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Review paper

Inhibitive action of some natural products on the corrosion of mild steel in NaCl and Sea water solution-An overview

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Abstract

Corrosion can be defined as a phenomenon of physico-chemical interaction of a metal and its environment, inducing degradation of the metal itself. A study of corrosion of Mild steel (MS) and it's inhibition was carried out by using weight loss (WL), temperature effect, polarization and EIS methods. Natural products were used as inhibitors to controlled or minimized the corrosion as they are cheap, non-toxic and eco-friendly. Adsorptions of various phytochemicals present in natural products extract on metal surface obey different types of adsorption isotherms. Morphology of film produced on metal surface was carried out by different techniques like, SEM, GC–MS, *Fourier-Transform Infrared* (*FT-IR), UV Spectroscopy, HPLC, EFM, EDX, XRD, Ellipsometry and AFM were used. Other techniques like Electric Noise (EN) analysis, Fluorescence, DFT and Quantum chemical computations were used. In this review, a work of MS corrosion in NaCl and Sea water solutions and it's inhibition by natural products were presented.*

Keywords: Mild Steel, NaCl, Sea Water, Natural Products, PP, EIS, FT-IR.

Introduction

Corrosion is basically defined as the deterioration of any metallic material due to the chemical or electrochemical attack of the material by its corrosive environment. It cannot be totally eliminated as it is a natural phenomenon but can be controlled; hence for centuries, researchers and scientists are persistent in searching more efficient ways for controlling corrosion of metals. Corrosion inhibitors are compounds that are added in small quantities to an environment to prevent corrosion of metals[1]. The uses of natural products as corrosion inhibitors are of enormous interest because they are environmentally friendly, readily available, inexpensive and can be used now a days as 'Green Inhibitors'. Inhibitors contain various organic compounds which can be adsorbed onto the metal surfaces and reduce the corrosion rate. The adsorption of inhibitors onto the metal surface depends on the molecular structure and electronic characteristics of the inhibitor's molecules.

Mild steel (MS) also known as low carbon steel. It is most commonly used metal alloy in manufacturing industries for structural and scientific research applications because its low cost, good mechanical properties, high strength, environmental stability, weight ratio and high thermal and electrical conductivities[2]. As a versatile engineering material, it is constantly exposed to various environments most of which are very corrosive such as oil and gas production systems. Seawater is inherently chemically aggressive. It is a complex chemical system affected by many factors such as concentration and access of dissolved oxygen, salinity, biological activity and several pollutants all of which could influence, in isolation or combined, the behavior of MS in Seawater. Inhibition efficiency of the plant extract usually evaluated by weight loss (WL), Potentiodynamic polarization (PP) and Electrochemical Impedance Spectra (EIS) methods. The present review gives the results of corrosion inhibition of MS in NaCl and Sea water by using various natural products as inhibitors published earlier than this review. Natural products were used as inhibitors for MS in NaCl and Sea water were presented in Table-1 and Table-2 respectively.

Solutions: For inhibition of corrosion of MS in NaCl[3-18] and Sea water[19-29] solutions were used.

Natural products used as corrosion inhibitors: Various parts of natural products were used such as, Leaves[9, 14,20,26,29], Fruits[11], Roots[7], Stem[7,8,23] and Plant extract[13,16,21,22].

Type of solvents: Solvents like double Distilled water[10,15,19,21,28], Ethanol[7,12,14,16-18,20,22-24,27], N-Hexane[25], NaOH[8] and Methanol[13] were used for the preparation extracts.

Additives: Additive such as Zinc nitrate[15] and Zn^{2+}[19,25] were added with plant extract to increase inhibition efficiency of inhibitor.

Techniques: Various techniques like weight loss[3-9,12,17,19-29], weight loss with temperature[8,9,20,22,26-28], Weight loss with time[4,8,12,20-23,29], Potentiometric polarization[3,6-8,10-12,14,16-19,21,28], EIS[3,7,11,14,15,18,21,24,28], and Synergistic effect[15,19,25] were used.

Other methods like Fluorescence[21], Electric Noise analysis (EN)[11], Ellipsometry[7] and Quantum Chemical Computations[7,17] were used.

Metal surface analysis: To study of surface film techniques like SEM[3,6-8,10-12,15,18,20,22,23,26-28], FT-IR spectroscopy[3,7,8,10-12,15,16,19-21,23,24,26,27], UV spectroscopy[7,10,11,21,27], Optical microscopy[4], EDX[8,20,27,28], EDS[11], DFT[6], XRD[7,15], GC-MS[17] and AFM[7,15,17,19] were used.

