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Review Article

CURCUMIN AS A GREEN CORROSION INHIBITOR-A REVIEW

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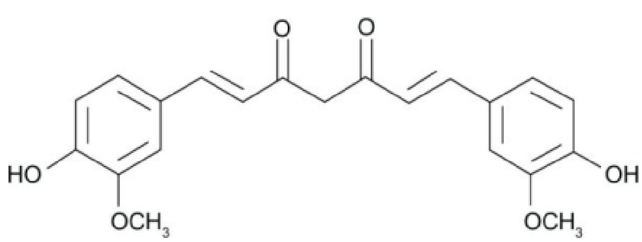
ABSTRACT

Corrosion is the deterioration of metals by its environment. The corrosion leads to economic loss, damage of structures, leakage, contamination of environment etc. Eventhough, corrosion is an unwanted process, it has some beneficial effects such as batteries, electrochemical millings, electroplating etc. Lot of research works are going on to minimize the corrosion rate. The corrosion inhibitors are used to protect metals when it is part of a closed system. The inhibitors are used in cooling towers, heat exchangers, filtering equipments, storage tanks etc. The inhibitors are also used in pickling solutions. Chromate is the first type inhibitor used and was replaced by other inhibitors due to its toxicity. The green inhibitors are preferred due to their environmental friendly nature, ease of availability, cost effectiveness, non toxic nature etc. This review discusses the inhibition efficiency of curcumin for protecting metals in different environmental conditions based on the literature.

Keywords: Corrosion inhibitor, Curcumin, Corrosion rate

1. INTRODUCTION

Curcumin, a bright yellow chemical compound obtained from Curcuma longa (turmeric) plant is well known for its antioxidant [1], anti inflammatory [2] and antimicrobial activities [3, 4]. It is also used in food flavouring [5], drugs [6, 7] and in cosmetics [8]. The curcumin is chemically diarylheptanoid which is responsible for the yellow colour. The chemical structure of curcumin is as below:



The diarylheptanoid exist in enolic form in organic solvents and in keto form in water [9]. Curcuma longa is cultivated in tropical and subtropical regions. The largest worldwide producer of turmeric is India [10]. The phenolic and carbonyl functional groups are present in the end and centre of the curcumin molecule.

Corrosion is the loss of metal by reacting with its environment. It is a greatest problem and lot of research works are going on to minimize the corrosion. The remedial method employed for minimizing the corrosion depends on the nature of metal, the environment in which metal is exposed, area of application etc. One of the most common methods to prevent the corrosion of metals in different electrolyte media in which both the electrolyte and the metal are the part of a closed system is by the use of suitable inhibitors [11]. Many inorganic and organic substances are used as corrosion inhibitors. Chromate inhibitors were the first employed for protecting metals. The toxic nature of chromate compounds and the chromate based inhibitors leads to their replacement with other inorganic inhibitors like sodium molybdate, sodium tungstate etc [12]. There are several organic compounds which contain N, S, and O have been proved as good corrosion inhibitors for metals [11]. Many of the synthetic inhibitors were hazardous in nature and costly and hence the attention was focussed on development of low cost environmental friendly inhibitors. The plant materials were used as corrosion inhibitors due to their environmental friendly nature, ease of availability and cost effectiveness. Many studies had been reported using curcumin as good corrosion inhibitor for protecting metals in different environmental conditions. The easily available, environmental friendly nature, low cost and medicinal power of curcumin will emerge it as a potential inhibitor for protecting metals in future.

1.1. Corrosion prevention of steel specimens by curcumin in different environments

1.1.1. In Water

Corrosion inhibition of carbon steel in well water by curcumin was reported in literature [13]. Curcumin was used in combination with other inorganic inhibitors of sodium molybdate and Zn^{2+}. In the above paper it was reported that combination of sodium molybdate (25 ppm), zinc ion (25ppm) and curcumin (250ppm) was found to be very effective in reducing the corrosion rate of steel specimen by forming a protective film consist of sodium molybdate-Fe^{2+}, Fe^{2+} -curcumin complex and $Zn(OH)_2$. Aqueous extract of curcumin for protecting the mild steel specimen in cooling system was reported by M. A. Quraishi et; al [14]. The inhibition efficiency was improved by blending aqueous extract of curcumin with hydroxyethylidene1-1 diphosphonic acid [14]. Curcumin extract as corrosion inhibitior for protecting mild steel specimen in petroleum refinery waste water was reported [15]. The authors of the above paper reported the inhibitory property of curcumin at different concentrations and at different temperature conditions.

