SO₄ and 0.5M NaCl. The corrosion experiment is based on weight loss method and during the experiment, time, concentration of the inhibitors and temperature were varied; the results showed that inhibition efficiencies of all the extracts when compared to blanks (controls) increase with concentration of the inhibitors in both media at room temperature. In acidic medium, stem bark extract has the highest inhibition efficiency of 86.02%, whereas in salt medium, root extract has maximum corrosion inhibition efficiency of 60.57%. Inhibition efficiencies in acidic and salt media decrease with increase in temperature. Corrosion rates at room temperature in absence and presence of extracts in both media decrease with increase in time. Activation energies of corrosion (E_a) increases with increase in inhibitors concentration in both media. Enthalpy and entropy change of corrosion values (ie ΔH_a and ΔS_a) in both media are positive and negative respectively. Langmuir isotherm is found to fit the experimental data obtained from acid and salt media better than Temkin isotherm. The overwhelmingly negative values of Gibb's free energy of adsorption (ΔG_{ads}) in the media shows the spontaneous nature of the adsorption process and the formation of stable protective films. Scanning electron microscopy (SEM) analysis reveals that corrosion inhibition of mild steel actually took place at the optimum concentrations (0.5% v/v) of the extracts. Mechanical properties investigated are more deteriorated in salt medium than in acidic medium, however, they are both significantly improved at 0.5% v/v stem bark extract in acidic medium and 0.5% v/v root extract in salt medium.

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ABBREVIATIONS AND DEFINATIONS

List of abbreviations of equation terms

E_a -Activation energy for the corrosion process

K_{ads} -Adsorption equilibrium constant

n -Avogadro's constant

K -Constant

CPR –Corrosion penetration rate

CR-Corrosion rate

i -Current density

θ -Degree of surface covered by adsorbed molecule

ρ -Density

ΔH_a -Enthalpy change of corrosion process

ΔS_a -Entropy change of corrosion process

i_o -Exchanged current density

C -Extract concentration

ΔG_{ads} -Gibb's free energy of absorption

IE-Inhibition efficiency

D -Large diameter of sample

L -Long length of sample

C_{ion} -Molar concentration of ions

R -Molar gas constant

E -New emf of half cell

n_1 .Number of electrons transferred

η_a -Over voltage

π -pi

h -plank's constant

l -Short length of sample

d-Small diameter of sample

E^0 -Standard emf of half cells

A-Surface area of sample

β -Tafel coefficient

T-Temperature in kelvin

t-time

V-volume

W-Weight lost

W_2 -Weight lost in absence of inhibitor

W_1 -Weight lost in presence of inhibitor

Definition of terms

- **Activation Energy (E_a):** This is the minimum amount of energy reacting species must possess to bring about chemical change or reaction.
- **Corrosion:** Corrosion is defined as destruction or deterioration of a material because of reaction with its environment.
- **Entropy:** is the measure of the degree of randomness of a system and is represented as (S) or change in entropy (ΔS)
- **Enthalpy:** is the heat or energy content of a system consisting mainly of atomic or molecular kinetic and potential energies and is denoted by (H) while sometimes as change in enthalpy (ΔH).
- **Free Energy (G):** is the energy available for doing work in a system, change in free energy is denoted by (ΔG).
- **Inhibitor:** inhibitor is a chemical compound that, when added to a liquid or gas, usually in small quantity decreases the corrosion rate of a material, typically a metal or an alloy.
- **Mechanical properties:** These are properties like tensile strength, yield strength, hardness, ductility, impact strength of a material.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Mild Steel is one of the most common of all ferrous alloys, and one of the least expensive steels used. It is to be found in almost every product created from metal. It is weldable, very durable (although it rusts), it is relatively hard and is easily annealed. Having less than 2 % carbon, it will magnetize well and being relatively inexpensive, can be used in most projects requiring a lot of steel (properties of mild steel.). In addition, mild steel is used in the fabrication of reaction vessels, boilers, pipelines (as seen in chemical or oil and gas industries), automobile industry. However, under process called corrosion, carbon steel is chemically attacked and gets deteriorated.

Corrosion can be defined in many ways. Some definitions are very narrow and deal with a specific form of corrosion, while others are quite broad and cover many forms of deterioration. The word corrode is derived from the Latin *corrodere* which means “to gnaw to pieces.” The general definition of corrosion is to eat into or wear away gradually, as if by gnawing. For purposes here, corrosion can be defined as a chemical or electrochemical reaction between a material, usually a metal, and its environment that produces a deterioration of the material and its properties (ASM International,2000). Estimates of the annual cost of corrosion in the United States of America vary between \$8billion and \$126billion (Fontana, 2005). For Saudi Aramco’s five domestic refineries, 36% of maintenance budget was due to corrosion. For gas sweetening plants, it was found that 25% of the maintenance budget was committed to corrosion control. For gas fractionation plants, 17% of the maintenance budget was due to corrosion. For production operations onshore, corrosion is responsible for 28% of maintenance costs. Offshore, corrosion accounts for 60% to70% of maintenance costs (Tems and Al Zahrani, 2006). Thus, corrosion needs to be

controlled and prevented if the overall efficiencies of the systems and their durabilities are to be enhanced and cost of production reduced by using appropriate corrosion inhibitors.

1.2 Statement of the Problem

Corrosion is indeed a nuisance and it is easily seen in metallic infrastructure or facilities like oil and gas industries, petrochemical industry, bridges, railways. Corrosion causes failures of oil and gas pipe lines, stress corrosion collapse of bridges and the costs of replacement and maintenance is becoming intolerable. It can cause sudden failures in ships and submarines by gradually eating-up the steel bodies and propellers. Storage tankers for storing crude or refined oil can be aggressively weakened by corrosion if they are not adequately protected, and eventually causes oil spillage. Corrosion reduces the durability of galvanized roofing sheets.

Shaded leaves and emptied pods from African locust bean trees constitute agricultural waste which when disposed inappropriately can lead to environmental pollution.

In search for ways to control corrosion, myriad methods have been developed, one of which is the use of corrosion inhibitors. Synthetic (inorganic) inhibitors though proven most of the times to be effective in mitigating corrosion, are often carcinogenic and not biodegradable (Olasehinde et al, 2013), hence when disposed off to the environment, they upset the ecosystem. Presently, green (organic) inhibitors are fast replacing inorganic ones because they prove to be equally effective in corrosion mitigation and not harmful to man and his environment.

1.3 The Present Research

Four different extracts were obtained from the pods, stembark, leaves and roots of locust bean plant. Then, their effects on mechanical properties and corrosion inhibitions of mild steel in 0.5M sulphuric acid and sodium chloride solutions were examined .

Sulphuric acid of 0.5M concentration is preferred because it is the optimum concentration of most acids (Yawas, 2005). As for the salt solution, 0.5M is approximately the average concentration of salt (NaCl) in seawaters and oceans (Science daily, 2014).

1.4 Aim and Objectives

The aim of this study is to investigate the mechanical and corrosion behaviours of mild steel using locust beans tree extracts (ie pod, stem bark, root and leaves) as corrosion inhibitors in 0.5M H₂SO₄ and NaCl solutions.

The following are the specific objectives:

- To carry out the physico-chemical and phyto-chemical analyses of the extracts (pods, leaves, bark and root).
- To carry out corrosion test on the extracts using gravimetric technique.
- Examine the effect of the four extracts on the corrosion rate of carbon steel in 0.5M H₂SO₄ and sodium chloride (NaCl) solutions.
- To compare the corrosion inhibition efficiencies of the extracts at different concentrations of the extracts and at different temperatures.
- To compare the photomicrographs of the carbon steel samples in contact with the sulphuric acid and sodium chloride solutions in the absence and presence of inhibitors.
- To investigate the mechanical properties (tensile strength, hardness and impact strength) of samples in contact with 0.5M sulphuric acid and sodium chloride solutions in the absence and presence of inhibitors.
- To determine the kinetic and thermodynamic parameters of the inhibitors and corrosion process.

1.5 Significance of the study

(a) Development of non-toxic and environment friendly organic inhibitors capable of mitigating corrosion of mild steel in 0.5M sulphuric acid medium and 0.5M NaCl solutions.

(b) It has the potential of unlocking the possibilities of making agricultural wastes beneficial to man. For example, the pods of locust bean tree after the sugary pulp along with the seeds are removed, are thrown away as waste most of the time, except on rare occasions when it is used locally for cementing floors in some of our villages, and the shaded leaves also litter our surroundings.

(c) Acids, most especially sulphuric acid solution is used in our industries in processes like descaling, pickling, cleansing of our steel vessels. (Saratha and Vasudha, 2010; Vijayalakshmi et al, 2011; James and Akaranta,2009). Carbon steel is normally aggressively attacked in acidic medium which would make most of our industries prone to corrosion failures if the corrosion is not mitigated or inhibited.

(d) Salty environment are also aggressive to steels, hence corrosion inhibitors would be required to reduce cost, due to corrosion .

1.6 Scope of the research

The scope of the research are as follows:

- Obtaining extracts from pods, leaves, stembark and roots of African locust bean tree.
- Carry out weight loss corrosion experiment, where the extracts would be used as inhibitors to the corrosion of mild steel immersed in 0.5M H_2SO_4 and 0.5M NaCl media.
- Study the surface morphologies of mild steel samples after corrosion experiment.

- Investigate the effects of inhibitors on the mechanical properties(tensile strength, impact strength and hardness) of mild steel.

CHAPTER TWO

2.0 LITERATURE REVIEW

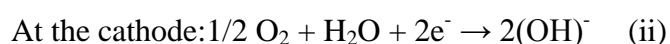
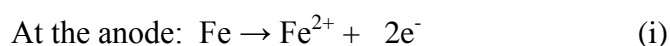
2.1 Corrosion

Corrosion is defined as destruction or deterioration of a material due to reaction with its environment (Fontana, 2005). Since corrosion is caused by chemical reaction, the rate at which corrosion takes place will depend to some extent on the temperature and concentration of the reactants and products. Mechanical stress and erosion are other factors that affect corrosion.

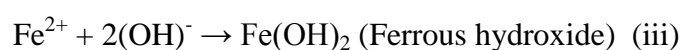
Corrosion is usually regarded as a electrochemical attack on metals or reverse extractive metallurgy, in that pure metals are converted to their oxides or sulphides or carbonates or silicates which occur naturally as ores. For example, pure iron when exposed to moisture and atmosphere gets converted to its oxide or rust. Nonmetallic materials such as ceramics and polymers do not suffer electrochemical attack because they do not have free mobile electrons as metals, but can be deteriorated by direct chemical attack (Bartel, 2008).

2.2 Electrochemical Corrosion of Metals

Electrochemical corrosion of metals involves oxidation-reduction (REDOX) reactions in which electrons produced during oxidation are being consumed in reduction process. For steel, corrosion occurs in stages. At the onset, it occurs at the anodic sites(anode) where oxidation reaction produces electrons which flow to the cathodic sites(cathode) where they will be consumed in reduction process as depicted in the equations :



Combining (i) and (ii) gives (iii):



The hydroxyl ions (OH)⁻ react with the ferrous ions from the anode to produce ferrous hydroxide, which is further oxidized in air to produce hydrated ferric oxide (red rust).

Corrosion leads to loss of strength, hardness, toughness and other desirable mechanical properties (Yawas,2005).

2.2.1 Standard electrode half-cell potentials for metals

Every metal has different tendency to corrode in a particular environment. For example, zinc is chemically attacked or corroded by dilute hydrochloric acid, where as gold is not. One method for comparing the tendency for metals to form ions in aqueous solution is to compare their half –cell oxidation or reduction potentials (voltages) to that of a standard hydrogen-hydrogen-ion half cell potential (Fontana, 2005). Fig.2.1 shows the setup for determining standard electrode potentials of zinc metal. In one beaker zinc metal is in contact with 1M solution of Zn²⁺ ions while in the other platinum plate is immersed in 1M solution of H⁺ ions through which hydrogen gas is passed at one atmosphere into the solution kept at 25⁰C. An external wire in series with a voltmeter and a switch connects the two electrodes externally and a potential drop between the electrodes is measured when the switch is closed. Therefore, the standard electrode potential of the reaction Zn→Zn²⁺ + 2e⁻ is -0.76 as depicted in Figure 2.1.

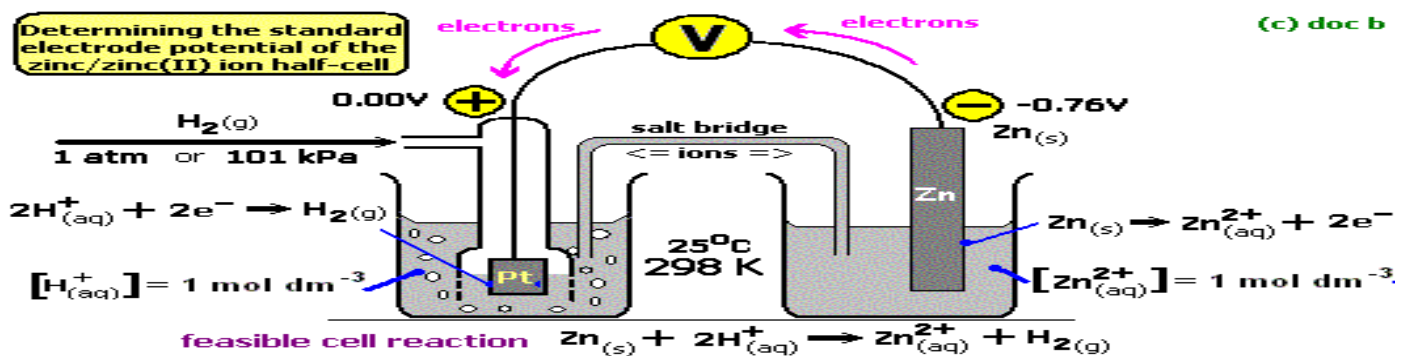


Figure:2.1 Experimental setup for determination of the standard electromotive force (emf) of zinc(www.citycollegiate.com)

Table 2.1 shows the standard half-cell electrode potentials of some selected metals. Those metals more reactive than hydrogen are assigned negative values and are said to be anodic to hydrogen whereas metals less reactive to hydrogen are give positive values, hence they are said to be cathodic to hydrogen.

Table 2.1 Standard Electrode Potentials of selected Metals (chemguide)

Reduction half-cell reaction Standard electrode potential (E^0 volts)

$\text{Li}_{(\text{aq})} + \text{e}^- \rightarrow \text{Li}_{(\text{s})}$	-3.03
$\text{K}^+_{(\text{aq})} + \text{e}^- \rightarrow \text{K}_{(\text{s})}$	-2.92
$\text{Ca}^{2+}_{(\text{aq})} + 2\text{e}^- \rightarrow \text{Ca}_{(\text{s})}$	-2.87
$\text{Na}^+_{(\text{aq})} + \text{e}^- \rightarrow \text{Na}_{(\text{s})}$	-2.71
$\text{Mg}^{2+}_{(\text{aq})} + 2\text{e}^- \rightarrow \text{Mg}_{(\text{s})}$	-2.37
$\text{Al}^{3+}_{(\text{aq})} + 3\text{e}^- \rightarrow \text{Al}_{(\text{s})}$	-1.66
$\text{Zn}^{2+}_{(\text{aq})} + 2\text{e}^- \rightarrow \text{Zn}_{(\text{s})}$	-0.76
$\text{Fe}^{2+}_{(\text{aq})} + 2\text{e}^- \rightarrow \text{Fe}_{(\text{s})}$	-0.44
$\text{Pb}^{2+}_{(\text{aq})} + 2\text{e}^- \rightarrow \text{Pb}_{(\text{s})}$	-0.13
$2\text{H}^+_{(\text{aq})} + 2\text{e}^- \rightarrow \text{H}_2$	0
$\text{Cu}^{2+}_{(\text{aq})} + 2\text{e}^- \rightarrow \text{Cu}_{(\text{s})}$	+0.34
$\text{Ag}^+_{(\text{aq})} + \text{e}^- \rightarrow \text{Ag}_{(\text{s})}$	+0.80
$\text{Au}^{3+}_{(\text{aq})} + 3\text{e}^- \rightarrow \text{Au}_{(\text{s})}$	+1.50

2.3 Galvanic cells

These consist of oxidation and reduction half cells where electrons produced during oxidation process is consumed or used up by reduction process.

2.3.1 Types of galvanic cells

- Macroscopic galvanic cells with electrolytes at one molar.

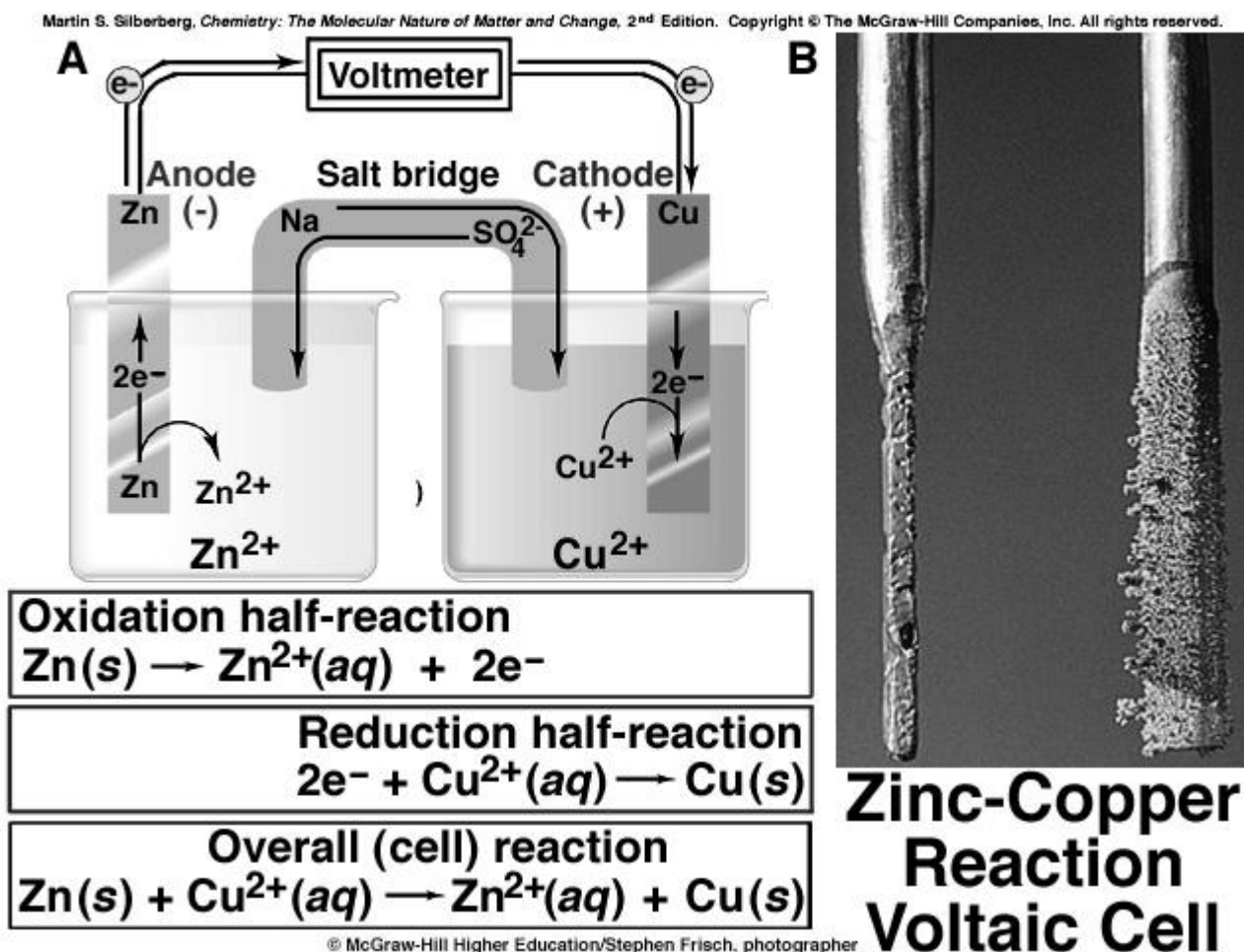


Figure 2.2: Macroscopic Galvanic Cells (www.citycollegiate.com)

The zinc metal and copper are in contact with 1M solution of their ions and forms the anode and cathode respectively (referred to figure 2.2A). Since Zinc is more reactive than copper, Zinc metal gradually get dissolved into solution (as shown in figure 2.2B) and the electrons generated during the oxidation process are carried to the copper electrode (cathode) through the wire conductor to reduce copper ions to metallic copper and get deposited on the cathode.

The overall electromotive force (emf) of the macroscopic galvanic cell is found as follows:

Oxidation half cell reaction E^0 value from table 1
 $Zn \rightarrow Zn^{2+} + 2e^-$ +0.76volt(v) for oxidation reaction
 Reduction half cell reaction
 $Cu^{2+} + 2e^- \rightarrow Cu$ +0.34v
 Thus, emf of the cell is $(+0.76) + (0.34) = 1.1v$

- Galvanic cells with electrolytes not at one molar.

Here since the concentration of the electrolyte is not 1molar, electrodes potentials are no more standard and can be determined using Nerst equation, which is written as:

$$E = E^0 + \frac{0.0592}{n} \log C_{ion} \dots \dots \dots (2.1)$$

Where E=new emf of half cells

E^0 =Standard emf of half cell

n=number of electrons transferred (for example $M \rightarrow M^{n+} + ne^-$)

C_{ion} =molar concentration of ions (Callister,1997).

- Galvanic cells with acid or alkaline electrolytes with no metal ions present.
- Microscopic galvanic cell corrosion of single electrodes
- Concentration galvanic cell
- Galvanic cells created by differences in composition, structure, and stress.

2.4 Corrosion Rates

The corrosion rate or rate of material removal as a consequence of the chemical action is an important corrosion parameter. This may be expressed as corrosion penetration rate (CPR), or the thickness lost of material per unit of time. The formula for this calculation is (Callister, 1997)

$$CPR = \frac{KW}{\rho At} \dots \dots \dots (2.2)$$

Where K (constant) = 87.6

W is the weight lost given in milligrams (mg)

ρ is the density given in grams per cubic centimetre(g/cm^3)

A the surface area of the sample in square centimetre (cm^2)

t is time given in hours

CPR is in millimetres per year (mm/yr) (Callister, 1997)

Inasmuch as there is an electric current associated with electrochemical corrosion reactions, we can also express corrosion rate in terms of this current, or more specifically, current density-that is current per unit surface area of material corroding which is represented as i . The rate r , in units of $\text{mol/m}^2\text{s}$ is determined using the expression (Callister,1997):

$$r = \left(\frac{i}{nF} \right) \dots \dots \dots (2.3)$$

where again n is the number of electrons associated with the ionization of each metal atom and F is $96,500 \text{ C/mol}$ (callister,1997).

2.5 Polarization

The displacement of each electrode potential from its equilibrium value is termed polarization,and the magnitude of this displacement is the over-voltage normally represented by the symbol η . Over-voltage is expressed in terms of plus or minus volts (or milli volts) relative to the equilibrium potentials. Basically, there are two types of polarization ,these are (Callister,1997):

- Activation polarization : This can be experienced during oxidation and reduction reactions and its overvoltage is given thus

$$\eta_{a=+} \text{ or- } \beta \log\left(\frac{i}{i_0}\right) \dots \dots \dots (2.4)$$

where i_0 and β are constants for given half –cell.

- Concentration polarization: This exists when the reaction rate is limited by diffusion in the solution and is only experienced during reduction reaction.

2.6 Passivity

Some normally active metals and alloys, under particular environmental conditions, lose their chemical reactivity and become extremely inert. This phenomenon, termed passivity, is displayed by chromium, iron, nickel, titanium, and many of their alloys. It is felt that this passive behaviour results from the formation of highly adherent and very thin oxide film on the metal surface, which serves as protective barrier to further corrosion (Callister,1997).

2.7 Forms of corrosion

2.7.1 Uniform or general attack corrosion

Uniform corrosion attack is characterized by an electrochemical or chemical reaction that proceeds uniformly on the entire metal surface exposed to the corrosive environment. However it is relatively easy to control by (1) protective coatings (2) inhibitors (3) cathodic protection (Bartel, 2008).

2.7.2 Galvanic or two metal corrosion

Galvanic corrosion is corrosion between dissimilar metals and has been discussed in section 2.3.1. Care must be taken in attaching dissimilar metals together because the difference in their electrochemical potential can lead to corrosion. Galvanized steel, which is steel coated with zinc, is an example where one metal (zinc) is sacrificed to protect the other (iron). The zinc that is hot-dipped or electroplated on the steel is anodic to the steel, and hence corrodes and protects steel, which is the cathode in this galvanic cell.

An important consideration in galvanic two-metal corrosion is the ratio of the cathodic to anodic areas. This is called the area effect. An unfavourable cathodic –anodic area ratio consists of a large cathodic area and a small anodic area. With certain amount of current flow to the metal couple, such as copper and iron electrodes of different sizes, the current density is greater for the smaller electrode than for the larger one. Thus, the smaller anodic

electrode will corrode much faster. Hence, a large cathode area to a small anode area ratio should be avoided (Bartel, 2008).

2.7.3 Pitting corrosion

Pitting is a form of localized corrosive attack that produces holes or pits in a metal. This form of corrosion is very destructive for engineering structures, it causes perforation of the metal. However, if perforation does not occur, minimum pitting is sometimes acceptable in engineering equipment. Pitting usually requires an initiation period, but once started, the pits grow at an ever increasing rate. Most pits develop and grow in the direction of gravity and on the lower surfaces of engineering equipment.

Pits are initiated at places where local increases in corrosion rates occur. Inclusions, other structural heterogeneities, and compositional heterogeneities on the metal surface are common places where pits initiate. Differences in ion and oxygen concentrations create concentration cells that can also initiate pits.

To avoid pitting corrosion in the design of engineering equipment, materials that do not have pitting –corrosion tendencies should be used. However, if this is not possible for some designs, then materials with the best corrosion resistance must be used (Bartel,2008).

2.7.4. Crevice corrosion

Crevice corrosion is a form of localized electrochemical corrosion that can occur in crevices and under shielded surfaces where stagnant solutions can exist. Crevice corrosion is of engineering importance when it occurs under gaskets, rivets, and bolts between valve disks and seats, under porous deposits, and in many other similar situations. Crevice corrosion occurs in many alloy systems such as stainless steels and titanium, aluminium and copper

alloys. For crevice corrosion to occur, a crevice must be wide enough to allow liquid to enter but narrow enough to keep the liquid stagnant.(Bartel, 2008).

To prevent or minimize crevice corrosion in engineering designs, the following methods and procedures can be used:

1. Use sound welded butt joints instead of riveted or bolted ones in engineering structures.
2. Design vessels for complete drainage where stagnant solutions may accumulate.
3. Use nonabsorbent gaskets such as Teflon, if possible (Bartel, 2008).

2.7.5 Intergranular corrosion

Intergranular corrosion is a localized corrosion attack at and /or adjacent to the grain boundaries of an alloy. Under ordinary conditions if a metal corrodes uniformly, the grain boundaries will only be slightly more reactive than the matrix.

However, under other conditions, the grain boundary regions can be very reactive, resulting in intergranular corrosion that causes loss of strength of the alloy and even disintegration at grain boundaries.

For example, many high- strength aluminium alloys and some copper alloys that have precipitated phases for strengthening are susceptible to intergranular corrosion under certain conditions. However, one of the most important examples of intergranular corrosion occurs in some austenitic (18% Cr-8%Ni) stainless steels that are heated into or slowly cooled through the 500 to 800⁰C temperature range. In this so- called sensitizing temperature range, chromium carbides ($Cr_{23}C_6$) can precipitate at the grain boundary interfaces (Bartel, 2008).

If an 18%Cr-8%Ni austenitic stainless steel contains more than about 0.02wt % carbon, chromium carbides ($Cr_{23}C_6$) can precipitate at the grain boundaries of the alloy if heated in the 500 to 800⁰C range for a long time. Type 304 is an austenitic stainless steel with 18%Cr-8%Ni and between 0.06 and 0.08 wt % carbon. Hence this alloy, if heated in the 500

to 800⁰C range for a sufficient time, will be put into the sensitized condition and be susceptible to intergranular corrosion. When the chromium carbides form at grain boundaries, they deplete the regions adjacent to the boundaries of chromium so that chromium levels in these areas decreases below the 12% chromium level necessary for passive or stainless behaviour. Failures of welds made with type 304 stainless steel or similar alloys can occur by the same chromium carbide precipitation mechanism as previously explained. This type of weld failure is called weld decay.

Intergranular corrosion of austenitic stainless steel can be control as follows:

1. Use high- temperature solution heat treatment after welding. By heating the welded joint at 500 to 800⁰C followed by water quenching, the chromium carbides can be redissolved and returned to solid solution.
2. Add element that can combine with the carbon in the steel so that chromium carbides cannot form. Columbium and titanium additions in alloy type 347 and 321 respectively, are used. These elements have greater for carbon than chromium. Alloys with Ti or Cb additions are said to be in the stabilized condition.
3. Lower the carbon content to about 0.03wt % or less so that significant amount of chromium carbides cannot be precipitated (Bartel, 2008).

2.7.6 Stress corrosion

Stress-corrosion cracking (SCC) of metals refers to cracking caused by the combined effects of tensile stress and a specific corrosion environment acting on the metal. During SCC the metal's surface is usually attacked very little while highly localized cracks propagate through the metal section. The stresses that cause SCC can be residual or applied. High residual stresses that SCC may result, for example, from thermal stresses introduced by

unequal cooling rates, poor mechanical design for stresses, phase transformations during heat treatment, cold working and welding. Only certain combinations of alloys and environment will cause SCC. For example, stainless steels crack in chloride environments but not in ammonia.

Containing once, in contrast, brasses (Cu-Zn alloys) crack in ammonia-containing environments but not in chloride ones. New combinations of alloys and environments that cause SCC are continually being discovered (Bartel, 2008).

Prevention of stress-corrosion cracking:

1. Lower the stress of the alloy below that which causes cracking. This may be done by lowering the stress on the alloy or by giving the material a stress-relief anneal. Plain- carbon steels can be stress-relieved at 600 to 650⁰C and austenitic stainless steels can be stress-relieved in the range 815 to 925⁰C.
2. Eliminate the detrimental environment.
3. Change if neither environment nor stress level can be changed. For example, use titanium instead of stainless steel for heat exchangers in contact with seawater.

2.7.7 Erosion corrosion

Erosion corrosion can be defined as the acceleration in the rate of corrosion attack in a metal due to the relative motion of a corrosive fluid and a metal surface. When the relative motion of corrosive fluid is rapid, the effects of mechanical wear and abrasion can be severe. Erosion corrosion is characterized by the appearance on the metal surface of grooves, valleys, pits, rounded holes, and other metal surface damage configurations that usually occur in the direction of the flow of the corrosive fluid (Bartel, 2008).

2.7.8 Selective leaching

Selective leaching is the preferential removal of one element of a solid alloy by a corrosion processes. The most common example of this type of corrosion is the

dezincification in which the selective leaching of zinc from copper in brasses occurs. Similar processes also occur in other alloy systems such as the loss of nickel, tin, and chromium from copper alloys, iron from cast iron, nickel from alloy steel, and cobalt from satellite. In the dezincification of a 70% Cu-30% Zn brass, for example, the zinc is preferentially removed from the brass, leaving a spongy, weak matrix of copper. The mechanism of dezincification involves the following three steps.

1. Copper and zinc are dissolved by aqueous solution.
2. Copper ions are replanted on brass
3. Zinc ions remain in the solution.

Since the copper remaining does not have the strength of the brass, the strength of the alloy is lowered.

Dezincification can be minimized or prevented by changing to a brass with a lower zinc content (that is 85%Cu-15% Zn brass) or to a cupronickel(70 to 90%Cu-10 to 30% Ni). Other possibilities are to change the corrosive environment or use cathodic protection (Bartel, 2008).

2.7.9 Cavitation damage

This type of corrosion is caused by the formation and collapse of air bubbles or vapor-filled cavities in a liquid near a metal surface. Cavitation damage occurs at the metal surfaces where high-velocity liquid flow and pressure changes exist such as encountered with pump impellers and ship propellers. Calculations indicate that rapidly collapsing vapour bubbles can produce localized pressures as high as $4.1 \times 10^8 \text{N/m}^2$. With repeated collapsing vapor bubbles, considerable damage to a metal surface can be done (Bartel, 2008).

2.7.10 Fretting corrosion

Fretting corrosion occurs at interfaces between materials under load subjected to vibration and slip .Fretting corrosion appears as grooves or pits surrounded by corrosion

products. In the case of the fretting corrosion of metals, metal fragments between the rubbing surfaces are oxidized and some oxide films are torn loose by the wearing action. As a result, there is accumulation of oxide particles that act as abrasives between the rubbing surfaces. Fretting corrosion commonly occurs between tight-fitting surfaces such as those found between shafts and bearings or sleeves (Bartel, 2008).

2.8 Methods of corrosion control

There are five primary methods of corrosion control:

- Material selection
- Coatings
- Inhibitors
- Cathodic protection
- Design

2.8.1 Material selection

Each metal and alloy has unique and inherent corrosion behaviour that can range from the high resistance of noble metals like gold and platinum, to the low corrosion resistance of active metals, for example, sodium and magnesium. Furthermore, the corrosion resistance of a metal strongly depends on the environment to which it is exposed, that is, the chemical composition, temperature, velocity, and so forth.

The general relation between the rate of corrosion, the corrosivity of the environment, and the corrosion resistance of a material is:

$$\frac{\text{Corrosivity of environment}}{\text{Corrosion resistance of metal}} = \text{rate of corrosive attack} \dots\dots\dots(2.5)$$

For a given corrosion resistance of the material, as the corrosivity of the environment increases, the rate of corrosion increases. For a given corrosivity of the environment, as the corrosion resistance of the material increases, the rate of corrosion decreases. Often an

acceptable rate of corrosion is fixed and the challenge is to match the corrosion resistance of the material and the corrosivity of the environment to be at or below the specified corrosion rate. Often there are several competing materials that can meet the corrosion requirements, and the material selection process becomes one of determining which of the selected materials provides the most economical solution for the particular service. Consideration of corrosion resistance is often as important in the selection process as the mechanical properties of the alloy. A common solution to a corrosion problem is to substitute an alloy with greater corrosion resistance for the alloy that has corroded.

2.8.2 Coatings

Coatings for corrosion protection can be divided into two broad groups - metallic and nonmetallic (organic and inorganic). With either type of coating, the intent is the same, that is, to isolate the underlying metal from the corrosive media.

i Metallic Coatings: The concept of applying a more noble metal coating on an active metal takes advantage of the greater corrosive resistance of the noble metal. An example of this application is tin-plated steel. Alternatively, a more active metal can be applied, and in this case the coating corrodes preferentially, or sacrificially, to the substrate. An example of this system is galvanized steel, where the sacrificial zinc coating corrodes preferentially and protects the steel.

ii Organic Coatings: The primary function of organic coatings in corrosion protection is to isolate the metal from the corrosive environment. In addition to forming a barrier layer to stifle corrosion, the organic coating can contain corrosion inhibitors. Many organic coating formulations exist, as do a variety of application processes to choose from for a given product or service.

iii Inorganic coatings include porcelain enamels, chemical-setting silicate cement linings, glass coatings and linings, and other corrosion resistant ceramics. Like organic coatings,

inorganic coatings for corrosion applications serve as barrier coatings. Some ceramic coatings, such as carbides and silicides, are used for wear-resistant and heat resistant applications, respectively.

2.8.3 Inhibitors

A corrosion inhibitor is a chemical compound that, when added to a liquid or gas, decreases the corrosion rate of a material, typically a metal or an alloy. They can be classified basically as follows:

(a) Passivating (anodic) inhibitors

Passivating inhibitors cause a large anodic shift of the corrosion potential, forcing the metallic surface into the passivation range. There are two types of passivating inhibitors: oxidizing anions, such as chromate, nitrite, and nitrate that can passivate steel in the absence of oxygen and the non-oxidizing ions, 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.