Adsorption isotherms: Langmuir adsorption isotherm[6,7-9,13,20,25,27], Temkin adsorption isotherm[13,16,26] and Frumkin adsorption isotherm[28] were followed.

Table-1: Natural products as corrosion inhibitor for MS in NaCl solution.

Inhibitor	Solution	Techniques	Findings	I.E. in %	Ref.
Allium sativum (Garlic)	3.5% Wt. NaCl	WL, PP, EIS, SEM and FT-IR.	As concentration of inhibitor increases, inhibition efficiency also increases.	--	3
Amaranthus cordatus	0.5 M and 1.0 M NaCl	WL with time.	Inhibition efficiency Increase with increase of plant extract.	99.51 WL in 0.5 M NaCl	4
Caffeine	3.5% NaCl	WL, Optical microscope.	Forming a protective layer	--	5
Camellia Sinensis Assamica	0.5 M NaCl	WL, PP, SEM and DFT calculations.	Langmuir adsorption isotherm.	85.0 WL	6
Catharanthus roseus	3.5% NaCl	WL, PP, EIS, SEM, UV-visible spectroscopy, FT-IR, AFM, XRD and Ellipsometry.	Mixed-type of inhibitor. Langmuir adsorption isotherm.	Root 84.0 WL63.0 PP 54.0 EIS Stem 96.0 WL 70.0 PP74.0 EIS	7
Chromolaens odorata stems extract	1 M NaCl	WL with time and temperature, PP, SEM, EDX and FT-IR.	Inhibitor act as mixed-type. Shows Langmuir adsorption isotherm.	91.05 WL 99.83 PP	8
Cyperus Esculentus Leaves	0.5 M NaCl	WL with temperature.	Langmuir adsorption isotherm.	92.86 WL	9
Glycyrrhiza glabra	3.5% NaCl	PP, UV, IR and SEM study.	Mixed-type of inhibitor.	57.00 PP	10
Juglans regia green fruit shell (JRS) extract	3.5% NaCl	PP, EIS, FT-IR, SEM, EDSand Electrochemical current noise analyses.	--	94.20 PP	11
Myrmecodia Pendans (MP) extract	3.5% NaCl	WL with time.PP, SEM and FT-IR.	Mixed-type inhibitor.	77. 63 WL 99.62 PP	12
Areca catechu (AC), *Laurus nobilis* (LN) and *Catharanthus roseus* (CR) plant extracts	0.5 M NaCl	WL with time.	AC and CR plant acted as an anodic-type and LN acted as a mixed-type of inhibitor. Langmuir and Temkin adsorption isotherms.	AC 50.00 WL CR 82.00 WLLN 65.00 WL	13
Ricinus communis leaves.	100 ppm NaCl	WL, PP and EIS measurements.	Inhibitor behave as anodic-type.	84.00 WL	14
Tamarindus indica (TAM)	3.5% NaCl + Zinc nitrate	EIS, FE-SEM, AFM, EIS, FTIR, GI-XRD and Synergistic behaviour.	Anodic-type of Inhibitor.	96.00 EIS	15
Thymus vulgar L. plant	NaCl	WL, PP and FT-IR.	Mixed- type of inhibitor. Follows Temkin's adsorption isotherm.	80.49 WL 66.78 PP	16

Tomato Pomace extract	0.5 M NaCl	WL, PP, SEM, AFM, GC–MS and Quantum-chemical calculations.	Mixed -type of inhibitor.	93.01 WL	17
Turmeric extract	3.5% Wt. NaCl	PP, EIS and SEM.	Inhibitor act as mixed-type.	81.60 PP 72.02 EIS	18

Table-2: Natural products as inhibitor for MS corrosion in Sea water.

