iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 9 **Issue:** VI **Month of publication:** June 2021

DOI: https://doi.org/10.22214/ijraset.2021.34866

www.ijraset.com

Call: 08813907089 | E-mail ID: ijraset@gmail.com

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 9 Issue VI Jun 2021- Available at www.ijraset.com

Green Corrosion Inhibitors for Copper in HCl and H_2SO_4 Solution - A Review

R. T. Vashi[1], V. A. Champaneri[2], N. I. Prajapati[3]
[1]Associate Professor, Department of Chemistry, Navyug Science College, Rander road, Surat, India
[2]Department of Chemistry, B. K. M. Science College, Tithal Road, Valsad, India
[3]Department of Chemistry, C.B. Patel Computer College & J. N. M. Patel Science College, Surat, India

Abstract: Corrosion is the deterioration of metal by chemical attack or reaction with its environment. It is a constant and continuous problem, often difficult to eliminate completely. Prevention would be more practical and achievable than complete elimination. Recently, a huge interested for the use of naturally occurring inhibitors extracted from plants have been emerged. Most of the natural products are non-toxic, biodegradable and readily available due to environmental concerns. The inhibitor is chemically adsorbed on the surface of the metal and forms a protective thin film with inhibitor effect or by combination between inhibitor ions and metallic surface. Corrosion of copper and its inhibition was analyzed by weight loss (Gravimetric), effect of temperature and time of immersion methods. Electrochemical methods such as, Potentiodynamic polarization and Electrochemical Impedance Spectra (EIS) were employed. The protective films formed on metal surface have been analyzed by various techniques such as Scanning Electron Microscope (SEM), Energy dispersive X-ray spectrometry (EDS) and. Atomic Force Microscopy (AFM), Fourier transform infrared spectroscopy (FT-IR), UV-Visible spectra, X-ray Diffraction spectroscopy (XRD), Energy Dispersive X-ray Spectroscopy (EDX), electrochemical frequency modulation (EFM) techniques. The results obtained from weight loss and electrochemical techniques were in good agreement. In this review paper, research works produced over the past background on the corrosion of copper in various medium and their corrosion inhibition by using a various green inhibitors were presented.
Keywords: Corrosion, Copper, Green inhibitors, Potentiodynamic Polarization, EIS, SEM.

I. INTRODUCTION

Corrosion is a natural phenomenon where metals and alloys try to revert to their more stable thermodynamics form due to reaction with the environment that surrounds them. Corrosion is expensive due to loss of materials or their properties, which leads to loss of time during maintenance, the shutting down of systems, and severe failure of some structures, which in some cases may be hazardous and cause injury. Our economy would be drastically changed if there were no corrosion.

Copper with a reddish orange colour is the fifth most usual metal in the earth's crust which is very useful in pure or alloying form. Copper and its alloys are widely used in industries because of some favourable properties such as good corrosion resistance, high electrical and thermal conductivity, mechanical workability and malleability [1]. Copper and its alloys are highly regarded because of their wide application in production of wire, sheets and pipelines in electronic industries, marine industries, power stations, heat exchangers and cooling towers [2] and recently in the manufacture of integrated circuits [3,4]. Copper is known as a noble metal which provides appropriate corrosion resistance in the atmosphere and in some of chemical environments due to the formation of a protective passive (oxide) film or nonconductive layer of corrosion products on its surface [5].

Corrosion of copper can be caused during this chemical treatment after the scale or oxides have been removed, which implies the dissolution of the metal and the consumption of the acid used. This also implies important economic losses for the industrialists [6]. According to widespread use of copper in different industries, the issue of corrosion and corrosion protection of copper has attracted a lot of attention and many studies have been conducted to date on this issue and are still ongoing.

One of the most practical methods for protection against excessive dissolution of metals by corrosion is use of proper inhibitors [7]. Corrosion inhibitors are substances which when added in small concentration to corrosive media decrease or prevent the reaction of the metal with the media [8]. A lot of work has been done to find and develop different types of organic and inorganic inhibitors. However, some of these inhibitors have disadvantages: high cost, toxic to humans, risk of pollution to the environment. In this context, researchers have to search alternatives by focusing on biodegradable, economical, renewable plant products as corrosion inhibitors that do not present any risk to human health and the environment [9].

©IJRASET: All Rights are Reserved

The plant extract are rich sources of molecules which have appreciably high inhibition efficiency and hence termed as "Green Inhibitors" [8]. According to Barakat et al. [10], plant extracts have been used for decades as effective corrosion inhibitors, their property due to their richness in complex organic compounds containing heteroatom's, aromatic rings and multiple bonds (double and triple bonds) have also been identified as adsorption centres that interact with active sites on the surface of a metal.

There are three types of inhibitors according to mechanism of electrochemical action, such as anodic, cathodic or mixed inhibitors. (i) Anodic inhibitors slow down the oxidation reaction, i.e.by blocking the anodic sites (seat of metal oxidation), which decrease the density of the metal dissolution current and shift the corrosion potential in the positive direction. (ii) Cathodic inhibitors show blocking the cathodic sites (oxygen reduction site in aerated neutral environment or H^+ proton reduction site in acidic environment) which decrease the density of the hydrogen reduction current and which displace the corrosion potential in the negative direction. Cathodic inhibitors are considered safer than anodic inhibitors because they are not likely to promote localized corrosion. (iii) mixed inhibitors which act on both cathodic and anodic reactions. They decrease the speed of both partial reactions with little change in the corrosion potential. The adsorption isotherm can be expressed as the relationship between the rate of recovery of an interface by the adsorbed species and the concentration of the species in solution. There are several models of adsorption isotherms such as Langmuir adsorption isotherm, Temkin adsorption isotherm, Freundlich and Flory-Huggins adsorption isotherm.

