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Review Paper

Corrosion inhibition of aluminium by seed extracts – a review

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Abstract

Environmentally and ecologically recognition among scientists has cause to the enlargement of green technology alternatives to reduce corrosion. Corrosion inhibitors are extensively used for the protection of metals and equipment and they are required to be acceptable and eco-friendly. Some of the researchers are tried to make use of green seed extract products as corrosion inhibitors. In this review paper, corrosion inhibition of various types of metal, medium and green inhibitors (seeds extract) have been reported. In the present paper, reported on green corrosion inhibitors has been assess, and the great review of work on seed extracts as a green corrosion inhibitors have been highlighted. Among the studied many green seed extract are showed better inhibition performance 95.34% in Piper guineense. All the described seed extracts were found to inhibition of the corrosion of aluminium metal and it's alloy in acidic or alkaline medium. Corrosion of aluminium and its inhibition was analyzed by weight loss, thermodynamic and kinetic methods. Electrochemical methods such as, Potentiodynamic polarization and EIS were also used. The protective films formed on metal surface have been analyzed by various techniques such as SEM, AFM, FT-IR, EDX, EN and GC-MS. The present review paper is an overview of works published on seeds extract for protection of aluminium from corrosion.

Keywords: Seed extracts, Aluminium, Corrosion, Inhibition efficiency, Adsorption.

Introduction

Corrosion like environmental pollution is unavoidable and is a serious problem for most of the industries in rapidly developing tropical countries like India. Corrosion is interminable and continuous problem often difficult to eliminate completely. For example, the surface effect produced by most direct chemical attacks is a uniform etching of the metal such as by an acid, rusting of iron and tarnishing of silver to prevent by inhibitors and proper coating. Corrosion is a complex form of material degradation by chemical attack or reaction with its environment. It has many serious complication for economic, health, safety, technologically and culturally consequences to our society. The Process of corroding or being corroded and damage caused to metal, stone or other materials by corrosion. The most frequent kind of corrosion result from electrochemical reactions. In this chemical reaction involving the transfer of electrons. Metallic corrosion is almost always an electrochemical process, it is important to understand the basic nature of electrochemical reactions. Corrosion of aluminium in aqueous solution is due to simultaneous oxidation and reduction reactions taking place on the surface of the aluminium metal. Aluminium is a thermodynamically reactive metal but it obligation its excellent corrosion resistance to the natural formation of a thin but very stable oxide film only at low potential. Because of its property of developing a protective coating of alumina, it can be used in the presence of water. Aluminium is the second most plentiful metallic element on earth. It is an important metal in many industries owing to its many excellent feature especially its good electrical and thermal conductivities, low density, high ductility, low cost and availability for the fabrication and construction industries and good corrosion resistance. It is classical used as a material for household apparatus, electronic appliances, automobiles, chemical batteries and machinery. In many efforts to mitigation of aluminium corrosion to the foremost fact is to separate the aluminium from corrosive environments like acidic medium or a basic medium.

This can be established using a corrosion inhibitors such a plant extract as a green inhibitors. Recently, in the present review to reported work have been shown the utilize of limited chemical inhibitors due to environmental prescription, plant extracts have again become important because they are the environmental and renewable sources for a wide spread of require green inhibitors. Seed extracts are observed as an incredible rich source of naturally coordinated chemical substances that can be extracted by effortless process with low cost. Seeds extract were used to control the corrosion of varied grades metals such as aluminium and aluminium alloys. In this review, various seeds extracts in controlling corrosion on metal in acidic or alkaline environments has been investigated. This review is mainly focused on acidic medium as well as alkaline medium.

Various methods such as weight loss, Hydrogen Evaluation, Potentiodynamic Polarization and Electrochemical Impedance Spectroscopy (EIS), were used to study the percentage of inhibition efficiency of assorted seeds extract on metal of corrosion inhibition. The adsorption isotherm model of the phyto-chemicals available in the various seeds extract onto the metal surface has been inspected. For this, different kind of adsorption isotherms, such as Langmuir, Temkin and Freundlich suggested.

Seeds extract was added in corrosive solutions to prevent the corrosion of metal a protective films formed on metal surface which is confirmed by various surface examination analysis, such as SEM, AFM, RSM, FT-IR, UV spectroscopy, Energy Dispersive X-ray spectroscopy (EDX) technique, X-Ray Diffraction (XRD), IR spectroscopy, EFM, GC-MS, DFT.

Metal Used: Seed extracts as a green inhibitors were used to control the corrosion of different grades aluminium[1-22] and aluminium alloy[23-30].