1.1.2. In NaCl

The cooling water plant of many industries operated using saline solution (NaCl) or sea water for getting better cooling efficiency. The corrosion of metal in saline solution was very high compared to ordinary water. The chloride content present in the saline water leads to pitting corrosion in metals. The biofouling was another issue, while using sea water in cooling towers. The efficiency of inhibitors were also evaluated in saline/ sea water medium, for taking consideration the cooling water system operated with saline / NaCl solution and also for industries using sea water for other application like heat exchangers filters etc. The inhibitory efficiency of turmeric for protecting mild steel in 3.5% NaCl was reported by M. Edraki *et al*. [16]. This work revealed that corrosion current was decreased and corrosion potential was shifted to positive values. A continuous film was formed on the mild steel specimen. The above factors increased the inhibition efficiency and decreased the corrosion rate of the mild steel samples. The corrosion inhibition of carbon steel in 1% NaCl solution was also reported in the literature [17]. K. A Saleh *et al.* [18] studied the inhibitory properties of nano curcumin for corrosion of carbon steel alloy in 3.5% NaCl medium. The kinetics and thermodynamics parameters for corrosion process were discussed in this article.

1.1.3. In Sea water

The inhibition efficiency of aqueous extract of curcuma longa plant material for protecting carbon steel in sea water was reported by S. Rajendran et;al. [19]. The article reported the inhibition efficiency of curcumin alone and also with Zn^{2+}. The corrosion inhibition of pure curcumin for protecting carbon steel in sea water was reported in literature [20]. This work studied the corrosion rate, apparent activation energy, free energy change etc. on corrosion process. The inhibition was due to the adsorption of curcumin on metals surface.

1.1.4. In HCl

The pickling solutions are used for cleaning the metal specimens. The pickling solution mainly contains an acid with inhibitor. The common acid used in pickling solution is hydrochloric acid. The inhibitory effect curcumin for protecting mild steel samples were reported in literature [21, 22]. Shetouani *et al.* [21] studied the corrosion of mild steel in 1.0 M HCl solution using curcumin as inhibitor. The weight loss method, electrochemical methods etc. were employed to evaluate the inhibitory efficiency. The inhibition efficiency increases with inhibitor concentration. The relationship between electronic structure and inhibition efficiency was also reported [21]. The inhibitor adsorbed on mild steel specimen and thereby reduces the corrosion rate [21, 22]. Al-Amiery *et al.* [23] used chlorocurcumin as inhibitor for mild steel corrosion in Hydrochloric acid. The above article reported that the inhibition efficiency increases with the concentration of the inhibitor and decrease with increase in temperature. The study of iron corrosion inhibition by turmeric root extract was reported by A. Kholod *et al.* [24]. The inhibitor efficiency increases with increase in concentration of inhibitor and a maximum efficiency of 88.90% at 8g/100 ml [24].

1.1.5. In H_2SO_4

The curcuma extract as green inhibitor for corrosion of carbon steel in 0.5M sulphurinc acid was reported [25,26]. EAF Frias *et al.* [25] reported that, the inhibitor behaved as cathodic type inhibitor and inhibition efficiency increases with increasing the inhibitor concentration. The maximum inhibitor efficiency reported in that article was 90%. M. Abdulla *et al.* [26] in their work revealed that the inhibition efficiency increases in increasing the concentration of the extract due to its horizontal adsorption of the carbon steel surface.

1.1.6. In chloride solution

The corrosion inhibition by an aqueous extract of rhizome (curcuma longa L) on carbon steel immersed in an aqueous solution with 60 ppm chloride content was reported by S. Rajendran *et al.* [27]. The presence of zinc ion along with curcumin showed synergistic effect and the protective film contains of Fe^{2+} -curcumin complex and zinc hydroxide [27].

