

Corrosion Control by Different Green Solution Techniques-An Overview

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Abstract

Corrosion control of metals is of technical, economical, environmental, and aesthetical importance. The use of inhibitors is one of the best options of protecting metals and alloys against corrosion. The environmental toxicity of organic corrosion inhibitors has prompted the search for green corrosion inhibitors as they are biodegradable, do not contain heavy metals or other toxic compounds. As in addition to being environmentally friendly and ecologically acceptable, plant products are inexpensive, readily available and renewable. Investigations of corrosion inhibiting abilities of tannins, alkaloids, organic, amino acids, and organic dyes of plant origin are of interest. This article briefly discusses some of the interesting features of the green inhibitors.

Key words: green inhibitors, corrosion inhibition, electrochemical studies, Metal.

Introduction

Metals are the most extensively used group of materials predominantly in mechanical engineering, transportation industry, electronics and also in the construction industry [1]. Metals have extensive application in industries and domestic uses; exist in nature as ores in the form of oxides, silicates, chlorides, etc. They are extracted from the ores by a series of metallurgical operations involving consumption of energy. The pure metal is considered at a higher energy state unstable tends to revert back to the compound form. The metals are converted into metallic compounds at the surface and these compounds were known as corrosion products. This phenomenon of destruction of metals is known as corrosion. The greater the energy expended in metal extraction more readily does the metal tends to corrode. It is a foremost problem that must be confronted for cost-effectiveness, environmental and safety reasons in various fields like biochemical, chemical, mechanical, medical engineering metallurgical and specifically in the design of varied number of mechanical parts which equally vary in, functionality, size and useful period [2].

Corrosion is defined as consecutive loss or decay of material due to the unavoidable reaction with the environment. It is also defined as the destruction or deterioration of materials under

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chemical or electrochemical action of surrounding environments [3]. Metal atoms are present in environment in compounds form for example, minerals. Some amount of energy is needed to extract metals from their minerals. Corrosion revert back the metal to its combined state which is similar to minerals from which metals were extracted. Thus, corrosion is defined as “Reverse extractive metallurgy” [4].

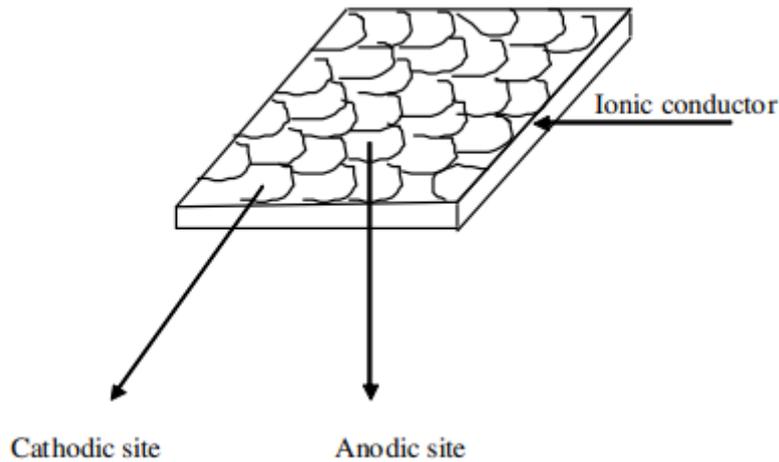


Fig. 1: Model for local cell theory of corrosion.

Corrosion occurs because of the creation of a large number of micro electrochemical cells or local cells (Fig. 1) at heterogeneities (impurities, defects, different phases, non-uniform stress distribution etc.,) on the metal surface. The corrosion is an electrochemical process in which a difference in electrical potential develops between two metals or between different parts of a single metal. This voltage can be measured when a metal is electrically connected to a standard electrode.

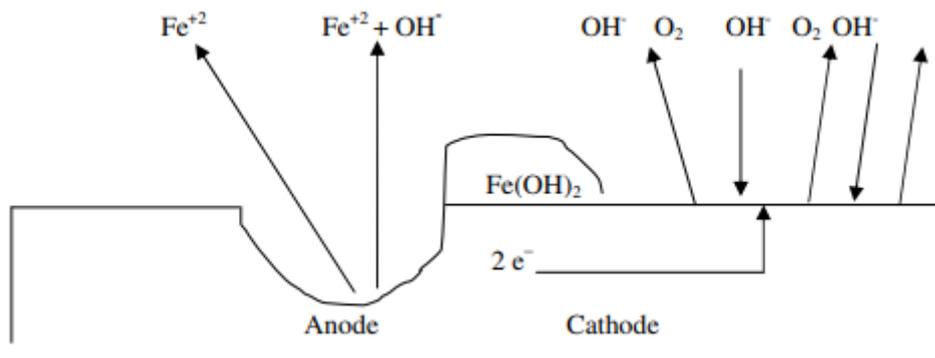


Fig.2: Reaction occurring during the corrosion of steel.

