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FATTY ACIDS AND ITS DERIVATIVES AS CORROSION INHIBITORS FOR MILD STEEL – AN OVERVIEW

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ABSTRACT

Steel is the most important engineering and construction material in the world. Corrosion problems have received a considerable amount of attention because of their attack on materials. Corrosion not only has economic implications, but also social and these engage the safety and health of people either working in industries or living in nearby towns. The use of inhibitors is one of the most practical methods for protection against corrosion. Organic compounds are investigated as corrosion inhibitors, but unfortunately most of these compounds are not only expensive but also toxic to living beings. Fatty acids extracted from plants have become an environmentally acceptable, readily available and renewable source for inhibitors. Many corrosion inhibitor molecules were synthesized by derivatization of fatty acids which was extracted from vegetable oils. Review of literature indicated that the derivatives of fatty acids like ethyl ester, ethoxylate, sulfate, imidazoline, sulfate-amine salt, hydrazides, thiosemicarbazides, phenyl hydrazides, triazoles, oxadiazoles,phenyl thiosemicarbazide etc. were the effective corrosion inhibitors for mild steel in aggressive media.

Contribution/ Originality: This study contributes to summarize the existing literature of fatty acid derivatives as corrosion inhibitors.

1. INTRODUCTION

The use of inhibitors is one of the most practical methods for protection against corrosion [1]. The process of corrosion inhibition is based on the adsorption of the inhibitor molecules on the active sites and/or deposition of the corrosion products on the alloy surface [2]. It has been reported that many inorganic, organic and polymeric compounds containing hetero atoms with high electron density such as phosphorus, nitrogen, sulfur, oxygen, with double or triple bonds in their structures can act as efficient inhibitors for the corrosion of steel due to their ability to provide active centers for the process of adsorption [3]. However, most of the effective corrosion inhibitors reported are not eco-friendly because of their toxicity and difficulties faced in their disposal especially in the marine industry, where aquatic life is at threat. Hence the use of many inorganic inhibitors, particularly those containing phosphate, chromate, and other heavy metals, is now being gradually restricted or banned by various environmental regulations [4]. This has prompted researchers to explore and utilize eco-friendly, cheap, and biodegradable corrosion inhibitors to replace conventional organic inhibitors.

Several natural products such as plant extract, amino acids, and biopolymers have been reported to be efficient corrosion inhibitors [5]. Out of these, plant extracts have become important as an environmentally acceptable, readily available and renewable source for wide range of inhibitors. They are the rich sources of ingredients such as fatty acids which have very high inhibition efficiency. Structural modification of many fatty acids resulted in various heterocylic derivatives, hence provided more active centres in their structures; which enabled easy adsorption on metal surface [6, 7]. The new generation of environmental regulations also requires such compounds which can replace the conventional toxic chemicals [8].

2. FATTY ACIDS AND ITS DERIVATIVES AS CORROSION INHIBITORS

2.1. Metal

Steel is most important metal widely used in various applications like construction, marine applications, industrial equipment's and petroleum industry. The excellent mechanical properties and low cost made steel as unique material for such industrial applications. The corrosion resistance of steel samples with different composition by fatty acid derivatives has been reviewed.

2.2. Medium

Industrial operations such as oil well acidification, acid pickling, acid cleaning and acid descaling are operating in acidic environment. Similarly, some industries are operating in marine environment having basic or chloride medium. The acidic, basic or chloride content on steel generally leads to severe metallic deterioration. Different concentrations of acids, bases and sodium chloride solution have been utilized to analyze the corrosion inhibition of steel by fatty acid derivatives.

2.3. Methods

Weight loss method is an important method to get the preliminary data of corrosion rate of a metal. Many other methods including potentiodynamic polarization, electrochemical impedance spectroscopy, gravimetric method, electrochemical frequency modulation etc. have been utilized to analyze the corrosion inhibition of steel samples by fatty acid derivatives. In some of the studies, scanning electron microscope has been used to analyze the formation of a protective film on the metal surface by the addition of inhibitors.

2.4. Corrosion Inhibitors

Several fatty acids and their derivatives have been preferably studied for the corrosion inhibition of steel samples as they are more environmentally benign, less toxic and more cost effective (Table 1). Several reports demonstrated that the sustainable use of bio products is good alternative to the synthesis of environmentally friendly inhibitors with high corrosion inhibition efficiencies. The spectral data like FT-IR and ^{1}H-NMR had been utilized to characterize the synthesized compounds. Majority of the fatty acid derivatives showed promising corrosion inhibition efficiencies under the outlined test conditions. The corrosion prevention efficiencies of various fatty acid derivatives were varied according to their chemical structures. The inhibition efficiency was also found to vary with concentration, temperature and immersion time. The potentiodynamic polarization data helped to identify the type of inhibitors. The surface and adsorption characteristics showed that all the investigated compounds have significant surface activity and distinguished inhibition efficiency.

Table-1. List of fatty acid derivatives used as corrosion inhibitors for various steel samples.