(b) Cathodic inhibitors

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 : (1) as cathodic poisons, (2) as cathodic precipitates, and (3) as oxygen scavengers. Some cathodic inhibitors, 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 oxides to form a protective layer on the metal. Oxygen scavengers help to inhibit corrosion by preventing the cathodic

depolarization caused by oxygen. The most commonly used oxygen scavenger at ambient temperature is probably sodium sulphate (Na_2SO_4).

(C) Organic inhibitors

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, usually designated as *film-forming*, protect the metal by forming a hydrophobic film on the metal surface. Their effectiveness depends on the chemical composition, their 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.

(d). Precipitation inhibitors

Precipitation-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 the phosphate.

(e). Volatile corrosion inhibitors.

Volatile corrosion inhibitors (VCIs), also called vapour phase inhibitors (VPIs), 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 or hydrazine, are transported with steam to prevent corrosion in condenser tubes by neutralizing acidic carbon dioxide or by shifting surface pH toward less acidic and corrosive values. In closed vapour

spaces, such as shipping containers, volatile solids such as salts of dicyclohexylamine, cyclohexylamine, and hexamethylene-amine are used.

2.8.4 Cathodic protection

Cathodic protection suppresses the corrosion current that causes damage in a corrosion cell and forces the current to flow to the metal structure to be protected. Thus, the corrosion or metal dissolution is prevented. In practice, cathodic protection can be achieved by two application methods, which differ based on the source of the protective current. An impressed-current system uses a power source to force current from inert anodes to the structure to be protected. A sacrificial-anode system uses active metal anodes, for example, zinc or magnesium, which are connected to the structure to provide the cathodic-protection current.

2.8.5. Design

The application of rational design principles can eliminate many corrosion problems and greatly reduce the time and cost associated with corrosion maintenance and repair. Corrosion often occurs in dead spaces or crevices where the corrosive medium becomes more corrosive. These areas can be eliminated or minimized in the design process. Where stress-corrosion cracking is possible, the components can be designed to operate at stress levels below the threshold stress for cracking.

Where corrosion damage is anticipated, design can provide for maximum interchangeability of critical components and standardization of components. Interchangeability and part standardization reduce the inventory of parts required. Maintenance and repair can be anticipated, and easy access can be provided. Furthermore, for the large items that are critical to the entire operation, such as primary pumps or large fans, redundant equipment is installed to permit maintenance on one unit while the other is operating. These practices are a sampling of rational design principles.

2.9 Locust bean tree

Locust bean tree is one of the important trees found in Nigeria, particularly in the northern region. The tree is also extremely hard; it is well suited to a wide range of soils, it survives fires, thrives in semiarid tropical climates, and has a low susceptibility to pests and diseases. The tree has a wide-reaching crown and can grow more than 20 metres tall. Often, people climb all the way to the top to pick the fruit – long pods, containing small seeds and a sweet edible pulp, that can grow as long as your forearm.



Plate: 2.1 *Parkia biglobosa* pods.



Plate: 2.2 *Parkia biglobosa* leaves



Plate: 2.3 Parkia biglobosa stem bark



Plate:2.4 Parkia biglobosa roots

The sugary pulp can be eaten raw, used in traditional sweet-meats or mixed with water to make a refreshing drink. Given its sweet taste, children love it, and because it keeps well for days, it is also popular among travelers.

While the pulp makes for a good energy snack, the seeds are the plant's most sought after product. Rich in protein, starch, fibre, sugar, and fat, as well as vitamins and minerals, such as calcium and iron, the seeds are about as nutritionally balanced a food as you can find.

The seeds are famous for their greasy extract, which is fermented and pressed into cakes or balls, known in West Africa as Dawadawa. It has a pungent odor, often compared to that of aged cheese, and is used as a condiment or an ingredient for soup .

2.10 Mild steel

Steel is any alloy of iron, and carbon consisting of 0.2% to 2.1% of carbon, as a hardening agent. Besides carbon, many other metals are a part of it. They include chromium, manganese, tungsten and vanadium. Other than a maximum limit of 2% carbon in the manufacture of carbon steel, the proportions of manganese (1.65%), copper (0.6%) and silicon (0.6%) are fixed, while the proportions of cobalt, chromium, niobium, molybdenum, titanium, nickel, tungsten, vanadium and zirconium are not.

2.10.1 Mechanical properties of carbon steels

Many materials when in service, are subjected to forces or loads; an example include the steel in an automobile axle and pressured vessels. In such situations, it is necessary to know the characteristics of the material and to design the member from which it is made, such that any resulting deformation will not be excessive for fracture to occur. The mechanical behaviour of a material reflects the relationship between its response or deformation to an applied load or force. Important mechanical properties are tensile strength, hardness, ductility and stiffness.

The mechanical properties of materials are ascertained by performing carefully designed laboratory experiments that replicate as nearly as possible the service conditions. Factors to be considered include the nature of the applied load and its duration, as well as the environmental conditions (Callister, 1997).

2.10.2 Application of mild steels

Among the carbon steels, low carbon steel which contains approximately 0.05–0.15% carbon is used in making presses and mild steels that contains 0.16–0.29% carbon, are usually used in manufacturing of vehicles, domestic goods, constructional steel, street signs, fence posts, wire, plate, tin cans, key rings almost anything you can think of. Shown in plate 2.5 are some of the mild steel products.



(a) Vehicle bodies



(b) Structural steels



(c) Rods



(d) Fence



(e) Pipes.

Plate 2.5: Applications of mild steel

2.11. Adsorption on solid surfaces

Adsorption is a phenomenon whereby a solid surface is covered by a thin film of atoms or molecules from solid or liquid or gaseous substances from its environment. Even the most carefully polished surfaces are not smooth in a microscopic sense, but are irregular, with valleys and peaks alternating over the area. The regions of irregularity are particularly susceptible to residual electrostatic force fields (Smith, 1967). At these locations, the surface atoms of the solid may attract atoms or molecules in the surrounding gas or liquid phase.

2.11.1 Types of adsorption

(a)Physical adsorption:This type of adsorption is non-specific and somewhat similar to the process of condensation.The forces attracting the molecules to the solid surface are relatively weak, and the heat evolved during the adsorption process is of the same order of magnitude as the heat of condensation, 0.5 to 5kcal/g mole.

(b)Chemisorption:The second type of adsorption is specific and involve forces much stronger than in physical adsorption.

2.12. Chemical thermodynamics

In its broader sense, thermodynamics is the science which deals with transformations of energy of all kinds from one form to another during physical and chemical changes(Smith and Van ness, 1975). Shown are some thermodynamics relationships:

$$(i) \quad \Delta U=Q-W \dots\dots\dots(2.6)$$

where ΔU is the change in the internal energy of a system

Q is the heat taken in by the system

W is the work done by the system on the surrounding

$$(ii) \quad \Delta H=\Delta U+P\Delta V \dots\dots\dots(2.7)$$

ΔH is the change in enthalpy(heat content) of a body

ΔV is change in the volume of the system

ΔU is change in the internal energy

P is pressure of the system

(iii) $\Delta G = \Delta H - T\Delta S$ (2.8)

where

ΔG is free energy change of the system

T is absolute temperature of the system

ΔS is change in entropy of the system

2.13 Review of related works

Loto et al (2011) investigated corrosion inhibition of Kola plant and tobacco extracts on mild steel in HCl, at ambient temperature by gravimetric and metallographic methods, and they discovered that tobacco extracts are better inhibitors than Kola leave extract.

Al-Otaibi et al (2012) examined the corrosion inhibitions of alcoholic extracts of eight plants, namely: *Lycium shawii*, *Teucrium oliverianum*, *Ochradenus baccatus*, *Anvillea garcinii*, *Cassia italica*, *Artemisia sieberi*, *Carthamus tinctorius* and *Tripleurospermum auriculatum*, grown in Saudi Arabia, were studied for their corrosion inhibitive effect on mild steel in 0.5 M HCl media using the open circuit potential (OCP), Tafel plots and A.C. impedance methods .The results of the experiment showed the plant extracts inhibited corrosion of mild steel in acidic media through adsorption and act as mixed-type inhibitors.

Olasehinde et al (2013) studied inhibitory action of *Nicotiana tabacum* extracts on the corrosion of mild steel in HCl by adsorption and thermodynamics methods and reached the following conclusions:

- The inhibition efficiency was markedly higher on the addition of *Nicotiana tabacum* leaves extracts in acidic medium compared with those in the absence of inhibitor.
- The inhibition efficiency increased with an increase in inhibitor concentration but decreased with rise in temperature and exposure time.
- Thermodynamics studies revealed that corrosion inhibition may be due to the spontaneous physical adsorption of the plant constituents on the surface of mild steel.
- Experimental data fitted with the Langmuir and Temkin adsorption isotherms. Kinetic treatment of the data followed a first order reaction.

Patel et al (2009), experimented on the corrosion inhibition of mild steel in 1M sulphuric acid by leaves extract of *Bauhinia purpurea* and were able to reveal that:

- The active molecules present in the extract of *Bauhinia purpurea* leaves have effectively inhibited corrosion of mild steel in 1 M H₂SO₄ at various temperatures by forming a protective barrier layer. It adsorbs on the steel surface according to the modified Langmuir adsorption isotherm. The inhibition efficiency of the extract increased gradually with increases in its concentration.
- Polarization measurements have shown that the extract of *Bauhinia purpurea* leaves has acted as a mixed inhibitor, retarding predominantly anodic dissolution of steel in 1M H₂ SO₄.
- The results of the EIS show that inhibition efficiency increases with the concentration to attain a maximum value of 96% at 200 ppm.
- The inhibition efficiency of the extract decreases marginally with the rise of the temperature.

Al-sultani et al (2013), researched the corrosion inhibition of spearmint plant extract on low carbon steel in 3.5% NaCl solution at constant temperature and discovered that weight loss decreases as the inhibitor concentration increases.

Rahbar and Zakeri (2010), investigated the effect of 20% salt(NaCl) solution on the mechanical and corrosion resistance of normal and high strength steels and discovered that the ultimate strength of steels are reduced.

Al-Turkustani et al (2010), investigated the corrosion inhibition of Zizyphus Spina-Christi(**ZSC**) as green inhibitor on mild steel in 1M H₂SO₄, using the gravimetric and electrochemical studies, and revealed that the effect of acid concentration on the corrosion rate of mild steel increases with acid concentration (0.25-1.5) M, showing first order corrosion reaction without changing the reaction mechanism. The results showed that when the concentration of **ZSC** extracts (aqueous extract and alcoholic extract) increased, the rate of steel corrosion is decreased, which indicates that the inhibition of the corrosion process is produced. Electrochemical impedance spectroscopy results showed that the corrosion and corrosion inhibition of steel occurred mainly by charge transfer. The electrochemical results of polarization also showed that the extracts of **ZSC** plant act as mixed type inhibitors; they retarded both cathodic and anodic reaction.

Yawas (2005), assessed the suitability of locust bean pods extract as corrosion inhibitor of mild steel in both hydrochloric and sulphuric acid media, and established that it is good inhibitor from room temperature up to 80⁰C.

Indepth studies on the use of different parts of locust beans tree have not been done, hence this work is designed to fill in this gap.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Materials

The following materials were used in the research:

- i. Shimadzu Optical Emission Spectrometer: For determining the elemental composition of the mild steel bar.
Manufacturer: Shimadzu Model:PDA 5000
- ii. Sartorius Analytical Digital weighing machine: used for measuring masses of samples.
Manufacturer:Sartorius Model:ED2245 Capacity:220grams
Precision:0.0001gram.
- iii. Phenom proX Scanning Electron Microscope(SEM): For taking the photomicrographs of the samples.
Manufacturer:Phenom world Eindhoven Model:ProX Capacity:5V-15V
Precision: 10^{-9} metre.
- iv. Indentec Universal Hardness Testing machine.
Manufacturer:Indentec Model:8187.5LKV(B) Capacity:10kgF-100kgF
Precision:0.1 Rockwell HRB.
- v. Monsanto Tensometer Tensile Testing machine.
Manufacturer:Monsanto Model: type W Capacity:20KN Precision: 0.05KN
- vi. Izod Impact Testing machine.
Manufacturer:W. & .T. Avery LTD Birmingham Model:670I Capacity:163Joules
Precision:0.1Joules
- vii. Water-Bath
Manufacturer: Grants instrument Model:JB2 Capacity: 90⁰C Precision:10⁰C

- viii Mechanical shaker
 Manufacturer :Stuart Scientific Model:Flash shaker SF1 Capacity: 10 oscillations
 per seconds Precision: 1 oscillation per second.
- ix Hot plate
 Manufacturer: Gallingham Capacity : 100⁰C Precision 10⁰C
- x Electric oven
 Manufacturer: Fisher scientific Model: Isotemp oven Capacity: 0⁰C – 220⁰C
 Precision: 10⁰C
- xi PH meter
 Manufacturer: Fisher Scientific Model :accumet Capacity: 14.00 precision: 0.01
- xii Metric rule and Vernier calliper: For dimensioning of the sample.
- xiii Forty 250ml and one 1000ml glass beakers: Used for containing various media for
 experimentation and preparation of standard solution.
- xiv One 1000ml measuring glass cylinder. Used for preparing standard solution.
- xv 2 Glass funnels.
- xvi Hacksaw: used to cut the steel bar into required dimensions.
- xvii 4 each of 320,600 and 800 grits silicon carbide paper.
- xviii One 360 degree celsius glass thermometer for temperature measurement.
- xix 11mm diameter mild steel bar of 40 metre total length
- xx 98% sulphuric acids 3.5 litres
- xxi Distilled water 250 litres
- xxii Acetone 3.5 litres
- xxiii Ethanol 3.5 litres
- xxiv Thread 500 metres
- xxv plant parts(pods, leaves, stembark and root)

- xxvi Salt (Nacl) 1kg
- xxvii Wire-brush 20 pieces
- xxviii Pistle and Mortar
- xxix Nickel crucible 1 piece
- xxx Desiccator 1 piece
- xxxi Dilute hydrochloric acid 250ml
- xxxii Filter paper 10 pieces
- xxxiii 250ml stopped conical flask 1
- xxxiv 1 Flat-bottomed evaporating dish
- xxxv Fehling solution 100ml
- xxxvi 20% KOH 100ml
- xxxvii Ferric chloride 100ml
- xxxviii Acetic acid anhydride 100ml
- xxxix 10% NaOH 100ml
- xl Mayer's reagent 100ml
- xli Chrome hide powder 200g
- xlii Barium chloride 100g

3.2 Methods

3.2.1 Elemental Composition Determination

The steel bars were bought locally in Zaria township..

The elemental analysis of the steel bar was carried out at Defence Industry Coporation of Nigeria (DICON) Kaduna, using Shimadzu Optical Emission Spectrometer (OES).

Procedure:

The steel sample was cut to the desired size and the circular cross-section to be arc in the machine was ground to remove scales, rust, dirt. It was then placed in the sample-chamber and firmly held in position by a clamp. When the sample-chamber was closed, a button was pressed to start generating the electric arc between the in-built electrode of the machine and the sample surface and after 20 seconds, result of the analysis was displayed on screen of a computer connected to the machine and hard copy was obtained from the printer of the machine.

3.2.2 Sample preparation

The steel bar was cut into pieces of length 55mm and diameter 11mm with a hack saw and then, machined to the dimensions shown in Figure 3.1. Samples were wire-brushed to remove rusts, then ground, using successive grades of silicon carbide paper of 320, 600, and 800 grits (Loto et al, 2001). Each coupon was washed thoroughly with distilled water and degreased with ethanol and acetone, and then air dried. Accurate weights of the samples were determined using a Sartorius analytical weighing balance at the Multi-user Research Laboratory of Chemistry Department, Ahmadu Bello University (A B U), Zaria.

3.2.3 Surface Area Determination of Tensile Test sample

Dimensions of the sample was evaluated with the aid of vernier calliper and metre rule. The total surface area of the sample was determined using equation 3.1.

$$\text{Total surface area of the sample } A = 2\left[2\pi\frac{D^2}{4} + \pi D l - \pi\frac{d^2}{4}\right] + \pi d L \dots\dots\dots (3.1)$$

Where $\pi = \pi$ (constant) $\approx 22/7$

$$D = 11\text{mm}$$

$$d = 5\text{mm}$$

$$L = 35\text{mm}$$

$$l = 10\text{mm}$$

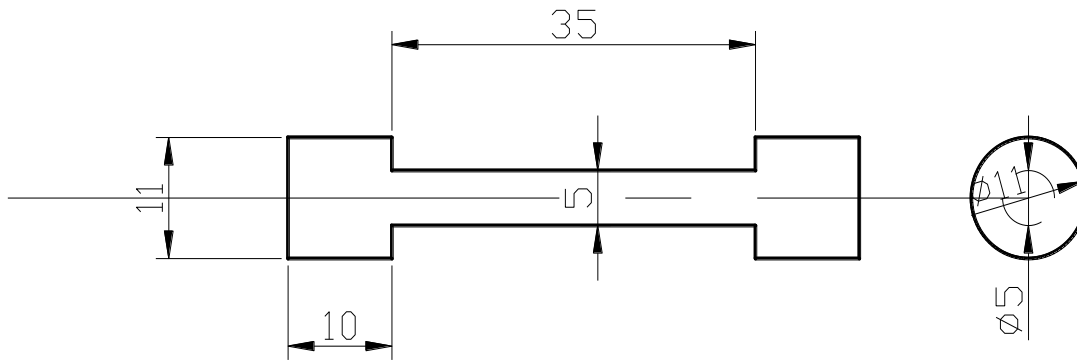


Figure 3.1:Standard(ASTM) Carbon Steel Specimen for Tensile Test(Dimensions in mm)

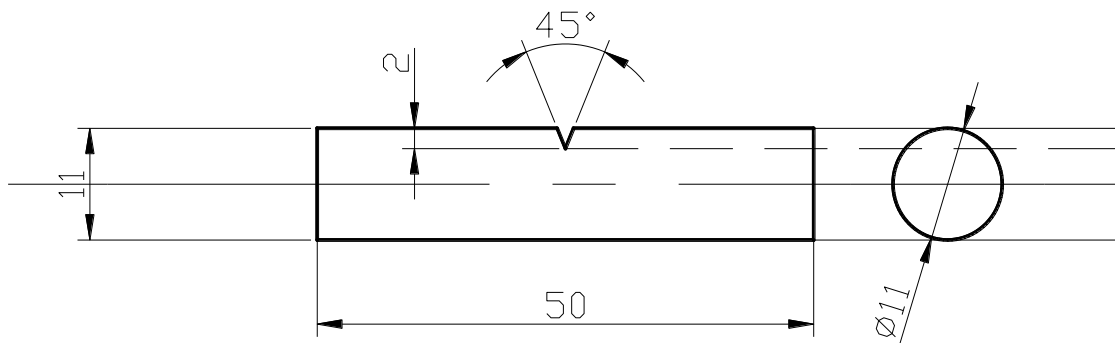


Figure 3.2:Standard Impact Test Specimen(Dimensions in mm).

3.2.4 Density Determination

Density (ρ) of the sample was calculated from equation 3.2 given as:

$$\rho = \frac{\text{mass of the sample in grams(g)}}{\text{volume of the sample in centimetre cube(cm}^3\text{)}} \dots\dots\dots(3.2)$$

$$\text{volume of sample} = 2\left[\pi\frac{D^2}{4}l\right] + \pi\frac{d^2}{4}L \dots\dots\dots(3.3)$$

Where D = 11mm
d = 5mm
l = 10mm
L = 35mm

3.2.5 Collection, Identification, Preparation, Physio-chemical analysis and Extraction of phytoconstituents of the plant parts.

The pods, leaves, stembark and roots of the African locust bean tree (*Parkia biglobosa*) were collected from uncultivated field in A.B.U. staff residential areas of Samaru Zaria.The

plant was indentified in the Department of Biological sciences of Ahmadu Bello University, Zaria. The plant parts were sun-dried and then pounded into powder, using pistle and mortar.

Physio-chemical analyses of the plant parts were carried out in the Department of Pharmacognosy in Faculty of Pharmaceutical Sciences, A.B.U., Zaria, using standardized procedures as obtainable in Brain and Tuner (1975) and Evans (1989).

Physio-chemical analyses procedures:

(a) Determination of ash value

- i Heat was applied to a nickel crucible at 105⁰C to a constant weight and its accurate weight was noted, then cooled and stored in a desiccator.
- ii About 2g of the powdered plant part (each of pod, leaves, stembark and root) was accurately weighed out into the crucible
- iii The crucible was heated with its content gently until it is moisture-free and is completely charred.
- iv The heat was increased gradually until most of the carbon (black residue) vapourised and finally heated strongly until the residue was free from carbon (almost white).
- v The crucible was cooled and weighed.
- vi Heating and cooling was continued until the weight of the residue (ash) was constant.
- vii The weight of the (ash) was evaluated by subtracting the weight of the crucible from the final weight (weight of the crucible and residue or ash).
- viii The ash value (in percentage) of the powdered plant part was calculated with reference to its initial weight.

(b) Determination of acid-insoluble Ash Value

- i The crucible with the ash from the above experiment was transferred to a beaker containing 25ml dilute hydrochloric acid.
- ii It was boiled for five minutes and filtered through an ash-less filter paper.
- iii Beaker and crucible were washed with water and passed the washings through the filter paper.
- iv The washing was repeated for three times, every-time passing the washings through the filter paper in a manner so that the residue was collected in the tip of the cone of the filter.
- v The funnel along with the filter paper was dried in an oven at 105⁰C.
- vi The weight of a clean and heated nickel crucible was accurately determined.
- vii The filter paper with the residue (step v) was folded into a small cone and transfer it to the charred crucible (step vi).
- viii The crucible was heated gently until the filter paper is completely charred then heated strongly for a few minutes.
- ix The crucible was cooled and weighed with its content and the final total weight noted.
- x The weight of the residue was calculated (the acid insoluble ash) by subtracting the weight of the crucible from the final weight(step 6).
- xi Acid-insoluble ash value (in percentage) was found with reference to the initial weight of the powdered plant part (in previous experiment).

(c) **Alcohol-soluble extractive value**

- i About 5g of the powdered plant part was accurately weighed out into a 250ml stopped conical flask.
- ii 100 ml of 90% ethanol was added and the stopper replaced firmly.

iii The flask was shaken on a mechanical shaker for 6 hours and then allowed for 18 hours.

iv The extract was quickly filter.

v Accurate weight of a clean and heated flat-bottomed evaporating dish was determined

vi 20ml of the filtrate (step iv) was taken into the charred evaporating dish (step v).

viiThe filtrate was evaporated to dryness on a hot plate.

viii The residue was dried to constant weight at 105⁰C in an oven and noted the final total weight.

ix Weight of the residue was obtained from the 20ml extract by subtracting the weight of the evaporating dish (step v) from the final weight (step viii).

x The alcohol-extractive value (in percentage) was calculated with reference to the initial weight of the powdered plant parts.

(d) Water-soluble extractive value

i The above procedure was repeated using chloroform-water (0.25% v/v chloroform in distilled water), in place of the ethanol as the extracting solvent.

ii Water-soluble extractive value was calculated in the same way as above.

To extract the phyto-constituents of the plant parts, 400grams of each powder of the pods, leaves, stembark and root were poured into four different separating funnels, and each soaked with 1litre of 70% ethanol, 30% distilled water and kept for three days so that the phyto-constituents would be extracted by leaching. The extracts were used in phyto-chemical analysis and the extractions were carried out in accordance to standard procedures as obtained in Brain and Tuner (1975) and Evans(1989).

Phyto- chemical screening procedures of extracts:

(a) Test for carbohydrates

Fehling Test:

To small portion of the extract in a test tube, 5ml of an equal mixture of Fehling solution A and B was added and boiled on a water bath, brick red precipitate was formed which indicates presence of reducing sugar.

(b) Test for Glycosides

To a portion of the extract, 5ml of dilute sulphuric acid was added and boiled on water bath for 10-15mins. This was then cooled and neutralized with 20% KOH. It was then divided into two portions.

- To the first portion, 5ml of a mixture of fehling's A and B was added and boiled; a brick red precipitate was seen which shows the presence of reducing sugars as a result of hydrolysis of Glycoside.
- To the second portion, about 3ml of Ferric chloride solution was added, a green to blue color was produced because of the release of phenolic aglycones due to the hydrolysis.

(c) Test for Steroid and Triterpenes

To a portion of the extract, equal volume of acetic acid anhydride was added and mixed gently. 1ml of concentrated sulphuric acid was added down the side of the test tube to form a lower layer. Colour changes were observed immediately and over a period of one hour. Blue to blue-green color in the upper layer was seen indicating the presence of steroid and a reddish, pink or purple color indicated the presence of triterpenes.

(d) Test for Saponin

Frothing Test:

About 10ml of distilled water was added to a portion of the extract and was shaken vigorously for 30 seconds. The tube was allowed to stand in a vertical position and was observed for 30mins. A honeycomb froth that persisted for 15mins was observed which shows presence of saponins.

(e) **Test for Tannins**

Ferric Chloride Test:

To a portion of the extract, 3-5 drops of ferric Chloride solution was added. A greenish-black precipitate indicated presence of condensed tannins while hydrolysable tannins gave a blue or brownish-blue precipitate.

(f) **Test for Flavonoids**

Sodium hydroxide Test:

Few drops of 10% sodium hydroxide were added to the extract. Yellow coloration was observed which indicates presence of flavonoid.

(g) **Test for Alkaloids**

Mayer's Test:

To a portion of the extract, few drops of Mayer's reagent were added. A cream precipitate was seen which indicates presence of alkaloids.

3.2.6. Quantitative Analysis of the plant parts

The powders of the plant parts were taken to the Nigerian Institute of Leather and Science Technology (NILEST), Zaria to quantitatively determine the following parameters using the standardized procedures (Society of Leather Trade's Chemist).

Parameters determined:

- (i) Moisture content of samples
- (ii) Total solids

- (iii) Total soluble
- (iv) Tannin contents
- (v) Non-tannin contents
- (vi) Total salts
- (vii) Total acids
- (vii) pH contents

Procedures:

(a) Determination of moisture content

2g of each pounded powdered sample was dried in an electric oven at 100⁰C for 1 hour and then cooled in the desiccators before reweighing. The process was continued until a constant weight was recorded.

$$\text{percentage moisture content} = \frac{(\text{weight of original sample} - \text{weight after drying}) \times 100\%}{\text{weight of original sample}} \dots(3.4)$$

(b) Determination of total soluble

The leached tannin was filtered with filter paper and the first 50ml discarded. The filtration was continued out of which 50ml was measured into an evaporating dish, heated on the water bath to dryness. The residue was dried in the oven at 100⁰C and then taken to the desiccators before reweighing. The process was continued to a constant weight.

$$\text{total soluble} = \frac{\text{weight of residue} \times 20 \times 100\%}{20} \dots\dots\dots(3.5)$$

(c) Determination of total solids

50ml of the leached tannin infusion was measured in a previously weighed evaporating dish over water bath and evaporated to dryness. The residue was further dried in an oven at 100⁰C for 1hour after which cooled in the desiccators before reweighing. The process was continued to a constant weight.

$$\text{weight of empty crucible} = w_1$$

weight of crucible + evaporated sample = w_2

weight of residue $R = w_2 - w_1$

weight of dried sample X

number of the residue in the leached infusion, Y

$$\text{percentage total solids} = \frac{R \times Y \times 100\%}{X} \dots\dots\dots(3.6)$$

(d) Determination of non-tannins content

6.25g of hide powder was weighed to a shake bottle containing 100ml of distilled water. It was then shaken vigorously by hand and then transferred to a mechanical shaker. The shaking was done for about 2 hours and 3mls of chrome alums added. It was then shaken again for one hour and allowed to stand overnight. The solution was shaken for 15 minutes after which it was washed with distilled water. The cake was poured into a conical flask containing 100mls of unfiltered tannin infusion plus 6.25g weight of washed chrome hide powder in distilled water. It was shaken and filtered using filter paper with 1g of kaolin added for quicker filtration. 50ml of the clear filtrate was evaporated in an evaporating dish of a known weight and dried in an oven at 100°C to constant weight.

weight of residue = R_g

number of the residue in the leached tannin infusion Y

weight of dried powdered sample used X

$$\text{percentage non tannin} = \frac{R_g \times 1.2 \times Y \times 100\%}{X} \dots\dots\dots(3.7)$$

(e) Determination of tannin content

The tannins content was determined by subtracting the non-tannin content from the total soluble.

Thus,

$$\text{percentage tannins} = \text{percentage total soluble} - \text{percentage non-tannin}$$

(f) Determination of total salt

50ml of the filtered tannin infusion was evaporated on the water bath, made ash and then boiled in 400ml of distilled water for about one hour on a water bath. 10ml of BaCl₂ solution was added and then heated again on a water bath. Then transferred to the oven and heated at 100⁰C to a constant weight.

$$\text{total salt} = \frac{\text{precipitate} \times 1000 \times 100\%}{166.5 \times \text{volume evaporated}} \dots\dots\dots(3.8)$$

where 1000 = 1liter of distilled water.

(g) Determination of total acid

100ml of the filtered tannin solution was distilled with 100ml carbonized distilled water and then filtered with sodium hydroxide to a pH of 6.8, and the acid in this solution might have dissociated. The volume of the sodium hydroxide used was recorded and the acid was calculated using the formula below.

$$\text{acid content} = \frac{\text{volume of NaOH} \times 100}{20} \dots\dots\dots(3.9)$$

(h) Determination of pH

The tannin infusion of individual extract was used to determine the pH using pH meter.

3.2.7. Preparation of 0.5M H₂SO₄ and NaCl standard solutions

(a) 0.5 M H₂SO₄ standard solution

Concentrated sulphuric acid has a density of 1.84g/cm³and percentage purity of 98%.It has a molar mass of 98g/mol.

1M H₂SO₄ has one mole of sulphuric acid i.e. 98gram dissolved in 1dm³(or1000cm³ or 1litre of solution) which then implies that 0.5MH₂SO₄ solution contains 49gram of sulphuric acid dissolved in 1000cm³ of the solution. Now, to determine the exact volume of acid required, say (v), we apply the following relation:

$$V \times 1.84 \times 0.98 = 49 \dots\dots\dots(3.10)$$

$$\text{or } v = 49/(1.84 \times 0.98) \approx 27.0\text{cm}^3$$

Thus, volume of sulphuric acid required is 27cm^3 which was then diluted with distilled water to 1000cm^3 mark to form 0.5 molar solution of H_2SO_4 (Ababio,2010).

(b) 0.5M NaCl standard solution

0.5M of salt or 29.25grams was measured and dissolved in 200ml beaker of distilled water then pour the solution into 1dm^3 flask and dilute with distilled water to the 1000cm^3 mark (Ababio, 2010).

3.2.8. Stock solutions of the extracts

Stock solutions of the extracts were prepared by refluxing 25grams each of pod ,leaves, stembark and root powders of locust bean tree in 0.5M H_2SO_4 for 3hours, and kept overnight for cooling. The cooled extracts were filtered and made up to 500ml with 0.5M H_2SO_4 acid to get 5%v/v extract of the inhibitor. Similar procedure was adopted in 0.5M NaCl and 5% v/v extract in 0.5M NaCl (Leelavathi et al,2013).

3.2.9. Preparation of test media

100ml of 0.5M sulphuric acid and 0.5M sodium chloride solutions were measured into each beaker, and different concentrations of each of the extracts (ranging from 0.1%v/v, 0.2%v/v, 0.3%v/v, 0.4%v/v and 0.5%v/v of 100ml environments) were added, except those without any extract or inhibitor added which served as control (Leelavathi et al,2013).

3.2.10 Weight loss method

After initial weighing, the specimens (one tensile and one impact) were immersed and suspended by thread in 100ml of 0.5M H₂SO₄ and NaCl solutions in the absence and presence of different concentrations (0.1% v/v, 0.2% v/v, 0.3% v/v, 0.4% v/v and 0.5% v/v) of four extracts. Samples were removed after every two days, for 10 days period at room temperature (30⁰C) and then washed in distilled water, rinsed in ethanol and acetone, dried and re-weighed to determine the weight loss. This enabled the evaluation of the corrosion rate (CR), inhibition efficiency (IE) %, and the degree of surface coverage (θ), using the following formulae (Olasehinde et al,2013):

$$CR = \frac{KW}{\rho At} \text{ (mm per yr)} \dots\dots\dots (3.11)$$

where W is the weight loss of the tensile specimen, irrespective of inhibitor presence, A- is the surface area of tensile samples, ρ- is the density of steel, t- is the time of exposure in hours

$$IE(\%) = (1 - \frac{W_1}{W_2}) \times 100\% \dots\dots\dots (3.12)$$

$$\theta = (1 - \frac{W_1}{W_2}) \dots\dots\dots (3.13)$$

Where W₁ and W₂ are the weight losses for mild steel in the presence and absence of inhibitor respectively. Equations 3.11- 3.13 were adopted from Wabane and Okafor (2001). The graphs showing the variations of corrosion rates and inhibition efficiencies with time and inhibitors concentrations were plotted.

3.2.11 Effects of temperature on corrosion inhibition

Fresh test media were prepared and new samples immersed, suspended and maintained at various temperatures (50⁰C, 70⁰C and 90⁰C) with the aid of water-bath in absence and presence of different concentrations (0.1% v/v, 0.2% v/v, 0.3% v/v, 0.4% v/v and 0.5% v/v) of the inhibitors for 2hours, but the samples were removed, washed, rinsed, dried

and re- weighed at intervals of 0.5 hour, and the corrosion rates, inhibition efficiencies and degree of surface coverages at each of the temperatures were calculated.

The relation between corrosion rate (CR) and temperature is expressed by Arrhenius equation (Mohana et al,2012):

$$CR = k \exp \left(- \frac{E_a}{RT} \right) \dots\dots\dots(3.14)$$

E_a is the activation energy,

R universal gas constant,

T absolute temperature

k is the pre-exponential factor.

Using equation 3.14, and the plot Log CR versus $1/T$, E_a values for the different concentrations of the inhibitors were determined. Also from an alternative Arrhenius equation:

$$\text{Log} \frac{CR}{T} = \text{Log} \left(\frac{R}{nh} \right) + \frac{\Delta S_a}{2.303R} - \frac{\Delta H_a}{2.303RT} \dots\dots\dots(3.15)$$

ΔS_a entropy change and ΔH_a enthalpy change of the corrosion processes can be calculated from the slopes and the intercepts of $\text{Log} \frac{CR}{T}$ versus $1/T$ graphs , (Mohana et al, 2012).

R universal constant.

n Avogadros constant and

h plank's constants.

3.2.12 Adsorption Isotherms

Adsorption isotherms are very important in determining the mechanism of interaction between mild steel surfaces and the adsorped inhibitor particles. There are different types of adsorption isotherms used to describe adsorption mechanism, these include Langmuir, Temkin and Frumkin (Olasehinde et al, 2013). In this study, Langmuir and Temkin isotherms have been used because are the most common.

(a)Langmuir Isotherm

Langmuir adsorption isotherm can be expressed according to the equation (Leelavathi et al,2013):

$$\frac{\theta}{C} = \frac{1}{K_{ads}} + \theta \dots\dots\dots (3.16)$$

where C is the inhibitor concentration, K_{ads} is the adsorption equilibrium constant and θ is the degree of surface coverage of the inhibitors. Thus, a plot of $\frac{\theta}{C}$ versus C should be a straight line with a slope of unity and intercepts of $\frac{1}{K_{ads}}$.