Although corrosion is a complicated process, it can be most easily comprehended as an electrochemical reaction involving the following three steps (Fig. 2):

- a) Loss occurs from that part of the metal called the cathodic area because of the lower potential at this site. In this case iron is lost to the water solution and becomes oxidized to Fe^{2+} ion.
- b) As a result of the formation of Fe^{2+} , two electrons are released to flow through the steel to the cathodic area.
- c) Oxygen in aqueous solution moves to the cathode and completes the electric circuit by using the electrons that flow to the cathode to form OH^- at the surface of the metal.

Corrosion is an activation-controlled chemical reaction, the rate of which is greatly affected by temperature. Usually, corrosion rate increases significantly as temperature increases. A rule of thumb is that when corrosion is controlled by diffusion of oxygen, the corrosion rate at given oxygen concentration approximately doubles for every 30 °C rise in temperature. In an open vessel, allowing dissolved oxygen to escape, the rate increases with temperature to about 80 °C and then falls to a very low value at the boiling point. The lower corrosion rate above 80 °C is related to a marked decrease of oxygen solubility in water and this effect eventually overshadows the accelerating effect of temperature alone. In a closed system, on the other hand, oxygen cannot escape, and the corrosion rate continues to increase with temperature until all the oxygen is consumed. When corrosion is accompanied by hydrogen evolution, the corrosion rate is more than double for every 30 °C rise in temperature [5]. In general, as temperature rises, diffusion increases, and both viscosity and over-voltage decrease causing depolarization by hydrogen evolution. Increased diffusion enables more dissolved oxygen to react with cathodic surface, thereby depolarizing the corrosion cell. A decrease in viscosity aids depolarization mechanism, and it favors the solution having atmospheric oxygen and enhances hydrogen evolution. In a domestic water system, an increase in temperature from 25 oC to 75 oC (Fig. 3) may increase the corrosion as much as 400 percent. An increase in temperature is normally expected to speed up a chemical reaction according to thermodynamic considerations [6].

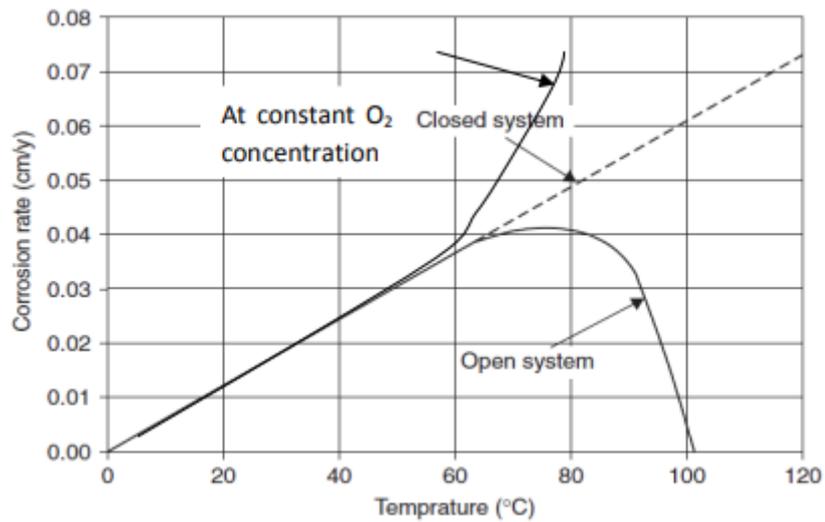


Fig. 3: Effect of temperature on the corrosion rate of low carbon steel in tap water.

Cohen [7] reported that the corrosion rate in the presence of oxygen is 65 times the rate in the absence of oxygen. Whitman [8] stated that the corrosion rate showed increase at higher velocity due to an increase in oxygen diffusion and breaking down of the protective films on the metal surfaces. Frese [9] showed that, iron tends to become passive with high oxygen. Fig. 4 shows the effect of oxygen concentration on the corrosion of low carbon steel in tap water at different temperatures.