1) *Plant Materials as Green Inhibitors:* Corrosion inhibitors are used various parts of the plant extracts such as, Leaves [19,22,24,25,28,29,31,33-36,42,46,50,51], Seeds [16,33,45], Fruits [20,37,48], Branches [33], Fruits [20,37,48], oil [32,44], Roots [33] and Plant extract [23,39,43]. . .
2) *Plant Extracts used:* Various solvents like double distilled water [39,40,], Alcohol [11,14,16,19,25,31,34,36,37,41,43,47,51] and Acetone [26,27] were used for making extract of the plant materials.
3) *Medium:* In this Review, for making plant extracts in HCl [11-38] and H_2SO_4 [39-55] environment has been investigated.
4) *Methods:* Various methods such as Weight loss method [11-15,17-20,24-29,31-40,42,43,45,47,50-55], Potentiodynamic polarization [15,17,18,21-27,29-32,34,36,39-47,52,54,55], EIS [15,17,18,21,23,25,26,29-31,34,39-42,44,47,48,52,55] and Kinetic parameters: Rate constant and Half- life period [51] were used for investigation of corrosion mechanism and to calculate the percentage of inhibition efficiency of green inhibitors. Metal surface analysis is confirmed by various surface morphological studied, like SEM [12,14,16,17-19,25-28,31,40,41,46-48,52,54,55], AFM [12,17,52,54,55], FT-IR spectroscopy [11,14,18,19,25,30,36,46,55], UV spectroscopy [19,36], EDX [17,19,22,25,26], , EDS [12], AAS [26], MDS [54], Ion chromatography [26] , XRD [19] , XPS [46,49,54,55], OMT [43] , EFM [18] and quantum mechanical study [17,18,22,30,48,49,53] were used.
5) *Adsorption isotherms:* The adsorption isotherm model for phyto-chemicals present in various green inhibitors extract into the metallic surface has been studied. For this, different kind of adsorption isotherms, such as Langmuir [11-20, 23,27,28,3-38,39,41,43-49,52-55], Freundlich [25,28,29,42,50,51], Frumkin [42], Temkin [19,20,21,28,51] and Flory-Huggins [28,39,43,47] adsorption isotherms were suggested. A list of various plant extract used as green corrosion inhibitors for Copper was shown in Table-1 and in Table-2.

Table- 1. Green corrosion inhibitors for copper in HCl solution.
(Wl = Weight loss, pp = Potentiodynamic Polarization, EIS = Electrochemical Impedance Spectroscopy)

No.	Inhibitor	Medium	Methods	Findings	I.E. (%)	Ref.
1	*Acacia nilotica*	0.5 N HCl	Weight loss with temperatures. Fourier transforms infrared spectroscopy (FT-IR).	Langmuir isotherm.	85.84 Wl	11
2	*Alginate biopolymer*	1.0 M HCl	Weight loss. Potentiodynamic polarization and EIS methods.Scanning electron microscopy (SEM), Energy dispersive X-ray spectrometry (EDS) and. Atomic Force Microscopy (AFM) techniques. Quantum calculations.	Cathodic inhibitor. Langmuir isotherm.	78.20 Wl 83.06 PP 82.12 EIS	12
3	*Aloe vera Barbadensis Gel*	HCl	Weight loss with temperature.	Langmuir adsorption Isotherm. A first order type of mechanism.	-	13

©IJRASET: All Rights are Reserved

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 9 Issue VI Jun 2021- Available at www.ijraset.com

4	*Azadirachta indica*	0.5 N HCl	Weight-loss with time, SEM and FT-IR.	Langmuir adsorption isotherm.	97.72 Wl	14
5	*Calligonum comosum*	2 M HCl	Weight loss. potentiodynamic polarization and EIS methods.	Mixed-type inhibitor. Langmuir adsorption isotherm.	80.06 Wl 90.36 PP	15
6	*Capparis decidua* seeds	0.5 M HCl	SEM.	Langmuir adsorption isotherm.	94.60 Wl 51.11 EIS	16
7	Chitosan	1 M HCl	Weight loss, polarization and EIS measurements. SEM, EDX spectrometry and AFM studies. quantum chemical and molecular dynamics simulation approaches.	Cathodic inhibitor. Langmuir adsorption isotherm.	87.34 PP 86.75 EIS	17
8	Chitosan	0.5 M HCl	Weight loss, potentiodynamic polarization, EIS and EFM measurements. SEM and FT-IR spectroscopy. quantum chemical calculations.	Mixed-type inhibitor. Langmuir adsorption isotherm.	-	18
9	*Cnidoscolus chayamansa* leaves	1.0 N HCl	Weight loss with time and temperature. UV, FT-IR, XRD and EDX, SEM spectral techniques.	Langmuir and Temkin adsorption isotherms.	70.57 Wl	19
10	*Coccinia Grandis* Fruit	1 N HCl	Weight loss with temperature.	Langmuir and Temkin adsorption isotherms.	57.00 Wl	20
11	*Egyptian licorice extract*	0.1 M HCl	Potentiodynamic polarization, EIS methods	Mixed-type inhibitor. Temkin adsorption isotherm.	89.55 PP 81.22 EIS	21
12	*Emilia sonchifolia* (ES) leaf extract	2 M HCl	Potentiodynamic polarization measurement, EDX emission spectroscopy and surface examination techniques. Computational simulations. Quantum chemical calculations and molecular dynamics simulations.	Mixed- type inhibitor.	99.75 PP	22
13	*Ephedra sarcocarpa* plant extract.	2 M HCl	Potentiodynamic polarization and EIS.	Langmuir adsorption isotherm.	94.50 PP	23
14	*Eucalyptus* leaves	1 M HCl	Weight loss measurements. galvanostatic polarization and surface characterization techniques.	Mixed-type inhibitor predominantly cathodic.	-	24
15	*Leucas* Aspera (MLA) leaf	HCl	Weight loss with time and temperature. potentiodynamic polarization, and EIS. Field emission SEM and EDX spectrometry analysis, FT-IR Spectra.	Mixed-type Predominent cathodic inhibitor. Freundlich isotherm	86.96 Wl 87.33 PP 67.91 EIS	25
16	*Mangrove Tannin*	0.5 M HCl	Weight loss method, potentiodynamic polarization, EIS, SEM along with EDX, atomic absorption spectroscopy (AAS) and ion chromatography (IC).	Cathodic inhibitor. Langmuir adsorption isotherm.	72.80 Wl 82.40 PP 87.60 EIS	26