Furthermore, from Equation 3.16, this relationship was obtained.

$$K_{ads} = \frac{1}{C(1-\theta)} \dots\dots\dots (3.17)$$

(b) Temkin isotherm

According to Temkin, the degree of surface coverage θ is related to the inhibitor concentration C. (Leelavathi et al,2013):

$$\text{Exp} (-2a\theta) = K_{ads}C \dots\dots\dots(3.18)$$

Where a is called the attractive parameter.

Re-arranging and taking the logarithms of both sides of Equation 3.18, Equation 3.19 emerged.

$$\theta = -\frac{2.303}{2a} \log K_{ads} - \frac{2.303}{2a} \log C \dots\dots\dots (3.19)$$

A plot of θ versus $\log C$ gives a straight line with a slope of $-\frac{2.303}{2a}$ if Temkin is obeyed.

The adsorption equilibrium constant, K_{ads} is related to Gibb's free energy of adsorption (ΔG_{ads}) in the following equation, (Mohana et al, 2012):

$$K_{ads} = \left[\frac{1}{55.5} \right] \exp \left(-\frac{\Delta G_{ads}}{RT} \right) \dots\dots\dots(3.20)$$

Where 55.5 is the concentration of water in solution (mol L^{-1}),

R universal gas constant and

T is the absolute temperature.

3.2.13 Scanning Electron Microscopy (SEM)

The model of the scanning electron microscope used is phenom proX and the working voltage is 15kv, and distance is 2 mm. The SEM images that were taken were the unimmersed sample, blank from the acidic medium at 30⁰C, blank from the salt medium at 30⁰C, sample immersed in 0.5M H₂SO₄ in presence of 0.5% v/v stem extract at 30⁰C and sample immersed in 0.5M NaCl in presence of 0.5% v/v root extract at 30⁰C.

3.2.14 Mechanical Properties Determination

Mechanical tests of tensile strength, impact and hardness were carried out on 0.5% v/v concentrations and blanks samples after corrosion experiment, at 30⁰C in both acidic and salt media.

3.2.14.1 Tensile strength test

The tensile strengths, tests were carried out using Monsanto Tensometer of maximum capacity of 20 kiloNewtons (KN) in strength of materials laboratory of Mechanical Engineering Department of ABU, Zaria. Each sample was held in between two clamps and loaded manually to fracture. From the loading plots; tensile strengths of the samples were determined.

3.2.14.2. Impact test

Izod impact machine was used, of Model 670I and having maximum capacity of 163 Joules. Each sample was firmly gripped in the machine, and pendulum hammer was raised to a known height and released to impact on the sample. The energy loss of the pendulum hammer, due to the impact was recorded as the impact strength of the samples.

3.2.14.3. Hardness test

Indentec Universal Hardness Testing machine was employed for the test, of Model 8187.5LKV(B), and Rockwell Hardness test method was used, of scale 'Rockwell HRB', indenter of 1.6mm (steel ball), minor load of 10kgF and maximum load of 100kgF. At the beginning of the experiment, the surfaces of the indenter, plunger rod and samples were freed from any dirt. Minor load was applied to zero reference then subsequently, maximum load was applied. The difference in depth was used to estimate hardness values.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Results:

Surface Area of Tensile Test Sample:

Based on the equation 3.1, the surface area was calculated as 1582mm^2 .

Density Determination:

Volume of the tensile test sample was evaluated using equation 3.3 as 2.587cm^3 .

Average mass of the tensile test sample = 20.8067g

Therefore, the density of steel $\rho = 20.8067/2.587 \approx 8.04\text{g/cm}^3$. from equation 3.2.

Table 4.1: Activation and thermodynamic parameters for mild steel immersed in 0.5MH₂SO₄ and 0.5M NaCl in absence and presence of different concentration of the inhibitors.

0.5MH ₂ SO ₄				0.5MNaCl		
Concentration of inhibitors C(v/v)	Activation energy of corrosion E _a (KJmol ⁻¹)	Enthalpy change of corrosion ΔH _a (KJmol ⁻¹)	Entropy change of corrosion ΔS _a (Jmol ⁻¹ K ⁻¹)	Activation energy of corrosion E _a (KJmol ⁻¹)	Enthalpy change of corrosion ΔH _a (KJmol ⁻¹)	Entropy change of corrosion ΔS _a (KJmol ⁻¹ K ⁻¹)
Pod						
blank	59.39	56.64	-37.07	44.94	42.18	-119.17
0.1	65.22	62.48	-24.89	47.14	44.38	-117.46
0.2	65.90	63.15	-23.15	47.22	44.46	-117.44
0.3	68.80	66.04	-15.45	47.39	44.65	-117.14
0.4	69.12	66.36	-14.89	47.08	44.33	-118.50
0.5	70.19	67.44	-11.94	47.64	44.88	-117.21
Leaves						
0.1	62.32	59.57	-32.97	47.16	44.40	-117.23
0.2	64.83	62.09	-25.84	47.68	44.94	-115.84
0.3	65.43	62.67	-24.39	48.29	45.53	-114.29
0.4	68.22	65.46	-16.65	48.60	45.84	-113.67
0.5	68.30	65.56	-17.00	49.38	46.64	-111.72
Stem						
0.1	65.25	62.50	-25.44	47.26	44.50	-116.64
0.2	68.07	65.31	-17.57	47.35	44.61	-116.58
0.3	70.08	67.34	-12.25	47.04	44.31	-117.56
0.4	75.65	72.89	2.90	47.58	44.84	-116.26
0.5	83.04	80.28	23.57	47.39	44.63	-117.37
Root						
0.1	65.52	62.78	-24.27	47.16	44.40	-117.69
0.2	66.42	63.66	-21.88	47.98	45.23	-115.49
0.3	68.93	66.19	-15.03	48.48	45.72	-114.44
0.4	70.40	67.65	-11.18	48.69	45.93	-114.15
0.5	74.75	72.01	0.79	48.83	46.07	-114.15

Table 4.2 : Regression coefficient (R^2) of the inhibitors in 0.5M H_2SO_4 and 0.5MNaCl using Langmuir and Temkin adsorptions isotherm models.

Inhibitors	0.5M H_2SO_4		0.5MNaCl	
	Langmuir isotherm R^2	Temkin isotherm R^2	Langmuir isotherm R^2	Temkin isotherm R^2
Pod				
30 $^{\circ}C$	0.9950	0.9150	0.9980	0.8990
50 $^{\circ}C$	0.9980	0.9330	0.9940	0.8980
70 $^{\circ}C$	0.9970	0.9490	0.9960	0.7360
90 $^{\circ}C$	0.9970	0.8550	0.9980	0.9740
Leaves				
30 $^{\circ}C$	0.9940	0.9420	0.9950	0.8980
50 $^{\circ}C$	0.9520	0.7410	0.9950	0.9250
70 $^{\circ}C$	0.9940	0.8710	0.9970	0.9380
90 $^{\circ}C$	0.9970	0.6680	0.9990	0.9110
Stembark				
30 $^{\circ}C$	0.9780	0.8830	0.9970	0.8370
50 $^{\circ}C$	0.9950	0.9630	0.9890	0.8210
70 $^{\circ}C$	0.9790	0.7850	0.9920	0.8520
90 $^{\circ}C$	0.9960	0.8180	0.9970	0.9180
Root				
30 $^{\circ}C$	0.9820	0.8360	0.9950	0.8790
50 $^{\circ}C$	0.9980	0.9850	0.9980	0.9300
70 $^{\circ}C$	0.9930	0.8460	0.9900	0.8370
90 $^{\circ}C$	0.9950	0.7760	0.9950	0.7320

Table 4.3 : ΔG_{ads} and K_{ads} values of the inhibitors in 0.5M H_2SO_4 at different temperatures

Concentration of the inhibitors C(% v/v)	Temperatures in degree Celsius							
	30 ⁰ C		50 ⁰ C		70 ⁰ C		90 ⁰ C	
	K_{ads}	ΔG_{ads} KJ/mol	K_{ads}	ΔG_{ads} KJ/mol	K_{ads}	ΔG_{ads} KJ/mol	K_{ads}	ΔG_{ads} KJ/mol
Pod								
0.1	14.16043	-16.79	9.83045	-16.92	6.959932	-16.99	6.678481	-17.85
0.2	7.701316	-15.26	5.46956	-15.35	3.809408	-15.27	3.360505	-15.78
0.3	7.424907	-15.17	4.692993	-14.94	2.941472	-14.53	2.546858	-14.94
0.4	6.232709	-14.73	3.597561	-14.22	2.49002	-14.06	2.093055	-14.35
0.5	5.641755	-14.48	3.03113	-13.76	2.052685	-13.5	1.725435	-13.77
Leaves								
0.1	10.45408	-16.03	6.999575	-16.01	6.760245	-16.9	6.679176	-17.85
0.2	7.27295	-15.12	3.749289	-14.33	3.537158	-15.06	3.363302	-15.78
0.3	5.159668	-14.25	2.926154	-13.67	2.57029	-14.15	2.269378	-14.59
0.4	5.416904	-14.37	2.416179	-13.15	2.120645	-13.6	1.794057	-13.89
0.5	4.188119	-13.73	2.895661	-13.64	1.879917	-13.25	1.540763	-13.43
Stembark								
0.1	17.38676	-17.31	10.41025	-17.08	8.59168	-17.59	8.04647	-18.41
0.2	11.06684	-16.17	6.142061	-15.66	4.557488	-15.78	4.044453	-16.34
0.3	9.286237	-15.73	5.173323	-15.2	3.279111	-14.84	2.974124	-15.41
0.4	12.29991	-16.44	4.711365	-14.95	3.145571	-14.72	2.369023	-14.72
0.5	19.36752	-17.58	4.131678	-14.6	3.02702	-14.61	2.083091	-14.34
Root								
0.1	15.60295	-17.04	10.17349	-17.02	7.576237	-17.23	7.145306	-18.06
0.2	8.335467	-15.46	5.981167	-15.59	3.941345	-15.36	3.584059	-15.97
0.3	7.364142	-15.15	4.791299	-14.99	2.844941	-14.44	2.547376	-14.94
0.4	6.879455	-14.98	3.790891	-14.36	2.394044	-13.94	2.092633	-14.35
0.5	8.570825	-15.53	3.353319	-14.03	2.126477	-13.61	1.814246	-13.92

Table 4.4 : ΔG_{ads} and K_{ads} values of the inhibitors in 0.5MNaCl at different temperatures

Concentration of the inhibitors C(% v/v)	Temperatures in degree celsius							
	30 ⁰ C		50 ⁰ C		70 ⁰ C		90 ⁰ C	
	K_{ads}	ΔG_{ads} KJ/mol	K_{ads}	ΔG_{ads} KJ/mol	K_{ads}	ΔG_{ads} KJ/mol	K_{ads}	ΔG_{ads} KJ/mol
Pod								
0.1	9.661817	-15.83	8.371377	-16.49	8.172732	-17.44	6.728003	-17.87
0.2	5.018434	-14.18	4.521996	-14.84	4.025678	-15.43	3.661758	-16.04
0.3	3.619512	-13.36	3.306773	-14	2.876882	-14.47	2.641721	-15.05
0.4	2.801777	-12.71	2.721659	-13.47	2.347545	-13.89	2.077497	-14.33
0.5	2.440695	-12.37	2.48959	-13.24	2.016064	-13.45	1.779468	-13.86
Leaves								
0.1	9.532013	-15.8	7.361865	-16.15	6.99091	-17	6.611986	-17.82
0.2	5.138286	-14.24	4.016726	-14.52	3.840951	-15.29	3.371003	-15.79
0.3	3.738402	-13.44	2.921162	-13.66	2.686502	-14.27	2.449688	-14.83
0.4	3.123538	-12.99	2.512029	-13.26	2.089472	-13.55	1.898698	-14.06
0.5	2.826721	-12.74	2.156924	-12.85	1.842828	-13.2	1.556978	-13.46
Stembark								
0.1	8.780753	-15.59	6.889039	-15.97	6.725904	-16.89	5.839702	-17.45
0.2	4.59251	-13.96	3.771545	-14.35	3.555784	-15.07	3.213552	-15.64
0.3	3.127617	-12.99	2.596546	-13.35	2.548933	-14.12	2.192063	-14.49
0.4	2.602041	-12.53	2.122995	-12.81	2.086314	-13.55	1.696391	-13.72
0.5	2.206807	-12.11	2.004004	-12.65	1.903963	-13.29	1.483865	-13.31
Root								
0.1	10.23227	-15.98	9.343295	-16.79	8.248175	-17.47	7.310023	-18.12
0.2	5.455439	-14.39	5.076074	-15.15	4.451796	-15.71	3.649771	-16.03
0.3	3.95519	-13.58	4.154359	-14.61	3.243883	-14.81	2.563762	-14.96
0.4	3.353704	-13.17	3.305515	-14.00	2.566626	-14.14	2.096856	-14.36
0.5	3.019072	-12.9	2.672078	-13.43	2.49615	-14.06	1.835827	-13.95

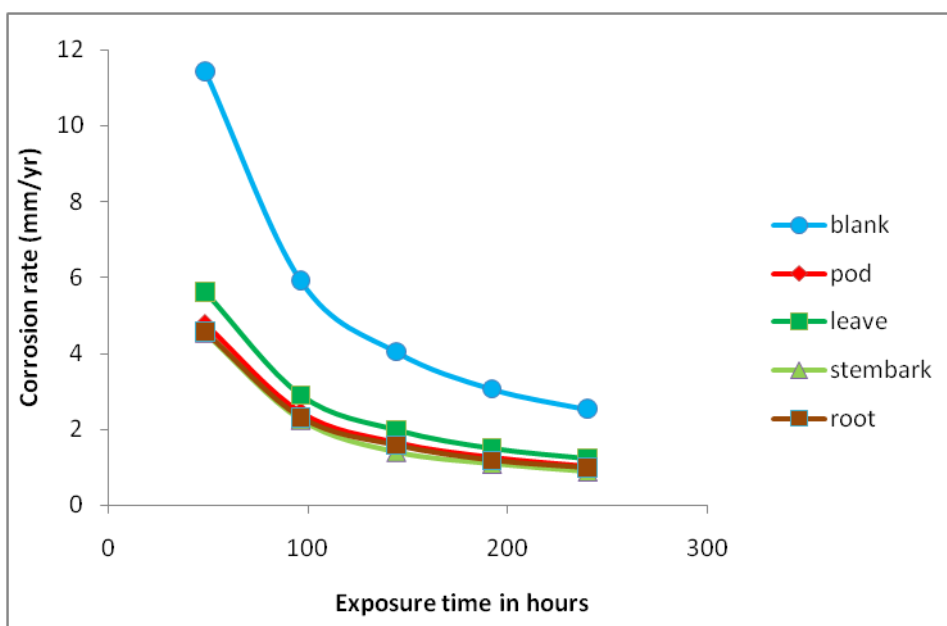


Figure 4.1: Variation of corrosion rate with exposure time of mild steel in $0.5\text{MH}_2\text{SO}_4$ at 0.1% v/v concentration of the inhibitors (at room temperature).

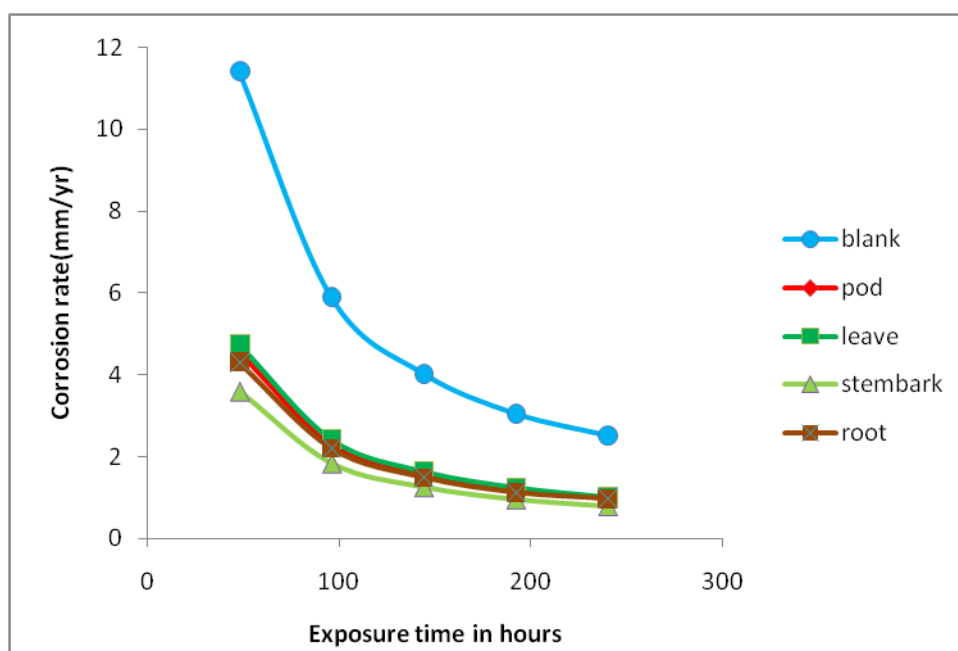


Figure 4.2: Variation of corrosion rate with exposure time of mild steel in $0.5\text{MH}_2\text{SO}_4$ at 0.2% v/v concentration of the inhibitors (at room temperature).

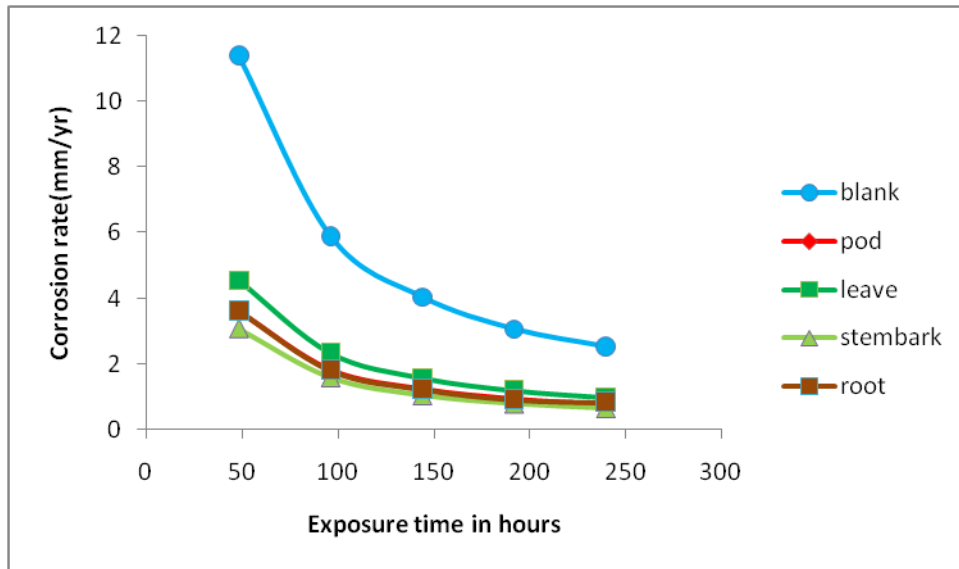


Figure 4.3: Variation of corrosion rate with exposure time of mild steel in $0.5\text{MH}_2\text{SO}_4$ at 0.3% v/v concentration of the inhibitors (at room temperature).

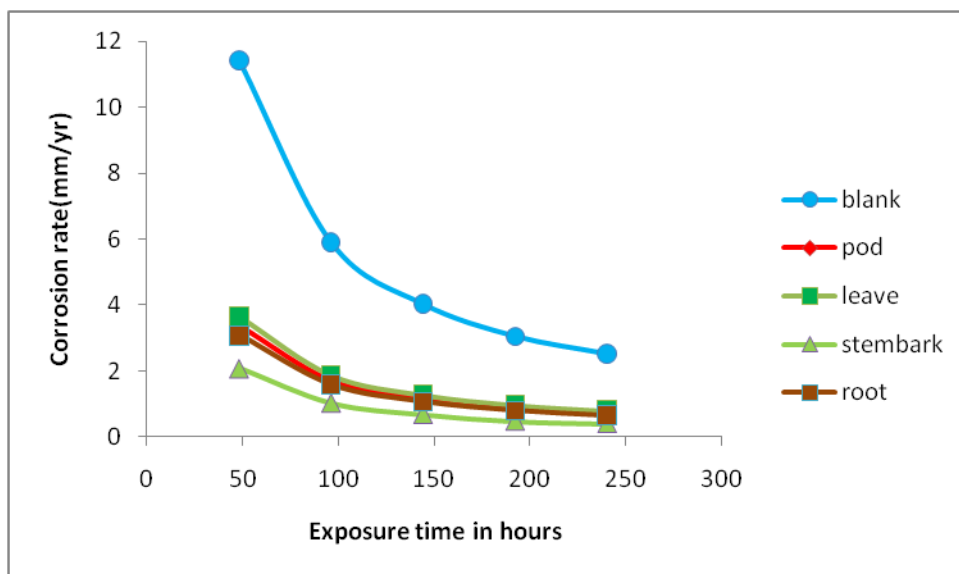


Figure 4.4: Variation of corrosion rate with exposure time of mild steel in $0.5\text{MH}_2\text{SO}_4$ at 0.4% v/v concentration of the inhibitors (at room temperature).

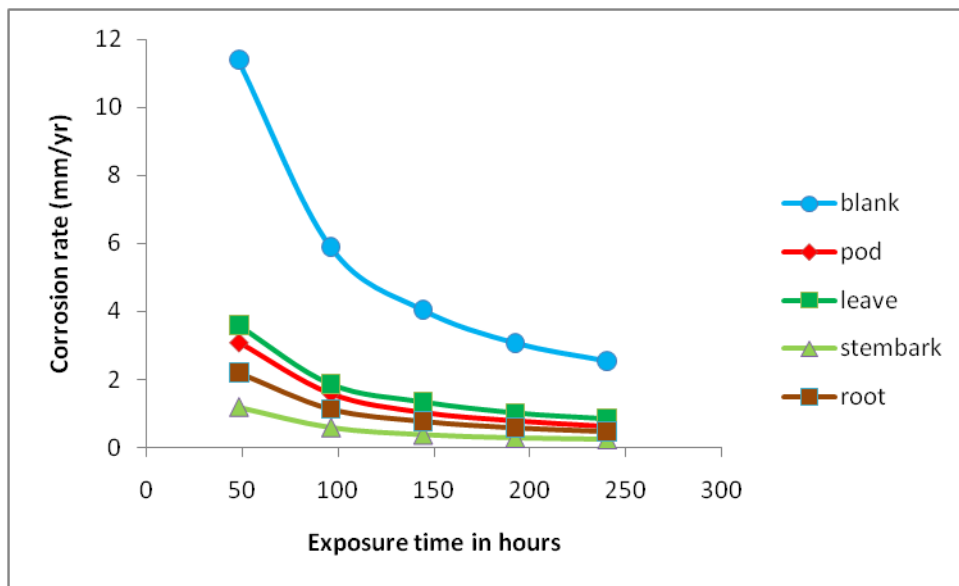


Figure 4.5: Variation of corrosion rate with exposure time of mild steel in 0.5M H₂SO₄ at 0.5% v/v concentration of the inhibitors (at room temperature).

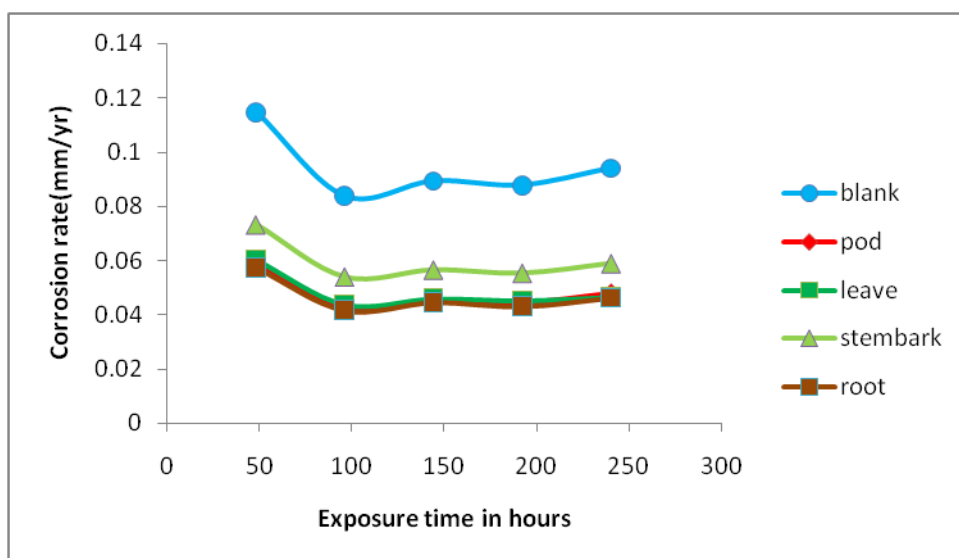


Figure 4.6: Variation of corrosion rate with exposure time of mild steel in 0.5M NaCl at 0.1% v/v concentration of the inhibitors (at room temperature).

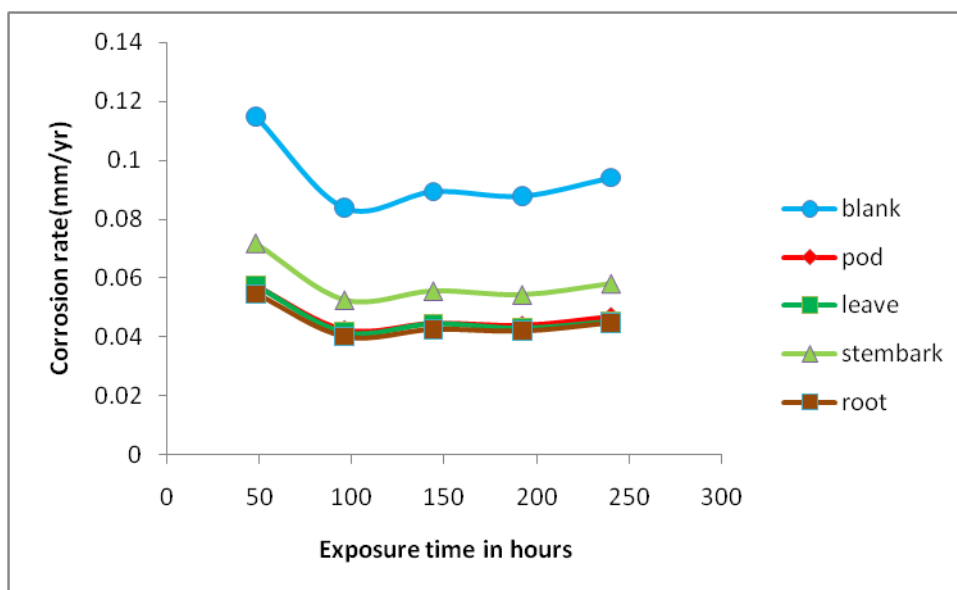


Figure 4.7: Variation of corrosion rate with exposure time of mild steel in 0.5MNaCl at 0.2% v/v concentration of the inhibitors(at room temperature).

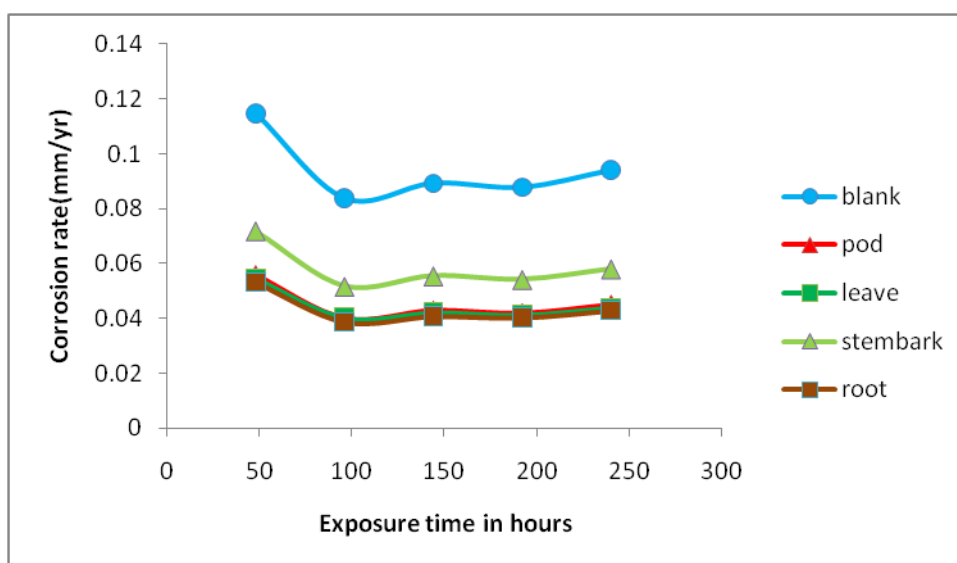


Figure 4.8: Variation of corrosion rate with exposure time of mild steel in 0.5MNaCl at 0.3% v/v concentration of the inhibitors(at room temperature).

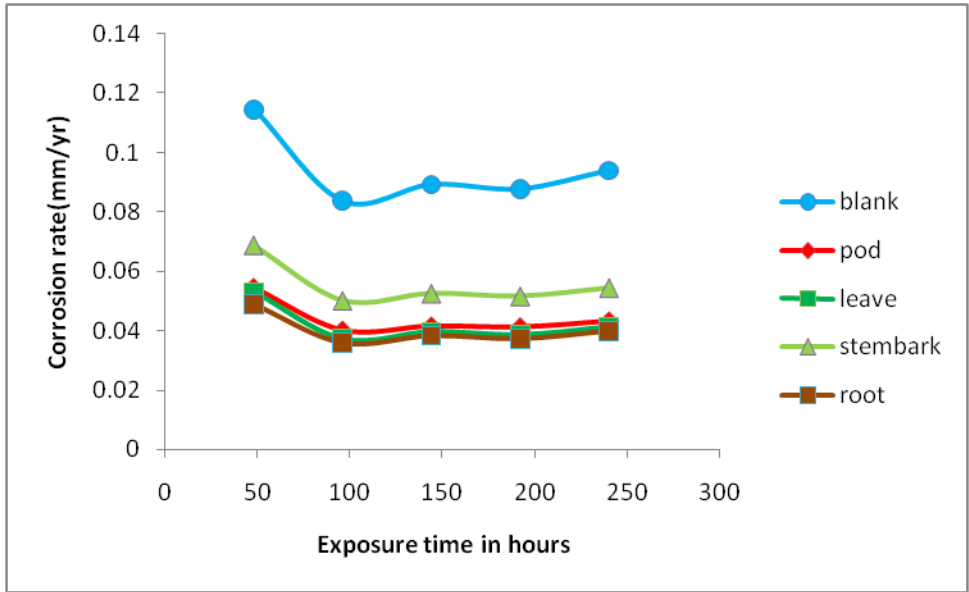


Figure 4.9: Variation of corrosion rate with exposure time of mild steel in 0.5MNaCl at 0.4% v/v concentration of the inhibitors(at room temperature).

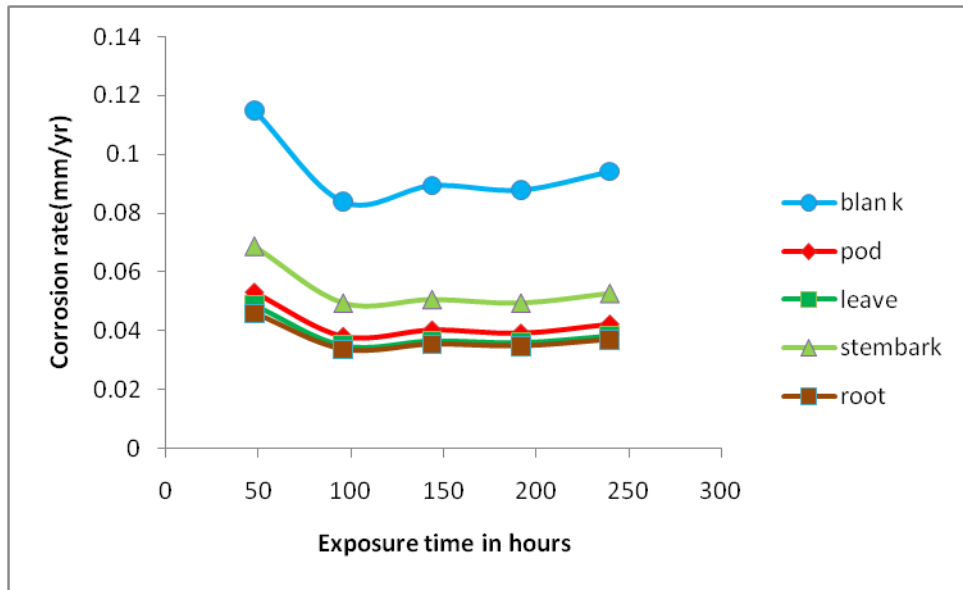


Figure 4.10: Variation of corrosion rate with exposure time of mild steel in 0.5MNaCl at 0.5% v/v concentration of the inhibitors(at room temperature).

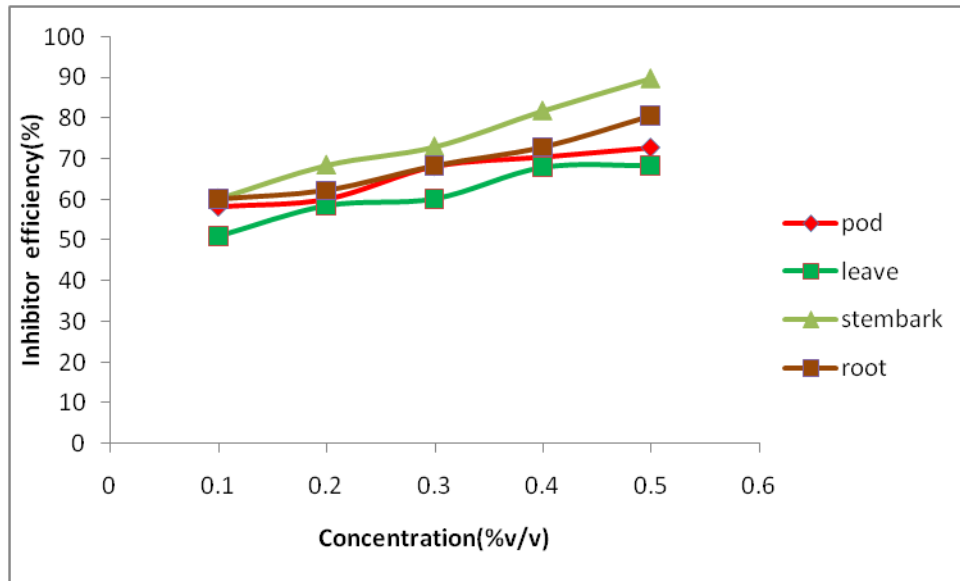


Figure 4.11: Variation of inhibitor efficiency with concentrations of inhibitors in $0.5\text{MH}_2\text{SO}_4$ after 2 days of exposure at ambient temperature.