Medium: Different seed extracts for corrosion control of aluminium in acidic medium such as HCl[1-16], H_2SO_4[17], H_3PO_4[18] and alkaline medium such as NaOH[19-22]. Aluminium alloy in alkaline medium such as NaOH[23], KOH[24], NaCl[25] and acidic medium such as HCl[26-29] and H_3PO_4[30] has been investigated.

Methods: Various methods such as Weight loss method[1-10,12-15,17-26,28,29], Thermodynamic method[1-4,6,8-24,26,27,29], Kinetic parameters[2,3,6,7,15,17,23,29], Potentiodynamic polarization[2,8,9,11,13,15-21,23,25,28,30] and Electrochemical Impedance Spectroscopy (EIS)[1-3,8,9,11,13,17-20,25,28,30] were used for investigation of corrosion inhibition mechanism and to calculate the percentage of inhibition efficiency of different seed extract as a green inhibitors.

Adsorption isotherms: The adsorption isotherm model for phyto-chemicals present in different seed extracts as a green inhibitors into the metallic surface has been studied. For this, different kind of adsorption isotherms, such as Frumkin[8], Temkin[10,24] and Langmuir[1-3,7-9,12-15,17-24,26-28,30].

Surface Morphological Studies: Seed extracts were added in a corrosive solutions to prevent the corrosion of aluminium, a protective layer was formed on metal surface which confirmed by various surface morphological studies, such as Scanning Electron Microscope (SEM)[1,3,4,8,13,15,17,18,25,30], Atomic Force Microscopy (AFM)[1-3], Response Surface Methodology (RSM)[12,13], Energy Dispersive X-ray Spectroscopy (EDX)[10,14,17,25], Fourier Transform-Infrared Spectroscopy (FT-IR)[8,10,13-18,22,25,29], UV visible spectroscopy[8,10,14], electrochemical noise measurement (EN)[25], Gas chromatography-Mass spectroscopy (GC-MS)[9,25], Density Functional Theory (DFT)[9] and Quantum chemical analysis in a HOMO and LUMO[9,28].

Active chemical-constituents present in seed extract: Seed extraction products were acts as a good potential corrosion inhibitor for aluminium and it's alloy in acidic and alkaline medium. The active constituents of seed as a green inhibitors varied from plant species in their structures were closely related to their number of organic molecule, e.g., Red areca nut[1] contain Arecoline, Arecaidine, Guvacoline and Guvacine, Tender areca nut[2] contains Myristic acid, Palmitic acid, Stearic acid, Lauric acid, Decanoic acid, Oleic acid, Dodecenoic acid, Tetradecenoic acid and Hexadecenoic acid, Mature areca nut[3] contains Arecoline (methyl ester of arecanine), Arecaine (N-methyl guvacine), Guvacine (tetrahydronicitinic acid), Arecaidine, Guvacoline, Arecolidine, Leucocyanidine, Catechin, Epicatechin, Procyanidins, Phthalic acid, Lauric acid, Myristic acid, *Cyamopsis tetragonolobus*[4] contains Genistein, Quercetin and Kempherol, *Citrus synensis* (Orange)[5] contains Linoleic acid, Palmitic acid, Isopropyl linoleate, Pentadecanoic acid, Stearic acid, Butyl linoleates, Glutaric acid, *Eucalyptus camaldulensis*[6] contains Cinole, Pinene and Aromadendrene, *Foeniculum vulgare Mill* (Fennel)[7,9] contains Anethole, Fenchone, Methyl chavicol, Limonene, Hydroxy Methyl Furfural and Hexadecanoic acid, *Trachyspermum copticum* (Azwain)[8,19] contains Thymol, Oleic acid, Linoleic acid, Terpinene, Cymene, Palmitic acid and Xylene, *Lawsonia inermis*[10] contains 2-hydroxy-1,4-naphthoquinone (lawsone), Carbohydrates, Phenolic, Flavonoids, Saponins, Proteins, Alkaloids, Terpenoids, Quinones, Coumarins, Xanthones, Fat, Resin and Tannins, *Trigonellafoenum graecum L.*(Fenugreek)[11] contains Saponins, Coumarin, Fenugreekine, Nicotinic acid, Phytic acid, Scopoletin and Trigonelline, *Azadirachta indica* (Neem)[12,16] contains Azadirachtin, Nimbolinin, Nimbin, Nimbidin, Nimbidol, Sodium nimbinate, Gedunin, Salannin, and Quercetin, *Akuamma*[13] contains Alkaloids, *Albizia lebbeck*[14] contains Alkaloids, Flavonoids, Tannins and Saponins, *Psidium guajava*[15] contains Quercetin, Carotene, Glucoside, Methionine and Ascorbic acid, *Carica Papaya*[17] conatins Proteins, Lipids and Crude fibre, *Garcinia indica*[18,23] conatains Benzophenones, Anthocyanins and Organic acids, *Piper longum*[20] contains Piperine, *Abrus precatorius*[21] contains Abrin, Alanine, Serine, Choline, Valine and Methyl ester, *Apium graveolens L.* (Celery)[22] contains Caffeic acid, Chlorogenic acid, Apiin, Apigenin, Rutaretin, Ocimene, Bergapten, and Isopimpinellin, *Xylopia aethiopica*[24] contains Crude lipid, Crude Protein, Crude fibre, Carbohydrate, Calcium and Potassium, *Linum usitatissimum*[25] contains Linolenic acid, Linoleic acid, Lignans, Cyclic peptides, Polysaccharides, Alkaloids, Cyanogenic glycosides, and Cadmium, *Piper guineense*[26] contains Chromium, Zinc, Iron, Potassium, Sodium and Phosphorus, *Napoleonaea imperialis*[27] contains Sodium, Potessium, Saponin and Cyanide, *Kola nitida*[28] contains Caffeine, Theobromine, Theophylline, Methylliberine, Polyphenols, Phlobaphens, Epicatechin, D-catechin, Tannic acid, Sugar, Cellulose and Water, *Piper nigrum Linn.*[29] contains Piperine, Piperidine, Niacin, Riboflavin and Thiamine, *Coriandrum sativum L.*[30] contains Linalool, Geranyl acetate, Caryphyllene, Camphor and Cymene. The preventative of aluminium and its oxide film in opposition the corrosive activity of acids has been extensively investigated and a significantly number of inhibitors have been deliberated by various authors on the inhibition of aluminium and aluminium alloy by different seed extracts are shown in Table -1.

