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Review: Eco-Friendly Corrosion Inhibitors on Mild Steel in Acidic Medium

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***Abstract** - Eco friendly corrosion inhibitors were chosen for this review, and their corrosion inhibition tendency was examined. The inhibitory property of these inhibitors on mild steel (MS) in an acidic environment are being explored. It was determined the rate of corrosion by the applications of chemical and electrochemical systems. Corrosion inhibition rises with inhibition efficiency and decreases with temperature, according to these studies. In all of these papers, on mechanisms of adsorption and thermodynamics were explored. Scanning Electron Microscopic investigations were used to discuss surface morphology. Few academics have recently published theoretical studies such as quantum studies. In this paper, all of the works have been discussed*.

Key Words: Inhibitors, Electrochemical measurements, Eco Friendly, Weight Loss, Tafel

1. Introduction

Technical, economic, environmental, and aesthetic perspective, mild steel corrosion control is critical. In the past, cathodic protection, control activities, metal impurity content reduction, surface treatment techniques, and the integration of appropriate alloys were all used to reduce corrosion. On the other hand, inhibitors among the top effective strategies to hinder corrosion in metals and alloys [1-4]. Corrosion hindrances become one of the most cost-effective and easy method of corrosion prevention in acidic environments [5-7]. These corrosion inhibitors reduce the rate of corrosion, hence minimising the economic costs of corrosive attack on commercial containers, machinery, and surroundings. Because both corrosion inhibitors, natural and inorganic are harmful and expensive, researchers have increasingly focused on developing ecologically acceptable corrosion prevention solutions. Several recent studies have concentrated on mild steel corrosion prevention through the use of green inhibitors in acidic solutions to mimic industrial processes, with promising results [8-10]. Many researchers have looked into the corrosion protection of mild steel against corrosive chloride attack using inorganic oxidants like chromate [11-14], Molybdate [15-18], and Tungstate, polar organic molecules such as oxygen, sulphur, and nitrogen [19], with heterocyclic compounds having functional groups and conjugated double bonds as corrosion inhibitors [19-21]. The interaction of polar functional groups through the adsorbent surface on metal particles is usually believed to constitute the mechanism of inhibition [21]. Polar functional groups are normally considered to behave as response centres in organic compounds. A variety of factors influence the adsorption of an inhibitor on a surface of the metal. These parameters include the metal's nature and surface charge, the adsorption process, the inhibitor's chemical composition, and the type of electrolyte utilised.

The use of various aliphatic and aromatic amines, as well as nitrogen-heterocyclic compounds, revealed that their inhibitory action is linked to several factors, including (I) molecule structure, (ii) adsorption type, (iii) charge distribution in the molecule, and (iv) the type of organic-metallic surface interaction.

The paper provides a summary of the subject of eco-friendly inhibitors for MS in acid environment. It also gives the insights on adsorption and inhibition tendency of the inhibitors.

2. Corrosion Inhibitors

Corrosion inhibitors are chemical substances that prevent metal from corroding when exposed to the environment in modest concentrations where a metal would corrode, reduce, slow, or prevent the metal from corroding. Inhibitors frequently act by adsorbing themselves to the metallic surface and producing a layer to protect it.

a. Inhibitors inhibit corrosion by polarization effect on the working electrode.

b. Due to polarization, it reduces the movement of metal ions.

c. Increasing the metallic surface's electrical resistance.

d. Reduction of diffusion of reactants to the metal surface.

e. Ion/molecule adsorption on metal surfaces

When selecting an inhibitor, several variables must be addressed, including cost and volume, ease of presence, and, very prominently, security to the ecosystem as well as its species.

2.1 Organic Inhibitors

Corrosion inhibitors that are organic are widely employed due of its wide temperature range in industrially performance, compatibility with covered substances, water dissolvability, low cost, and low toxicity. Organic corrosion inhibitors bind to the metal's surface, providing a protective coating that repels water and prevents corrosion. Lone pairs of electrons in nitrogen, oxygen, sulphur, and phosphorus, in addition to structural agglomerations containing –electrons that interact with metal and favour the adsorption process, are effective organic corrosion inhibitors. Even while most synthetic organic inhibitors are pricey, they have a harmful and damaging impact on the environment, posing a variety of dangers when discharged into numerous streams. Because of the toxicity of these organic inhibitors, researchers are now looking into using nontoxic pharmaceuticals or natural compounds as inhibitors that are also environmentally friendly and biodegradable. This has boosted the popularity of medicines and green corrosion inhibitors.