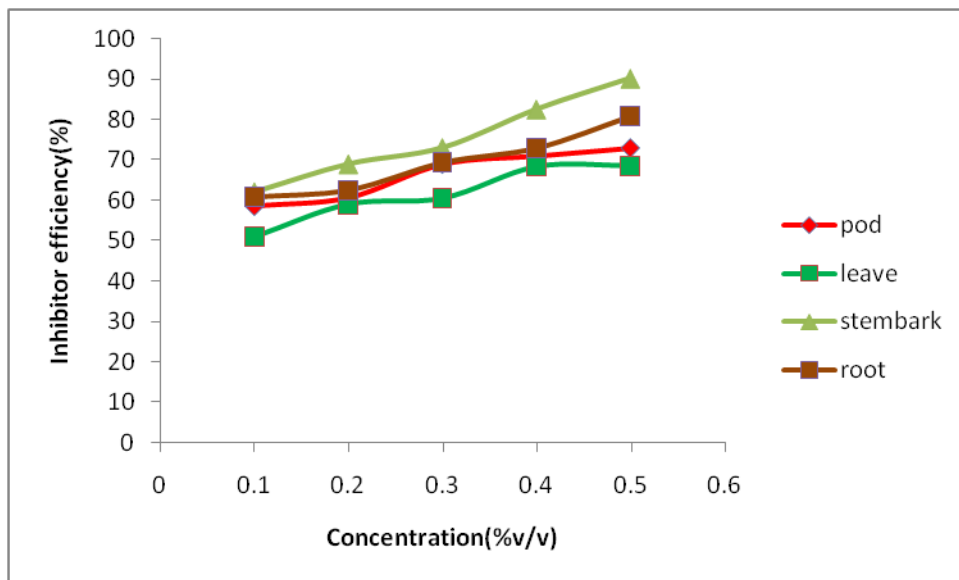


Figure 4.12: Variation of inhibitor efficiency with concentration of inhibitors in $0.5\text{MH}_2\text{SO}_4$ after 4 days of exposure at ambient temperature

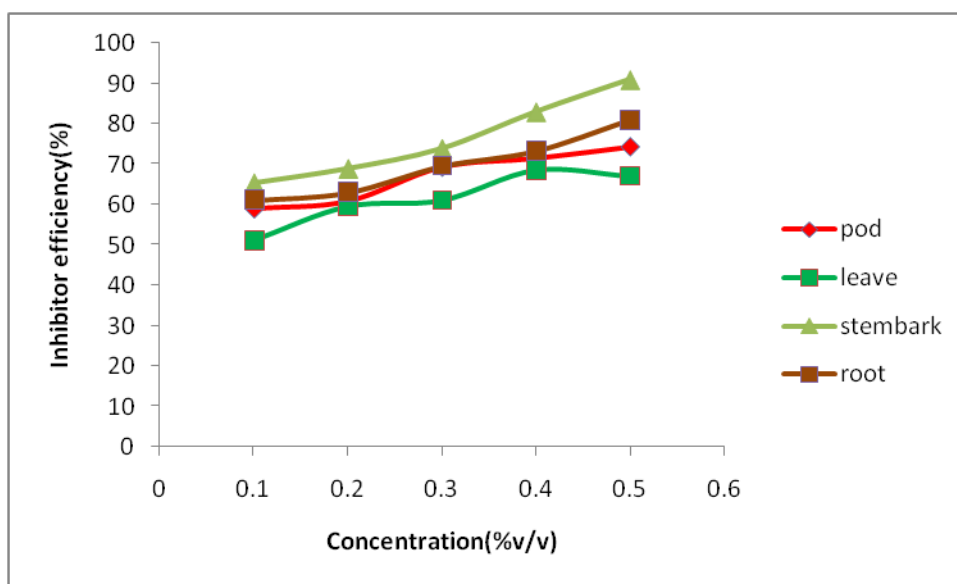


Figure 4.13: Variation of inhibitor efficiency with concentration of inhibitors in 0.5M H_2SO_4 after 6 days of exposure at ambient temperature

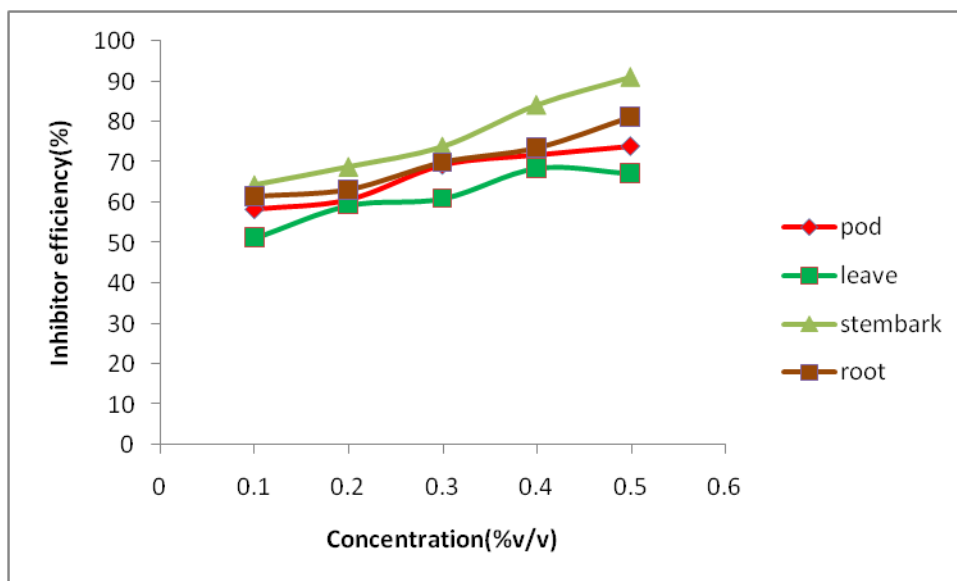


Figure 4.14: Variation of inhibitor efficiency with concentrations of inhibitors in 0.5M H_2SO_4 after 8 days of exposure at ambient temperature.

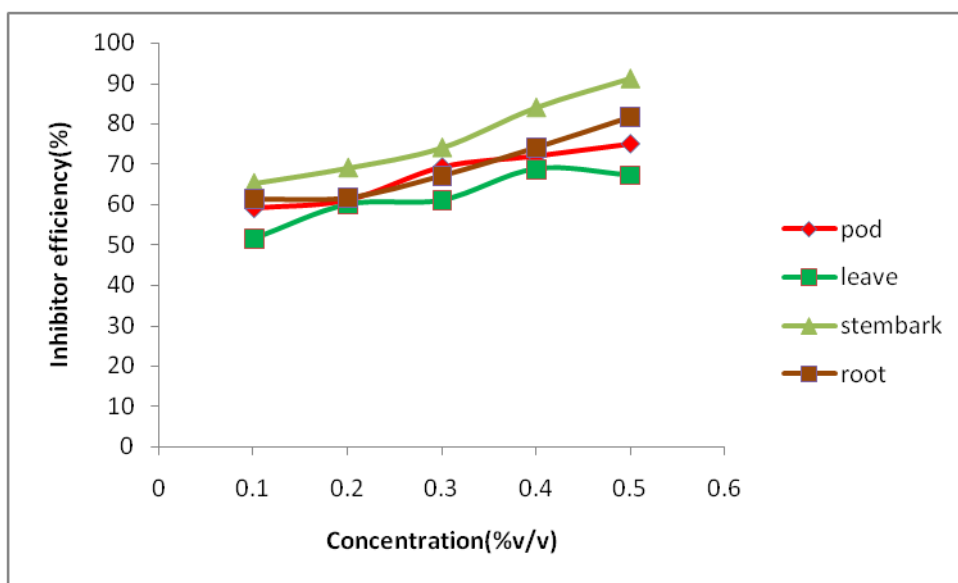


Figure 4.15: Variation of inhibitor efficiency with concentrations of inhibitors in 0.5M H₂SO₄ after 10 days of exposure at ambient temperature.

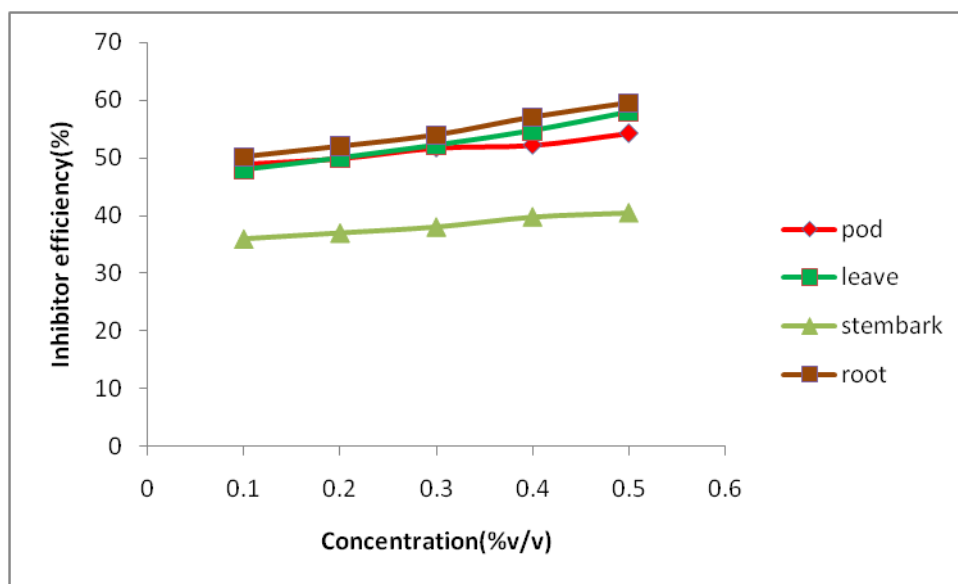


Figure 4.16: Variation of inhibitor efficiency with concentrations of inhibitors in 0.5M NaCl after 2 days of exposure at ambient temperature

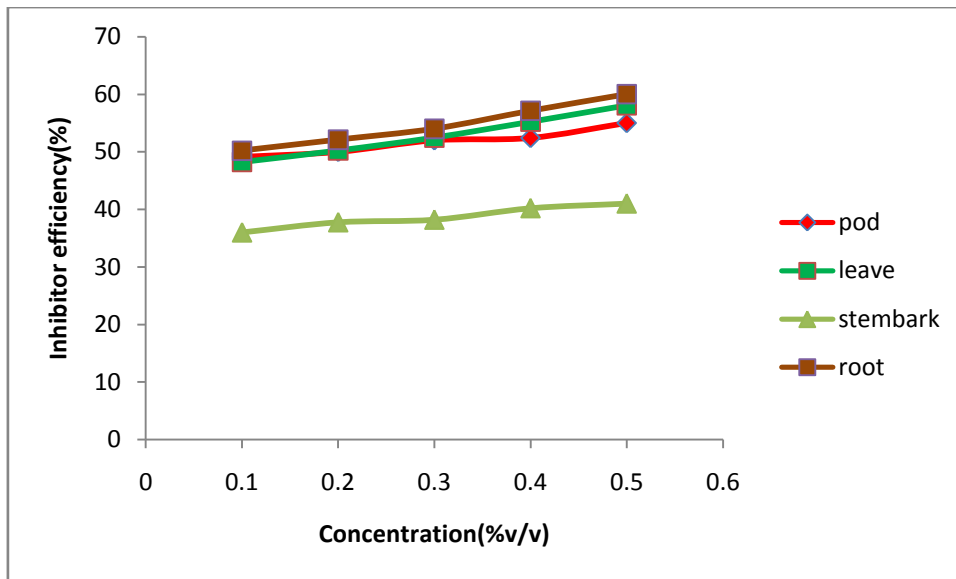


Figure 4.17: Variation of inhibitor efficiency with concentrations of inhibitors in 0.5MNaCl after 4 days of exposure at ambient temperature.

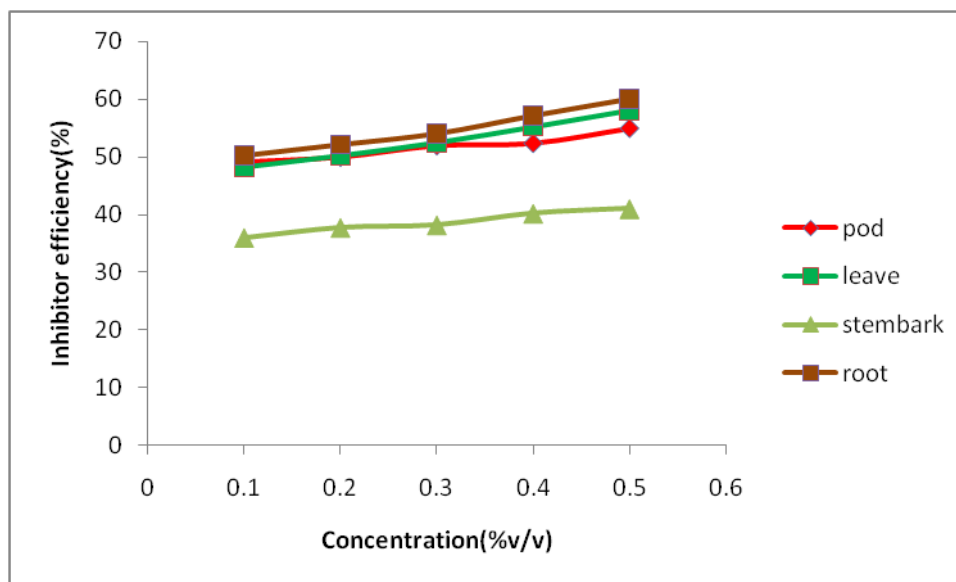


Figure 4.18: Variation of inhibitor efficiency with concentrations of inhibitors in 0.5MNaCl after 6 days of exposure at ambient temperature.

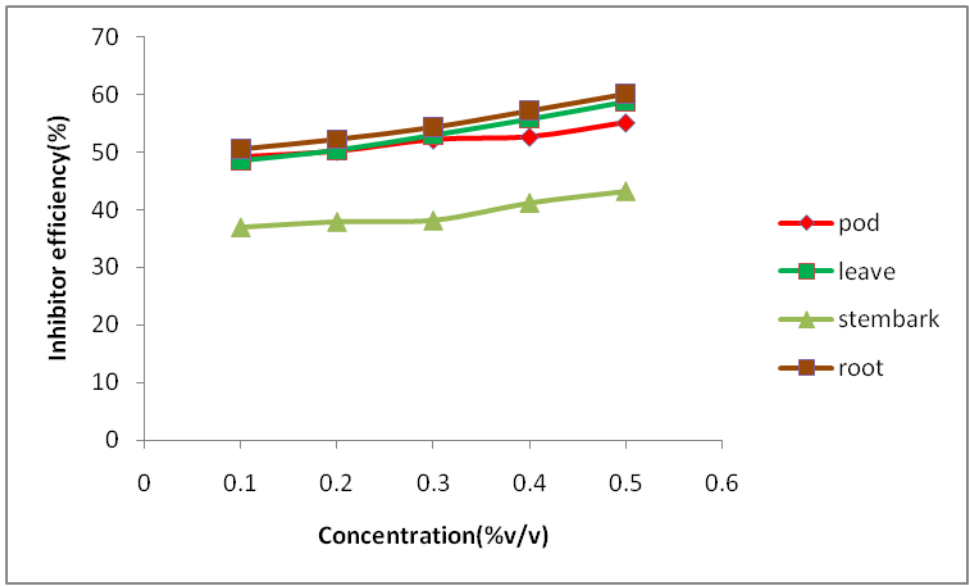


Figure 4.19: Variation of inhibitor efficiency with concentrations of inhibitors in 0.5MNaCl after 8 days of exposure at ambient temperature.

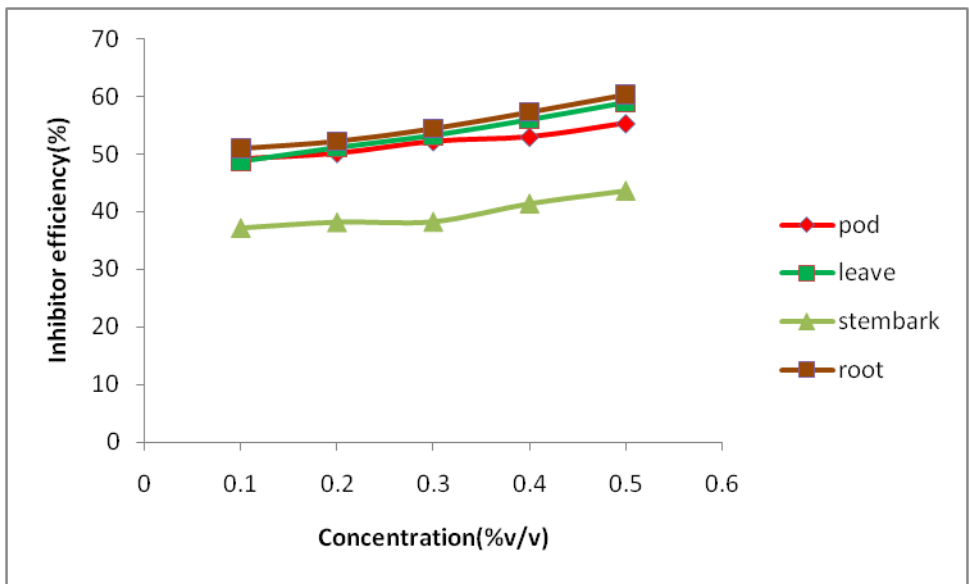


Figure 4.20: Variation of inhibitor efficiency with concentrations of inhibitors in 0.5MNaCl after 10 days of exposure at ambient temperature.

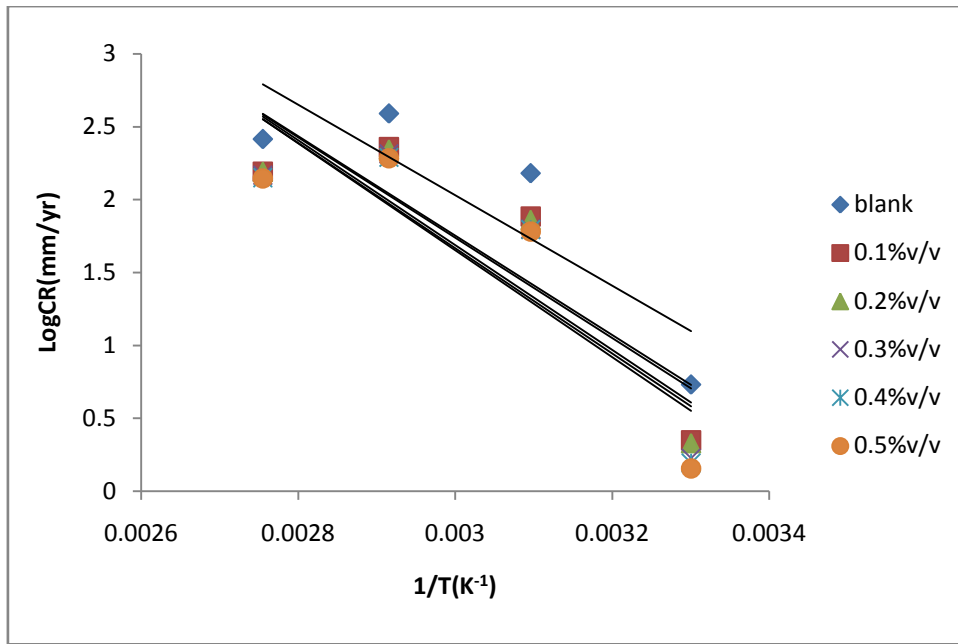


Figure 4.21: Arrhenius plot of mild steel immersed in 0.5M₂SO₄ in absence and presence of different concentrations of the pod extract.

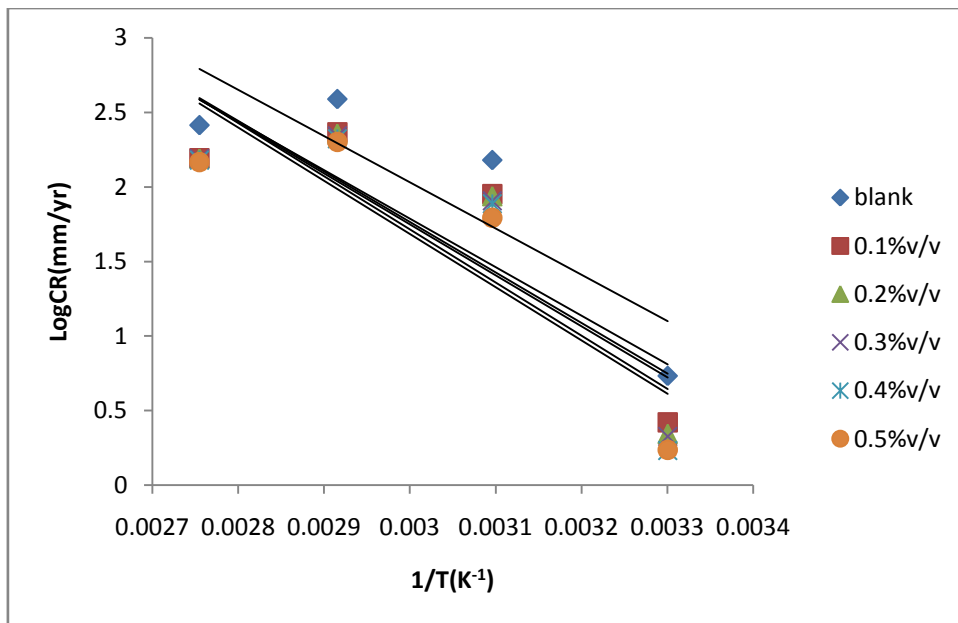


Figure 4.22: Arrhenius plot of mild steel immersed in 0.5M₂SO₄ in absence and presence of different concentrations of the leaf extract.

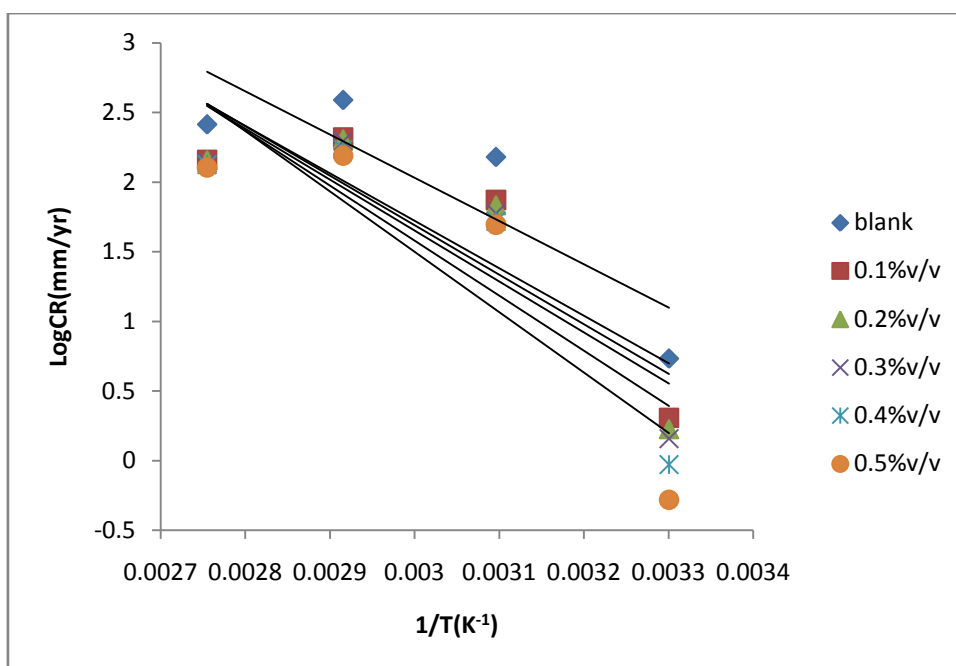


Figure 4.23: Arrhenius plot of mild steel immersed in 0.5M H_2SO_4 in absence and presence of different concentrations of the stem bark extract.

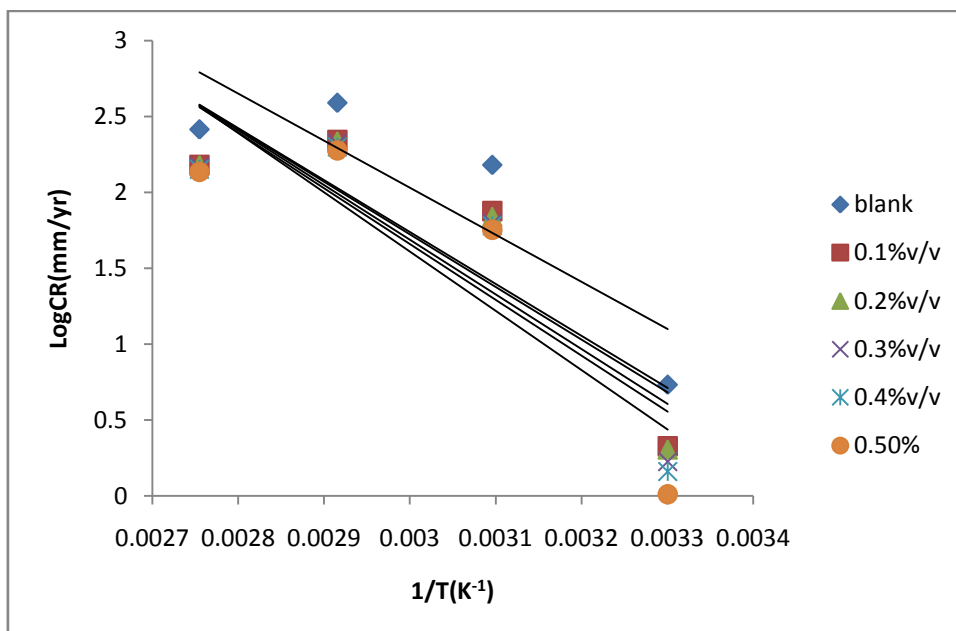


Figure 4.24: Arrhenius plot of mild steel immersed in 0.5M H_2SO_4 in absence and presence of different concentrations of the root extract.

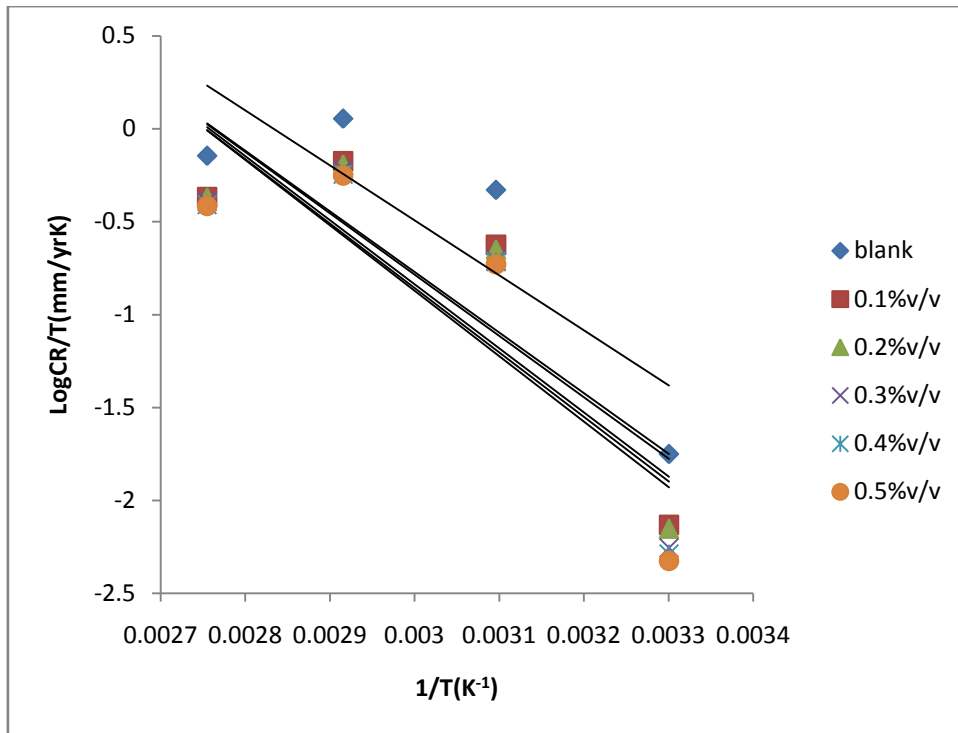


Figure 4.25: Alternative Arrhenius plot of mild steel immersed in $0.5\text{M}\text{H}_2\text{SO}_4$ in absence and presence of different concentrations of the pod extract.

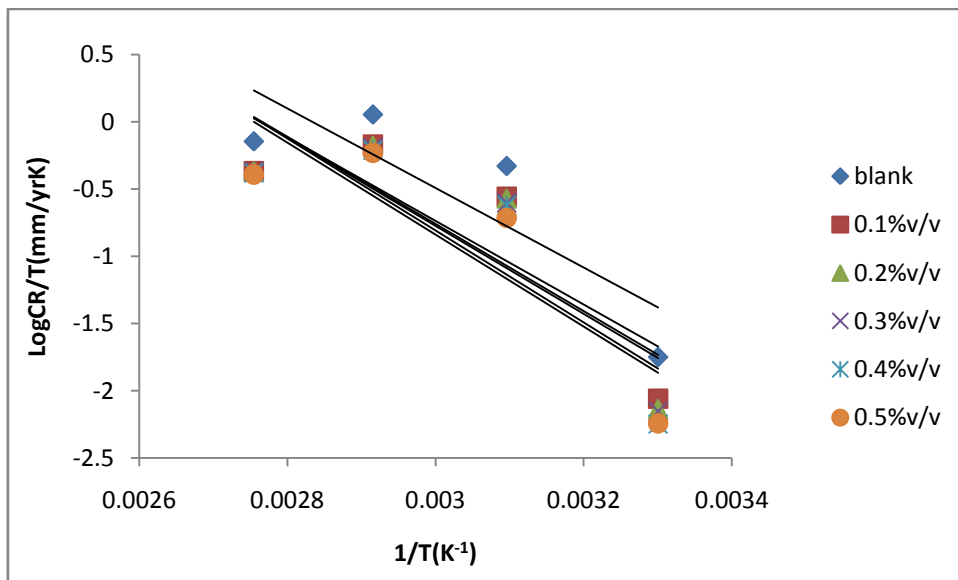


Figure 4.26: Alternative Arrhenius plot of mild steel immersed in $0.5\text{M}\text{H}_2\text{SO}_4$ in absence and presence of different concentrations of the leaf extract

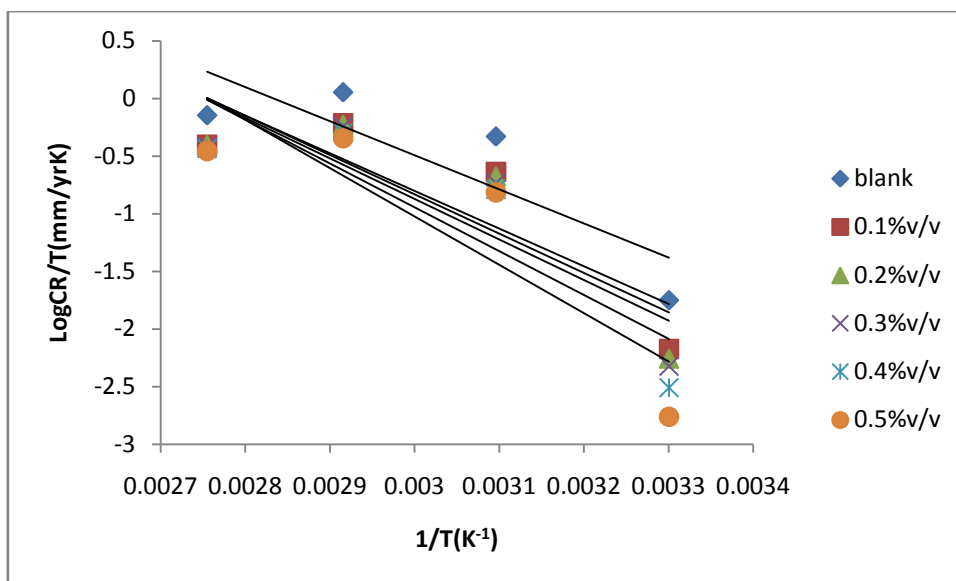


Figure 4.27: Alternative Arrhenius plot of mild steel immersed in 0.5M₂SO₄ in absence and presence of different concentrations of the stem bark extract.

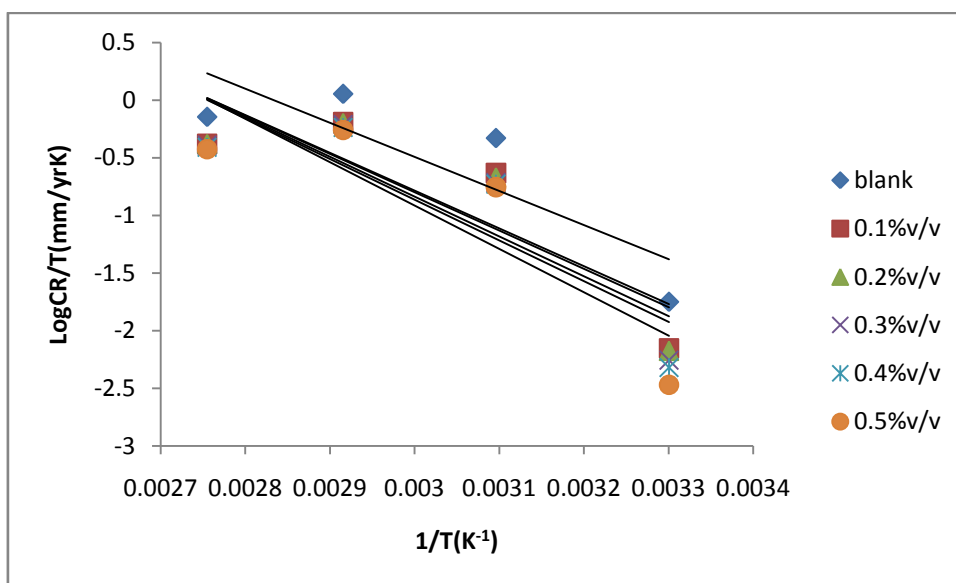


Figure 4.28: Alternative Arrhenius plot of mild steel immersed in 0.5M₂SO₄ in absence and presence of different concentrations of the root extract

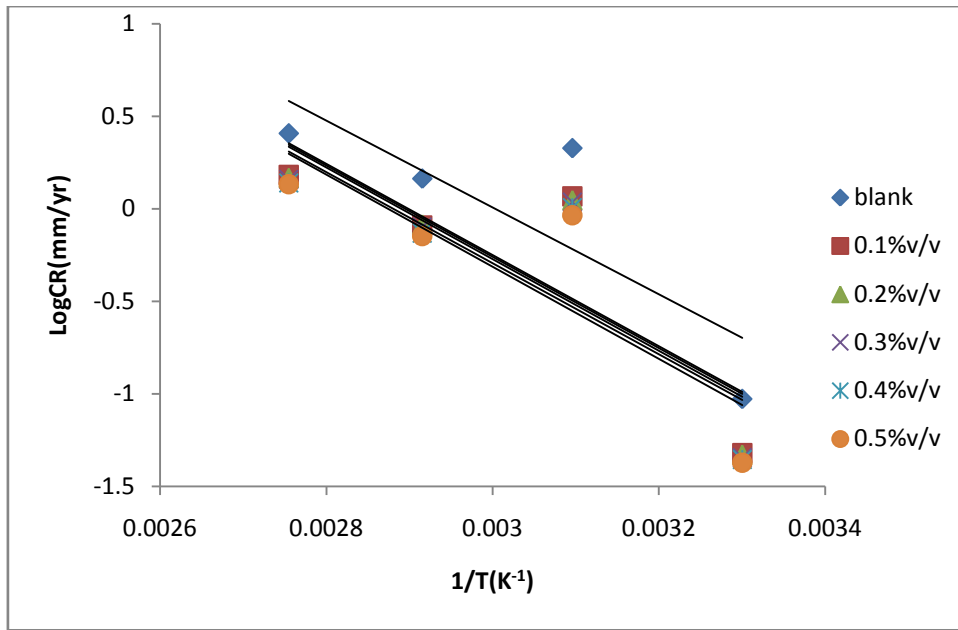


Figure 4.29: Arrhenius plot of mild steel immersed in 0.5M NaCl in absence and presence of different concentrations of the pod extract.