Table-1: Seed extract even as a green corrosion inhibitors for aluminum in different media.

Inhibitor	Metal & Medium	Finding	Method/ Technique	I.E. (%)	Remark	Ref
Red areca nut	Al in HCl	Weight loss, thermodynamic parameters	Electrochemical parameters, SEM, AFM	83.33	Mixed type of inhibitor, Langmuir adsorption isotherm	1
Tender areca nut	Al in HCl	Weight loss, thermodynamic, kinetic parameters	Potentiodynamic polarization, EIS method, AFM	94.44	Mixed type of inhibitor, Langmuir adsorption isotherm	2
Mature areca nut	Al in HCl	Weight loss, thermodynamic, kinetic parameters	Tafel plot, SEM, AC impedance, AFM	94.44	Mixed type of inhibitor, Langmuir adsorption isotherm	3
Cyamopsis tetragonolobus	Al in HCl	Weight loss, thermodynamic parameters	SEM technique	88.53	Chemisorptions and physical absorption	4
Citrus synensis (Orange)	Al in HCl	Weight loss	Phyto-chemical analysis	38.37	-	5
Eucalyptus camaldulensis	Al in HCl	Weight loss, thermodynamic, kinetic parameters	-	85.00	Chemical adsorption mechanism	6
Foeniculum vulgare Mill (Fennel)	Al in HCl	Weight loss, temperature effect, kinetic parameters	-	92.01	Langmuir adsorption isotherm	7
Azwain seed	Al in HCl	Weight loss, thermodynamic parameters	Potentiodynamic polarization, SEM, AC impedance spectroscopy, Uv-V spectrum, FT-IR	90.00	Mixed type of inhibitor, Langmuir and Frumkin adsorption isotherm	8
Fennel seeds	Al in HCl	Weight loss, galvanostatic method	potentiodynamic polarization, EIS, DFT, GC-MS, Quantum chemical parameters like HOMO and LUMO	92.90	Mixed type of inhibitor, Langmuir adsorption isotherm	9
Lawsonia inermis	Al in HCl	Weight loss, thermodynamic parameters	FT-IR, EDX, UV spectral analysis	84.52	Temkin adsorption isotherm	10
Trigonellafoenum graecum L. (Fenugreek)	Al in HCl	Thermodynamic parameters, Chemical composition study	Potentiodynamic polarization parameters, EIS	86.60	Mixed type of inhibitor	11
Azadirachta indica (Neem)	Al in HCl	Weight loss, thermodynamic parameters	Response Surface Method (RSM)	84.76	Langmuir adsorption isotherm	12
Akuamma	Al in HCl	Weight loss, thermodynamic parameters	Potentiodynamic polarization, EIS, Response Surface Method, FT-IR and SEM	72.60	Mixed type of inhibitor, Langmuir adsorption isotherm	13
Albizia lebbeck	Al in HCl	Weight loss, thermodynamic parameters	UV visible, EDX and FT-IR Spectral data	90.00	Langmuir adsorption isotherm	14
Psidium guajava	Al in HCl	Weight loss, thermodynamic, kinetic parameters	Potentiodynamic polarization parameters, FT-IR and SEM	81.20	Langmuir adsorption isotherm	15
Azadirachta indica (Neem)	Al in HCl	Thermodynamic parameter	Potentiodynamic polarization parameter, FT-IR	88.68	Mixed type of inhibitor	16