Vegetable oil / Fatty acid	Derivative	Steel Sample	Medium	Adsorption Isotherm	Type of Inhibitor	Reference
Azelaic acid	Sodium, calcium and lead salts	Steel	pH range 4.0-6.0	Langmuir	Mixed	[9]
Capric acid	Sodium, calcium and lead salts	Steel	pH range 4.0-6.0	Langmuir	Mixed	[9]
Caproic acid	Sodium, calcium and lead salts	Steel	pH range 4.0-6.0	Langmuir	Mixed	[9]
Caprylic acid	Sodium, calcium and lead salts	Steel	pH range 4.0-6.0	Langmuir	Mixed	[9]
Castor seed oil	Ethyl esters	Mild steel	HCl and petroleum - water mixtures	Langmuir	Mixed	[10]
Corchorus olitorius stems	-	Mild steel	0.5M H2SO4	Langmuir	Mixed	[11]
Corn oil	Surfactants	Mild steel	NaCl	Langmuir	Mixed	[12]
	Diethanolamine complexes	Mild steel	1% NaCl	Langmuir	Mixed	[13]
Cotton seed oil	Ethoxylate	Steel	1M HCl	Langmuir	Mixed	[14]
	Diethanolamine complexes	Mild steel	1% NaCl	Langmuir	Mixed	[13]
Decanoic acid,	1-aminoanthraquinon e amide	Steel (API 5L-X60)	White petrol–water mixture	Langmuir	Anodic	[15]
Diospyros Kaki L.f husk	-	Steel	1M HCl	Langmuir	Mixed	[16]
Ethoxylated nonyl phenols	Amide	Carbon Steel	1M HCl	Langmuir	Mixed	[17]
	Amine	Carbon steel (Type L52)	1M HCl	Langmuir	Mixed	[18]
Hexadecanoyl chloride	Amido-amine derivatives	Carbon steel	1M HCl	Temkin	Mixed	[19]
Karanja oil	Triazoles	Mild steel	1M HCl	Langmuir	Mixed	[20]
	Phenyl semicarbazides	Mild steel	1M HCl	Langmuir	Mixed	[21]
	Hydrazides and thiosemicarbazides	Mild steel	15% HCl	Temkin's	Mixed	[22]
	Imidazoline	Mild steel	15% HCl	Temkin's	Mixed	[23]
Lauric acid	Oxadiazole	Steel	1M HCl and 1N H2SO4	Temkin's	Mixed	[24]
	Oxadiazole	Mild steel	1M HCl	Langmuir	Cathodic	[25]
	Oxadiazoles	Mild steel	20% Formic acid	Langmuir	Mixed	[26]
	Oxadiazoles	Steel (N-80) and mild steel	15% HCl	Temkin's	Mixed	[27]
	Triazole	Mild steel	20% Formic acid	Temkin's	Mixed	[28]
	Triazoles	Oil Well Steel (N-80) and Mild Steel	15% HCl	Temkin's	Mixed-	[29]
Linoleic acid	Polyethylene glycol	Mild steel	0.05M HCl	Langmuir	Mixed	[30]
	Triethanolamine salts	Iron	0.5M deaerated H2S04	Langmuir	Mixed	[31]
Linolenic acid	Triethanolamine salts	Iron	0.5M deaerated H2S04	Langmuir	Mixed	[31]
Linseed oil	Oil	Carbon steel	1M HCl	Langmuir	Mixed	[32]
	Ethoxylate	Steel	1M HCl	Langmuir	Mixed	[14]
Neem oil	Triazoles	Mild steel	1M HCl	Langmuir	Mixed	[20]
	Phenyl semicarbazides	Mild steel	1M HCl	Langmuir	Mixed	[21]