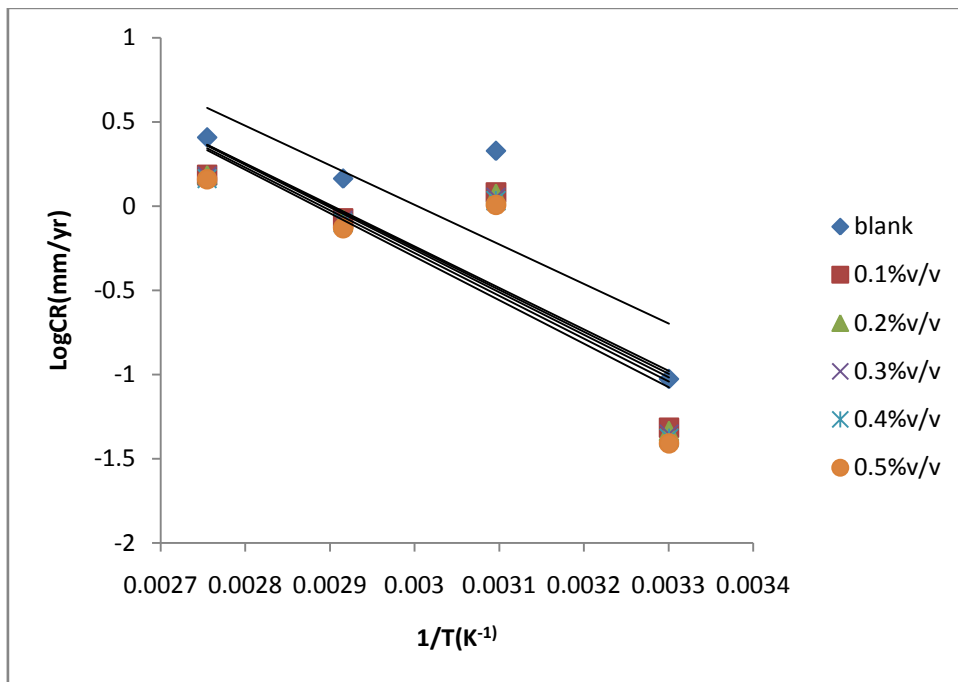


Figure 4.30: Arrhenius plot of mild steel immersed in 0.5M NaCl in absence and presence of different concentrations of the leaf extract

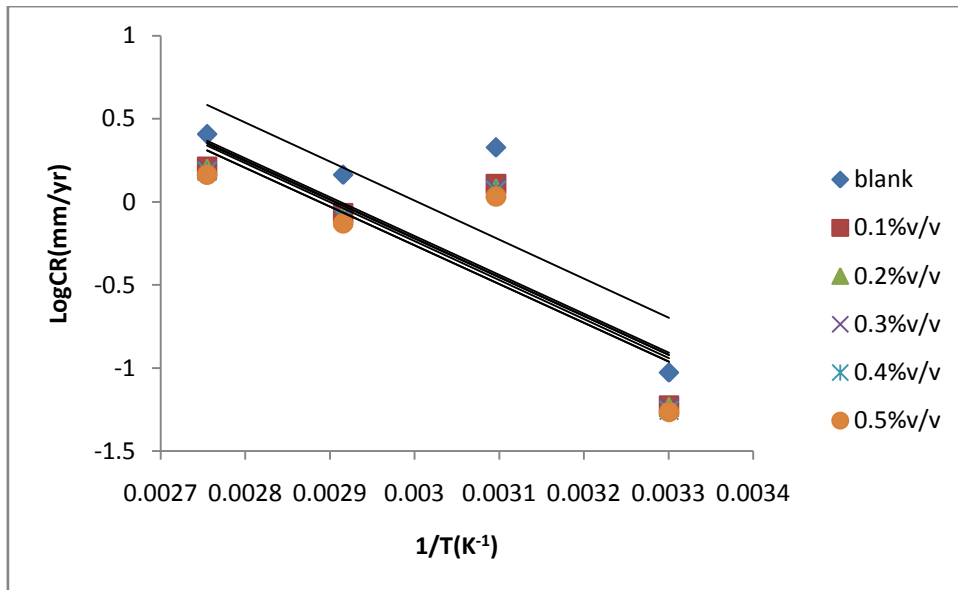


Figure 4.31: Arrhenius plot of mild steel immersed in 0.5M NaCl in absence and presence of different concentrations of the stem bark extract.

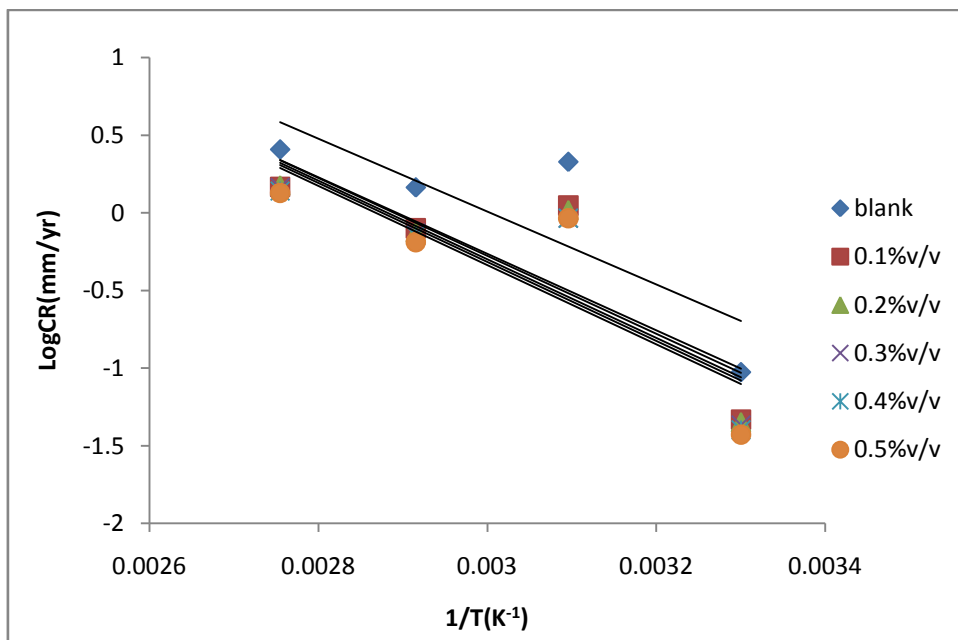


Figure 4.32: Arrhenius plot of mild steel immersed in 0.5M NaCl in absence and presence of different concentrations of the root extract

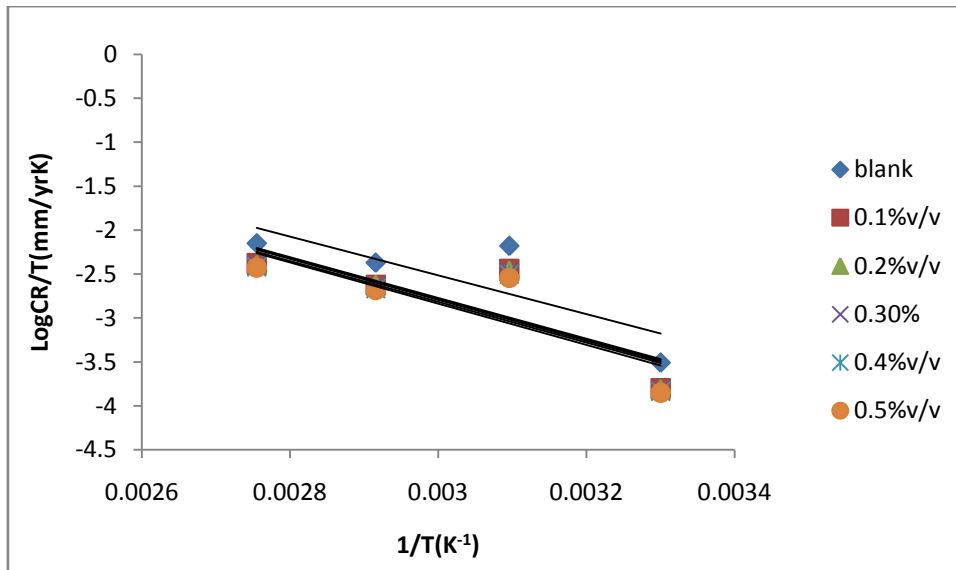


Figure 4.33: Alternative Arrhenius plot of mild steel immersed in 0.5MNaCl in absence and presence of different concentrations of the pod extract.

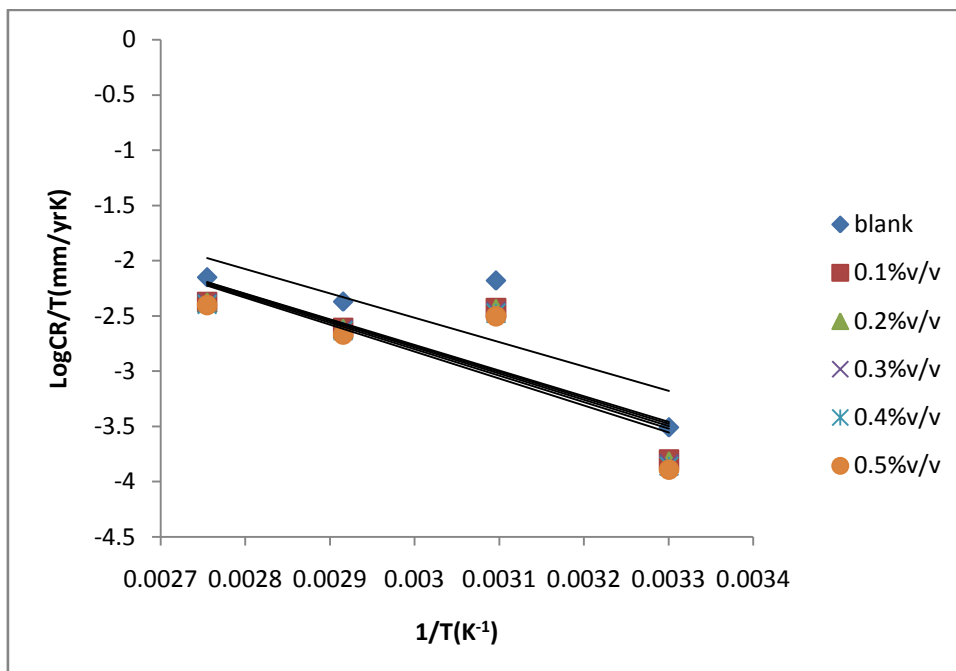


Figure 4.34: Alternative Arrhenius plot of mild steel immersed in 0.5MNaCl in absence and presence of different concentrations of the leaf extract.

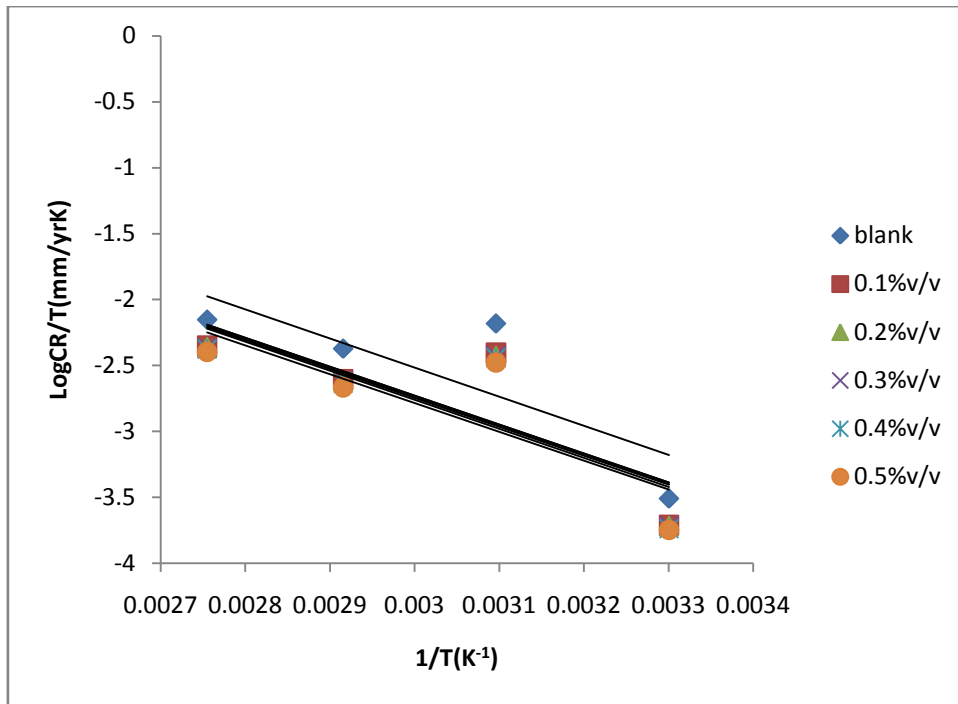


Figure 4.35: Alternative Arrhenius plot of mild steel immersed in 0.5M NaCl in absence and presence of different concentrations of the stem bark extract

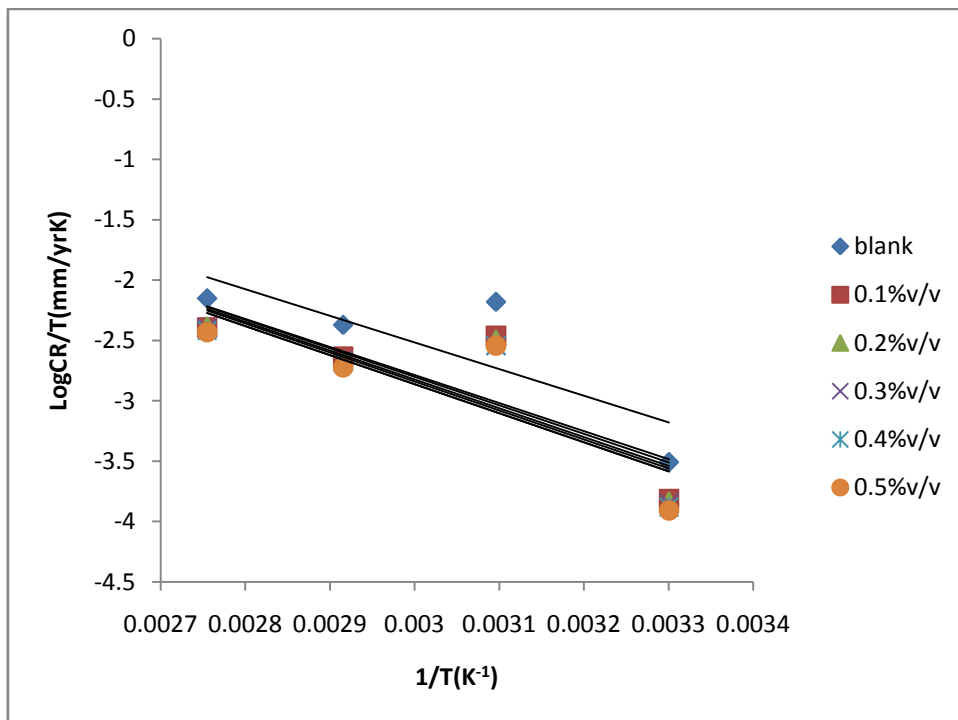


Figure 4.36: Alternative Arrhenius plot of mild steel immersed in 0.5M NaCl in absence and presence of different concentrations of the root extract.

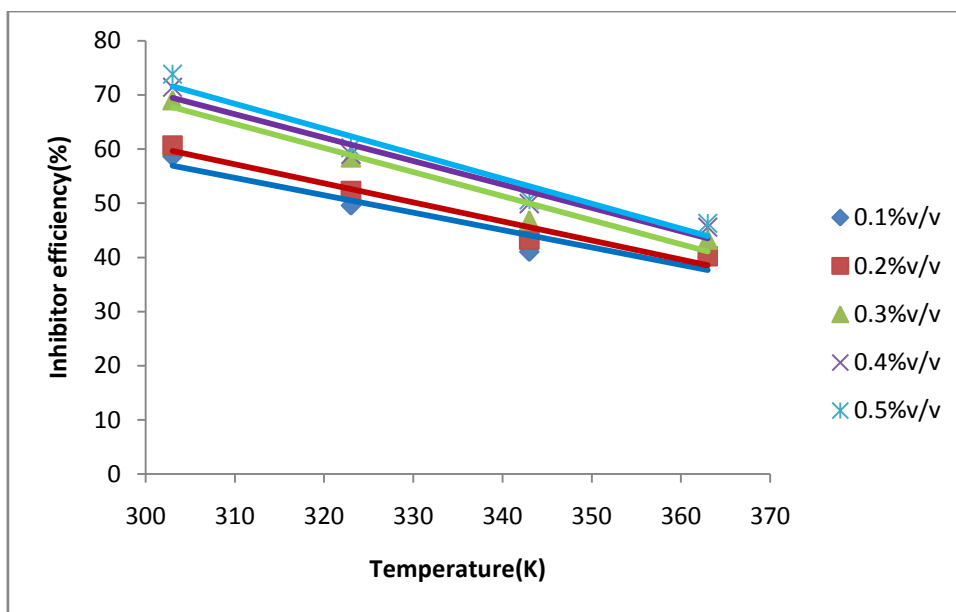


Figure 4.37: Variations of average inhibitor efficiency with temperature in 0.5M H_2SO_4 in presence of different concentrations of the pod extract.

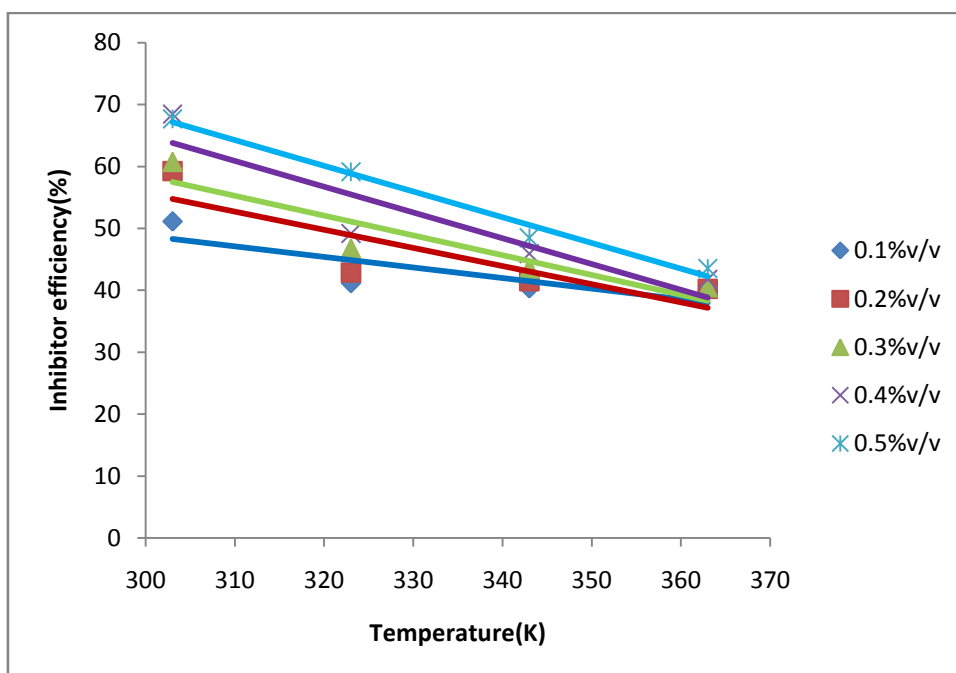


Figure 4.38: Variations of average inhibitor efficiency with temperature in 0.5M H_2SO_4 in presence of different concentrations of the leaf extract.

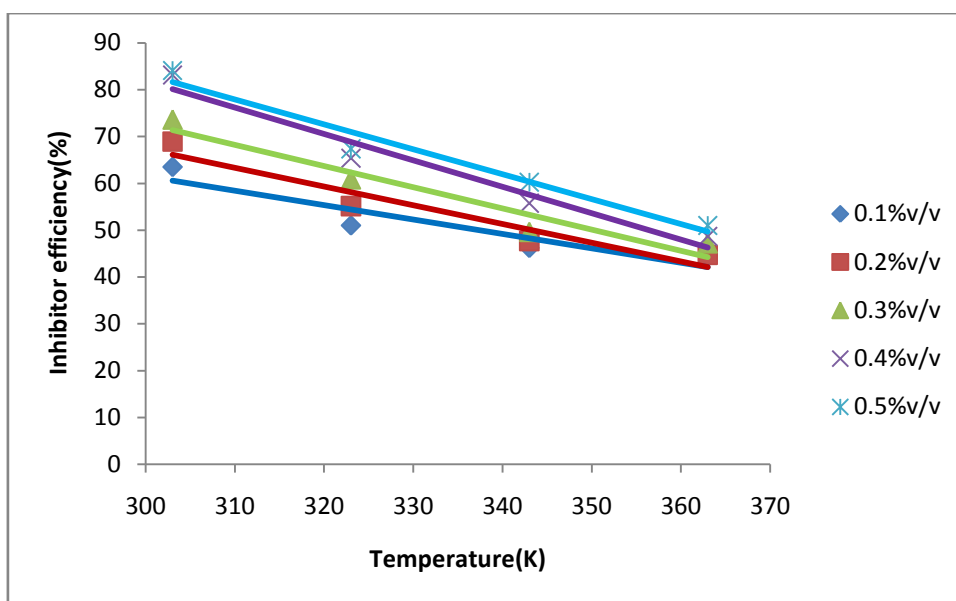


Figure 4.39: Variations of average inhibitor efficiency with temperature in 0.5M H_2SO_4 in presence of different concentrations of the stem bark extract.

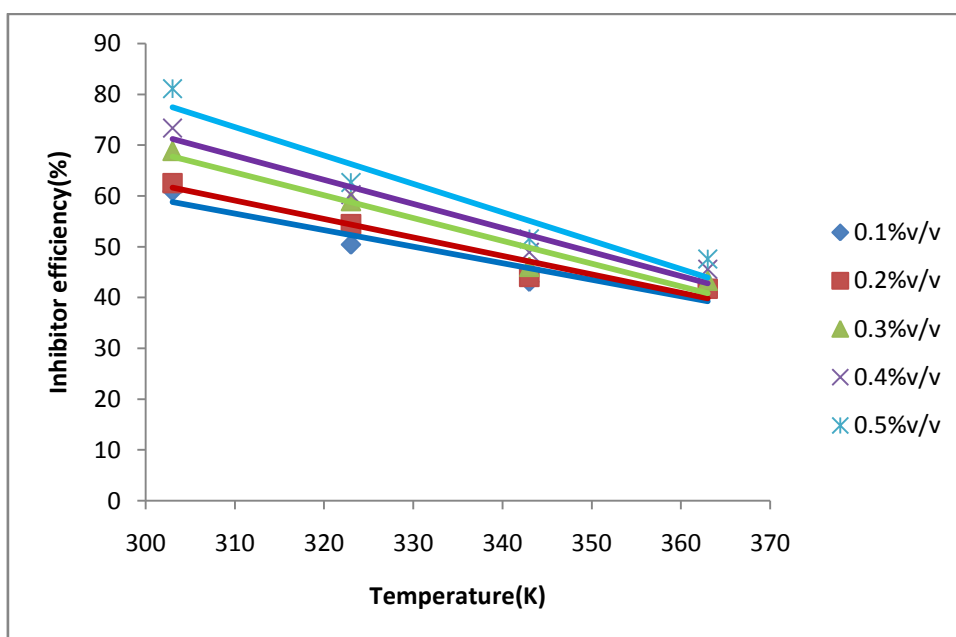


Figure 4.40: Variations of average inhibitor efficiency with temperature in 0.5M H_2SO_4 in presence of different concentrations of the root extract.

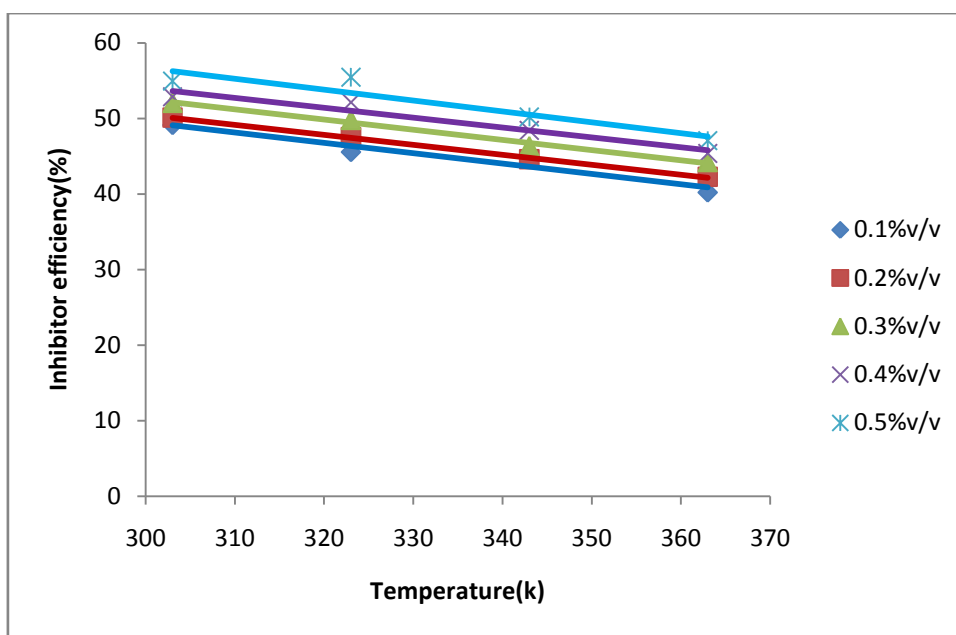


Figure 4.41: Variations of average inhibitor efficiency with temperature in 0.5MNaCl in presence of different concentrations of the pod extract.

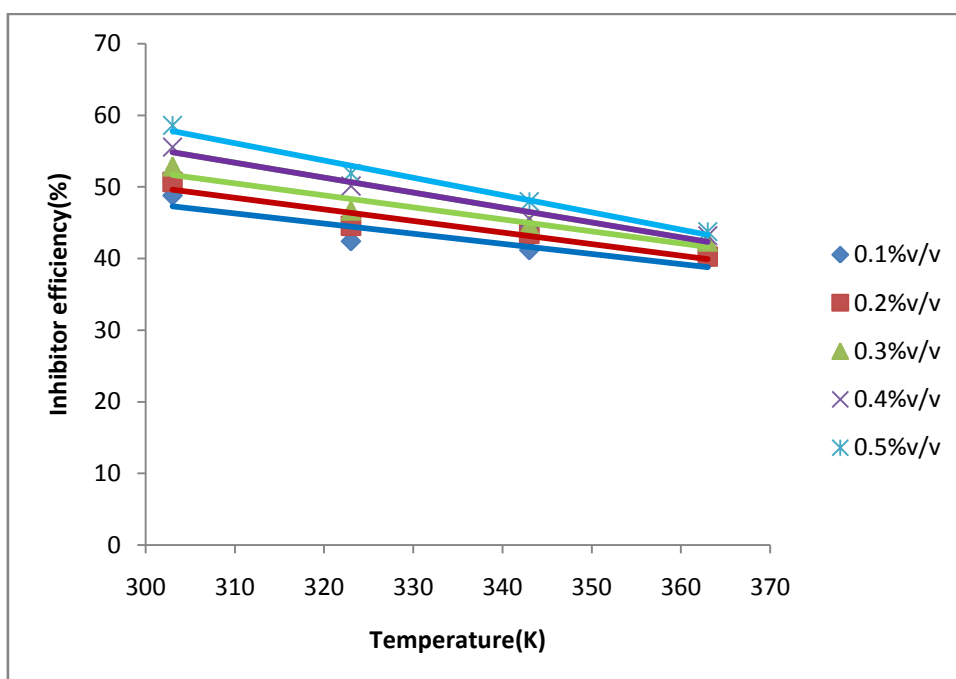


Figure 4.42: Variations of average inhibitor efficiency with temperature in 0.5MNaCl in presence of different concentrations of the leaf extract.

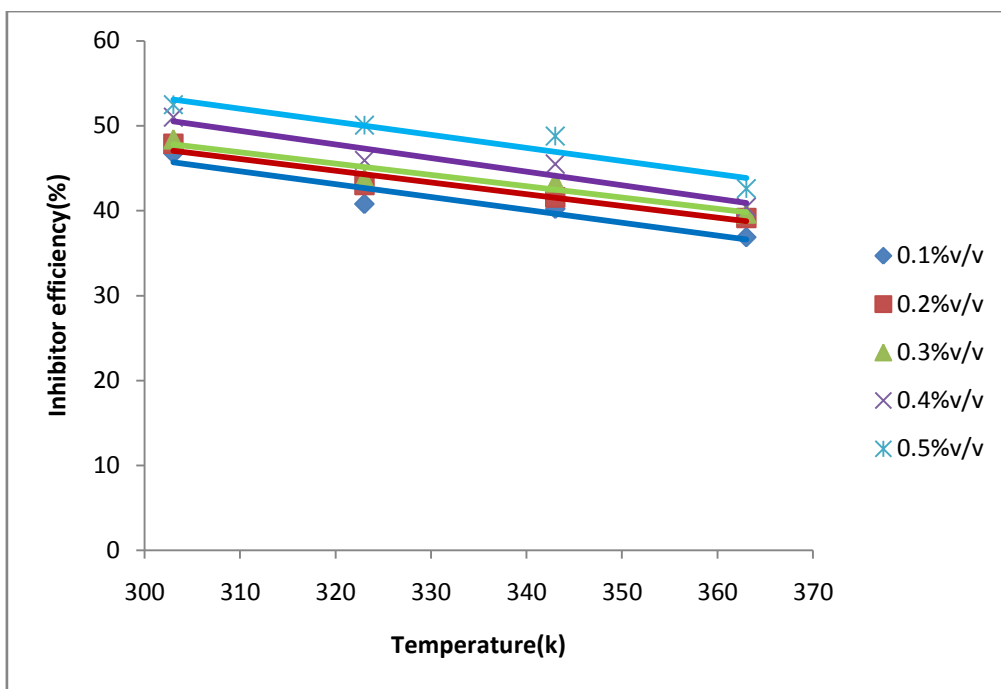


Figure 4.43: Variations of average inhibitor efficiency with temperature in 0.5MNaCl in presence of different concentrations of the stem bark extract.

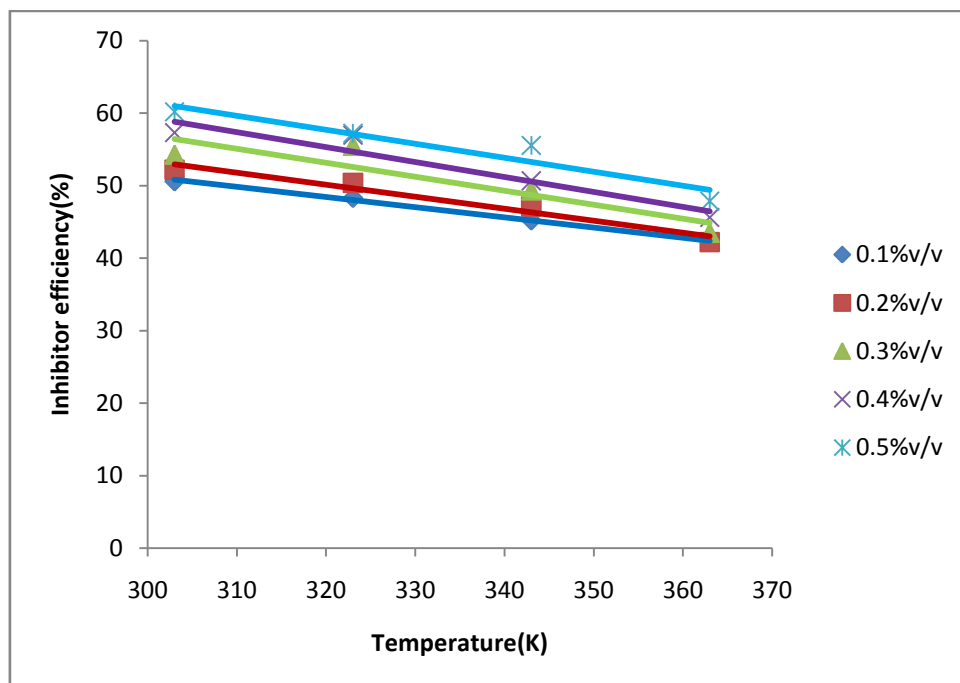


Figure 4.44: Variations of average inhibitor efficiency with temperature in 0.5MNaCl in presence of different concentrations of the root extract

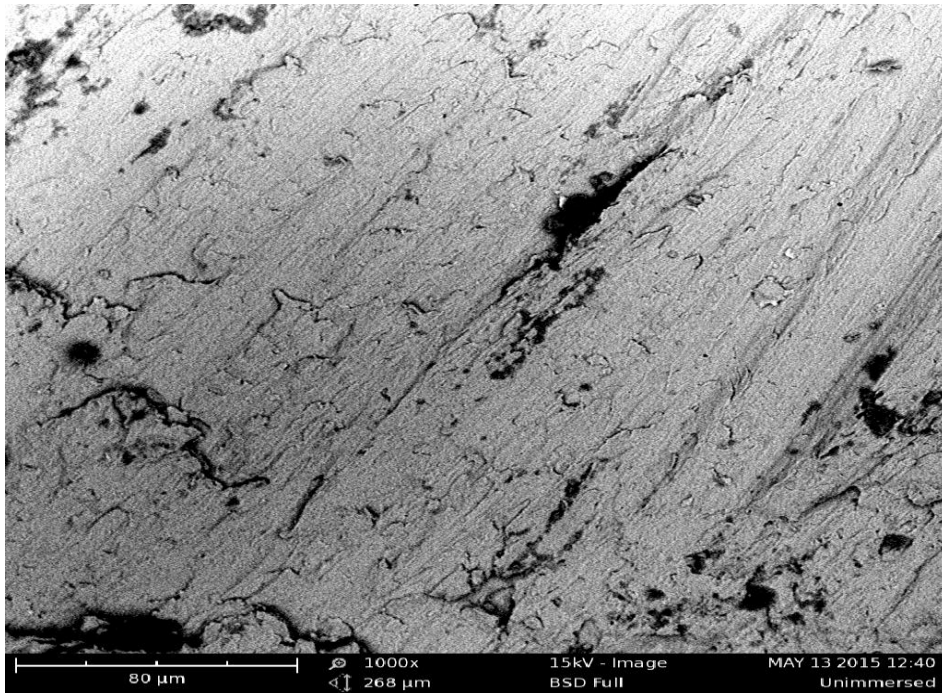


Plate 4.1: SEM image of polished unimmersed sample at 1000x magnification.

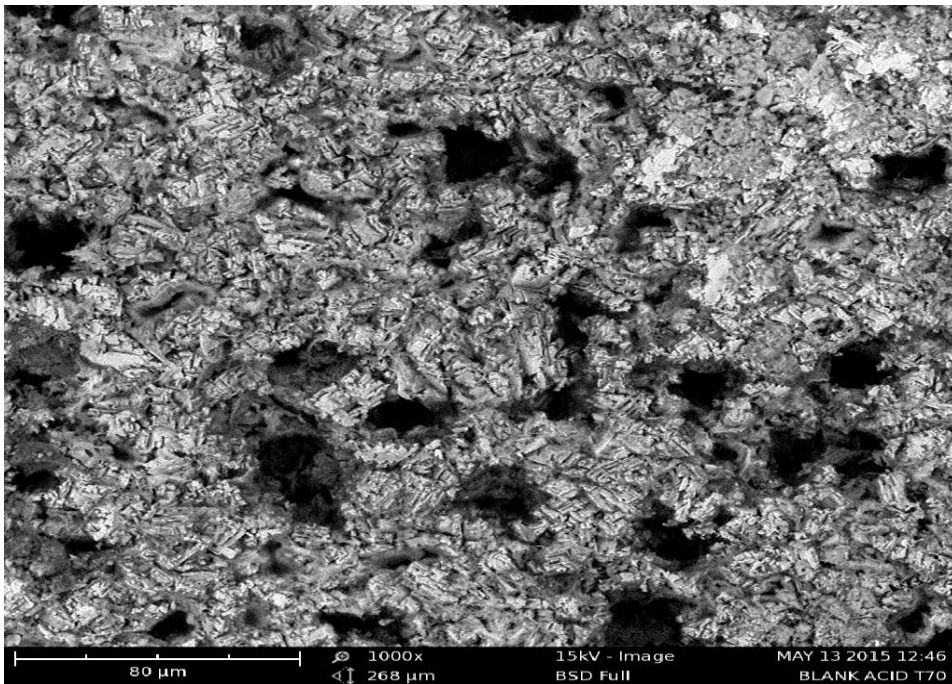


Plate 4.2: SEM image of sample immersed in blank acidic solution for 10 days at 30⁰C at 1000x magnification.