©IJRASET: All Rights are Reserved

17	*Mangrove Tannin*	1.0 M HCl	Weight loss, potentiodynamic polarization and SEM analysis.	Cathodic inhibitor Langmuir adsorption isotherm.	68.80 PP	27
18	*Momordica balsamina Li nn.*(African Pumpkin) *Leaf Extract*	0.8 M HCl	Weight loss with temperature. SEM.	Langmuir, Freundlich, Flory-Huggins and Temkin adsorption isotherms.	71.43 Wl	28
19	*Morinda tinctoria* le aves	0.5 M HCl	Weight loss with time and temperature. potentiodynamic polarization and EIS methods .	Freundlich isotherm.	65.39 PP 79.77 EIS	29
20	*Phosphatidy choline* (PC) exracted from egg yolk	1 M HCl	Potentiodynamic polarization and EIS methods. FT-IR spectroscopic quantum chemical results.	-	96.40 PP 99.30 EIS	30
21	*Prosopis Cineraria* Leaves	0.5 N HCl	Weight loss with time. Potentiodynamic polarization and EIS. SEM.	Anodic inhibitor. Langmuir adsorption isotherm.	74.88 Wl 94.10 PP 75.26 EIS	31
22	*Sesmum indicum* oil	0.5 N HCl	Weight loss. potentiodynamic polarization	Mixed-type inhibitor. Langmuir adsorption isotherm.	80.00 Wl 86.70 PP	32
23	*Tecomell Aundulata Root –brances- leaves- seeds*	1 N HCl	Weight loss with temperature.	-	Root-86.72 Wl Brances-89.27 Wl Leaves-86.13 Wl Seeds-93.84 Wl	33
24	Tea Leaves	0.01,0.1, 0.5 and 1.0 M HCl	Weight loss, potentiodynamic polarization, EIS and SEM.	Cathodic inhibitor, Langmuir adsorption isotherm	93.00 Wl 99.00 PP	34
25	*Terminallia-cattapa* leaf extract	0.5 M HCl	Weight loss with temperature.	Langmuir adsorption isotherm.	72.72 Wl	35
26	*Wrightia tinctoria* leaves extract	1.0 M HCl	Weight loss with time and temperature. UV, FT-IR and SEM.	Langmuir adsorption isotherm.	87.87 Wl	36
27	*Ziziphus mauritiana* fruit.	0.5 N HCl	Weight loss with time. FT-IR spectroscopy.	Langmuir adsorption isotherm.	88.52 Wl	37
28	*Zenthoxyl-umalatum*	0.1 M HCl	Weight loss measurement and potentiometry polarization technique.	Langmuir adsorption isotherm.	98.28 Wl 95.80 PP	38

©IJRASET: All Rights are Reserved

6) Active Phytoconstituents Present in Green Inhibitors

a) In HCl Media: Plant extraction products are acts as a good potential corrosion inhibitor for Copper in HCl media. The active constituents of green inhibitors are varied from one plant species to another species but their structures are closely related to their number of organic molecules, e.g., *Acacia nilotica* [11,56] contains Terpenoids, Tannins, alkaloids, Saponins, Glycosides, Nitrogen, phosphorus. Gallic acid, Chlorogenic acid, galloylated flavan-3,4-diol (leucocyanidin), catechin and 7,3',4',5,-tetrahydroxyflavan3,4-diol have been reported from the pods. *Aloe vera Barbadensis Gel* [12,57] contain compounds such as salicylates, magnesium lactate, acemennan, lupeol, campestrol, sterol, linolenic, aloctin and anthraquinones. *Azadirachta indica* (AZ) extract [14,42,58] contain saponnin, tannin, alkaloid, glycoside, anthraquinone and flavonoid. *Cnidoscolus Chayamansa* leaves [19] contain hydrocyanic glycosides, Flavonoids, Terpenoids, Glycosides, Steroids, Alkaloids, Carbohydrates, Amino acid and Tannins. *Egyptian licorice extract* [21] *contain* Glycyrrhizic acid and glabridin. *Mangrove Tannin* [26,27,59] contain mainly four flavanoid monomers, namely: catechin, epicatechin, epigallocatechin and epicatechin gallate. *Prosopis Cineraria* leaves [31,60,61] contains specigerine, steroids such as campestrol, cholesterol, sitosterol, stigmasterol, Tricosan-1-ol, Methyl docosanoate, Diisopropyl-10,11-dihydroxyicosane-1,20- dioate. Amino acids isolated from leaves and pods are Aspartic acid, Glutamic acid, Serine, Glycine, Histidine, Threonine, Arginine, Alanine, Proline, Tyrosine, Valine, Methionine, Cysteine, Isoleucine, Leucine, Phenylalanine and Lysine. *Sesmum indicum* oil [32] contains lignans such as sesamol, sesamin and sesamolin. The percentage composition of fatty acid is 44%, stearic acid 4.2%, palmitic acid 9% and arachidic acid 0.7%. Tea Leaves contain [34,62] polysaccharides, volatile oils, vitamins, minerals, purines, alkaloids (e.g.caffeine) and polyphenols (catechins and flavonoids). *Wrightia tinctoria* leaves [36] mainly contian flavonoids, alkaloids, saponins, and triterpenes. *Ziziphus mauritiana* fruit [37,63] contain phytochemicals such as fructose, glucose and galactose organic acids, citric, malonic and malic identified and other organic components such as tannins, phenolic compounds and flavonoids phenolic compounds identified are vanillic acid, ferulic acid and p-hydroxybenzoic acid, gallic acid.