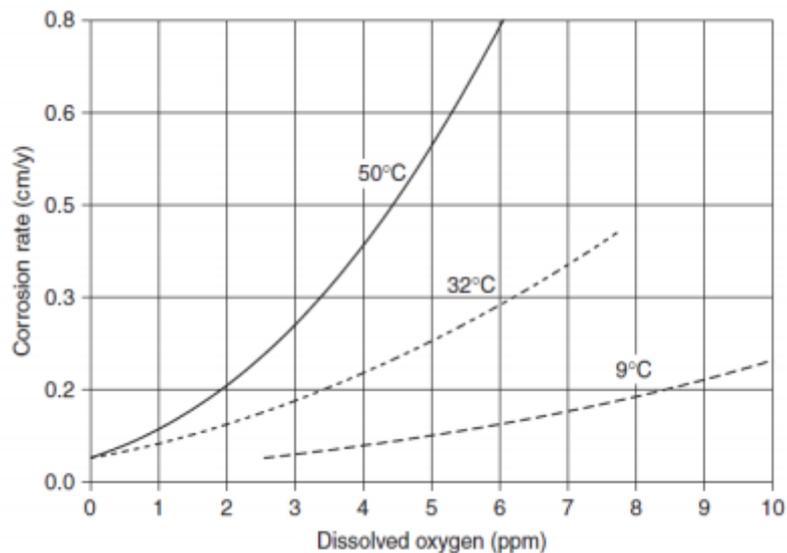


Fig. 4: Effect of oxygen concentration on the corrosion of low carbon steel in tap water at different temperatures.

In order to avoid or reduce the corrosion of metallic materials, inhibitors used in cooling system must satisfy the following criteria [10]:

- a) It must give good corrosion protection at a very low concentration of inhibitor.
- b) It must protect all exposed materials from the attack of corrosion.
- c) It must remain efficient in extreme operating conditions (higher temperature and velocity).
- d) In case of an under or over dosage of inhibitor, corrosion rate should not increase drastically.
- e) The inhibitor or reaction products of the inhibitor should not form any deposits on the metal surface particularly at locations where heat transfer takes place.
- f) It should suppress both uniform and localized corrosion.
- g) It should have long range effectiveness.
- h) It should not cause toxicity and pollution problems.

Green Inhibitors

Green corrosion inhibitors are biodegradable and do not contain heavy metals or other toxic compounds. Some research groups have reported the successful use of naturally occurring substances to inhibit the corrosion of metals in acidic and alkaline environment. Delonix regia extracts inhibited the corrosion of aluminum in hydrochloric acid solutions [11], rosemary leaves were studied as corrosion inhibitor for the Al + 2.5Mg alloy in a 3% NaCl solution at 25°C [12], and El-Etre investigated natural honey as a corrosion inhibitor for copper [13] and investigated opuntia extract on aluminum [14]. The inhibitive effect of the extract of khillah (*Ammi visnaga*) seeds on the corrosion of SX 316 steel in HCl solution was determined using weight loss measurements as well as potentiostatic technique.

Many theories to substantiate the mode of action of these green inhibitors have been put forth by several workers. Mann has suggested that organic substances, which form onium ions in acidic solutions, are adsorbed on the cathodic sites of the metal surface and interfere with the cathodic reaction. Various mechanisms of action have been postulated for the corrosion inhibition property of the natural products.

Argemone mexicana. It is a contaminant of mustard seeds contain an alkaloid berberine which has a long-chain of aromatic rings, an N atom in the ring, and, at several places H atoms attached to C are replaced by groups, $-\text{CH}$, $-\text{OCH}_3$, and $-\text{O}$. The free electrons on the O and N atoms form bonds with the electrons on the metal surface. Berberine in water ionizes

to release a proton, thus the now negatively charged O atom helps to free an electron on the N atom and forms a stronger bond with the metallic electrons.

Garlic. It contains allyl propyl disulphide. Probably, this S-containing unsaturated compounds affects the potential cathodic process of steel.

Carrot. It contains pyrrolidine in aqueous media, pyrrolidine ionizes, and the N atom acquires a negative charge, and the free electrons on N possess still higher charge, resulting in stronger bond formation at N. Carrot does not ionize in acidic media and thus does not protect in acids.

Conclusion

Corrosion is a natural process which reduces the binding energy in metals. The end result of corrosion involves a metal atom being oxidized, whereby it loses one or more electrons. The corrosion manifests itself as a break-up of bulk metal to metal powder. Corrosion degrades the useful properties of materials.

Corrosion inhibition efficiencies of the plant extracts have been compared with that of commercial inhibitor, hexamine. To find the industrial applicability of the inhibitor, the plant extracts were tested in the local industry.

The study can be further extended to analyse the effect of these extracts in other corrosive media like nitric acid, citric acid etc. and other metals like aluminium, copper, nickel etc.

Though a number of natural products as corrosion inhibitors have been studied, reports on testing their applicability in different industries are very few. The inhibitor can be tested in actual work spot of manufacturing and storehouse of electronic components and to other types of industrial materials and can be standardised as commercial inhibitors.

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