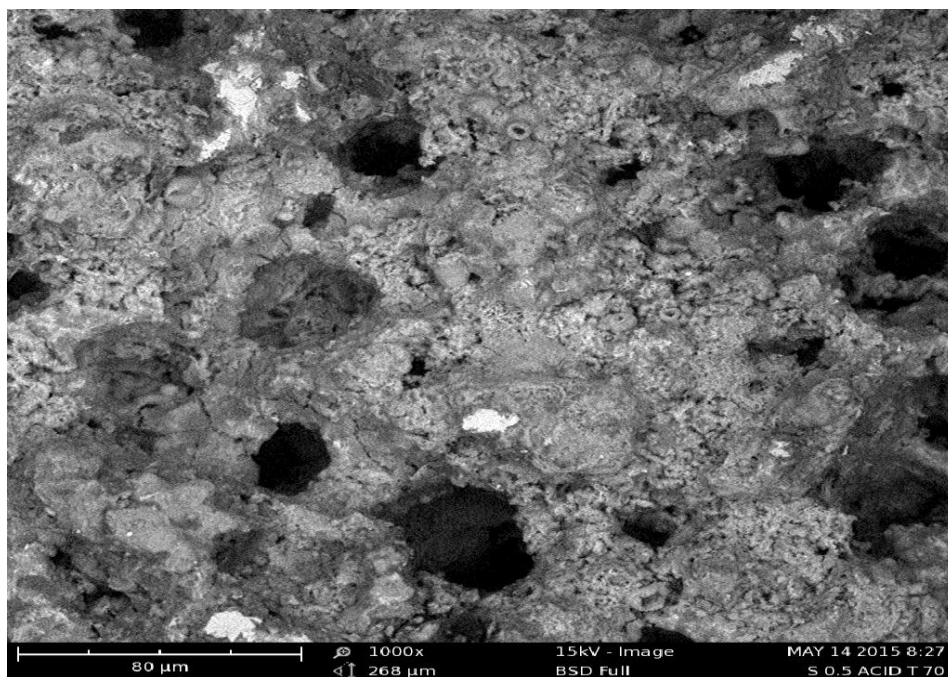


Plate 4.3: SEM image of sample immersed in acidic medium for 10days at 30⁰C in presence of 0.5% v/v stem bark extract at 1000x magnification.

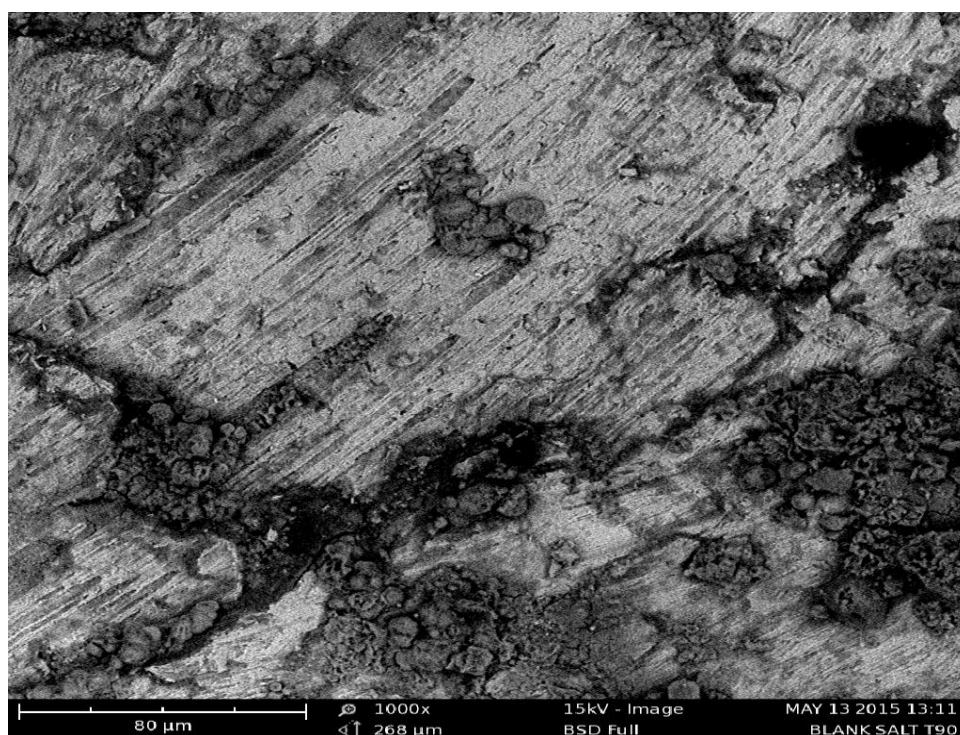


Figure 4.4: SEM image of sample immersed in blank salt medium for 10days at 30⁰C at 1000x magnification.

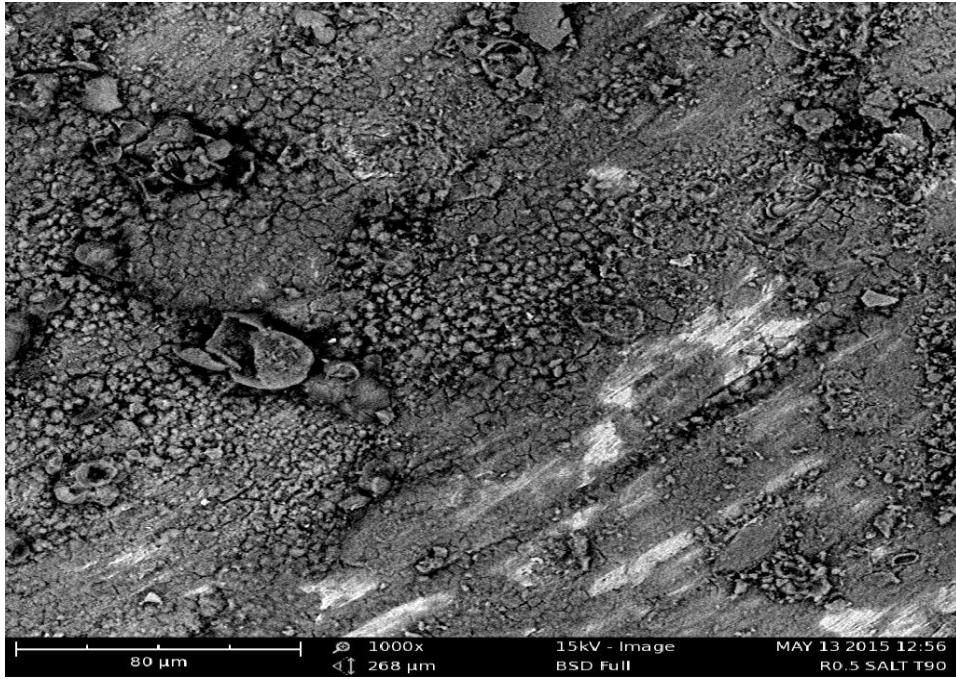


Plate 4.5: SEM image of sample immersed in salt medium for 10days at 30⁰C in the presence of 0.5% v/v Root extract at 1000x magnification.

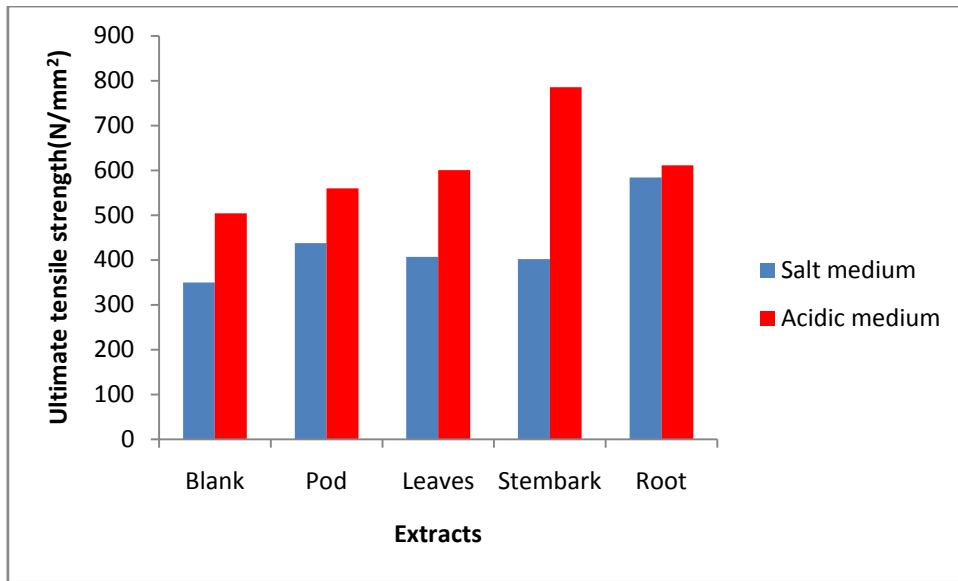


Figure 4.45: Comparison of ultimate tensile strengths of samples from acidic and salt media.

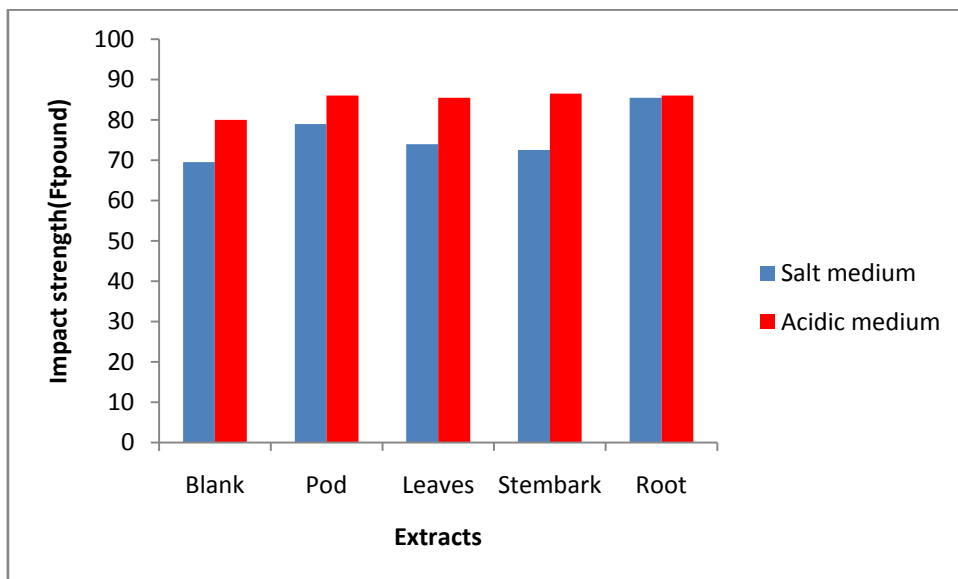


Figure 4.46: Comparison of impact strengths of samples from acidic and salt media.

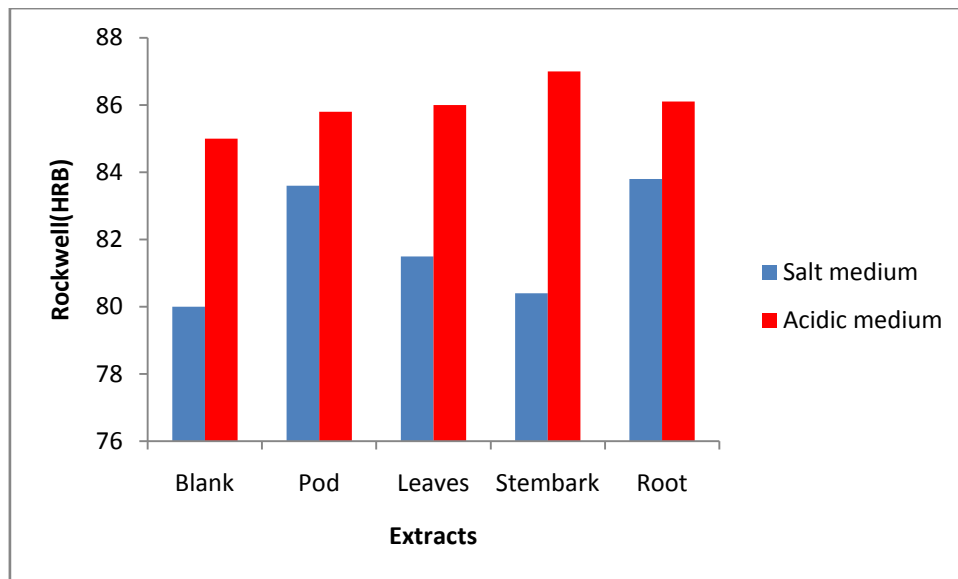


Figure 4.47: Comparison of Rockwell(HRB) hardness of samples from acidic and salt media

4.2 Discussion of results

4.2.1 Corrosion rates at Room temperature

From Figures 4.1-4.5 for the acidic medium, corrosion rates decrease with time in absence and presence of different concentrations of the extracts. However, corrosion rates in blank media are higher than inhibited environments. This actually concurs with what Patel et al (2013) discovered that corrosion rate of mild steel in 0.5M H₂SO₄ at room temperature in blank media is greater than in inhibited environments. Likewise in salt media, corrosion rates of the uninhibited media are markedly higher when compared to the inhibited environments which can be seen in Figures 4.6-4.10. Al-sultani et al (2013) reached the same observation. In both media, the inhibited environments are less aggressive than the blanks because inhibitors are adsorbed on the mild steel surfaces, hence, corrosion rates are reduced.

4.2.2 Effect of temperature .

From Figures 4.21-24 and Figures 4.29-32, one sees LogCR plotted against 1/T which shows that the corrosion rates in absence and presence of extracts increase with temperature. As temperature increases, 1/T values become smaller and smaller that it approaches zero gradually, and LogCR becomes larger, giving rise to negative-slope straight lines as shown in Mohana et al, (2012). Activation energy (E_a) values depicted in Table 4.1 for both acidic and salt media are obtained from the slopes of Log CR versus 1/T plots; using the fact that Arrhenius equation can be written in the modified form as:

$$\text{LogCR} = \text{Logk} - \frac{E_a}{2.303RT} \dots\dots\dots (4.1)$$

So that the slopes of the lines are equated to $-\frac{E_a}{2.303R}$, where R is a universal gas constant.

As seen from the Table, E_a values for blanks from both media are smaller as compared to the inhibited environments; its values increase with increase in the concentration of the inhibitors in both acidic and salt media.

From Figures 4.25-28 and 4.33-36 however, the values of enthalpy change (ΔH_a) and the entropy change (ΔS_a) of the corrosion processes can be evaluated from the slopes and intercepts of $\text{Log} \frac{CR}{T}$ versus $1/T$ plots of both media, based on the alternative Arrhenius equation with slopes as $(-\frac{\Delta H_a}{2.303R})$ and intercepts of $(\log(\frac{R}{nh}) + \frac{\Delta S_a}{2.303R})$. In Table 4.1, ΔS_a values from both media are generally negative, which implies that corrosion in blank and inhibited environments produce less thermodynamically disordered systems whereas ΔH_a values are all positive, indicating that the corrosion reactions in both the acidic and salt media are endothermic in nature.

From Figures 4.37-40 for the acidic medium and Figures 4.41-44 for the salt medium, it can be seen that the inhibition efficiencies (IE) of the extracts vary with temperature. IE of extracts on average decreases with increase in temperature. Increase in temperature was observed to lower the inhibition efficiency of some inhibitors, and this behaviour can be explained on the basis that an increase in temperature resulted in desorption of some adsorbed inhibitor molecules from the steel surface (Yawas ,2005) and (Leelavathi et al, 2013) .

4.2.3 Effect of concentration.

From figures 4.11- 4.15 in acidic medium and figures 4.16-4.20 in salt medium, inhibition efficiency of the extracts at room temperature increases with increase in concentration of the inhibitors, which is in line with Olasehinde et al (2013) and Al-sultani et al (2013). As can be deduced, corrosion rates in both media would be decreasing with increase in inhibitors concentration because as inhibitors concentration is increased, larger

surface area of the steel will be covered by the adsorbed inhibitors molecules, which consequently implies continuing reduction in direct contact area between the steel and corrosive environments, meaning continuing reduction in corrosion rates.

4.2.4 Effect of time

From Figures 4.1- 4.5 and 4.6- 4.10 ,corrosion rate(CR) decreases with time in blank and inhibited environments, in both media at room temperature (30⁰C) due to passivation, and action of inhibitors in inhibited environments.

4.2.5 Adsorption consideration

The adsorption equilibrium constant k_{ads} from both media were calculated using either Equation (3.17) or modified form of Equation (3.19) which is given as:

$$\text{Log}k_{ads} = - \frac{2a}{2.303} - \text{Log}C \dots\dots\dots(4.2)$$

depending on which isotherms fits the experimental datas more, or has a regression coefficient(R^2) closer to unity as seen in Table 4.2. ΔG_{ads} , Gibb’s free energy of adsorption is evaluated using Equation 3.20. ΔG_{ads} and k_{ads} values for the media are displayed in Tables 4.3 and 4.4 .According to Olasehinde et al (2013); Zarrok et al (2013) and Ramesh and Airody (2008);the negative values of ΔG_{ads} ensures the spontaneity of the adsorption process and stability of the adsorped layer on the mild steel surface and generally, the values of ΔG_{ads} around -20kj/mol or lower are consistent with physiosorption, while those around -40kj/mol or higher involve chemisorptions.

4.2.6 Scanning electron microscopy (SEM).

Plate 4.1 shows the SEM image of unimmersed ground sample, revealing the relatively smooth and uncorroded surfaces. SEM image of a sample immersed in blank acidic medium at the temperature of 30⁰C for 10days is depicted in Plate 4.2 with dense pits and cavities and when compared to Plate 4.3 of the similar sample immersed in acid medium at the same temperature for the same period but inhibited by 0.5%v/v stem extract, it can be seen that the density of pits per unit surface area is greater in the blanked sample, implying corrosion inhibition actually took place. Similarly, Plate 4.4 which was immersed in blanked salt medium at the temperature of 30⁰C for maximum period of 10days, when compared to Plate 4.5 that was immersed in same medium at the same temperature for the same period except that it was inhibited with 0.5%v/v root extract, it appears Plate 4.4 shows granular corrosion cracks, whereas Plate 4.5 is relatively smooth and shielded by thin film of the inhibitor. This indicates that corrosion inhibition is achieved by adsorption of the inhibitors unto the mild steel surface.

4.2.7. Mechanical properties

From Figures 4.45- 4.47, it can be seen that in acidic medium, the mechanical properties (ie tensile strength, impact and hardness) are lowest in uninhibited environments, due to the fact that corrosion badly affects mechanical properties (Yawas, 2005). This is because microscopic pits and cracks develop during corrosion serve as stress risers or stress concentration points, which thus weaken the strength of steels. However, are greater in stem bark extract due to its highest corrosion inhibition efficiency of 86.02% at 30⁰C. Equally, in salt medium, mechanical properties are most deteriorated in uninhibited medium(blank) and similar conclusion was reached in Rahbar and Zakeri (2010). They investigated the effect of 20% salt(NaCl) solution on the mechanical and corrosion resistance of steel, and discovered that the ultimate strength of steels are reduced. Maximum values were obtained in

root extract as a result of its maximum corrosion inhibition efficiency value of 60.57% at 30⁰C. In conclusion, all the mechanical properties were more deteriorated in salt medium than in acidic medium.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 Conclusions

From the results and discussions of this study, the following conclusions can be drawn:

- i The phyto-chemical screening of the extracts revealed the presence of tannins.
- ii Corrosion rates in absence and presence of extracts decrease with time at room temperature. Inhibited environments in both media are generally less aggressive than the blanks at all temperatures.
- iii The corrosion inhibition efficiencies (IE) of extracts in both media increase with concentration of the inhibitors at room temperature (30⁰C). The average corrosion inhibition efficiencies of extracts in acidic and salt media decrease with temperature. In acidic medium, the highest inhibition efficiency of 86.02% occurred at temperature 30⁰C in 5%v/v of stem extract whereas, in the salt medium the highest inhibition efficiency is 60.57% at 30⁰C in 5%v/v of root extract. The inhibitors, based on their inhibition efficiencies can be ranked from most effective to the worst as: stembark > root > pod > leaves in acidic medium and as: root > pod > leaves > stembark in salt medium.
- iv The scanning electron microscopy (SEM) analysis strengthened the argument that corrosion inhibition of mild steel actually happened at the optimum concentrations of the extracts.
- v The mechanical properties investigated were more deteriorated in salt medium than in acidic medium however, they are both significantly improved at the optimum concentrations of the extracts (ie 0.5%v/v stembark in acidic medium and 0.5%v/v root in salt medium).

vi Activation energies (E_a) in both media increase with the concentrations of the inhibitors. ΔH_a , (enthalpy change of the corrosion) values in both media are positive showing the endothermic nature of the process and entropy change of the corrosion (ΔS_a) values are almost entirely negative, showing that the corrosion process produces less thermodynamically disordered state. The ΔG_{ads} values from the media were entirely negative and less than -20Kj/mol showing the spontaneous nature of the physisorption process and the formation of stable protective films.

5.2 Recommendations

i Electrochemical methods of corrosion techniques like electrochemical impedance spectroscopy (EIS), potentiodynamic polarization should be carried out to confirm the results obtained.

ii Corrosion inhibition potentials of the extracts mixtures should be experimented. For example, form inhibitors solution from mixture of two or more extracts at a time.

iii Corrosion inhibition efficacies of the extracts on other ferrous metals and alloys should be tested.

vi Experiments should be carried out with higher and lower concentrations of the corrosive media (ie sulphuric acid and salt)

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APPENDICES

Appendix I: Elemental composition of the steel sample.

Carbon	Silicon	Manganese	Phosphorus	Chromium	Molybdenum
0.2734%	0.1575%	0.5919%	0.0365%	0.0834%	0.1192%

Titanium	Nitrogen	Nickel	Aluminum	Cobalt	Iron
0.0154%	0.0668%	0.4022%	0.0388%	0.0798%	98.1351%

Appendix II: Physio-chemical analysis of pod, leave, stembark and root of *Parkia biglobosa*.

SN	Plant parts	Ash-value in percentage	Acid-insoluble ash value in percentage	Alcohol-soluble extractive Value in percentage	Water-soluble extractive Value in percentage
1	Leaves	6 +0.15	0+0.15	2+0.15	3.2+0.15
2	Pods	10+0.15	5.5+0.15	14.2+0.15	14.2+0.15
3	Stembark	8.5+0.15	1+0.15	2+0.15	1.6+0.15
4	Roots	12.5+0.15	4+0.15	2.2+0.15	1.6+0.15

Appendix III: Phyto-chemical screening of pod, leaves, stem bark and root of parkia biglobosa

SN	Constituents	Leaves	Pods	Stembark	Roots
1	Carbohydrates	+	+	+	-
2	Glycosides	+	+	+	+
3	Steroids	+	+	+	-
4	Tanins	+	+	+	+
5	Flavonoids	+	+	+	+
6	Saponins	+	+	+	+
7	Alkaloids	+	+	+	+
8	Triterpenes	+	-	-	-

KEY:+ Presence -Absence

Appendix IV: Quantitative Analysis of pod, leaves, stembark and root powders of *parkia biglobosa*.

SN		Pod	Leaves	Stembark	Root
1	Moisture content (%)	10.9	10	10.2	9.7
2	Total Solids (%)	42.9	66.7	11.11	88.7
3	Total soluble (%)	4	6	6	3
4	Non-tannins Content (%)	3.87	2.67	3.94	2.91
5	Tannins content (%)	0.13	3.33	2.06	0.09
6	Total salt (%)	1.44	0.61	2.04	0.96
7	Total acid (%)	2.70	0.50	2.50	1.25
8	PH	5.80	6.67	6.08	6.61

Appendix V : Corrosion of mild steel in 0.5M sulphuric acid at room temperature after 48 hours of exposure

Concentration of inhibitors C (v/v%)	Initial weight (g)	Final weight (g)	Weight lost(g)	Corrosion rate(mm/yr) CR	Inhibitor efficiency (%) IE	Degree of surface coverage(θ)
Pod						
Blank	19.6471	18.8509	0.7962	11.4241	0	0
0.1	19.6196	19.2869	0.3327	4.7737	58.22	0.5822
0.2	21.3197	21.0013	0.3184	4.5685	60.10	0.6010
0.3	19.9860	19.7332	0.2528	3.6272	68.25	0.6825
0.4	19.7338	19.4995	0.2343	3.3618	70.57	0.7057
0.5	20.1532	19.9374	0.2158	3.0964	72.89	0.7289
Leaves						
0.1	22.4934	22.1024	0.3910	5.6102	50.89	0.5089
0.2	18.8312	18.5007	0.3305	4.7421	58.49	0.5849
0.3	20.5360	20.2192	0.3168	4.5455	60.21	0.6021
0.4	19.2087	18.9540	0.2547	3.6545	68.01	0.6801
0.5	21.7438	21.4926	0.2512	3.6043	68.45	0.6845
Stem						
0.1	19.9140	19.5977	0.3163	4.5384	60.28	0.6028
0.2	20.2509	19.9999	0.2510	3.6014	68.47	0.6847
0.3	21.5935	21.3784	0.2151	3.0863	72.98	0.7298
0.4	22.3867	22.2416	0.1451	2.0819	81.77	0.8177
0.5	20.7440	20.6016	0.1424	2.0432	82.11	0.8211
Root						
0.1	21.1082	20.7899	0.3183	4.5671	60.02	0.6002
0.2	22.4868	22.1860	0.3008	4.3160	62.22	0.6222
0.3	21.9273	21.6750	0.2523	3.6201	68.31	0.6831
0.4	23.7193	23.5038	0.2155	3.0921	72.94	0.7294
0.5	21.7441	21.5907	0.1534	2.2010	80.73	0.8073

Appendix VI : Corrosion of mild steel in 0.5M sulphuric acid at room temperature after 96 hours of exposure

Concentration of inhibitors C (v/v%)	Initial weight(g)	Final weight (g)	Weight lost(g)	Corrosion rate(mm/yr) CR	Inhibitor efficiency (%) IE	Degree of surface coverage(θ)
Pod						
Blank	19.6471	18.8239	0.8232	5.9058	0	0
0.1	19.6196	19.2780	0.3416	2.4507	58.50	0.5850
0.2	21.3197	20.9952	0.3245	2.3280	60.58	0.6058
0.3	19.9860	19.7307	0.2553	1.8316	68.99	0.6899
0.4	19.7338	19.4952	0.2386	1.7118	71.02	0.7102
0.5	20.1532	19.9309	0.2223	1.5948	73.00	0.7300
Leaves						
0.1	22.4934	22.0899	0.4035	2.8948	50.99	0.5099
0.2	18.8312	18.4939	0.3373	2.4198	59.03	0.5903
0.3	20.5360	20.2108	0.3252	2.3330	60.49	0.6049
0.4	19.2087	18.9477	0.2610	1.8725	68.29	0.6829
0.5	21.7438	21.4845	0.2593	1.8603	68.50	0.6850
Stem						
0.1	19.9140	19.6013	0.3127	2.2434	62.02	0.6202
0.2	20.2509	19.9952	0.2557	1.8344	68.94	0.6894
0.3	21.5935	21.3712	0.2223	1.5948	73.00	0.7300
0.4	22.3867	22.2430	0.1437	1.0309	82.54	0.8254
0.5	20.7440	20.6041	0.1399	1.0037	83.00	0.8300
Root						
0.1	21.1082	20.7862	0.3220	2.3101	60.89	0.6089
0.2	22.4868	22.1788	0.3080	2.2096	62.58	0.6258
0.3	21.9273	21.6754	0.2519	1.8072	69.40	0.6940
0.4	23.7193	23.4971	0.2222	1.5941	73.01	0.7301
0.5	21.7441	21.5868	0.1573	1.1285	80.89	0.8089

Appendix VII: Corrosion of mild steel in 0.5M sulphuric acid at room temperature after 144 hours of exposure

Concentration of inhibitors C (v/v%)	Initial weight(g)	Final weight (g)	Weight lost(g)	Corrosion rate(mm/yr) CR	Inhibitor efficiency (%) IE	Degree of surface coverage(θ)
Pod						
Blank	19.6471	18.8031	0.8440	4.0367	0	0
0.1	19.6196	19.2726	0.3470	1.6596	58.89	0.5889
0.2	21.3197	20.9879	0.3318	1.5869	60.69	0.6069
0.3	19.9860	19.7261	0.2599	1.2430	69.21	0.6921
0.4	19.7338	19.4923	0.2415	1.1550	71.39	0.7139
0.5	20.1532	19.9355	0.2177	1.0412	74.21	0.7421
Leaves						
0.1	22.4934	22.0800	0.4134	1.9772	51.02	0.5102
0.2	18.8312	18.4893	0.3419	1.6352	59.49	0.5949
0.3	20.5360	20.2068	0.3292	1.5745	60.99	0.6099
0.4	19.2087	18.9428	0.2659	1.2717	68.50	0.6850
0.5	21.7438	21.4653	0.2785	1.3320	67.00	0.6700
Stem						
0.1	19.9140	19.6222	0.2918	1.3956	65.43	0.6543
0.2	20.2509	19.9892	0.2617	1.2516	68.99	0.6899
0.3	21.5935	21.3736	0.2199	1.0517	73.94	0.7394
0.4	22.3867	22.2433	0.1434	0.6858	83.01	0.8301
0.5	20.7440	20.6094	0.1346	0.6438	84.05	0.8405
Root						
0.1	21.1082	20.7793	0.3289	1.5731	61.03	0.6103
0.2	22.4868	22.1741	0.3127	1.4956	62.95	0.6295
0.3	21.9273	21.6699	0.2574	1.2311	69.50	0.6950
0.4	23.7193	23.4935	0.2258	1.0799	73.25	0.7325
0.5	21.7441	21.5836	0.1605	0.7676	80.98	0.8098

Appendix VIII : Corrosion of mild steel in 0.5M sulphuric acid at room temperature after 192 hours of exposure

Concentration of inhibitors C (v/v%)	Initial weight(g)	Final weight (g)	Weight lost(g)	Corrosion rate(mm/yr) CR	Inhibitor efficiency (%) IE	Degree of surface coverage(θ)
Pod						
Blank	19.6471	18.7932	0.8539	3.0630	0	0
0.1	19.6196	19.2648	0.3548	1.2727	58.45	0.5845
0.2	21.3197	20.9850	0.3347	1.2006	60.80	0.6080
0.3	19.9860	19.7246	0.2614	0.9377	69.39	0.6939
0.4	19.7338	19.4938	0.2400	0.8609	71.89	0.7189
0.5	20.1532	19.9314	0.2218	0.7956	74.03	0.7403
Leaves						
0.1	22.4934	22.0767	0.4167	1.4947	51.20	0.5120
0.2	18.8312	18.4838	0.3474	1.2461	59.32	0.5932
0.3	20.5360	20.2031	0.3329	1.1941	61.02	0.6102
0.4	19.2087	18.9399	0.2688	0.9642	68.52	0.6852
0.5	21.7438	21.4639	0.2799	1.0040	67.22	0.6722
Stem						
0.1	19.9140	19.6108	0.3032	1.0876	64.49	0.6449
0.2	20.2509	19.9861	0.2648	0.9499	68.99	0.6899
0.3	21.5935	21.3715	0.2220	0.7963	74.00	0.7400
0.4	22.3867	22.2526	0.1341	0.4810	84.30	0.8430
0.5	20.7440	20.6180	0.1260	0.4520	85.25	0.8525
Root						
0.1	21.1082	20.7798	0.3284	1.1780	61.54	0.6154
0.2	22.4868	22.1729	0.3139	1.1260	63.24	0.6324
0.3	21.9273	21.6710	0.2563	0.9194	69.98	0.6998
0.4	23.7193	23.4934	0.2259	0.8103	73.55	0.7355
0.5	21.7441	21.5838	0.1603	0.5750	81.23	0.8123

Appendix IX: Corrosion of mild steel in 0.5M sulphuric acid at room temperature after 240 hours of exposure

Concentration of inhibitors C (v/v%)	Initial weight(g)	Final weight (g)	Weight lost(g)	Corrosion rate(mm/yr) CR	Inhibitor efficiency (%) IE	Degree of surface coverage(θ)
Pod						
Blank	19.6471	18.7665	0.8806	2.5270	0	0
0.1	19.6196	19.2585	0.3611	1.0362	58.99	0.5899
0.2	21.3197	20.9763	0.3434	0.9854	61.00	0.6100
0.3	19.9860	19.7151	0.2709	0.7774	69.24	0.6924
0.4	19.7338	19.4871	0.2467	0.7079	71.99	0.7199
0.5	20.1532	19.9331	0.2201	0.6316	75.01	0.7501
Leaves						
0.1	22.4934	22.0659	0.4275	1.2268	51.45	0.5145
0.2	18.8312	18.4787	0.3525	1.0116	59.97	0.5997
0.3	20.5360	20.1930	0.3430	0.9843	61.05	0.6105
0.4	19.2087	18.9339	0.2748	0.7886	68.79	0.6879
0.5	21.7438	21.4552	0.2886	0.8282	67.23	0.6723
Stem						
0.1	19.9140	19.6076	0.3064	0.8793	65.21	0.6521
0.2	20.2509	19.9780	0.2729	0.7831	69.01	0.6901
0.3	21.5935	21.3647	0.2288	0.6566	74.01	0.7401
0.4	22.3867	22.2451	0.1416	0.4063	83.92	0.8392
0.5	20.7440	20.6209	0.1231	0.3533	86.02	0.8602
Root						
0.1	21.1082	20.7668	0.3414	0.9797	61.23	0.6123
0.2	22.4868	22.1481	0.3387	0.9720	61.54	0.6154
0.3	21.9273	21.6368	0.2905	0.8336	67.01	0.6701
0.4	23.7193	23.4902	0.2291	0.6574	73.98	0.7398
0.5	21.7441	21.5818	0.1623	0.4657	81.57	0.8157

Appendix X: Corrosion of mild steel in 0.5M sulphuric acid at 50 degree celsius after 0.5hours of exposure

Concentration of inhibitors C (v/v%)	Initial weight(g)	Final weight (g)	Weight lost(g)	Corrosion rate(mm/yr) CR	Inhibitor efficiency (%) IE	Degree of surface coverage(θ)
Pod						
Blank	22.4846	22.3077	0.1769	243.67	0	0
0.1	22.4415	22.3513	0.0902	124.20	49.01	0.4901
0.2	19.9533	19.8680	0.0853	117.50	51.76	0.5176
0.3	20.6716	20.5977	0.0739	101.80	58.21	0.5821
0.4	20.6132	20.5405	0.0727	100.10	58.89	0.5889
0.5	20.4265	20.3558	0.0707	97.38	60.01	0.6001
Leaves						
0.1	19.2699	19.1643	0.1056	145.50	40.31	0.4031
0.2	22.2603	22.1584	0.1019	140.40	42.41	0.4241
0.3	19.2715	19.1769	0.0946	130.30	46.51	0.4651
0.4	21.1756	21.0853	0.0903	124.40	48.98	0.4898
0.5	20.0892	20.0162	0.0730	100.6	58.71	0.5871
Stem						
0.1	20.3987	20.3113	0.0874	120.40	50.59	0.5059
0.2	22.4573	22.3768	0.0805	110.90	54.52	0.5452
0.3	20.6318	20.5613	0.0705	97.11	60.12	0.6012
0.4	22.4118	22.3505	0.0613	84.44	65.33	0.6533
0.5	22.4799	22.4220	0.0579	79.75	67.28	0.6728
Root						
0.1	23.1524	23.0644	0.0880	121.20	50.25	0.5025
0.2	20.9038	20.8225	0.0813	112.00	54.02	0.5402
0.3	20.8540	20.7809	0.0731	100.70	58.69	0.5869
0.4	20.8073	20.7367	0.0706	97.25	60.07	0.6007
0.5	20.2530	20.1863	0.0667	91.88	62.31	0.6231