b) In H_2SO_4 Media: Plant extraction products are acts as a good potential corrosion inhibitor for Copper in H_2SO_4 media. The active constituents of green inhibitors are varied from one plant species to another species but their structures are closely related to their number of organic molecule,e.g., *Allium sativum* [40] contain Diallyl disulfde (26.623%), Trisulfide, methyl2-propenyl (16.459%) and Trisulfide, di-2-propenyl (34.104%). *Arghel* [41,64] contains Argelosides, Glycoside, Choline, Phytosterols, Flavonoids and Amyrine. *Cannabis* Plant [43, 65] contain cannabidiol-type (CBD) and cannabinol, endogenous cannabinoids anandamide (AEA), 2- arachidonoyl glycerol (2-AG). *Cinnamon* essential oils [44] contain 86.21% of CiO with Trans-cinnamaldehyde (46.30%), δ-cadinene (8.16%) and β-Cubebene (5.20 %). *Citrullus colocynthis* Fruits [45,66] contain Alkaloids, flavonoids and saponins compounds. *Myrianthu sarboreus* leaves [51] contain Alkaloid, Flavonoid, Saponin, Tannin, Terpenoids and Carbohydrates. *Newbouldialaevis* extracts [53] contain lapachol and newbouldiaquinone. Papaya leaves extract [55] contain DL-ascorbic acid (DLA), 5,7-Dimethoxy-chromen-2-one (DCO), 2-Amino-4- methylsulfanyl-butyric acid (AMB), 3,4-Ditydroxy-benzoic acid (DBA).), 2-Hydroxy-succinic acid (HSA), 3-[3-(3,4-Dihydroxy-phe nyl)-acryloxy]-1,4,5-trihydroxy-cyclohexanecarboxylic acid (DTA).

Table- 2. Green corrosion inhibitors for copper in H_2SO_4 solution.
(Wl = Weight loss, pp = Potentiodynamic Polarization, EIS = Electrochemical Impedance Spectroscopy)

No.	Inhibitor	Medium	Methods	Findings	I.E. (%)	Ref.
1	*Alhagi maurorum* plant extract	0.5 M H_2SO_4	Weight loss, Potentiodynamic polarization (PP) and EIS.	Cathodic-type inhibitor, Langmuir, Flory–Huggins adsorption isotherms. kinetic–thermodynamic model,	87.90 Wl 83.40 PP 88.00 EIS	39
2	*Allium sativum*	0.5 M H_2SO_4	Weight loss with temperature. Potentiodynamic polarization. EIS. Surface analysis by SEM/EDX.	Cathodic inhibitor.	97.00 Wl 94.60 PP 94.80 EIS	40
3	*Arghel*	0.5 M H_2SO_4	Potentiodynamic polarization and EIS measurements. SEM.	Mixed-type inhibitor. Langmuir's isotherm.	93.26 PP 76.84 EIS	41
4	*Azadirachta indica leaves*	0.5 M H_2SO_4	Weight loss and polarization techniques.	Frumkin adsorption isotherm.	86.40 PP	42

©IJRASET: All Rights are Reserved

5	*Cannabis* Plant	0.5 M H_2SO_4	Weight loss. potentiodynamic polarization and EIS, optical micrograph techniques.	Cathodic-type inhibitor. Langmuir and Flory Huggins adsorption isotherm. Kinetic-Thermodynamic model.	96.00 PP 91.00 EIS	43
6	*Cinnamon essential oil*	0.5 M H_2SO_4	Polarization and EIS	Cathodic-type inhibitor. Langmuir adsorption isotherm.	89.60 PP 87.24 EIS	44
7	*Citrullus colocynthis* Fruits	1 M H_2SO_4,	Weight loss with time and temperature. Electrochemical polarization methods.	Mixed-type inhibitor. Langmuir adsorption isotherm.	90.58 Wl 98.41 PP	45
8	*Davidiainvo lucrata* leaf extract (DLE)	0.5 M H_2SO_4	Potentiodynamic polarisation measurements. FT-IR and X-ray photoelectron spectroscopy (XPS). SEM and AFM. quantum chemical calculation and molecular dynamics simulation.	Langmuir adsorption isotherm.	90.00 PP	46
9	*Fenugreek* extract	2 M H_2SO_4	Gravimetric, Linear polarization and EIS measurements. SEM.	Langmuir and Florry-Huggins isotherm.	76.56 Wl 84.18 EIS 83.81 PP	47
10	*Idesia polycarpa* maxim fruits extract	0.5 M H_2SO_4	EIS and SEM techniques. Quantum chemical calculation.	Langmuir adsorption model. physisorption and chemisorption.	93.80 EIS	48
11	Losartan Potassium	0.5 M H_2SO_4	Potentiodynamic polarization. Surface morphological observation by X-ray photoelectron spectroscopy (XPS), quantum chemical calculation and molecular dynamics (MD) simulation.	Mixed-type inhibitor. Langmuir adsorption model.	-	49
12	*Morinda tinctorial* leaves extract	0.25 M H_2SO_4	Weight loss with temperature and Potentiodynamic polarization.	Mixed-type inhibitor. Freundlich adsorption isotherm.	$<$ 60 Wl 49.61 PP	50
13	*Myrianthus arboreus leaves*	2 M H_2SO_4	Weight loss method at various time and temperatures. Rate constant (k) and half-life parameters.	Freundlich and Temkin adsorption isotherms. First order reaction.	97.67 Wl	51
14	*Myrtus communis*	0.5 M H_2SO_4	Weight loss with time. Potentiodynamic polarization, EIS, AFM and SEM methods.	Mixed- type inhibitor. Langmuir adsorption isotherm.	88.50 PP 90.70 EIS	52
15	*Newbouldia laevis* extracts	0.5 M H_2SO_4	Gravimetric with temperature. Quantum Chemical calculations.	Langmuir isotherm.	77.53 Wl	53
16	*Papain freeze* dried	H_2SO_4	Weight loss with temperature. Potentiodynamic polarization measurements. AFM and SEM. XPS. Molecular dynamics simulations (MDS).	Mixed-type inhibitor. Langmuir adsorption isotherm.	95.00 Wl	54
17	Papaya leaves extract	H_2SO_4	Weight loss with temperature. Potentiodynamic polarization, EIS. FT-IR, SEM, XPS and AFM techniques.	Mixed-type inhibitor. Langmuir adsorption isotherm.	92.90 PP 95.50 EIS	55

7) *Mechanism of Corrosion Inhibition:* In acidic solutions, transition of the metal/solution interface is attributed to the adsorption of the inhibitor molecules at the metal/solution interface, forming a protective film. The rate of adsorption is usually rapid, and hence, the reactive metal surface is shielded from the acid solutions [67]. The adsorption of an inhibitor depends on its chemical structure, its molecular size, the nature and charged surface of the metal, and distribution of charge over the whole inhibitor molecule. In fact, adsorption process can occur through the replacement of solvent molecules from the metal surface by ions and molecules accumulated near the metal/solution interface. Ions can accumulate at the

©IJRASET: All Rights are Reserved

metal/solution interface in excess of those required to balance the charge on the metal at the operating potential. These ions replace solvent molecules from the metal surface, and their centres reside at the inner Helmholtz plane. Since all the different parts of plant extract possess several heteroatoms containing active constituents, therefore there may be a synergism between the molecules accounting for the good inhibition efficiencies.