1.2. Other metals

Literature showed use of curcumin extract as corrosion inhibitor for protecting aluminium in simulated concrete pore solution [28]. This study revealed that the corrosion rate of aluminium was decreased when curcumin was added to simulated concrete pore solution and the presence of curcumin-zinc ion system decreases the corrosion of Aluminium [28]. The aqueous extract of curcumin as green corrosion inhibitor at quasi –cooking condition to inhibit leaching of aluminium was reported by AS Layla [29]. The curcumin was adsorbed on aluminium surfaces, coordinated with Al^{3+} and formed Al^{3+} -curcumin complex on metal surface [29]. The above study also reported that the presence of curcumin decreased leaching of aluminium from aluminium cookwares into food by 60-80%. The corrosion inhibition of brass by curcumin derivatives in nitric acid solution was reported by A. S. Fouda and K. M. Elattar [30]. The inhibitor behaved as mixed type.

1.3. Polymer type inhibitor

The curcumin- citric acid-aspartic acid polymer as scale and corrosion inhibitor was reported by S. Dong et.al; [31]. The curcumin- citric acid-aspartic acid polymer was a good corrosion inhibitor with efficiency of 84.1% evaluated by polarization and impedance studies [31].

1.4. Anticorrosion in drilling equipment

A study was reported in literature that use of turmeric in drilling fluid combat the high corrosion rate of drilling equipments [32] K. Muneeb *et al.* studied the corrosion rate of mild steel in various acidic conditions in presence and absence of turmeric and found that the corrosion rate was decreased when turmeric was present [32].

1.5. Mechanism of inhibition

1.5.1. Adsorption behavior

All the studies revealed that curcumin was adsorbed on the surface of metal and there by reduces the corrosion rate. The curcmin was adsorbed on metal surface in all medium such as acidic, neutral and saline environments. The Langmuir type adsorption was reported in water [15, 29], Hydrochloric acid medium [21, 22, 24], sea water [20], NaCl [18] H_2SO_4 [24]. Frumkins adsorption isotherm was reported for adsorption of curcumin on brass in nitric acid solution [30].

1.5.2. Nature of Inhibitor

The polarization studies reported in literature [19, 22, 23, 30] revealed that, the inhibitor shift both anodic and cathodc polarization curves and behaved as mixed type inhibitor.

1.5.3. Protective film

The inhibitor (curcumin) adsorbed on the surface of metal and forms a protective film. The nature of the protective film reported was studied using FTIR spectrum. [13, 19, 27]. The film consists of Fe^{2+} -curcumin complex [13, 19, 27].

1.6. Maximum Inhibition efficiency reported

The maximum inhibition efficiency of curcumin reported in the literature under different environmental conditions is summarized in Table 1.

Table 1: Inhibition efficiency of curcumin reported in iliterature

Specimen	Concentration of Curcumin	Inhibitor in combination	Medium	Maximum Inhibition efficiency	Ref.
Mild steel	1.2%	Nil	Refinery waste water	84%	15
Carbon steel	50 ppm	Nil	1% NaCl	89.88 %	17
Carbon steel	2.7×10^{-5} M	Nil	3.5% NaCl	86.21 %	18
Carbon Steel	2.7×10^{-5} M	Nil	Sea Water	77.5 %	20
Mild steel	10g/L	Nil	1 M HCl	92%	22
Carbon steel	10 mL	Zn^{2+}(50 ppm)	Sea Water	93%	19
Iron	8g/100mL	Nil	0.5M HCl	88.9%	24
Carbon steel	1000 ppm	Nil	0.5M H_2SO_4	90%	25

2. CONCLUSION

Many studies reported curcumin as good corrosion inhibitors for protecting metals in different environmental conditions. The easily available, environmental friendly nature, low cost and medicinal power of curcumin will emerge it as a potential inhibitor for protecting metals in future. This review discusses the inhibition efficiency of curcumin for protecting metals under different environmental conditions based on the literature.

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