Appendix XI: Corrosion of mild steel in 0.5M sulphuric acid at 50 degree celsius after 1 hour of exposure

Concentration of inhibitors C (v/v%)	Initial weight(g)	Final weight (g)	Weight lost(g)	Corrosion rate(mm/yr) CR	Inhibitor efficiency (%) IE	Degree of surface coverage(θ)
Pod						
Blank	22.4846	22.2714	0.2132	146.83	0	0
0.1	22.4415	22.3334	0.1081	74.45	49.29	0.4929
0.2	19.9533	19.8510	0.1023	70.46	52.01	0.5201
0.3	20.6716	20.5830	0.0886	61.02	58.42	0.5842
0.4	20.6132	20.5258	0.0874	60.19	58.99	0.5899
0.5	20.4265	20.3417	0.0848	58.40	60.21	0.6021
Leaves						
0.1	19.2699	19.1446	0.1253	86.30	41.21	0.4121
0.2	22.2603	22.1381	0.1222	84.16	42.68	0.4268
0.3	19.2715	19.1579	0.1136	78.24	46.71	0.4671
0.4	21.1756	21.0669	0.1087	74.86	49.01	0.4901
0.5	20.0892	20.0016	0.0876	60.33	58.89	0.5889
Stem						
0.1	20.3987	20.2936	0.1051	72.38	50.69	0.5069
0.2	22.4573	22.3604	0.0969	66.74	54.54	0.5454
0.3	20.6318	20.5476	0.0842	57.99	60.51	0.6051
0.4	22.4118	22.3382	0.0736	50.69	65.47	0.6547
0.5	22.4799	22.4098	0.0701	48.28	67.11	0.6711
Root						
0.1	23.1524	23.0468	0.1056	72.73	50.47	0.5047
0.2	20.9038	20.8063	0.0975	67.15	54.25	0.5425
0.3	20.8540	20.7665	0.0875	60.26	58.97	0.5897
0.4	20.8073	20.7226	0.0847	58.33	60.27	0.6027
0.5	20.2530	20.1731	0.0799	55.03	62.51	0.6251

Appendix XII: Corrosion of mild steel in 0.5M sulphuric acid at 50 degree celsius after 1.5hours of exposure

Concentration of inhibitors C (v/v%)	Initial weight(g)	Final weight (g)	Weight lost(g)	Corrosion rate(mm/yr) CR	Inhibitor efficiency (%) IE	Degree of surface coverage(θ)
Pod						
Blank	22.4846	22.2348	0.2498	114.69	0	0
0.1	22.4415	22.3166	0.1249	57.35	49.98	0.4998
0.2	19.9533	19.8347	0.1186	54.45	52.52	0.5252
0.3	20.6716	20.5683	0.1033	47.43	58.63	0.5863
0.4	20.6132	20.5111	0.1021	46.88	59.11	0.5911
0.5	20.4265	20.3274	0.0991	45.50	60.32	0.6032
Leaves						
0.1	19.2699	19.1231	0.1468	67.40	41.22	0.4122
0.2	22.2603	22.1179	0.1424	65.38	43.01	0.4301
0.3	19.2715	19.1388	0.1327	60.93	46.88	0.4688
0.4	21.1756	21.0495	0.1261	57.90	49.53	0.4953
0.5	20.0892	19.9868	0.1024	47.02	59.01	0.5901
Stem						
0.1	20.3987	20.2776	0.1211	55.60	51.50	0.5150
0.2	22.4573	22.3449	0.1124	51.61	55.02	0.5502
0.3	20.6318	20.5349	0.0969	44.49	61.21	0.6121
0.4	22.4118	22.3256	0.0862	39.58	65.49	0.6549
0.5	22.4799	22.3987	0.0812	37.28	67.51	0.6751
Root						
0.1	23.1524	23.0292	0.1232	56.57	50.68	0.5068
0.2	20.9038	20.7904	0.1134	52.07	54.62	0.5462
0.3	20.8540	20.7516	0.1024	47.02	59.01	0.5901
0.4	20.8073	20.7081	0.0992	45.55	60.30	0.6030
0.5	20.2530	20.1601	0.0929	42.65	62.82	0.6282

Appendix XIII: Corrosion of mild steel in 0.5M sulphuric acid at 50 degree celsius after 2 hour of exposure

Concentration of inhibitors C (v/v%)	Initial weight(g)	Final weight (g)	Weight lost(g)	Corrosion rate(mm/yr) CR	Inhibitor efficiency (%) IE	Degree of surface coverage(θ)
Pod						
Blank	22.4846	22.1933	0.2913	100.31	0	0
0.1	22.4415	22.2959	0.1456	50.14	50.01	0.5001
0.2	19.9533	19.8155	0.1378	47.45	52.68	0.5268
0.3	20.6716	20.5511	0.1205	41.50	58.62	0.5862
0.4	20.6132	20.4938	0.1194	41.12	59.01	0.5901
0.5	20.4265	20.3113	0.1152	39.67	60.45	0.6045
Leaves						
0.1	19.2699	19.1008	0.1691	58.23	41.96	0.4196
0.2	22.2603	22.0952	0.1651	56.85	43.31	0.4331
0.3	19.2715	19.1168	0.1547	53.27	46.89	0.4689
0.4	21.1756	21.0272	0.1484	51.10	49.07	0.4907
0.5	20.0892	19.9726	0.1166	40.15	59.98	0.5998
Stem						
0.1	20.3987	20.2567	0.1420	48.90	51.24	0.5124
0.2	22.4573	22.3304	0.1269	43.70	56.42	0.5642
0.3	20.6318	20.5194	0.1124	38.71	61.42	0.6142
0.4	22.4118	22.3100	0.1018	35.06	65.04	0.6504
0.5	22.4799	22.3856	0.0943	32.47	67.63	0.6763
Root						
0.1	23.1524	23.0077	0.1447	49.83	50.32	0.5032
0.2	20.9038	20.7727	0.1311	45.15	54.98	0.5498
0.3	20.8540	20.7352	0.1188	40.91	59.22	0.5922
0.4	20.8073	20.6919	0.1154	39.74	60.40	0.6040
0.5	20.2530	20.1450	0.1080	37.19	62.92	0.6292

Appendix XIV: Corrosion of mild steel in 0.5M sulphuric acid at 70 degree celsius after 0.5hour of exposure

Concentration of inhibitors C (v/v%)	Initial weight(g)	Final weight (g)	Weight lost(g)	Corrosion rate(mm/yr) CR	Inhibitor efficiency (%) IE	Degree of surface coverage(θ)
Pod						
Blank	20.1692	19.8628	0.3064	422.05	0	0
0.1	22.3559	22.1733	0.1826	251.50	40.39	0.4039
0.2	19.9075	19.7313	0.1762	242.70	42.50	0.4250
0.3	19.8086	19.6444	0.1642	226.20	46.42	0.4642
0.4	20.4434	20.2880	0.1554	214.10	49.29	0.4929
0.5	20.2602	20.1085	0.1517	209.00	50.49	0.5049
Leaves						
0.1	21.2949	21.1111	0.1838	253.20	40.00	0.4000
0.2	21.2619	21.0818	0.1801	248.10	41.21	0.4121
0.3	20.5200	20.3463	0.1737	239.30	43.30	0.4330
0.4	20.8508	20.6843	0.1665	229.30	45.67	0.4567
0.5	22.4388	22.2801	0.1587	218.60	48.21	0.4821
Stem						
0.1	21.0133	20.8469	0.1664	229.20	45.68	0.4568
0.2	22.3937	22.2320	0.1617	222.70	47.21	0.4721
0.3	20.9718	20.8167	0.1551	213.64	49.39	0.4939
0.4	22.3648	22.2288	0.1360	187.33	55.60	0.5560
0.5	20.4142	20.2919	0.1223	168.50	60.07	0.6007
Root						
0.1	19.0326	18.8578	0.1748	240.80	42.96	0.4296
0.2	19.5960	19.4240	0.1720	236.90	43.86	0.4386
0.3	19.9957	19.8302	0.1655	228.00	45.98	0.4598
0.4	19.9476	19.7883	0.1593	219.40	48.01	0.4801
0.5	22.6297	22.4802	0.1495	205.9	51.20	0.5120

Appendix XV: Corrosion of mild steel in 0.5M sulphuric acid at 70 degree celsius after 1 hour of exposure

Concentration of inhibitors C (v/v%)	Initial weight(g)	Final weight (g)	Weight lost(g)	Corrosion rate(mm/yr) CR	Inhibitor efficiency (%) IE	Degree of surface coverage(θ)
Pod						
Blank	20.1692	19.6236	0.5456	375.76	0	0
0.1	22.3559	22.0341	0.3218	221.60	41.01	0.4101
0.2	19.9075	19.5977	0.3098	213.40	43.21	0.4321
0.3	19.8086	19.5188	0.2898	199.60	46.89	0.4689
0.4	20.4434	20.1675	0.2755	189.70	49.50	0.4950
0.5	20.2602	19.9907	0.2095	185.60	50.61	0.5061
Leaves						
0.1	21.2949	20.9697	0.3252	224.00	40.39	0.4039
0.2	21.2619	20.9417	0.3202	220.50	41.31	0.4131
0.3	20.5200	20.2109	0.3091	212.90	43.35	0.4335
0.4	20.8508	20.5551	0.2957	203.70	45.80	0.4580
0.5	22.4388	22.1578	0.2810	193.50	48.50	0.4850
Stem						
0.1	21.0133	20.7186	0.2947	203.00	45.98	0.4598
0.2	22.3937	22.1075	0.2862	197.10	47.54	0.4754
0.3	20.9718	20.6972	0.2746	189.10	49.67	0.4967
0.4	22.3648	22.1229	0.2419	166.60	55.67	0.5567
0.5	20.4142	20.1966	0.2176	149.90	60.11	0.6011
Root						
0.1	19.0326	18.7217	0.3109	214.10	43.01	0.4301
0.2	19.5960	19.2909	0.3051	210.10	44.08	0.4408
0.3	19.9957	19.7010	0.2947	203.00	45.99	0.4599
0.4	19.9476	19.6695	0.2781	191.50	49.02	0.4902
0.5	22.6297	22.3646	0.2651	182.60	51.42	0.5142

Appendix XVI: Corrosion of mild steel in 0.5M sulphuric acid at 70 degree celsius after 1.5hour of exposure

Concentration of inhibitors C (v/v%)	Initial weight(g)	Final weight (g)	Weight lost(g)	Corrosion rate(mm/yr) CR	Inhibitor efficiency (%) IE	Degree of surface coverage(θ)
Pod						
Blank	20.1692	19.3738	0.7954	365.2	0	0
0.1	22.3559	21.8886	0.4673	214.60	41.25	0.4125
0.2	19.9075	19.4587	0.4488	206.10	43.58	0.4358
0.3	19.8086	19.3870	0.4216	193.60	46.99	0.4699
0.4	20.4434	20.0425	0.4009	184.10	49.60	0.4960
0.5	20.2602	19.8683	0.3919	179.90	50.73	0.5073
Leaves						
0.1	21.2949	20.8210	0.4739	217.60	40.42	0.4042
0.2	21.2619	20.7960	0.4659	213.90	41.42	0.4142
0.3	20.5200	20.0718	0.4482	205.80	43.65	0.4365
0.4	20.8508	20.4205	0.4303	197.60	45.90	0.4590
0.5	22.4388	22.0300	0.4088	187.70	48.60	0.4860
Stem						
0.1	21.0133	20.5855	0.4278	196.40	46.21	0.4621
0.2	22.3937	21.9799	0.4138	190.0	47.98	0.4798
0.3	20.9718	20.5724	0.3994	183.40	49.78	0.4978
0.4	22.3648	22.0128	0.3520	161.60	55.75	0.5575
0.5	20.4142	20.0986	0.3156	144.90	60.32	0.6032
Root						
0.1	19.0326	18.5809	0.4517	207.40	43.21	0.4321
0.2	19.5960	19.1513	0.4447	204.20	44.09	0.4409
0.3	19.9957	19.5663	0.4294	197.20	46.01	0.4601
0.4	19.9476	19.5436	0.4040	185.50	49.21	0.4921
0.5	22.6297	22.2453	0.3844	176.50	51.67	0.5167

Appendix XVII: Corrosion of mild steel in 0.5M sulphuric acid at 70 degree celsius after 2 hour of exposure

Concentration of inhibitors C (v/v%)	Initial weight(g)	Final weight (g)	Weight lost(g)	Corrosion rate(mm/yr) CR	Inhibitor efficiency (%) IE	Degree of surface coverage(θ)
Pod						
Blank	20.1692	19.0329	1.1363	391.30	0	0
0.1	22.3559	21.6912	0.6647	228.90	41.50	0.4150
0.2	19.9075	19.2675	0.6400	220.40	43.68	0.4368
0.3	19.8086	19.2087	0.5999	206.60	47.21	0.4721
0.4	20.4434	19.8890	0.5544	190.90	51.21	0.5121
0.5	20.2602	19.7008	0.5594	192.60	50.77	0.5077
Leaves						
0.1	21.2949	20.6191	0.6758	232.70	40.53	0.4053
0.2	21.2619	20.6005	0.6614	227.80	41.79	0.4179
0.3	20.5200	19.8820	0.6380	219.70	43.85	0.4385
0.4	20.8508	20.2396	0.6112	210.50	46.21	0.4621
0.5	22.4388	21.8536	0.5852	201.50	48.50	0.4850
Stem						
0.1	21.0133	20.4108	0.6025	207.50	46.98	0.4698
0.2	22.3937	21.8029	0.5908	203.40	48.01	0.4801
0.3	20.9718	20.3982	0.5736	197.50	49.52	0.4952
0.4	22.3648	21.8631	0.5017	172.80	55.85	0.5585
0.5	20.4142	19.9638	0.4504	155.10	60.36	0.6036
Root						
0.1	19.0326	18.3876	0.6450	222.10	43.24	0.4324
0.2	19.5960	18.9630	0.6330	218.00	44.29	0.4429
0.3	19.9957	19.3845	0.6112	210.50	46.21	0.4621
0.4	19.9476	19.3730	0.5746	197.90	49.43	0.4943
0.5	22.6297	22.0825	0.5472	188.40	51.84	0.5184

Appendix XVIII: Corrosion of mild steel in 0.5M sulphuric acid at 90 degree celsius after 0.5 hour of exposure

Concentration of inhibitors C (v/v%)	Initial weight(g)	Final weight (g)	Weight lost(g)	Corrosion rate(mm/yr) CR	Inhibitor efficiency (%) IE	Degree of surface coverage(θ)
Pod						
Blank	20.6296	20.4283	0.2013	277.28	0	0
0.1	20.1925	20.0717	0.1208	166.40	39.98	0.3998
0.2	19.7274	19.6066	0.1208	166.40	40.01	0.4001
0.3	19.1404	19.0257	0.1147	158.00	43.01	0.4301
0.4	18.7987	18.6884	0.1103	151.93	45.21	0.4521
0.5	21.1637	21.0550	0.1087	149.70	46.00	0.4600
Leaves						
0.1	22.2185	22.0937	0.1248	171.90	37.98	0.3798
0.2	20.1968	20.0750	0.1218	167.80	39.49	0.3949
0.3	19.8005	19.6801	0.1204	165.80	40.21	0.4021
0.4	19.2489	19.1307	0.1182	162.80	41.29	0.4129
0.5	22.1808	22.0665	0.1143	157.40	43.21	0.4321
Stem						
0.1	19.7760	19.6600	0.1160	159.80	42.38	0.4238
0.2	22.0617	21.9494	0.1123	154.70	44.21	0.4421
0.3	19.4778	19.3703	0.1075	148.10	46.59	0.4659
0.4	19.9879	19.8836	0.1043	143.70	48.21	0.4821
0.5	19.6113	19.5115	0.0998	137.50	50.41	0.5041
Root						
0.1	20.0022	19.8819	0.1203	165.70	40.23	0.4023
0.2	20.3156	20.1977	0.1179	162.40	41.41	0.4141
0.3	21.9421	21.8274	0.1147	158.00	43.02	0.4302
0.4	20.1207	20.0106	0.1101	151.70	45.29	0.4529
0.5	20.5191	20.4128	0.1063	146.40	47.21	0.4721

Appendix XIX: Corrosion of mild steel in 0.5M sulphuric acid at 90 degree celsius after 1 hour of exposure

Concentration of inhibitors C (v/v%)	Initial weight(g)	Final weight (g)	Weight lost(g)	Corrosion rate(mm/yr) CR	Inhibitor efficiency (%) IE	Degree of surface coverage(θ)
Blank	20.6296	20.2742	0.3554	244.77	0	0
0.1	20.1925	19.9793	0.2132	146.80	40.01	0.4001
0.2	19.7274	19.5149	0.2125	146.40	40.21	0.4021
0.3	19.1404	18.9386	0.2018	139.00	43.21	0.4321
0.4	18.7987	18.6047	0.1940	133.60	45.41	0.4541
0.5	21.1637	20.9725	0.1912	131.70	46.21	0.4621
Leaves						
0.1	22.2185	22.0052	0.2133	146.90	39.98	0.3998
0.2	20.1968	19.9843	0.2125	146.40	40.21	0.4021
0.3	19.8005	19.5888	0.2117	145.80	40.42	0.4042
0.4	19.2489	19.0413	0.2076	143.00	41.59	0.4159
0.5	22.1808	21.9797	0.2011	138.50	43.41	0.4341
Stem						
0.1	19.7760	19.5751	0.2009	138.40	43.47	0.4347
0.2	22.0617	21.8651	0.1966	135.40	44.68	0.4468
0.3	19.4778	19.2902	0.1876	129.20	47.21	0.4721
0.4	19.9879	19.8055	0.1824	125.60	48.68	0.4868
0.5	19.6113	19.4354	0.1759	121.20	50.52	0.5052
Root						
0.1	20.0022	19.7933	0.2089	143.90	41.21	0.4121
0.2	20.3156	20.1083	0.2073	142.80	41.68	0.4168
0.3	21.9421	21.7402	0.2019	139.10	43.20	0.4320
0.4	20.1207	19.9270	0.1937	133.40	45.50	0.4550
0.5	20.5191	20.3322	0.1869	128.70	47.42	0.4742

Appendix XX: Corrosion of mild steel in 0.5M sulphuric acid at 90 degree celsius after 1.5 hours of exposure.

Concentration of inhibitors C (v/v%)	Initial weight(g)	Final weight (g)	Weight lost(g)	Corrosion rate(mm/yr) CR	Inhibitor efficiency (%) IE	Degree of surface coverage(θ)
Pod						
Blank	20.6296	20.0703	0.5593	256.8	0	0
0.1	20.1925	19.8573	0.3352	153.90	40.06	0.4006
0.2	19.7274	19.3932	0.3342	153.40	40.25	0.4025
0.3	19.1404	18.8245	0.3159	145.00	43.51	0.4351
0.4	18.7987	18.4949	0.3038	139.50	45.68	0.4568
0.5	21.1637	20.8640	0.2997	137.60	46.42	0.4642
Leaves						
0.1	22.2185	21.8841	0.3344	153.50	40.21	0.4021
0.2	20.1968	19.8639	0.3329	152.80	40.48	0.4048
0.3	19.8005	19.4687	0.3318	152.30	40.68	0.4068
0.4	19.2489	18.9246	0.3243	148.90	42.01	0.4201
0.5	22.1808	21.8654	0.3154	144.80	43.60	0.4360
Stem						
0.1	19.7760	19.4600	0.3160	145.10	43.50	0.4350
0.2	22.0617	21.7540	0.3077	141.30	44.98	0.4498
0.3	19.4778	19.1831	0.2947	135.30	47.31	0.4731
0.4	19.9879	19.7012	0.2867	131.60	48.74	0.4874
0.5	19.6113	19.3374	0.2739	125.80	51.02	0.5102
Root						
0.1	20.0022	19.6779	0.3243	148.90	42.01	0.4201
0.2	20.3156	19.9908	0.3248	149.10	41.92	0.4192
0.3	21.9421	21.6254	0.3167	145.40	43.40	0.4340
0.4	20.1207	19.8168	0.3039	139.50	45.67	0.4567
0.5	20.5191	20.2268	0.2923	134.20	47.74	0.4774

Appendix XXI: Corrosion of mild steel in 0.5M sulphuric acid at 90 degree celsius after 2 hour of exposure

Concentration of inhibitors C (v/v%)	Initial weight(g)	Final weight (g)	Weight lost(g)	Corrosion rate(mm/yr) CR	Inhibitor efficiency (%) IE	Degree of surface coverage(θ)
Pod						
Blank	20.6296	19.8753	0.7543	259.75	0	0
0.1	20.1925	19.7408	0.4517	155.50	40.12	0.4012
0.2	19.7274	19.2772	0.4502	155.00	40.31	0.4031
0.3	19.1404	18.7144	0.4260	146.70	43.52	0.4352
0.4	18.7987	18.3912	0.4075	140.30	45.98	0.4598
0.5	21.1637	20.7611	0.4026	138.60	46.63	0.4663
Leaves						
0.1	22.2185	21.7811	0.4374	150.60	42.01	0.4201
0.2	20.1968	19.7493	0.4475	154.10	40.68	0.4068
0.3	19.8005	19.3533	0.4472	154.00	40.71	0.4071
0.4	19.2489	18.8131	0.4358	150.10	42.23	0.4223
0.5	22.1808	21.7572	0.4236	145.90	43.84	0.4384
Stem						
0.1	19.7760	19.3913	0.3847	132.50	49.00	0.4900
0.2	22.0617	21.6468	0.4149	142.90	45.00	0.4500
0.3	19.4778	19.0818	0.3960	136.40	47.50	0.4750
0.4	19.9879	19.6031	0.3848	132.50	48.99	0.4899
0.5	19.6113	19.2501	0.3612	124.40	52.12	0.5212
Root						
0.1	20.0022	19.5741	0.4281	147.40	43.25	0.4325
0.2	20.3156	19.8781	0.4375	150.70	42.00	0.4200
0.3	21.9421	21.5171	0.4250	146.40	43.65	0.4365
0.4	20.1207	19.7119	0.4088	140.80	45.80	0.4580
0.5	20.5191	20.1260	0.3931	135.40	47.89	0.4789

Appendix XXII: Corrosion of mild steel in 0.5M Sodium chloride at room temperature after 48hours of exposure

Concentration of inhibitors C (v/v%)	Initial weight(g)	Final weight (g)	Weight lost(g)	Corrosion rate(mm/yr) CR	Inhibitor efficiency (%) IE	Degree of surface coverage(θ)
Pod						
Blank	22.0153	22.0073	0.0080	0.1148	0	0
0.1	21.5516	21.5475	0.0041	0.0588	49.03	0.4903
0.2	21.3220	21.3180	0.0040	0.0574	49.98	0.4998
0.3	21.8521	21.8482	0.0039	0.0560	51.74	0.5174
0.4	20.4596	20.4558	0.0038	0.0545	52.21	0.5221
0.5	20.7911	20.7874	0.0037	0.0531	54.23	0.5423
Leaves						
0.1	20.4372	20.4330	0.0042	0.0603	48.01	0.4801
0.2	20.0948	20.0908	0.0040	0.0574	50.02	0.5002
0.3	20.8451	20.8413	0.0038	0.0545	52.24	0.5224
0.4	22.1076	22.1039	0.0037	0.0531	54.76	0.5476
0.5	21.7789	21.7755	0.0034	0.0488	57.99	0.5799
Stem						
0.1	21.0830	21.0787	0.0043	0.0617	45.97	0.4597
0.2	21.0336	21.0294	0.0042	0.0603	47.03	0.4703
0.3	22.1913	22.1871	0.0042	0.0603	48.99	0.4899
0.4	19.5216	19.5176	0.0040	0.0574	50.17	0.5017
0.5	18.8980	18.8942	0.0038	0.0545	52.18	0.5218
Root						
0.1	20.5927	20.5887	0.0040	0.0574	50.19	0.5019
0.2	19.4438	19.4400	0.0038	0.0545	52.01	0.5201
0.3	20.7106	20.7069	0.0037	0.0531	53.98	0.5398
0.4	19.5130	19.5096	0.0034	0.0488	57.09	0.5709
0.5	18.5789	18.5757	0.0032	0.0459	59.54	0.5954

Appendix XXIII: Corrosion of mild steel in 0.5M Sodium chloride at room temperature after 96 hours of exposure

Concentration of inhibitors C (v/v%)	Initial weight(g)	Final weight (g)	Weight lost(g)	Corrosion rate(mm/yr) CR	Inhibitor efficiency (%) IE	Degree of surface coverage(θ)
Pod						
Blank	22.0153	22.0036	0.0117	0.0839	0	0
0.1	21.5516	21.5456	0.0060	0.0430	49.13	0.4913
0.2	21.3220	21.3161	0.0059	0.0423	50.00	0.5000
0.3	21.8521	21.8465	0.0056	0.0402	52.01	0.5201
0.4	20.4596	20.4540	0.0056	0.0402	52.42	0.5242
0.5	20.7911	20.7858	0.0053	0.0380	55.02	0.5502
Leaves						
0.1	20.4372	20.4311	0.0061	0.0438	48.21	0.4821
0.2	20.0948	20.0890	0.0058	0.0416	50.21	0.5021
0.3	20.8451	20.8395	0.0056	0.0402	52.46	0.5246
0.4	22.1076	20.1024	0.0052	0.0373	55.21	0.5521
0.5	21.7789	21.7740	0.0049	0.0352	58.07	0.5807
Stem						
0.1	21.0830	21.0767	0.0063	0.0452	46.01	0.4601
0.2	21.0336	21.0275	0.0061	0.0438	47.77	0.4777
0.3	22.1913	22.1852	0.0061	0.0438	48.22	0.4822
0.4	19.5216	19.5158	0.0058	0.0416	50.21	0.5021
0.5	18.8980	18.8924	0.0056	0.0402	52.20	0.5220
Root						
0.1	20.5927	20.5869	0.0058	0.0416	50.21	0.5021
0.2	19.4438	19.4382	0.0056	0.0402	52.11	0.5211
0.3	20.7106	20.7052	0.0054	0.0387	54.01	0.5401
0.4	19.5130	19.5080	0.0050	0.0359	57.13	0.5713
0.5	18.5789	18.5742	0.0047	0.0337	60.02	0.6002

Appendix XXIV: Corrosion of mild steel in 0.5M Sodium chloride at room temperature after 144 hours of exposure

Concentration of inhibitors C (v/v%)	Initial weight(g)	Final weight (g)	Weight lost(g)	Corrosion rate(mm/yr) CR	Inhibitor efficiency (%) IE	Degree of surface coverage(θ)
Pod						
Blank	22.0153	21.9966	0.0187	0.0894	0	0
0.1	21.5516	21.5421	0.0095	0.0454	49.12	0.4912
0.2	21.3220	21.3127	0.0093	0.0445	50.12	0.5012
0.3	21.8521	21.8431	0.0090	0.0430	52.13	0.5213
0.4	20.4596	20.4509	0.0087	0.0416	52.62	0.5262
0.5	20.7911	20.7827	0.0084	0.0402	55.12	0.5512
Leaves						
0.1	20.4372	20.4276	0.0096	0.0459	48.58	0.4858
0.2	20.0948	20.0855	0.0093	0.0445	50.40	0.5040
0.3	20.8451	20.8363	0.0088	0.0421	53.00	0.5300
0.4	22.1076	22.0993	0.0083	0.0397	55.76	0.5576
0.5	21.7789	21.7712	0.0077	0.0368	58.78	0.5878
Stem						
0.1	21.0830	21.0731	0.0099	0.0473	47.00	0.4700
0.2	21.0336	21.0239	0.0097	0.0464	47.96	0.4796
0.3	22.1913	22.1816	0.0097	0.0464	48.21	0.4821
0.4	19.5216	19.5125	0.0091	0.0435	51.22	0.5122
0.5	18.8980	18.8891	0.0089	0.0426	52.32	0.5232
Root						
0.1	20.5927	20.5834	0.0093	0.0445	50.48	0.5048
0.2	19.4438	19.4349	0.0089	0.0426	52.20	0.5220
0.3	20.7106	20.7021	0.0085	0.0407	54.33	0.5433
0.4	19.5130	19.5050	0.0080	0.0383	57.24	0.5724
0.5	18.5789	18.5715	0.0074	0.0354	60.21	0.6021

Appendix XXV: Corrosion of mild steel in 0.5M sodium chloride at room temperature after 192 hours of exposure

Concentration of inhibitors C (v/v%)	Initial weight(g)	Final weight (g)	Weight lost(g)	Corrosion rate(mm/yr) CR	Inhibitor efficiency (%) IE	Degree of surface coverage(θ)
Pod						
Blank	22.0153	21.9908	0.0245	0.0879	0	0
0.1	21.5516	21.5392	0.0124	0.0445	49.20	0.4920
0.2	21.3220	21.3098	0.0122	0.0438	50.16	0.5016
0.3	21.8521	21.8404	0.0117	0.0420	52.20	0.5220
0.4	20.4596	20.4481	0.0115	0.0413	52.98	0.5298
0.5	20.7911	20.7802	0.0109	0.0391	55.32	0.5532
Leaves						
0.1	20.4372	20.4246	0.0126	0.0452	48.67	0.4867
0.2	20.0948	20.0828	0.0120	0.0430	51.09	0.5109
0.3	20.8451	20.8336	0.0115	0.04125	53.21	0.5321
0.4	22.1076	22.0968	0.0108	0.0387	55.97	0.5597
0.5	21.7789	21.7688	0.0101	0.0362	58.97	0.5897
Stem						
0.1	21.0830	21.0701	0.0129	0.0463	47.21	0.4721
0.2	21.0336	21.0209	0.0127	0.0456	48.21	0.4821
0.3	22.1913	22.1786	0.0127	0.0456	48.30	0.4830
0.4	19.5216	19.5097	0.0119	0.0427	51.42	0.5142
0.5	18.8980	18.8864	0.0116	0.0416	52.62	0.5262
Root						
0.1	20.5927	20.5807	0.0120	0.0430	50.97	0.5097
0.2	19.4438	19.4321	0.0117	0.0420	52.23	0.5223
0.3	20.7106	20.6994	0.0112	0.0402	54.47	0.5447
0.4	19.5130	19.5026	0.0104	0.0373	57.35	0.5735
0.5	18.5789	18.5692	0.0097	0.0348	60.42	0.6042

Appendix XXVI: Corrosion of mild steel in 0.5M Sodium chloride at room temperature after 240 hours of exposure

Concentration of inhibitors C (v/v%)	Initial weight(g)	Final weight (g)	Weight lost(g)	Corrosion rate(mm/yr) CR	Inhibitor efficiency (%) IE	Degree of surface coverage(θ)
Pod						
Blank	22.0153	21.9825	0.0328	0.0941	0	0
0.1	21.5516	21.5349	0.0167	0.0479	49.22	0.4922
0.2	21.3220	21.3057	0.0163	0.0468	50.20	0.5020
0.3	21.8521	21.8364	0.0157	0.0451	52.21	0.5221
0.4	20.4596	20.4445	0.0151	0.0433	54.00	0.5400
0.5	20.7911	20.7764	0.0147	0.0422	55.12	0.5512
Leaves						
0.1	20.4372	20.4210	0.0162	0.0465	50.54	0.5054
0.2	20.0948	20.0790	0.0158	0.0453	51.69	0.5169
0.3	20.8451	20.8298	0.0153	0.0439	53.41	0.5341
0.4	22.1076	22.0932	0.0144	0.0413	56.02	0.5602
0.5	21.7789	21.7655	0.0134	0.0385	59.01	0.5901
Stem						
0.1	21.0830	21.0658	0.0172	0.0494	47.58	0.4758
0.2	21.0336	21.0167	0.0169	0.0485	48.41	0.4841
0.3	22.1913	22.1743	0.0170	0.0488	48.32	0.4832
0.4	19.5216	19.5058	0.0158	0.0453	51.98	0.5198
0.5	18.8980	18.8826	0.0154	0.0442	52.97	0.5297
Root						
0.1	20.5927	20.5766	0.0161	0.0462	51.02	0.5102
0.2	19.4438	19.4282	0.0156	0.0448	52.34	0.5234
0.3	20.7106	20.6957	0.0149	0.0428	54.54	0.5454
0.4	19.5130	19.4991	0.0139	0.0399	57.65	0.5765
0.5	18.5789	18.5660	0.0129	0.0370	60.57	0.6057

Appendix XXVII: Corrosion of mild steel in 0.5M sodium chloride at 50 degree Celsius after 0.5 hour of exposure

Concentration of inhibitors C (v/v%)	Initial weight(g)	Final weight (g)	Weight lost(g)	Corrosion rate(mm/yr) CR	Inhibitor efficiency (%) IE	Degree of surface coverage(θ)
Pod						
Blank	22.4320	22.4297	0.0023	3.1700	0	0
0.1	21.1364	21.1351	0.0013	1.7907	45.31	0.4531
0.2	22.2871	22.2859	0.0012	1.6529	47.20	0.4720
0.3	18.9785	18.9773	0.0012	1.6529	49.51	0.4951
0.4	19.4981	19.4970	0.0011	1.5152	51.24	0.5124
0.5	23.5525	23.5515	0.0010	1.3774	55.06	0.5506
Leaves						
0.1	22.4277	22.4264	0.0013	1.7907	42.01	0.4201
0.2	20.7427	20.7414	0.0013	1.7907	44.31	0.4431
0.3	18.5826	18.5814	0.0012	1.6529	46.41	0.4641
0.4	19.4369	19.4357	0.0012	1.6529	49.98	0.4998
0.5	19.7484	19.7473	0.0011	1.5152	51.43	0.5143
Stem						
0.1	19.6523	19.6509	0.0014	1.9284	40.32	0.4032
0.2	20.0857	20.0844	0.0013	1.7907	42.63	0.4263
0.3	19.9057	19.9044	0.0013	1.7907	43.54	0.4354
0.4	19.5439	19.5426	0.0013	1.7907	45.63	0.4563
0.5	20.1105	20.1093	0.0012	1.6529	49.65	0.4965
Root						
0.1	19.4155	19.4143	0.0012	1.6529	48.02	0.4802
0.2	20.9827	20.9816	0.0011	1.5152	50.21	0.5021
0.3	19.1938	19.1928	0.0010	1.3774	55.41	0.5541
0.4	20.0057	20.0047	0.0010	1.3774	56.78	0.5678
0.5	22.1090	22.1080	0.0010	1.3774	57.01	0.5701

Appendix XXVIII: Corrosion of mild steel in 0.5M Sodium chloride at 50 degree celsius after 1hour of exposure

