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REVIEW ARTICLE

An overview of green corrosion inhibitors

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Abstract

Corrosion inhibitors that are eco-friendly have become increasingly important due to growing environmental awareness and various regulations that restrict the use of conventional corrosion inhibitors because of their harmful effects. Natural products are a great source for making eco-friendly corrosion inhibitors since they contain elements such as O, C, N, and S, which are essential for forming organic compounds that adhere to metals or alloys. These compounds form a protective film that prevents corrosion. The use of green chemistry and new synthetic methods for producing green chemicals has led to the development of new green corrosion inhibitors. These inhibitors can adsorb substances, making them effective in a variety of environments while also protecting metals and alloys that are not chemically related.

1. Introduction

Metal corrosion inhibition is a major concern in the industrial sector. The aim is to prevent widespread corrosion of various components of oil manufacturing factories, pipelines, tubes, and wellhead equipment. Corrosion occurs when dissolved hydrogen sulfide, carbon dioxide, and salts encounter a metal surface [1]. Hydrogen sulfide, oxygen, acids like naphthenic and carbon dioxide, and caustic alkalis other than ammonium hydroxides are also some of the main things that corrode steel. Where hydrocarbons and electrolytes meet and where two-phase environments mix, steel also corrodes [2]. The process of corrosion requires four factors to take place. The first is the anode, where metal disbanding occurs. Through oxidation, electrons and metal ions can move freely. Positively charged ions use up the electrons as they travel along an external conductor, a metallic path, to a cathode close to the anode in a process known as reduction. Metal ions from the anode move along an ionic current path to the cathode. In addition to these four metallic conductors on the outside, the cathode, ionic current path, and anode are all connected to the dynamics of liquids. For example, fast water speeds expose the metal's new surface to water through protective films that are far away; a lower pH makes electrons more available; high water temperatures; the amount of dissolved oxygen; and the presence of dissolved salts, which make water more conductive. Industrial equipment and installations widely use metals, which makes them susceptible to corrosion. Alloys and metals are prone to corrosion, either through man-made liquids or through one or more natural liquids. These reactions can destroy the metal and result in a loss of cohesion. Corrosion is the gradual deterioration of substances due to a reaction with their environment. Therefore, we use suitable inhibitors to ensure the lifespan of these valuable metals. This has led to the use of inhibitors that can respond to corrosive factors in the environment [3]. Corrosion inhibitors are chemical substances

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that effectively reduce the rate of corrosion when added in lower concentrations to an environment. The chemical that can act as a corrosion inhibitor may be organic or inorganic. But because inorganic corrosion inhibitors are bad for the environment, plant extracts have become necessary because they are safe for the environment, easy to obtain, cheap, and renewable sources of substances. Because of the utility of organic inhibitors in several productions nowadays, the inhibition of organics is another area of research. Most of the well-known acid inhibitors are organic compounds, including sulfur, nitrogen, oxygen, and various bonds in the molecules. The ion pair of electrons available on the atoms allows for easy absorption into the surface of the metal. [4].

2. Theory of green corrosion inhibitors

It is essential to bear in mind that extra techniques, for example, the elimination of dissolved oxygen and the modification of pH can struggle with corrosion in various cases. Four different types of environments that affect the use of inhibitors in the pH range of 5–9 include natural waters, provided waters, and industrial waters. [6]. Solutions of aqueous acid are utilized in the analysis of metals and post-service cleaning of metals [7]. Main and minor production and refining of oil [8] Various environments. There are various groups of inhibitors. Several kinds, ordered as an inhibitor solution of near-neutral pH, are “dangerous” or “safe.” The inhibitor is essential to be present above the smallest concentration permitted for the inhibitor to be active (safe). An inhibitor present at a critical concentration might result in a localized attack; in this case, the inhibitor is named an inhibitor of danger. Inhibitors are either cathodic or anodic based on how they change the process of metal dissolution. For example, cathodic oxygen reduction happens in near-neutral solutions, while the hydrogen discharge reaction happens in acidic solutions. Inhibitors are classified as oxidizing and nonoxidizing based on their ability to passivate metal. Nonoxidizing inhibitors rely on dissolved oxygen to maintain the passive film, whereas oxidizing inhibitors do not require dissolved oxygen. This differentiation is significant in comprehending how various inhibitors interact with metals to prevent corrosion. Sodium salts of carboxylic acids act as inhibitors of inorganic corrosion, like organic inhibitors. Organic inhibitors are classified as hard, borderline, or soft, depending on the donor atom present in them. Oxygen-containing organic inhibitors are categorized as hard inhibitors, sulfur-containing inhibitors are designated as soft inhibitors, and nitrogen-containing inhibitors are classified as borderline inhibitors. Two methods can be used to prevent corrosion in aqueous solutions or water. The first method involves using oxygen scavengers to remove dissolved oxygen, while the second method involves adjusting the pH level of solutions to reduce corrosion. To remove oxygen from solutions, a combination of cobalt chloride and sodium sulfite, or hydrazine, can be added to deaerator the solution. For steel and iron, the pH level can be adjusted to 9.0 by adding an alkali such as sodium hydroxide. However, for metals like aluminum, adjusting the pH level to 9.0 is not recommended as it can cause corrosion. Therefore, pH adjustment should be avoided in a mixed metal system.