II. CONCLUSION

In this review paper, research works produced over the past background on the corrosion of copper in various medium and their corrosion inhibition by using a different green inhibitors were presented. Various solvents are used to formulate extracts of fruits, flower, leaves, seeds, roots, peels, bark, stem and seed oil. Weight loss (gravimetric) with time and temperature effect are common methods to investigate the corrosion rate and inhibition efficiency for the evaluate green (natural) inhibitors. According to extracted results from corrosion tests, the increase in the concentration of corrosion inhibitor in the bulk of the solution (to an optimum concentration) and also increase in immersion time result in improving corrosion inhibition performance. The increase in temperature usually leads to a decrease in corrosion inhibition efficiency. Some studies were performed using Potentiodynamic polarization and EIS, for finding which type of inhibitor, whether it is anodic or cathodic or as mixed type. To study surface analysis of protective film formed on metal various study such as SEM, AFM, FT-IR, EFM, AAS, UV-Spectroscopy, EDX, XRD, EDS, LPR , XPS , MDS and Quantum Chemical study (HOMO and LUMO) of the molecular modeling were used. According to some author's adsorption isotherm occurred through the Langmuir, Freundlich, Temkin, Frumkin and Flory-Huggins. Kinetic-thermodynamic model. All the results obtained from EIS, LPR, and weight loss are in good agreement with each other.

REFERENCES

[1] M. A. Amin, K. Khaled,"Copper corrosion inhibition in O_2- saturated H_2SO_4 solutions". Corros. Sci., 2010, 52, 1194–1204.
[2] B. Duran, G. Bereket, M. Duran, "Electrochemical synthesis and characterization of poly (m-phenylenediamine) films on copper for corrosion protection". Prog. Org. Coat., 2012, 73, 162–168.
[3] V. Oteino-Alergo, N. Huynh, T. Notoya, S. E. Bottle, D. P. Schwcinsberg. "Inhibitive effect of 4- and 5-carboxybenzotriazole on copper corrosion in acidic sulphate and hydrogen sulphide solutions", Corros. Sci., 1999, 41(4,1), 685-697.
[4] H. Y. Tsai, S. C. Sun, S. J. Wang. "Characterization of Sputtered Tantalum Carbide Barrier Layer for Copper Metallization", J. Electrochem. Soc., 2000, 147, 2766-2772.
[5] T. Suter, E. Moser, H. Bo¨hni,, "The characterization of the tarnishing of Cu-15Ni-8Sn and Cu-5Al-5Sn alloys". Corros. Sci., 1992, 34, 1111–1122.
[6] G. Quartarone., M. Battilana, L. Bonaldo , T. Tortato, "Investigation of the inhibition effect of indole-3-carboxylic acid on the copper corrosion in 0.5M H_2SO_4". Corros Sci., 2008, 50(12), 3467–3474. https://doi.org/10.1016/j.corsci.2008.09.032
[7] J. M. Sykes, "25 years of progress in electrochemical methods", Br. Corros. J., 1990, 25, (3), 175–183.
[8] P. B. Raja, M. G. Sethuraman "Natural products as corrosion inhibitor for metals in corrosive media—a review". Mater. Lett., 2008, 62(1), 113–116. https://doi.org/10.1016/j.matlet.2007.04.079
[9] A. Fateh, M. Aliofkhazraei , A. R. Rezvanian . Review of corrosive environments for copper and its corrosion inhibitors". Arab. J. Chem., 2017, 13, 481–544. https://doi.org/10.1016/j.arabjc.2017.05.021.
[10] Y. Barakat., A. Hassan, M. A. Paraka. "Corrosion Inhibition of mild steel in aqueous solution containing H_2S by some naturally occurring substances". Materialwiss Werkstofech, 1998, 9(7), 365.
[11] S. Yadav, and A. Sharma "Effect of temperature on protective propensity of Acacia nilotica on acid corrosion of copper", Rev. Res., 2013,.2(7), 1-15.
[12] A. Jmiai , B. El Ibrahimi , A. Tara , S. El Issami , O. Jbara , L. Bazzi. "Alginate biopolymer as green corrosion inhibitor for copper in 1 M hydrochloric acid: experimental and theoretical approaches". J. Mol. Struct., 2018, 1157, 408–417. https://doi.org/10.1016/j.molst ruc.2017.12.060.
[13] H. Kalada., A. O. James. "The inhibitive effect of Aloe vera Barbadensis Gel on copper in Hydrochloric acid medium". J. of Engg. and Appl. Sci., 2014, 5(1), 24-49.
[14] S. Yadav, A. Sharma, G. Chaudhary and M. A. Sharma. "Inhibitive and adsorption properties of Ethanolic Extract of fruit of Azardirachta indica on the corrosion of copper in HCl". International Journal of Innovative Research Science, Engineering and Technology. IJIRSET. 2014, 3(9), 16127-16136.
[15] M. Shabani-Nooshabadi, F. S. Hoseiny, Y. Jafari, "Green approach to corrosion inhibition of copper by the extract of Calligonum comosum in strong acidic medium". Metall. Mater. Trans. 2014b, A 46, 293–299.
[16] P. S. Pratihar, M. P. S. Verma, A. Sharma, "Capparis decidua seeds: potential green inhibitor to combat acid corrosion of copper". Rasayan J. Chem., 2015, 8(4), 411–421.
[17] A. Jmiai, B. El Ibrahimi, A. Tara, S. El Issami, O. Jbara, L. Bazzi, M. Hilali. "Chitosan as an eco-friendly inhibitor for copper corrosion in acidic medium: protocol and characterization". Cellulose, 2017, 24, 3843–3867.https://doi.org/10.1007/s1057 0-017-1381-z.
[18] M. N. El-haddad , "Chitosan as a green inhibitor for copper corrosion in acidic medium" Int. J. of Bio. Macromolecules, 2013, 55, 142−149. DOI: 10.1016/j. ijbiomac.2012.12.044.
[19] A. Bright., S. Michlin Ruphina Maragatham., J. Malarvizhi. and Dr.. S. Selvaraj., "Inhibitive effect of Cnidoscolus chayamansa leaves extract on Copper in Acid environment", Int. J. of Multidisciplinary Res. and Devel., 2015, 2(4), 35-44.
[20] M. S. Rani, and C. Subha "Adsorption and Inhibitive Properties of Coccinia Grandis Fruit Extract as Green Corrosion Inhibitor for Copper in Acid Media", J. of Chem. and Chem. Sci., 2019, 9(2), 63-73.