Table -1: Few Organic Corrosion Inhibitors and its Properties

Name of the Compound (Drug)	**Biology of Compound**	**Adsorption Method**	**Features**	**Inhibition efficiency with respect to inhibitor concentration**	**Ref**
Donaxine	Adiponectin receptor (AdipoR1)1	Langmuir adsorption is followed by a mixed type inhibitor	Temperature is an adverse effect on inhibition efficiency	98% at 7.5 mM	22
Penicillin G	Antibacterial	Langmuir adsorption is followed by a mixed type inhibitor	Water soluble	98% at 10 mM	23
Atenolol	β1receptorantagonis t	Langmuir adsorption is followed by a mixed type inhibitor	Theoretical studies supports practical results	93.8% at 300ppm	24
Cephalothin	Broad spectrum antibiotics	Langmuir adsorption	Efficiency decreases with temperature	92% ppm at 660	25
Telmisartan	Angiotensin II receptor, Antihypertension	Mixed type and follows Temkin adsorption	Mechanism was established	97.39% at 125 mgL^{-1}	26
Metronidazole	antimicrobial, anti-trichomonas antigiardial,	Anodic type inhibitor and follows Temkin adsorption	Theoretical Studies were carried out	80.01% at10μM	27

Tinidazole	Antibacterial, anticancer, antitubercular, antifungal	Langmuir adsorption is followed by a mixed type inhibitor	Higher efficiency at room temperature	90% at 400 Ppm	28
Cimetidine	Histamine H2 receptor Antagonist	Langmuir adsorption is followed by a mixed type inhibitor	Theoretical Studies were carried out	95.6% at 500ppm	29
Ranitidine	H2 histamine receptor Antagonist	Langmuir adsorption is followed by a mixed type inhibitor	Theoretical Studies were carried out	95.53% at $2x10^{-3}$M	30
Ketosulphide	-	Langmuir adsorption is followed by a mixed type inhibitor	Theoretical Studies were carried out	75.4% at 100ppm	31
Chlorphenicol	Primarily bacteriostaticactivity .	Langmuir adsorption is followed by a mixed type inhibitor	Higher efficiency at room temperature	78.10% at 50ppm	32
Hydralazine	Antihypertensive agent	Langmuir adsorption is followed by a mixed type inhibitor.	Theoretical Studies were carried out	94.11% at1250 ppm	33
Aspirin	Non-steroidal Anti-inflammatory agent.	Mixed type inhibitor and follows Langmuir adsorption	Experimental results were Supported by theoretical results	77.58% at 50ppm	34
Ketosulfone	Antihypertensive agent	Langmuir adsorption is followed by a mixed type inhibitor.	Higher efficiency at room temperature	85.80%at200pp m	35
Chloroquinolin es	Anti-cancer activity	Langmuir adsorption is followed by a mixed type inhibitor.	Higher efficiency at room temperature	94% at 5.00×10^{-4}	36

2.2. Corrosion inhibitors made from plant extracts

Extraction of plant sources yields molecules with a variety of chemical, biological, and physical properties, some of which have complicated molecular structures. Natural occurring substances are frequently employed because to their environmental friendliness, cost effectiveness, and accessibility. These advantages support the use of plant extracts and their derivatives as metal and alloy corrosion inhibitors in a range of settings. Because the active ingredient's composition determines how green inhibitors work, several researchers have offered a variety of ideas to explain this phenomena. Corrosion inhibitors can be made from plant extracts, sometimes known as green corrosion inhibitors.

Green corrosion inhibitors are recyclable and contain no toxic metals or other possibly dangerous substances. They are also environmentally friendly. Researchers have proven that the easily available occurring compounds to keep metals from corroding in acidic and alkaline environments conditions is a valid method of corrosion prevention.

The adsorption of natural corrosion inhibitors on metal surfaces is determined by the nature of the metal, testing medium, chemical composition of the inhibitor, nature of linkers present in the inhibitor, presence of additives, solution temperature, and solution concentration. Table 2 lists recent investigations on the suppression of MS by means of plant extracts by various authors.