Carica papaya	Al in H_2SO_4	Weight loss, thermodynamic and kinetic parameters	Potentiodynamic polarization parameter, EIS, SEM, EDX, FT-IR	90.20	Mixed type of inhibitor, Langmuir adsorption isotherm	17
Garcinia indica	Al in H_3PO_4	Weight loss and thermodynamic parameters	Potentiodynamic polarization parameters, EIS, SEM and FT-IR	85.34	Mixed type of inhibitor, Langmuir adsorption isotherm	18
Trachyspermum copticum (Azwain)	Al in NaOH	Weight loss and thermodynamic parameters	Potentiodynamic polarization and electrochemical	94.00	Mixed type of inhibitor, Langmuir adsorption isotherm	19
Piper longum	Al in NaOH	Weight loss and thermodynamic parameters	Potentiodynamic polarization parameter and EIS	94.00	Mixed type of inhibitor, Langmuir adsorption isotherm	20
Abrus precatorius	Al in NaOH	Weight loss and thermodynamic parameters	Potentiodynamic polarization parameters	75.20	Langmuir adsorption isotherm	21
Apium graveolens L. (Celery)	Al in NaOH	Weight loss, thermodynamic parameters, hydrogen evolution	FT-IR Spectroscopy	93.33	Langmuir and Dubinin-Radushkevich adsorption isotherm	22
Garcinia indica	Al alloy AA6063 in NaOH	Weight loss, thermodynamics, kinetic parameters	Potentiodynamic Polarization parameter	70.25	mixed type of inhibitor, Langmuir adsorption isotherm	23
Xylopia aethiopica	Al alloy in KOH	Weight loss, thermodynamic parameters	-	84.53	Langmuir and Temkin adsorption isotherm	24
Linum usitatissimum	Al alloy AA2024 in NaCl	Weight loss	Potentiodynamic polarization, EIS, FT-IR, SEM, EDX, GC-MS, electrochemical noise measurement (EN)	82.00	Cathodic type of inhibitor	25
Piper guineense	Al alloy in HCl	Weight loss, thermodynamic parameters	-	95.34	Langmuir and Temkin adsorption isotherm	26
Napoleonaea imperialis	Al alloy AA 1060 in HCl	Thermodynamic and synergism parameters	-	71.05	Langmuir adsorption isotherm	27
Kola nitida	Al alloy AA 3003 in HCl	Weight loss	Potentiodynamic polarization, EIS, Quantum chemical parameters like HOMO and LUMO	78.50	Mixed type of inhibitor, Langmuir adsorption isotherm	28
Piper nigrum Linn.	Al alloy AA1100 in HCl	Weight loss, thermodynamic, kinetic parameters	FT-IR technique	85.69	El-Awady's Thermodynamic kinetic model	29
Coriandrum sativum L.	Al alloy AA6063 in H_3PO_4	Temperature effect	Potentiodynamic polarization parameter, EIS and SEM	73.10	Mixed type of inhibitor, Langmuir adsorption isotherm	30

Conclusion

In this review paper, reported research works produced over the past background on the corrosion of aluminium and it's alloy in various medium and their corrosion inhibition by using a variety of seed extracts as a green inhibitors was presented. Aluminium metal and aluminium alloys material were tested where inhibition efficiency increases with their concentration of the seed extracts as a green inhibitors increased. Corrosion rate and inhibition efficiency of green inhibitors were found using methods like, weight loss, thermodynamic and kinetic studies. Inhibition efficiency was found above 85.00% in almost all green inhibitors. Many investigators were performed Potentiodynamic polarization and EIS and found mixed type inhibition in most of the green inhibitors. Investigators were also investigated adsorption isotherm through the Langmuir, Temkin and Frumkin. Investigators were used methods like, SEM, AFM, FT-IR, UV-Spectroscopy, EDX, DFT and Quantum Chemical study such as HOMO and LUMO of the molecular modeling for the understand surface morphology.

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