©IJRASET: All Rights are Reserved

[21] M. A. Deyab "Egyptian licorice extract as a green corrosion inhibitor for copper in hydrochloric acid solution". J. Ind. Eng. Chem., 2015, 22, 384–389. https://doi.org/10.1016/j.jiec.2014.07.036 .

[22] S. R.. Oguike, O. Oni, A. U. Barambu, D. Balarak, T. Buba, C. U. Okeke, L. S. Momoh, S. Onimisi, W. J. Nwada, "Computational Stimulation and Experimental Study on Corrosion Inhibition Qualities of Emilia sonchifolia Leaf Extract for Copper (CU131729) in Hydrochloric Acid", Comput. Chem., 2021, 9, 18-36.

[23] M. S.-Nooshabadi, F. S. Hoseiny and Y. Jafari "Corrosion Inhibition of Copper by Ephedra Sarcocarpa Plant Extract as Green Corrosion Inhibitor in Strong Acidic Medium" Anal. Bioanal. Electrochem. 2014, 6(3), 341-354.

[24] K. Pravinar, A. Hussein, G. Varkey, and G. Singh, "Inhibition effect of aqueous extracts of Eucalyptus leaves on the acid corrosion of mild steel and copper". Transaction of the SAEST, 1993, 28(1): 8-12.

[25] N. Kavitha, J. Ravichandran, A. Murugesh,. "An Eco-friendly *Leucas Aspera* Leaves Extract Inhibitor for Copper Corrosion in Hydrochloric Acid Medium". J. Bio. Tribo. Corros., 2020, 6(4), 103. DOI: 10.1007/s40735-020-00400-8.

[26] A. M. Shah, A. A. Rahim, S. A. Hamid and S. Yahya, "Green Inhibitors for Copper Corrosion by Mangrove Tannin". Int. J. Electrochem. Sci., 2013, 8(2) 2140-2153.

[27] A. M. Shah, A. A. Rahim, S. Yahya., B. Raja, "Acid Corrosion Inhibition of Copper by Mangrove Tannin.", Pig. and Resin Techn.. 2011, 40(2),118–122.

[28] B. M. Maibulangu, M. B. Ibrahim, L. K. Akinola, "Inhibitory Effect of African Pumpkin (*Momordica balsamina* Linn.) Leaf Extract on Copper Corrosion in Acidic Media", J. Appl. Sci. Environ. Manage., 2017, 21(6) .1067-1071.

[29] K. Krishnaveni., J. Ravichandran, "Influence of aqueous extract of leaves of Morinda tinctoria on copper corrosion in HCl medium" J. Electroanal. Chem., 2014, 735, 24–31.

[30] D. Sukul, A. Pal, S. Mukhopadhyay, S. K. R. Saha, P. Banerjee, "Electrochemical behaviour of uncoated and phosphatidylcholine coated copper in hydrochloric acid medium". J. Mol. Liq., 2018, 249, 930– 940. https://doi.org/10.1016/j.molliq.2017.11.129.

[31] P. S. Pratihar, J. Rawat, "Corrosion Inhibition of Copper Metal by Prosopis Cineraria Leaves as Green Corrosion Inhibitor in Acidic Medium", Int. J. for Res. in Appl. Sci. & Engg. Tech. (IJRASET), 2017, 5(VI), 2412-2421.

[32] A. Sharma, A. Varshney and S. Varshney, "Sesmum indicum Oil as a Potential Inhibitor for the Corrosion of Copper in Acidic Environment", Oriental J. of Chem., 2016, 32(5), 2769-2775.

[33] V. K. Swami, D. Sharma, S. Kumar, "Corrosion inhibition of copper by acid of Tecomella undulata", Int. J. Chem. Sc., 2013, 11,1457–1463.

[34] R. Senthooran, N. Priyantha , "Inhibition of Corrosion of Copper in HCl by Tea Leaves Extracts: I. Corrosion Rate Measurements" Annual Res, J. SLSAJ, 2012, 12, 1-10.

[35] Dr. S. Ananthalakshmi, A. Anbarasan, R. Kavitha, S. Kalaivani, "Adsorption and corrosion inhibiting behaviour of Terminalliacattapa leaf extract on copper steel", Int. J. of basic and appl. Res., 2019, 9 (5), 444-452.

[36] P. Deivanayagam, I. Malarvizhi, S. Selvaraj, "wrightia tinctoria leaves extract as effective corrosion inhibitor on copper in acid environment", Int. J. of chem. and pharm. analysis, 2016, 3(3), 1-10.

[37] S. Yadav, G. Choudhary, A. Sharma, "Green approach to corrosion inhibition of aluminium and copper by Ziziphus mauritiana fruit extract in hydrochloric acid solution". Int. J. Chem. Tech. Res., 2013, 5, 1815–1823.