Table -2: Plant extracts as corrosion inhibitors for mild steel

Sl. No	Name of the Inhibitor	Active constituents	Inhibition efficiency (%)	Remarks	Ref
1	Cotula cinerea,	Anagyrine, cytosine	67 %	Weight loss and electrochemical methods were used to investigate mild steel corrosion in sulphuric acid.	37
2	Rauvolfia serpentina	Reserpine, ajmalicine, ajmaline, isoajmaline, ajmalinine, chandrine	94 %	Corrosion studies at 303,313,and 323 K	38
3	Nauclea latifolia	Monoterpene, triterpene indole alkaloid, saponins	76 %	corrosion studies in H2SO4 solutions at 30^0 and 60^0C	39
4	Embilicauflicianalis, Terminaliachebula and Terminalia bellirica	Emblicanin A & B, puniglucanin, pedunculagin, tannic acid, chebulinic acid, and gallic acid	80 %	Chemical and Electrochemical method in HCl medium	40
5	Carica papaya and Azadirachta indica	Papain, carpaine, chymopapain, azadirachtin, salanningedunin, and azadirone	87 %	Inhibition increases with concentration of the inhibitor	41
6	Mentha pulegium	Pulegone	80 %	It is cathodic inhibitor	42
7	Zanthoxylum alatun	Terpineol, isoxazolid ine, and imidazolinedione	85 %	Corrsoion studies at 50–80◦C in HCl medium	43
8	Thyme, Coriander, Hibiscus, Anis, Black Cumin and Garden Cress	Thymol, malic acid, salicin, glutamic acid, leucine, and methionine	85 %	Mixed type inhibitor	44
9	Phoenix dactylifera, Lawsoniainermis, and Zea mays	Lawsone, esculetin, fraxetin, allantoin, sterols, and hordenine	90 %	Used as inhibitor for steel and Aluminum	45
10	Datura metel	Scopolamine, b-sitosterol, daturadiol, tropine, and daturilin	86 %	Electrochemical studies were carried out in these experiments	46
11	Ricinus communis	Ricinoleic or ricinic acid, ricinolein, and palmitin	84 %	Studied in Electrochemical Method.	47

12	Mentha pulegium	Pugelone, alpha-pinene, limonene, methone, andpiperitone	80 %	Corrosion rate was decreases with temperature	48
13	Carica papaya	Chymopapain,pectin,carposide,carpaine,pseudocarpaine,dehydrocarpines,carotenoids, cryptoglavine, cis-violaxanthin, and antheraxanthin	92 %	Gravimetric and gasometric techniques were used	49
14	Acacia seyal	Catechu, dimethyltryptamine(DMT)	95 %	Corrosion studies on mild steel in drinking water	50
15	Calotropis procera	a-and b-Amyrins,cyanidin-3-rhamnoglucoside,cycloart-23-en-3b,25-diol,cyclosadol	89 %	Chemical and Electrochemical method was used	51

Following the review of the summary literature in the table, plant extracts as green corrosion inhibitors, they've been studied. for mild steel. The results of the review summary analysis are presented in Table 2. The research was carried out in sulphuric acid and hydrochloric acid, with some cases present in together, then so encompassed a wide range of real-world industrial settings using steel that were exposed to the acids in question. Although only in limited quantities, it is worth noting this nitric acid and as well as salt media were tested. Researchers have discovered that green corrosion inhibitors are beginning to appear in genuine wastewater as a result of their research into the industrial effluent medium, which could pave the way for their widespread use.

3. Effects of Temperature and Inhibitor Concentration

In all assays, increasing inhibitor concentration resulted in better inhibition efficiency, with the exception of one involving a Caesalpiniapulcherrima extract, in which inhibition efficiency increased as inhibitor concentration declined. The reason is, environment friendly inhibitors is used in very less dose, they are less expensive and safer for the environment, which is a great piece of news to hear. The inhibitory efficiency reduced in the majority of cases as the temperature climbed, demonstrating that the approach works best at ambient temperature or mild temperatures. At high temperatures in a few cases, the inhibitory efficiency was high, which can be advantageous in applications using mild steel.

4. Corrosion investigation techniques

The weight loss strategy was used in all of the cases in order to assess inhibitory effectiveness. Gravimetric analysis was another approach that was widely used. Among the most often used techniques for evaluating inhibitor type and adsorption mechanism, potentiodynamic polarisation and electrochemical impedance spectroscopy were commonly used techniques. The use of tafel polarisation, as well as gasometric and thermometric approaches, was employed in a few instances. The Langmuir isotherm model was used to describe the adsorption of plant extracts and acid ions on MS surfaces in the vast great popular of the investigations conducted on the subject

5. Research Gap

All of the studies described in this paper show that mild steel can be inhibited effectively in acidic environments. The inhibitors have been proven to be environmentally beneficial by researchers. The majority of researchers aren't focused on high-temperature research. Theoretical research like as quantum mechanics and molecular dynamics are useful in determining the structure-property link and its impact on corrosion inhibition efficiency.

6. CONCLUSION

Eco Friendly Corrosion inhibitors were tabulates in this paper. With increasing concentrations, all of these inhibitors show increased inhibitory efficiency. In our research, the majority of the inhibitors were discovered to be mixed inhibitors. Electrochemical impedance spectroscopy, linear polarisation resistance, and weight loss all provide similar findings. This paper will give the more benefits for the fresh researchers to initiate the research in corrosion topic.

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