Concentration of inhibitors C (v/v%)	Initial weight(g)	Final weight (g)	Weight lost(g)	Corrosion rate(mm/yr) CR	Inhibitor efficiency (%) IE	Degree of surface coverage(θ)
Pod						
Blank	22.4320	22.4290	0.003	2.0700	0	0
0.1	21.1364	21.1348	0.0016	1.1019	45.50	0.4550
0.2	22.2871	22.2855	0.0016	1.1019	47.20	0.4720
0.3	18.9785	18.9770	0.0015	1.0331	49.69	0.4969
0.4	19.4981	19.4967	0.0014	0.9642	52.01	0.5201
0.5	23.5525	23.5512	0.0013	0.8953	55.26	0.5526
Leaves						
0.1	22.4277	22.4260	0.0017	1.1708	42.21	0.4221
0.2	20.7427	20.7410	0.0017	1.1708	44.50	0.4450
0.3	18.5826	18.5810	0.0016	1.1019	46.60	0.4660
0.4	19.4369	19.4354	0.0015	1.0331	50.10	0.5010
0.5	19.7484	19.7470	0.0014	0.9642	51.73	0.5173
Stem						
0.1	19.6523	19.6505	0.0018	1.2397	40.68	0.4068
0.2	20.0857	20.0840	0.0017	1.1708	43.03	0.4303
0.3	19.9057	19.9040	0.0017	1.1708	43.64	0.4364
0.4	19.5439	19.5423	0.0016	1.1019	45.86	0.4586
0.5	20.1105	20.1090	0.0015	1.0331	50.05	0.5005
Root						
0.1	19.4155	19.4139	0.0016	1.1019	48.12	0.4812
0.2	20.9827	20.9812	0.0015	1.0331	50.38	0.5038
0.3	19.1938	19.1925	0.0013	0.8953	55.42	0.5542
0.4	20.0057	20.0044	0.0013	0.8953	56.89	0.5689
0.5	22.1090	22.1077	0.0013	0.8953	57.12	0.5712

Appendix XXIX: Corrosion of mild steel in 0.5M sodium chloride at 50 degree Celsius after 1.5 hour of exposure

Concentration of inhibitors C (v/v%)	Initial weight(g)	Final weight (g)	Weight lost(g)	Corrosion rate(mm/yr) CR	Inhibitor efficiency (%) IE	Degree of surface coverage(θ)
Pod						
Blank	22.4320	22.4283	0.0037	1.7000	0	0
0.1	21.1364	21.1344	0.0020	0.9183	45.68	0.4568
0.2	22.2871	22.2852	0.0019	0.8724	47.58	0.4758
0.3	18.9785	18.9766	0.0019	0.8724	49.98	0.4998
0.4	19.4981	19.4963	0.0018	0.8265	52.23	0.5223
0.5	23.5525	23.5509	0.0016	0.7346	55.47	0.5547
Leaves						
0.1	22.4277	22.4256	0.0021	0.9642	42.41	0.4241
0.2	20.7427	20.7407	0.0020	0.9183	44.68	0.4468
0.3	18.5826	18.5806	0.0020	0.9183	46.82	0.4682
0.4	19.4369	19.4351	0.0018	0.8265	50.14	0.5014
0.5	19.7484	19.7466	0.0018	0.8265	51.98	0.5198
Stem						
0.1	19.6523	19.6501	0.0022	1.0101	41.03	0.4103
0.2	20.0857	20.0836	0.0021	0.9642	43.13	0.4313
0.3	19.9057	19.9036	0.0021	0.9642	43.96	0.4396
0.4	19.5439	19.5419	0.0020	0.9183	45.99	0.4599
0.5	20.1105	20.1087	0.0018	0.8265	50.15	0.5015
Root						
0.1	19.4155	19.4136	0.0019	0.8724	48.38	0.4838
0.2	20.9827	20.9809	0.0018	0.8265	50.40	0.5040
0.3	19.1938	19.1922	0.0016	0.7346	55.45	0.5545
0.4	20.0057	20.0041	0.0016	0.7346	56.97	0.5697
0.5	22.1090	22.1074	0.0016	0.7346	57.22	0.5722

Appendix XXX: Corrosion of mild steel in 0.5M Sodium chloride at 50 degree celsius after 2 hours of exposure

Concentration of inhibitors C (v/v%)	Initial weight(g)	Final weight (g)	Weight lost(g)	Corrosion rate(mm/yr) CR	Inhibitor efficiency (%) IE	Degree of surface coverage(θ)
Pod						
Blank	22.4320	22.4274	0.0046	1.5800	0	0
0.1	21.1364	21.1339	0.0025	0.8609	45.78	0.4578
0.2	22.2871	22.2847	0.0024	0.8265	47.98	0.4798
0.3	18.9785	18.9762	0.0023	0.7920	50.02	0.5002
0.4	19.4981	19.4959	0.0022	0.7576	53.01	0.5301
0.5	23.5525	23.5505	0.0020	0.6887	56.02	0.5602
Leaves						
0.1	22.4277	22.4251	0.0026	0.8953	42.98	0.4298
0.2	20.7427	20.7402	0.0025	0.8609	44.70	0.4470
0.3	18.5826	18.5802	0.0024	0.8265	46.99	0.4699
0.4	19.4369	19.4346	0.0023	0.7920	50.26	0.5026
0.5	19.7484	19.7462	0.0022	0.7576	52.41	0.5241
Stem						
0.1	19.6523	19.6496	0.0027	0.9298	41.13	0.4113
0.2	20.0857	20.0831	0.0026	0.8953	43.20	0.4320
0.3	19.9057	19.9031	0.0026	0.8953	44.01	0.4401
0.4	19.5439	19.5414	0.0025	0.8609	46.21	0.4621
0.5	20.1105	20.1082	0.0023	0.7920	50.35	0.5035
Root						
0.1	19.4155	19.4131	0.0024	0.8265	48.69	0.4869
0.2	20.9827	20.9804	0.0023	0.7920	50.52	0.5052
0.3	19.1938	19.1918	0.0020	0.6887	55.65	0.5565
0.4	20.0057	20.0037	0.0020	0.6887	57.11	0.5711
0.5	22.1090	22.1070	0.0020	0.6887	57.42	0.5742

Appendix XXXI: Corrosion of mild steel in 0.5M sodium chloride at 70 degree Celsius after 0.5 hour of exposure

Concentration of inhibitors C (v/v%)	Initial weight(g)	Final weight (g)	Weight lost(g)	Corrosion rate(mm/yr) CR	Inhibitor efficiency (%) IE	Degree of surface coverage(θ)
pod						
Blank	19.2865	19.2851	0.0014	1.9300	0	0
0.1	19.7367	19.7359	0.0008	1.1019	43.27	0.4327
0.2	20.6836	20.6828	0.0008	1.1019	44.15	0.4415
0.3	19.5305	19.5297	0.0008	1.1019	46.12	0.4612
0.4	19.6250	19.6243	0.0007	0.9642	48.18	0.4818
0.5	20.2234	20.2227	0.0007	0.9642	50.02	0.5002
Leaves						
0.1	20.0122	20.0114	0.0008	1.1019	40.29	0.4029
0.2	19.1170	19.1162	0.0008	1.1019	43.11	0.4311
0.3	20.3746	20.3738	0.0008	1.1019	43.98	0.4398
0.4	19.6004	19.5996	0.0008	1.1019	45.26	0.4526
0.5	19.0896	19.0889	0.0007	0.9642	46.95	0.4695
Stem						
0.1	19.1258	19.1250	0.0008	1.1019	39.87	0.3987
0.2	20.0786	20.0778	0.0008	1.1019	41.23	0.4123
0.3	19.2421	19.2413	0.0008	1.1019	43.11	0.4311
0.4	18.4896	18.4888	0.0008	1.1019	45.03	0.4503
0.5	17.9702	17.9695	0.0007	0.9642	47.21	0.4721
Root						
0.1	19.6007	19.5999	0.0008	1.1019	45.06	0.4506
0.2	20.1421	20.1414	0.0007	0.9642	46.78	0.4678
0.3	20.0574	20.0567	0.0007	0.9642	49.02	0.4902
0.4	20.0385	20.0378	0.0007	0.9642	50.49	0.5049
0.5	19.0662	19.0656	0.0006	0.8265	55.08	0.5508

Appendix XXXII: Corrosion of mild steel in 0.5M Sodium chloride at 70 degree celsius after 1 hour of exposure

Concentration of inhibitors C (v/v%)	Initial weight(g)	Final weight (g)	Weight lost(g)	Corrosion rate(mm/yr) CR	Inhibitor efficiency (%) IE	Degree of surface coverage(θ)
pod						
Blank	19.2865	19.2846	0.0019	1.3100	0	0
0.1	19.7367	19.7356	0.0011	0.7578	44.50	0.4450
0.2	20.6836	20.6825	0.0011	0.7578	44.55	0.4455
0.3	19.5305	19.5295	0.0010	0.6887	46.22	0.4622
0.4	19.6250	19.6240	0.0010	0.6887	48.32	0.4832
0.5	20.2234	20.2225	0.0009	0.6198	50.18	0.5018
Leaves						
0.1	20.0122	20.0111	0.0011	0.7578	41.28	0.4128
0.2	19.1170	19.1159	0.0011	0.7578	43.34	0.4334
0.3	20.3746	20.3735	0.0011	0.7578	44.20	0.4420
0.4	19.6004	19.5994	0.0010	0.6887	45.42	0.4542
0.5	19.0896	19.0886	0.0010	0.6887	47.21	0.4721
Stem						
0.1	19.1258	19.1247	0.0011	0.7578	40.02	0.4002
0.2	20.0786	20.0775	0.0011	0.7578	41.45	0.4145
0.3	19.2421	19.2410	0.0011	0.7578	43.22	0.4322
0.4	18.4896	18.4886	0.0010	0.6887	45.43	0.4543
0.5	17.9702	17.9692	0.0010	0.6887	49.01	0.4901
Root						
0.1	19.6007	19.5997	0.0010	0.6887	45.26	0.4526
0.2	20.1421	20.1411	0.0010	0.6887	47.01	0.4701
0.3	20.0574	20.0564	0.0010	0.6887	49.22	0.4922
0.4	20.0385	20.0376	0.0009	0.6198	50.61	0.5061
0.5	19.0662	19.0653	0.0009	0.6198	56.16	0.5616

Appendix XXXIII: Corrosion of mild steel in 0.5M sodium chloride at 70 degree Celsius after 1.5 hour of exposure

Concentration of inhibitors C (v/v%)	Initial weight(g)	Final weight (g)	Weight lost(g)	Corrosion rate(mm/yr) CR	Inhibitor efficiency (%) IE	Degree of surface coverage(θ)
pod						
Blank	19.2865	19.2835	0.003	1.3800	0	0
0.1	19.7367	19.7351	0.0016	0.7346	46.02	0.4602
0.2	20.6836	20.6819	0.0017	0.7805	44.81	0.4481
0.3	19.5305	19.5289	0.0016	0.7346	46.32	0.4632
0.4	19.6250	19.6235	0.0015	0.6887	48.54	0.4854
0.5	20.2234	20.2219	0.0015	0.6887	50.24	0.5024
Leaves						
0.1	20.0122	20.0104	0.0018	0.8265	41.46	0.4146
0.2	19.1170	19.1153	0.0017	0.7805	43.56	0.4356
0.3	20.3746	20.3729	0.0017	0.7805	45.00	0.4500
0.4	19.6004	19.5988	0.0016	0.7346	45.66	0.4566
0.5	19.0896	19.0881	0.0015	0.6887	48.67	0.4867
Stem						
0.1	19.1258	19.1240	0.0018	0.8265	40.32	0.4032
0.2	20.0786	20.0769	0.0017	0.7805	41.68	0.4168
0.3	19.2421	19.2404	0.0017	0.7805	43.44	0.4344
0.4	18.4896	18.4880	0.0016	0.7346	45.65	0.4565
0.5	17.9702	17.9687	0.0015	0.6887	49.36	0.4936
Root						
0.1	19.6007	19.5991	0.0016	0.7346	45.10	0.4510
0.2	20.1421	20.1405	0.0016	0.7346	47.28	0.4728
0.3	20.0574	20.0559	0.0015	0.6887	49.42	0.4942
0.4	20.0385	20.0370	0.0015	0.6887	50.77	0.5077
0.5	19.0662	19.0649	0.0013	0.5969	55.32	0.5532

Appendix XXXIV: Corrosion of mild steel in 0.5M Sodium chloride at 70 degree celsius after 2 hours of exposure

Concentration of inhibitors C (v/v%)	Initial weight(g)	Final weight (g)	Weight lost(g)	Corrosion rate(mm/yr) CR	Inhibitor efficiency (%) IE	Degree of surface coverage(θ)
pod						
Blank	19.2865	19.2830	0.0035	1.2100	0	0
0.1	19.7367	19.7348	0.0019	0.6543	46.10	0.4610
0.2	20.6836	20.6817	0.0019	0.6543	44.90	0.4490
0.3	19.5305	19.5286	0.0019	0.6543	46.64	0.4664
0.4	19.6250	19.6232	0.0018	0.6198	48.67	0.4867
0.5	20.2234	20.2217	0.0017	0.5854	50.36	0.5036
Leaves						
.0.1	20.0122	20.0102	0.0020	0.6887	41.55	0.4155
0.2	19.1170	19.1150	0.0020	0.6887	43.77	0.4377
0.3	20.3746	20.3727	0.0019	0.6543	45.33	0.4533
0.4	19.6004	19.5985	0.0019	0.6543	45.77	0.4577
0.5	19.0896	19.0878	0.0018	0.6198	48.99	0.4899
Stem						
0.1	19.1258	19.1237	0.0021	0.7232	40.64	0.4064
0.2	20.0786	20.0766	0.0020	0.6887	41.88	0.4188
0.3	19.2421	19.2401	0.0020	0.6887	43.56	0.4356
0.4	18.4896	18.4877	0.0019	0.6543	45.85	0.4585
0.5	17.9702	17.9684	0.0018	0.6198	49.50	0.4950
Root						
0.1	19.6007	19.5988	0.0019	0.6543	45.38	0.4538
0.2	20.1421	20.1403	0.0018	0.6198	47.33	0.4733
0.3	20.0574	20.0556	0.0018	0.6198	49.62	0.4962
0.4	20.0385	20.0368	0.0017	0.5854	50.76	0.5076
0.5	19.0662	19.0646	0.0016	0.5510	55.51	0.5551

Appendix XXXV: Corrosion of mild steel in 0.5M sodium chloride at 90 degree Celsius after 0.5 hour of exposure

Concentration of inhibitors C (v/v%)	Initial weight(g)	Final weight (g)	Weight lost(g)	Corrosion rate(mm/yr) CR	Inhibitor efficiency (%) IE	Degree of surface coverage(θ)
pod						
Blank	19.4346	19.4316	0.003	4.1300	0	0
0.1	19.9843	19.9825	0.0018	2.4794	40.03	0.4003
0.2	19.8925	19.8908	0.0017	2.3416	42.04	0.4204
0.3	20.4509	20.4492	0.0017	2.3416	44.05	0.4405
0.4	19.4693	19.4677	0.0016	2.2039	45.11	0.4511
0.5	19.4153	19.4137	0.0016	2.2039	46.67	0.4667
Leaves						
0.1	19.7848	19.7830	0.0018	2.4794	39.04	0.3904
0.2	19.9302	19.9284	0.0018	2.4794	40.11	0.4011
0.3	20.5387	20.5369	0.0018	2.4794	41.51	0.4151
0.4	20.9761	20.9744	0.0017	2.3416	42.77	0.4277
0.5	19.8311	19.8294	0.0017	2.3416	43.68	0.4368
Stem						
0.1	19.6304	19.6285	0.0019	2.6171	36.68	0.3668
0.2	20.3162	20.3143	0.0019	2.6171	38.22	0.3822
0.3	19.7469	19.7451	0.0018	2.4794	39.49	0.3949
0.4	19.8350	19.8332	0.0018	2.4794	40.21	0.4021
0.5	19.9749	19.9732	0.0017	2.3416	42.37	0.4237
Root						
0.1	19.8371	19.8354	0.0017	2.3416	42.01	0.4201
0.2	20.1407	20.1389	0.0018	2.4794	41.58	0.4158
0.3	20.2944	20.2927	0.0017	2.3416	43.20	0.4320
0.4	19.6779	19.6763	0.0016	2.2039	45.47	0.4547
0.5	19.3751	19.3735	0.0016	2.2039	47.23	0.4723

Appendix XXXVI: Corrosion of mild steel in 0.5M Sodium chloride at 90 degree celsius after 1 hour of exposure

Concentration of inhibitors C (v/v%)	Initial weight(g)	Final weight (g)	Weight lost(g)	Corrosion rate(mm/yr) CR	Inhibitor efficiency (%) IE	Degree of surface coverage(θ)
pod						
Blank	19.4346	19.4307	0.0039	2.6900	0	0
0.1	19.9843	19.9820	0.0023	1.5841	40.19	0.4019
0.2	19.8925	19.8902	0.0023	1.5841	42.24	0.4224
0.3	20.4509	20.4487	0.0022	1.5152	44.15	0.4415
0.4	19.4693	19.4672	0.0021	1.4463	45.33	0.4533
0.5	19.4153	19.4132	0.0021	1.4463	47.08	0.4708
Leaves						
.0.1	19.7848	19.7825	0.0023	1.5841	39.97	0.3997
0.2	19.9302	19.9279	0.0023	1.5841	40.21	0.4021
0.3	20.5387	20.5364	0.0023	1.5841	41.98	0.4198
0.4	20.9761	20.9739	0.0022	1.5152	43.03	0.4303
0.5	19.8311	19.8289	0.0022	1.5152	43.70	0.4370
Stem						
0.1	19.6304	19.6279	0.0025	1.7218	36.89	0.3689
0.2	20.3162	20.3138	0.0024	1.6529	39.20	0.3920
0.3	19.7469	19.7445	0.0024	1.6529	39.55	0.3955
0.4	19.8350	19.8327	0.0023	1.5841	40.41	0.4041
0.5	19.9749	19.9727	0.0022	1.5152	42.50	0.4250
Root						
0.1	19.8371	19.8348	0.0023	1.5841	42.11	0.4211
0.2	20.1407	20.1384	0.0023	1.5841	42.20	0.4220
0.3	20.2944	20.2922	0.0022	1.5152	43.40	0.4340
0.4	19.6779	19.6758	0.0021	1.4463	45.60	0.4560
0.5	19.3751	19.3731	0.0020	1.3774	48.01	0.4801

Appendix XXXVII: Corrosion of mild steel in 0.5M sodium chloride at 90 degree Celsius after 1.5 hour of exposure

Concentration of inhibitors C (v/v%)	Initial weight(g)	Final weight (g)	Weight lost(g)	Corrosion rate(mm/yr) CR	Inhibitor efficiency (%) IE	Degree of surface coverage(θ)
pod						
Blank	19.4346	19.4306	0.004	1.8400	0	0
0.1	19.9843	19.9819	0.0024	1.1019	40.31	0.4031
0.2	19.8925	19.8902	0.0023	1.0560	42.39	0.4239
0.3	20.4509	20.4487	0.0022	1.0101	44.30	0.4430
0.4	19.4693	19.4671	0.0022	1.0101	45.45	0.4545
0.5	19.4153	19.4132	0.0021	0.9642	47.28	0.4728
Leaves						
.0.1	19.7848	19.7824	0.0024	1.1019	40.01	0.4001
0.2	19.9302	19.9278	0.0024	1.1019	40.31	0.4031
0.3	20.5387	20.5364	0.0023	1.0560	42.89	0.4289
0.4	20.9761	20.9738	0.0023	1.0560	43.28	0.4328
0.5	19.8311	19.8289	0.0022	1.0101	43.85	0.4385
Stem						
0.1	19.6304	19.6279	0.0025	1.1479	36.91	0.3691
0.2	20.3162	20.3138	0.0024	1.1019	39.40	0.3940
0.3	19.7469	19.7445	0.0024	1.1019	39.68	0.3968
0.4	19.8350	19.8326	0.0024	1.1019	40.56	0.4056
0.5	19.9749	19.9726	0.0023	1.0560	42.68	0.4268
Root						
0.1	19.8371	19.8348	0.0023	1.0560	42.33	0.4233
0.2	20.1407	20.1384	0.0023	1.0560	42.40	0.4240
0.3	20.2944	20.2921	0.0023	1.0560	43.60	0.4360
0.4	19.6779	19.6757	0.0022	1.0101	45.69	0.4569
0.5	19.3751	19.3730	0.0021	0.9642	47.97	0.4797

Appendix XXXVIII: Corrosion of mild steel in 0.5M Sodium chloride at 90 degree celsius after 2 hours of exposure

Concentration of inhibitors C (v/v%)	Initial weight(g)	Final weight (g)	Weight lost(g)	Corrosion rate(mm/yr) CR	Inhibitor efficiency (%) IE	Degree of surface coverage(θ)
pod						
Blank	19.4346	19.4300	0.0046	1.5800	0	0
0.1	19.9843	19.9816	0.0027	0.9298	40.35	0.4035
0.2	19.8925	19.8899	0.0026	0.8953	42.43	0.4243
0.3	20.4509	20.4483	0.0026	0.8953	44.35	0.4435
0.4	19.4693	19.4668	0.0025	0.8609	45.65	0.4565
0.5	19.4153	19.4129	0.0024	0.8265	47.30	0.4730
Leaves						
.0.1	19.7848	19.7820	0.0028	0.9642	40.19	0.4019
0.2	19.9302	19.9275	0.0027	0.9298	40.45	0.4045
0.3	20.5387	20.5361	0.0026	0.8953	43.06	0.4306
0.4	20.9761	20.9735	0.0026	0.8953	43.58	0.4358
0.5	19.8311	19.8285	0.0026	0.8953	43.86	0.4386
Stem						
0.1	19.6304	19.6275	0.0029	0.9986	36.99	0.3699
0.2	20.3162	20.3134	0.0028	0.9642	39.68	0.3968
0.3	19.7469	19.7441	0.0028	0.9642	39.97	0.3997
0.4	19.8350	19.8323	0.0027	0.9298	40.52	0.4052
0.5	19.9749	19.9723	0.0026	0.8953	42.82	0.4282
Root						
0.1	19.8371	19.8345	0.0026	0.8953	42.47	0.4247
0.2	20.1407	20.1381	0.0026	0.8953	42.60	0.4260
0.3	20.2944	20.2918	0.0026	0.8953	43.70	0.4370
0.4	19.6779	19.6754	0.0025	0.8609	45.70	0.4570
0.5	19.3751	19.3727	0.0024	0.8265	48.23	0.4823

Appendix XXXIX: Arrhenius table of values for mild steel immersed in 0.5M H₂SO₄ at 30°C

Concentration of inhibitors C (%v/v)	CR(average)	LogCR	(CR/T)	Log (CR/T)
pod				
Blank	5.39132	0.731695	0.017793	-1.74975
0.1	2.23858	0.349973	0.007388	-2.13147
0.2	2.13388	0.32917	0.007043	-2.15227
0.3	1.68338	0.226182	0.005556	-2.25526
0.4	1.55948	0.19298	0.005147	-2.28846
0.5	1.43192	0.155919	0.004726	-2.32552
Leave				
0.1	2.64074	0.421726	0.008715	-2.05972
0.2	2.21096	0.344581	0.007297	-2.13686
0.3	2.12628	0.32762	0.007017	-2.15382
0.4	1.7103	0.233072	0.005645	-2.24837
0.5	1.72576	0.23698	0.005696	-2.24446
Stembark				
0.1	2.02886	0.307252	0.006696	-2.17419
0.2	1.68408	0.226363	0.005558	-2.25508
0.3	1.43714	0.157499	0.004743	-2.32394
0.4	0.93718	-0.02818	0.003093	-2.50962
0.5	0.89920	-0.04614	0.002968	-2.52759
Root				
0.1	2.1216	0.326664	0.007002	-2.15478
0.2	2.02384	0.306176	0.006679	-2.17527
0.3	1.68228	0.225898	0.005552	-2.25554
0.4	1.44676	0.160396	0.004775	-2.32105
0.5	1.02756	0.011807	0.003391	-2.46964

Appendix XL: Arrhenius table of values for mild steel immersed in 0.5MH₂SO₄ at 50°C

Concentration of inhibitors C (%v/v)	CR(average)	LogCR	CR/T	Log (CR/T)
pod				
Blank	151.375	2.180054	0.468653	-0.32915
0.1	76.535	1.88386	0.23695	-0.62534
0.2	72.465	1.860128	0.22435	-0.64907
0.3	62.9375	1.798909	0.194853	-0.71029
0.4	62.0725	1.792899	0.192175	-0.7163
0.5	60.2375	1.779867	0.186494	-0.72934
Leaves				
0.1	89.3575	1.951131	0.276649	-0.55807
0.2	86.6975	1.938007	0.268413	-0.5712
0.3	80.685	1.906793	0.249799	-0.60241
0.4	77.065	1.886857	0.238591	-0.62235
0.5	62.025	1.792567	0.192028	-0.71664
Stembark				
0.1	74.32	1.871106	0.230093	-0.6381
0.2	68.2375	1.834023	0.211262	-0.67518
0.3	59.575	1.775064	0.184443	-0.73414
0.4	52.4425	1.719683	0.162361	-0.78952
0.5	49.445	1.694122	0.15308	-0.81508
Root				
0.1	75.0825	1.875539	0.232454	-0.63366
0.2	69.0925	1.839431	0.213909	-0.66977
0.3	62.2225	1.793947	0.192639	-0.71526
0.4	60.2175	1.779723	0.186432	-0.72948
0.5	56.6875	1.753487	0.175503	-0.75572

Appendix XLI: Arrhenius table of values for mild steel immersed in 0.5MH₂SO₄ at 70°C

Concentration of the inhibitors C (%v/v)	CR(average)	Log CR	CR/T	Log (CR/T)
pod				
Blank	388.5775	2.589478	1.132879	0.054184
0.1	229.15	2.36012	0.668076	-0.17517
0.2	220.65	2.343704	0.643294	-0.19159
0.3	206.5	2.31492	0.602041	-0.22037
0.4	194.7	2.289366	0.567638	-0.24593
0.5	191.775	2.282792	0.559111	-0.2525
Leaves				
0.1	231.875	2.365254	0.67602	-0.17004
0.2	227.575	2.357125	0.663484	-0.17817
0.3	219.425	2.341286	0.639723	-0.19401
0.4	210.275	2.322788	0.613047	-0.21251
0.5	200.325	2.301735	0.584038	-0.23356
Stembark				
0.1	209.025	2.320198	0.609402	-0.2151
0.2	203.3	2.308137	0.592711	-0.22716
0.3	195.91	2.292057	0.571166	-0.24324
0.4	172.0825	2.235737	0.501698	-0.29956
0.5	154.6	2.189209	0.450729	-0.34608
Root				
0.1	221.1	2.344589	0.644606	-0.19071
0.2	217.3	2.33706	0.633528	-0.19823
0.3	209.675	2.321547	0.611297	-0.21375
0.4	198.575	2.297925	0.578936	-0.23737
0.5	188.35	2.274966	0.549125	-0.26033

Appendix XLII: Arrhenius table of values for mild steel immersed in 0.5M H₂SO₄ at 90°C

Concentration of the inhibitors C (%v/v)	CR(average)	Log CR	CR/T	Log (CR/T)
pod				
Blank	259.65	2.414388	0.715289	-0.14552
0.1	155.65	2.192149	0.428788	-0.36776
0.2	155.3	2.191171	0.427824	-0.36874
0.3	147.175	2.167834	0.405441	-0.39207
0.4	141.3325	2.150242	0.389346	-0.40966
0.5	139.4	2.144263	0.384022	-0.41564
Leaves				
0.1	155.725	2.192358	0.428994	-0.36755
0.2	155.275	2.191102	0.427755	-0.36881
0.3	154.475	2.188858	0.425551	-0.37105
0.4	151.2	2.179552	0.416529	-0.38035
0.5	146.65	2.166282	0.403994	-0.39362
Stembark				
0.1	143.95	2.158212	0.396556	-0.40169
0.2	143.575	2.157079	0.395523	-0.40283
0.3	137.25	2.137512	0.378099	-0.42239
0.4	133.35	2.124993	0.367355	-0.43491
0.5	127.225	2.104572	0.350482	-0.45533
Root				
0.1	151.475	2.180341	0.417287	-0.37957
0.2	151.25	2.179695	0.416667	-0.38021
0.3	147.225	2.167982	0.405579	-0.39193
0.4	141.35	2.150296	0.389394	-0.40961
0.5	136.175	2.134097	0.375138	-0.42581

Appendix XLIII: Arrhenius table of values for mild steel in 0.5M NaCl at 30⁰C

Concentration of the inhibitors C (%v/v)	CR(average)	Log CR	CR/T	Log (CR/T)
pod				
Blank	0.09402	-1.02678	0.00031	-3.50822
0.1	0.04792	-1.31948	0.000158	-3.80093
0.2	0.04696	-1.32827	0.000155	-3.80971
0.3	0.04526	-1.34429	0.000149	-3.82573
0.4	0.04418	-1.35477	0.000146	-3.83622
0.5	0.04252	-1.37141	0.00014	-3.85285
Leaves				
0.1	0.04834	-1.31569	0.00016	-3.79714
0.2	0.04636	-1.33386	0.000153	-3.8153
0.3	0.04439	-1.35271	0.000147	-3.83416
0.4	0.04202	-1.37654	0.000139	-3.85799
0.5	0.0391	-1.40782	0.000129	-3.88927
Stembark				
0.1	0.04998	-1.3012	0.000165	-3.78265
0.2	0.04892	-1.31051	0.000161	-3.79196
0.3	0.04898	-1.30998	0.000162	-3.79142
0.4	0.0461	-1.3363	0.000152	-3.81774
0.5	0.04462	-1.35047	0.000147	-3.83191
Root				
0.1	0.04654	-1.33217	0.000154	-3.81362
0.2	0.04482	-1.34853	0.000148	-3.82997
0.3	0.0431	-1.36552	0.000142	-3.84697
0.4	0.04004	-1.39751	0.000132	-3.87895
0.5	0.03736	-1.42759	0.000123	-3.90904

Appendix XLIV: Arrhenius table of values for mild steel immersed in 0.5M NaCl at 50°C

Concentration of the inhibitors C (% v/v)	CR(average)	Log CR	CR/T	Log (CR/T)
pod				
Blank	2.13	0.32838	0.006594	-2.18082
0.1	2153.203	3.333085	6.666262	0.823882
0.2	1.113425	0.046661	0.003447	-2.46254
0.3	1.0876	0.036469	0.003367	-2.47273
0.4	1.015875	0.00684	0.003145	-2.50236
0.5	0.924	-0.03433	0.002861	-2.54353
Leaves				
0.1	1.20525	0.081077	0.003731	-2.42813
0.2	1.185175	0.073782	0.003669	-2.43542
0.3	1.1249	0.051114	0.003483	-2.45809
0.4	1.076125	0.031863	0.003332	-2.47734
0.5	1.015875	0.00684	0.003145	-2.50236
Stembark				
0.1	1.277	0.106191	0.003954	-2.40301
0.2	1.20525	0.081077	0.003731	-2.42813
0.3	1.20525	0.081077	0.003731	-2.42813
0.4	1.16795	0.067424	0.003616	-2.44178
0.5	1.076125	0.031863	0.003332	-2.47734
Root				
0.1	1.113425	0.046661	0.003447	-2.46254
0.2	1.0417	0.017743	0.003225	-2.49146
0.3	0.924	-0.03433	0.002861	-2.54353
0.4	0.924	-0.03433	0.002861	-2.54353
0.5	0.924	-0.03433	0.002861	-2.54353

Appendix XLV: Arrhenius table of values for mild steel immersed in 0.5M NaCl at 70°C

Concentration of the inhibitors C (%v/v)	CR(average)	Log CR	CR/T	Log (CR/T)
pod				
Blank	1.4575	0.163609	0.004249	-2.37169
0.1	0.81215	-0.09036	0.002368	-2.62566
0.2	0.823625	-0.08427	0.002401	-2.61956
0.3	0.794875	-0.0997	0.002317	-2.635
0.4	0.74035	-0.13056	0.002158	-2.66586
0.5	0.714525	-0.14598	0.002083	-2.68128
Leaves				
0.1	0.843725	-0.0738	0.00246	-2.60909
0.2	0.832225	-0.07976	0.002426	-2.61505
0.3	0.823625	-0.08427	0.002401	-2.61956
0.4	0.794875	-0.0997	0.002317	-2.635
0.5	0.74035	-0.13056	0.002158	-2.66586
Stembark				
0.1	0.85235	-0.06938	0.002485	-2.60468
0.2	0.832225	-0.07976	0.002426	-2.61505
0.3	0.832225	-0.07976	0.002426	-2.61505
0.4	0.794875	-0.0997	0.002317	-2.635
0.5	0.74035	-0.13056	0.002158	-2.66586
Root				
0.1	0.794875	-0.0997	0.002317	-2.635
0.2	0.751825	-0.12388	0.002192	-2.65918
0.3	0.74035	-0.13056	0.002158	-2.66586
0.4	0.714525	-0.14598	0.002083	-2.68128
0.5	0.64855	-0.18806	0.001891	-2.72335

Appendix XLVI: Arrhenius table of values for mild steel immersed in 0.5M NaCl at 90°C

Concentration of the inhibitors C (%v/v)	CR(average)	Log CR	CR/T	Log (CR/T)
pod				
Blank	2.56	0.40824	0.007052	-2.15167
0.1	1.5238	0.182928	0.004198	-2.37698
0.2	1.46925	0.167096	0.004048	-2.39281
0.3	1.44055	0.158528	0.003968	-2.40138
0.4	1.3803	0.139973	0.003802	-2.41993
0.5	1.360225	0.133611	0.003747	-2.4263
Leaves				
0.1	1.5324	0.185372	0.004221	-2.37453
0.2	1.5238	0.182928	0.004198	-2.37698
0.3	1.5037	0.177161	0.004142	-2.38275
0.4	1.452025	0.161974	0.004	-2.39793
0.5	1.44055	0.158528	0.003968	-2.40138
Stembark				
0.1	1.62135	0.209877	0.004467	-2.35003
0.2	1.584025	0.199762	0.004364	-2.36014
0.3	1.5496	0.19022	0.004269	-2.36969
0.4	1.5238	0.182928	0.004198	-2.37698
0.5	1.452025	0.161974	0.004	-2.39793
Root				
0.1	1.46925	0.167096	0.004048	-2.39281
0.2	1.5037	0.177161	0.004142	-2.38275
0.3	1.452025	0.161974	0.004	-2.39793
0.4	1.3803	0.139973	0.003802	-2.41993
0.5	1.343	0.128076	0.0037	-2.43183

Appendix XLVII: Ultimate tensile strength of samples immersed in acidic medium at 0.5%v/v concentrations of the extracts at 30⁰C.

Samples	Maximum load(KN)	Strength(N/mm ²)
Blank	9.90	504.30
Pod	11.00	560.20
Leaves	11.80	601.00
Stembark	15.43	785.80
Root	12.00	611.2

AppendixXLVIII: Ultimate tensile strength of samples immersed in salt medium at 0.5%v/v concentrations of the extracts at 30⁰C

Samples	Maximum load(KN)	Strength(N/mm ²)
Blank	6.90	350.00
Pod	8.60	438.00
Leaves	8.00	407.44
Stembark	7.90	402.34
Root	11.50	584.38

Appendix XLIX: Izod impact strength of samples immersed in acidic medium at 0.5%v/v concentrations of the extracts at 30⁰C

Samples	Impact strength(Joules)
Blank	108.5
Pod	116.6
Leaves	115.9
Stembark	117.3
Root	116.6

Appendix L: Izod impact strength of samples immersed in salt medium at 0.5%v/v concentrations of the extracts at 30⁰C

Samples	Impact strength(Joules)
Blank	94.2
Pod	107.1
Leaves	100.3
Stembark	98.3
Root	115.9

Appendix LI: Rockwell HRB hardness of samples immersed in acid medium at 0.5%v/v concentrations of the extracts at 30⁰C

Samples	HRB
Blank	85.00
Pod	85.80
Leaves	86.00
Stembark	87.00
Root	86.10

Appendix LII: Rockwell HRB hardness of samples immersed in salt medium at 0.5%v/v concentrations of the extracts at 30⁰C

Samples	HRB
Blank	80.0
Pod	83.6
Leaves	81.5
Stembark	80.4
Root	83.8

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