[38] J. S. Chauhan, "Anticorrosion behaviour of Zenthoxylum alatum extract in acidic media". Asian J. of Chem., 2009, 21(3), 1975-1978.

[39] B. A. Abd-El-Nabey, S. El-Housseinyi, G. A. El-Naggar, E. A. Matter, G. Esmail, "Inhibitive Action of Alhagim aurorum plant extracts on the corrosion of copper in 0.5 M H_2SO_4 acid". Phy. Chem.., 2015, 5(3), 49-62.

[40] K. Mzioud· A. Habsaoui· M. Ouakki· M. Galai· S. El Fartah· M. Ebn Touhami, "Inhibition of copper corrosion by the essential oil of Allium sativum in 0.5 M H_2SO_4 solutions", SN Applied Sci. ,2020, 2, 1611 https://doi.org/10.1007/s42452-020-03393-8.

[41] A. M. Hefnawy, S. F. A. Ali, "Arghel extract: a promising green corrosion inhibitor". Prot Met. Phy. Chem., 2017, 53(6), 1120–1124. https:// doi.org/10.1134/S2070205117060107.

[42] L. Valek, and S. Martinez, "Copper corrosion inhibition by Azadirachta indica leaves extract in 0.5 M sulphuric acid", Materials Letters, 2007, 61, 148-151. https://doi.org/10.1016/j.matlet.2006.04.024.

[43] B. A. Abd-El-Nabey, A. M. Abdel-Gaber, M. El. Said Ali, E. Khamis, S. El-Housseiny "Inhibitive Action of Cannabis Plant Extract on the Corrosion of Copper in 0.5 M H_2SO_4". J. Electrochem. Sci., 2013, 8, 5851-5865.

[44] K. Dahmani, M. Galai, M. Cherkaoui, A. El Hasnaoui, A. El Hessni, "Cinnamon essential oil as a novel eco-friendly corrosion inhibitor of copper in 0.5 M Sulfuric Acid medium". J. Mater. Environ. Sci., 2017, 8, 1676–1689.

[45] M. E. Al-Dokheily, H. M. Kredy and R. N. Al-Jabery, "Inhibition of Copper Corrosion in H2SO4, NaCl and NaOH Solutions by Citrullus colocynthis Fruits Extract", J. Nat. Sci. Res., 2014, 4(17), 60-73.

[46] X. Zhang, W. Li, X. Zuo, B. Tan, C. Xu, S. Zhang, "Investigating the inhibitive effect of Davidia involucrate leaf extract as a biological eco-friendly inhibitor for copper in acidic media". J. of Mol. Liq., 2021, 325, 115214.

[47] S. M. Ali, and H. A. Al lehaibi "The inhibitive performance of fenugreek for corrosion of copper and nickel in sulfuric acid". Int J Electrochem Sci., 2016, 11, 953–966.

[48] X. Zhang, W. Li, G. Yu, X. Zuo, W. Luo, J. Zhang, B. Tan, A. Fu, S. Zhang, "Evaluation of Idesia polycarpa maxim fruits extract as a natural green corrosion inhibitor for copper in 0.5 M sulfuric acid solution". J. of Mol. Liq., 2020, 318, 114080.

[49] H. Li, S. Zhang, B. Tan, Y. Qiang, W. Li, S. Chen, L. Guo. "Investigation of Losartan Potassium as an eco-friendly corrosion inhibitor for copper in 0.5 M H_2SO_4 ,J. of Mol. Liq.", 2020, 305, 112789.,https://doi.org/10.1016/j.molliq.2020.112789.

[50] K. Krishnaveni , J. Ravinchandran, "A study on the inhibition of copper corrosion in sulphuric acid by aqueous extract of leaves of Morinda tinctoria". J. of Failure Anal. and Prev., 2015, 15(5),711-721. https://doi. org/10.1007/s11668-015-0002-0.

[51] G. I. Udom, G. A. Cookey and A. A. Abia, "Corrosion Inhibition and Adsorption Characteristics of Myrianthus arboreus Leaves Extract on Copper in Sulphuric Acid Solution", Chem. Sci. Int. J., 2018, 23(3), 1-13.

[52] M. Bozorg, T. S. Farahani, J. Neshati, Z. Chaghazardi, G. M. Ziarani, "Myrtus communis as green inhibitor of copper corrosion in sulphuric acid", Ind. and Engg. Chem. Res., 2014, 53, 4295-4303.

©IJRASET: All Rights are Reserved

[53] K. B Okeoma, I. M. Mejeha, S. C Akajiaku, F. C. Eze, C. E. Orji, "Investigative studies on the inhibitive effects of Newbouldialaevis extracts and magnetic fields on copper corrosion in aqueous acidic media", Int. J. of Engg. and Sci., 2016, 6(2), 05-14.

[54] L. Gao, S. Peng, X. Huang, Z. Gong, "A combined experimental and theoretical study of papain as a biological eco-friendly inhibitor for copper corrosion in H_2SO_4 medium". Appl. Surf. Sci., 2020, 511, 145446. DOI: 10.1016/j.apsusc.2020.145446 .

[55] B. Tan, B. Xiang, S. Zhang, Y. Qiang, L. Xu, S. Chen, J. He, "Papaya leaves extract as a novel eco-friendly corrosion inhibitor for Cu in H_2SO_4 medium", J. of Colloid and Interface Sci., 2021, 582, 918-931. https://doi.org/10.1016/j.jcis.2020.08.093 .

[56] S. Malviya, S. Rawat, M. Verma, A Kharia, "Preliminary Phytochemical Investigations of Acacia nilotica Linn Plant", Current Pharma Res., 2011, 1(2), 91-100.

[57] A. M. Al-Turkustani, S. T. Arab, R. H. Al-Dahiri "Aloe Plant Extract as Environmentally Friendly Inhibitor on the Corrosion of Aluminum in Hydrochloric Acid in Absence and Presence of Iodide Ions". Modern Appl. Sci., 2010, 4(5), 105-124.