Octanoic acid	1-aminoanthraquinone amide	Steel (API 5L-X60)	White petrol–water mixture	Langmuir	Anodic	[15]
Oenanthic acid	Sodium, calcium and lead salts	Steel	pH range 4.0-6.0	Langmuir	Mixed	[9]
Oleic acid	1-aminoanthraquinone amide	Steel (API 5L-X60)	White petrol–water mixture	Langmuir	Anodic	[15]
	Ethoxylate	Low carbon steel		L-shaped isotherm	Mixed	[33]
	Ethyl esters	Low carbon steel	1M HCl	S-shaped isotherm	Mixed	[34]
	Imidazoline	Carbon steel	1% NaCl	Langmuir	Mixed	[35]
	Oxadiazole	Steel	1M HCl and 1M H_2SO_4	Temkin's	Mixed	[24]
	Oxadiazoles	Mild steel	20% Formic acid	Langmuir	Mixed	[26]
	Oxadiazoles	Steel (N-80) and mild steel	15% HCl	Temkin's	Mixed	[27]
	Phosphonated	Steel		Langmuir	Mixed	[36]
	Polyethylene glycol	Mild steel	0.05M HCl	Langmuir	Mixed	[30]
	Triazole	Mild steel	20% Formic acid	Temkin's	Mixed	[28]
	Triazoles	Oil Well Steel (N-80) and Mild Steel	15% HCl	Temkin's	Mixed	[29]
	Triethanolamine salts	Iron	0.5M deaerated H_2SO_4	Langmuir	Mixed	[31]
Palm kernel oil	-	Carbon steel	1M NaOH	Langmuir	Mixed	[37]
Palm oil	-	Ductile Iron and Mild Steel	1M NaOH	Langmuir	Mixed	[38]
	Monoethanolamine Surfactants	Mild steel	1% NaCl	Langmuir	Mixed	[39]
	Diethanolamine complexes	Mild steel	1% NaCl	Langmuir	Mixed	[13]
Palmitic acid	Oxadiazoles	Mild steel	1M HCl	Langmuir	Cathodic	[25]
	Imidazoline	Mild steel	15% HCl	Temkin's	Mixed	[23]
	Hydrazide	Mild steel	1M HCl	Langmuir	Mixed	[40]
	Ethoxylate	Low carbon steel		L-shaped isotherms	Mixed	[33]
Pelargonic acid	Sodium, calcium and lead salts	Steel	pH range 4.0-6.0	Langmuir	Mixed	[9]
Rice bran oil	Amide	Steel	3.5% NaCl	Langmuir	Mixed	[41]
	Triazoles	Mild steel	1M HCl	Langmuir	Mixed	[20]
	Phenyl semicarbazides	Mild steel	1M HCl	Langmuir	Mixed	[21]
Ricinoleic acid	Polyethylene glycol	Mild steel	0.05M HCl	Langmuir	Mixed	[30]
Rosmarinus officinalis	-	1018carbon steel	0.5M H_2SO_4	Langmuir	Mixed	[42]
Rubber seed oil	Ethyl esters	Mild steel	HCl and petroleum - water mixtures	Langmuir	Mixed	[10]
Sebacic acid	Sodium, calcium and lead salts	Steel	pH range 4.0-6.0	Langmuir	Mixed	[9]
Soya bean oil	Ethoxylate	Steel	1M HCl	Langmuir	Mixed	[14]
Stearic acid	Hydrazides and thiosemicarbazides	Mild steel	15% HCl	Temkin's	Mixed	[22]
	Imidazoline	Mild steel	15% HCl	Temkin's	Mixed	[23]
	Polyethylene glycol	Mild steel	0.05M HCl	Langmuir	Mixed	[30]
	Imidazoline	Carbon steel	1% NaCl	Langmuir	Mixed	[35]

	Ethoxylate	Low carbon steel		L-shaped isotherms	Mixed	[33]
Suberic acid	Sodium, calcium and lead salts	Steel	pH range 4.0-6.0	Langmuir	Mixed	[9]
Sugar cane wax	Imidazolines	1018 carbon Steel	1M HCl	Langmuir	Mixed	[43]
Sulfated fatty acid	Potassium salt	Mild steel	1% NaCl	Langmuir	Mixed	[44]
Sunflower oil	Sulfate	Carbon steel	1% NaCl	Langmuir	Mixed	[45].
	Surfactant	Mild steel	1% NaCl	Langmuir	Mixed	[46]
	Surfactants	Carbon steel		Langmuir	Mixed	[47]
	Diethanolamine complexes	Mild steel	1% NaCl	Langmuir	Mixed	[13]
Tall oil	Ethyl esters	Low carbon steel	1M HCl	S- shaped isotherm	Mixed	[34]
	Diethylenetriamine imidazoline	Mild steel	Chloride solution	Langmuir	Mixed	[48]
	Acid anhydrides	Carbon steel		Langmuir	Mixed	[49]
	Ethoxylate	Steel	1M HCl	Langmuir	Mixed	[14]
Terminalia catappa seed oil	Esters	Mild steel	1M HCl	Langmuir	Mixed	[50]
Tetradecanoyl chloride	Amido-amine derivatives	Carbon steel	1M HCl	Temkin	Mixed	[19]
Undecanoic acid	Hydrazides and thiosemicarbazides	Mild steel	15% HCl	Temkin's	Mixed	[22]
	Oxadiazole	Steel	1M HCI and 1M H_2SO_4	Temkin's	Mixed	[24]
	Oxadiazoles	Mild steel	20% Formic acid	Langmuir	Mixed	[26]
	Oxadiazoles	Steel (N-80) and mild steel	15% HCl	Temkin's	Mixed	[27]
	Phenylamide	Steel	2M HCl	Langmuir	Mixed	[51]
	Triazole	Mild steel	20% Formic acid	Temkin's	Mixed	[28]
	Triazoles	Oil Well Steel (N-80) and Mild Steel	15% HCl	Temkin's	Mixed	[29]

3. CONCLUSIONS

This review summarized the corrosion inhibition of steel samples by fatty acid derivatives in various medium. From the above discussion, it is evident that fatty acid derivatives are environmentally benign, less toxic and more cost effective corrosion inhibitors against mild steel. These fatty acid derivatives can be utilized in diverse industrial fields as corrosion inhibitors. However, there is need of further study to establish the detailed mechanisms of corrosion inhibition by fatty acid derivatives using computational modelling. This will help to design more appropriate heterocylic derivatives of fatty acid, which can serve as better corrosion inhibitors.

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