Inhibitor	Solution	Techniques	Findings	I.E. in %	Ref.
Asafoetida extract (ASF)	Sea water + Zn^{2+} (5 ppm)	WL, PP, AFM and FT-IR spectroscopic techniques.	Mixed-type of inhibitor.	98.00 WL	19
Cansjera Rheedii leaves	Natural Sea Water	WL with time and temperature. SEM, FT-IR, and EDX spectroscopy.	Langmuir adsorption isotherm.	96.15 WL	20
Cuminum cyminum (Jeera) plant extracts	Sea water	WL, PP, EIS techniques. Fluorescence, FT-IR and UV-spectroscopy.	Anodic type inhibitor.	93.00 WL	21
Ficus exasperata plant extract	Sea water	WL with time and temperature. SEM.	Good eco-friendly inhibitor.	86.31 WL	22
Jatropha Stem Extract (JSE)	Sea water	WL with time, SEM and FT-IR spectrum.	Inhibition efficiency increase with the inhibitor concentration.	81.70 WL	23
Lawsonia Inermis (Henna)	Sea water	WL, EIS and FTIR.	--	--	24
Monodora myristica	Sea water + Zn^{2+}	WL and the linear polarization resistance (LPR) measurement.	Act as mixed-type of inhibitor. Follows Langmuir isotherm.	78.80 PP	25
Nymphae Pubescens (water lily) leaf extract	Sea water	WL with temperature, SEM and FT-IR Spectroscopy.	Temkin adsorption isotherm.	85.91 WL	26
Sauropus Androgynus Leaves (SAL)	Natural Sea water	WL with temperature, UV, FT-IR, EDX and SEM.	Langmuir adsorption isotherm.	65.67 WL at 303 K and 87.62 WL at 313 K	27
Tephrosia Purpurea	Natural Sea water	WL with temperature. PP, EIS, SEM image and EDX spectroscopy.	Act as Cathodic-type inhibitor. Follows Frumkin isotherm.	89.35 WL 88.04 PP 96.57 EIS	28
Vernonia amygdalina (Bitter Leaf)	Sea water	WL with time.	Corrosion rate decreases with the increase in concentrations of inhibitor.	--	29

Phytoconstituents present in natural products: **(i)** in NaCl solutions**:** ***Allium sativum***[3,30] containsdiallyl disulfde, methyl2-propenyl, and trisulfide, di-2-propenyl. ***Catharanthus roseus***[7] contain alkaloids, polyphenolic compounds, and flavonoids. ***Cyperus esculentus***[9,31] leaves contain alkaloids, tannins, steroids, flavonoids, saponins, phenols etc. ***Glycyrrhiza glabra***[10] contain licoagrochalcone and flavonoids. ***Myrmecodia Pendans*** (MP)[12] extracts contains flavonoids, like catechin, rutine, myrcetin, kaepferol, quercetin, luteoline and apigenin. ***Ricinus Communis***[14,32] contain alkaloids, glycosides, flavonoids, phenolics, phytates, saponins and tannins. ***Tamarindus indica***[15] extract contain apigenin, naringenin, eriodyctoyl and taxifolin. ***Thymus Vulgare***[16,33] contain carvacrol, tannin, thymol, saponins, linalool and flavonoids. ***Tomato pomace***[17] contain alcohols, fatty acids, aldehydes, ketones and terpenoids. **(ii)** in Sea water**:** ***Asafoetida Extract*** (ASF)[19] contains umbelliferone as a main constituent. ***Cansjera Rheedii***[20] leaf contains glycosides, phenolic compounds, saponins, flavonoids, alkaloids and tannins. ***Cuminum Cyminum***[21] contains *p*-cymene, cuminaldehyde, and terpenoid. ***Ficus exasperata***[22] plant extract contain alkaloids, tannins, saponins, flavonoids and glycosides. ***Jatropha Curcas***[23,34] leaves contain Tannis, Terpenes, Anthra-quinone, Alkaloids, flavonoids, Deoxy sugar, Cardiac glycoside. ***Lawsonia inermis***[24,35] contains naphthoquinone, Terpenoids,

Sterols, Coumarin, Amino and Fatty acid. ***Monodora myristica***[25] contains alkaloid, saponin, tannin and flavonoid. ***Nymphae Pubscens***[26,36] leaf extractcontain alkaloids, terpenes, tannins,glycosides, saponins, phenolic substances and flavonoids. ***Vernonia Amygdalina*** (Bitter Leaf)[29] contain amino acids, tannins, saponins, flavonoids and alkaloid.

Conclusion

Corrosion inhibitions efficiency of natural products depends on various factors like it's concentration, type of extraction solvent, immersion time and temperature. Phytochemicals obtained from plant extracts were adsorbed on the MS surface and reduce the corrosion rate. Effectiveness of a corrosion inhibitor generally evaluated by WL, PP and EIS methods. Results of the study shows inhibition efficiencies above 50%, most of them around 80 to 99.51% (WL).

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