[58] N. O. Eddy, and E. E. Ebenso, "Inhibitive and Adsorption Properties of Ethanol Extract of Seeds and Leaves of Azadirachta Indica on the Corrosion of Mild Steel in H_2SO_4", African J. Pure Apply. Chem., 2008, 2(6), 1-9.

[59] A. A. Rahim, and J. Kassim, "Recent development of vegetal tannins in corrosion protection of iron and steel", Recent Patents on Mat. Sci., 2008, 1(3), 223-31.

[60] A. Malik, S. B. Kalidhar, "Phytochemical investigation of Prosopis cineraria L. leaves", Indian J. Pharm. Sci., 2007, 69(4).

[61] A. Khatri, A. Rathore, U. K. Patil, "Prosopis cineraria (l.) druce: a boon plant of desert an overview", Int. J. Biomed. Adv. Res., 2010, 1(05).

[62] C. A. Loto, "Inhibition effect of Tea (Camellia Sinensis) extract on the corrosion of mild steel in dilute sulphuric acid", J. Mater. Environ. Sci., 2011, 2 (4), 335-344.

[63] M. Muchuweti, G. Zenda, A. R. Ndhlala, A. Kasiyamhuru,, "Sugars, organic acid and phenolic compounds of Ziziphus mauritiana Fruit", European Food Res. and Tech., 2005, 221(3-4), 560-574. Doi:10.1007/s00217-005-1204-6.

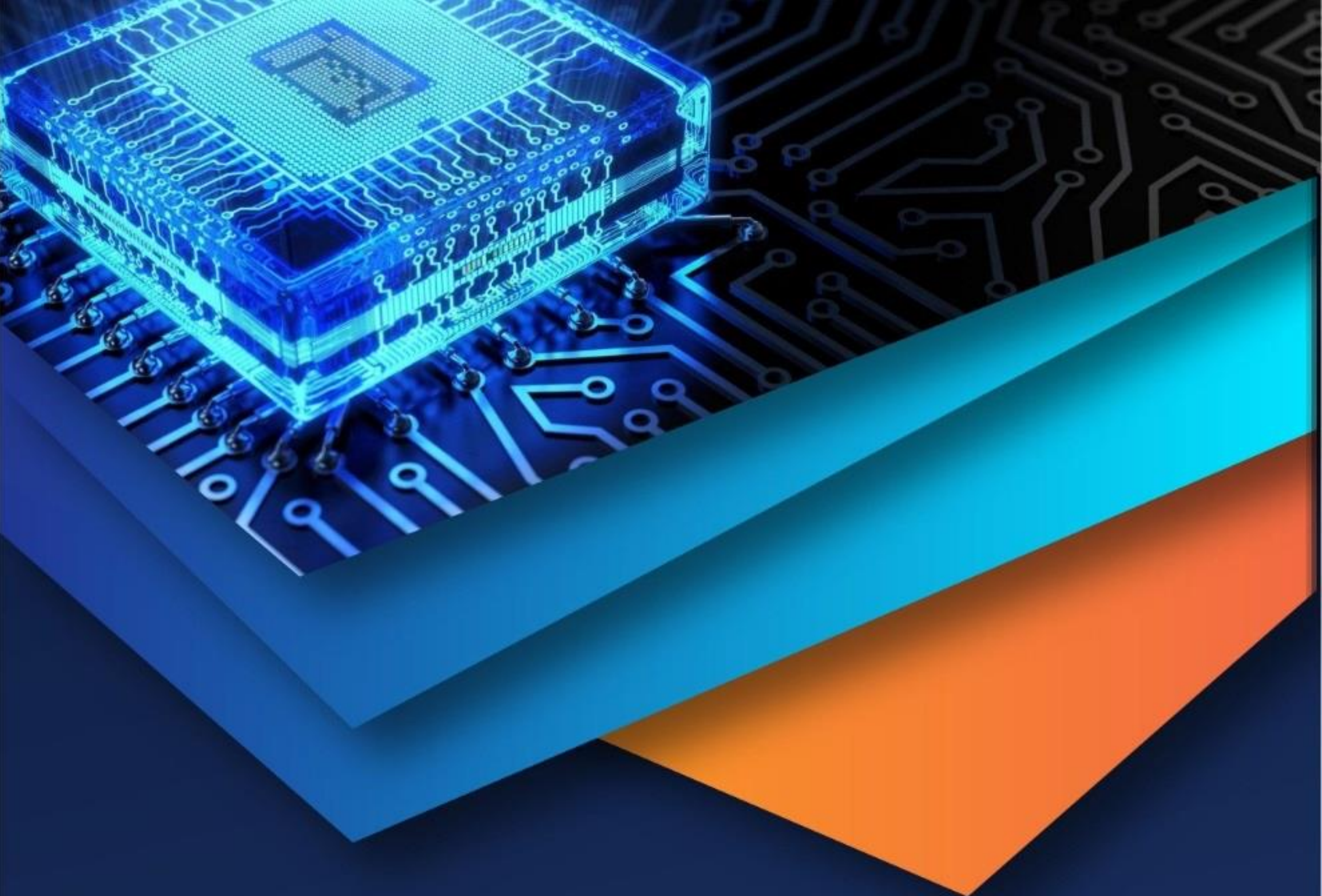
[64] R. A. Alhady Mohamed, Propagation of *Solenostemmaarghel* (Del.) Hayne *In vitro,* Am.- Eurasian J. Agric. Environ. Sci., 2011, 11, 771.

[65] M. Frankhauser. F. Grotenhermen. First ed. Berlin: Verl Hans Huber, 2001, 1, 57-71.

[66] A. Djilani, B. Legseir , R. Soulimani , A. Dickob , C. Younos , "New Extraction Technique for Alkaloids", J. Braz. Chem. Soc., 2006, 17(3), 518-520.

[67] C. Y. Chao, L. F. Lin, and D. D. Macdonald, "A point defect model for anodic passive films," J. of the Electrochem. Soc., 1981, 128 (6), 1187–1194.

©IJRASET: All Rights are Reserved



10.22214/IJRASET

45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Call : 08813907089 (24*7 Support on Whatsapp)