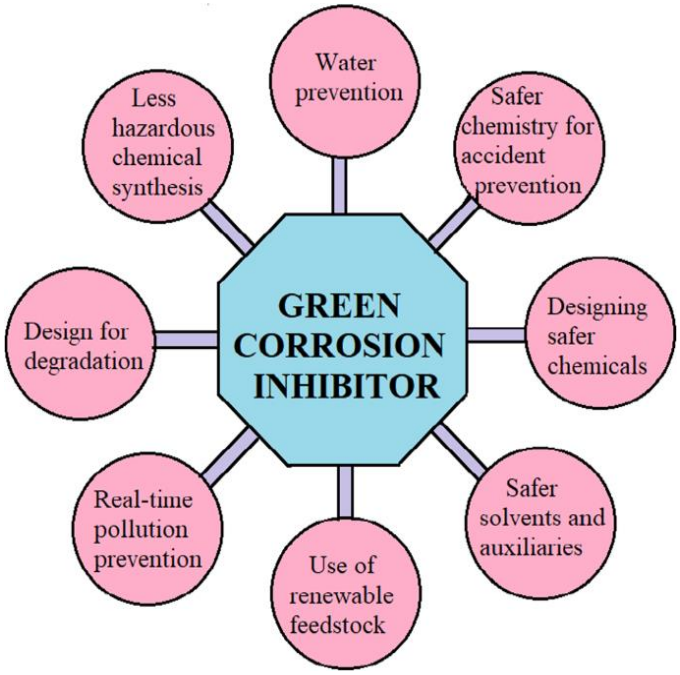

Figure 1: Characteristics of eco-friendly corrosion inhibitors [10].

Green corrosion inhibitors are a type of corrosion inhibitor that is environmentally friendly, biodegradable, and cost-effective. "They can be obtained from sustainable sources, but they may still pose health and safety risks.". There are two types of green corrosion inhibitors: organic and inorganic. The molecular structure of a green inhibitor is very important to how well it works. Heteroatoms (O, N, and S) in free electron pairs and in the molecular weight chains of alkyl make the inhibition work better. Organic compounds tend to have better inhibition effectiveness than inorganic compounds. Research into the properties of corrosion-inhibiting compounds derived from plant tannins, organic amino acids, and alkaloids is of particular interest. Natural substances produced from natural sources, such as plants, flavonoids, and alkaloids, are the inhibitors of organic green. Scientists have found a group of interesting compounds in plant and fruit peels that are being studied for their potential use in stopping metal from rusting. Eventually, these compounds could be used instead of harmful synthetic ones. [17,18]. They have been known as stocks of normal green compounds that have exact molecular structures that are complex and have biological, chemical, and physical properties. In general, natural products are effective in inhibiting the corrosion of metals. Certain plant-based chemicals and their by-products are effective as corrosion inhibitors due to their low cost, eco-friendliness, and natural breakdown ability. Different studies have tested the inhibitory potential of these extracts in various settings. Figure 1 offers a characterization of green corrosion inhibitors.

3. Types of Green inhibitors

As more people become aware of the importance of protecting the environment, the use of traditional corrosion inhibitors has become restricted due to their hazardous nature. In response, green corrosion inhibitors have gained attention as a safer alternative .

Corrosion inhibitors are materials or mixtures that are applied sparingly to metal surfaces exposed to corrosive environments to stop or reduce metal corrosion. They are also known as adsorption site blockers, adsorption inhibitors, and surface-blocking agents .[11,12] These organic compound-based active inhibitors are used to aid the organic compounds in forming a supramolecular layer with metal or alloy surfaces; thus, the layer acts as a barrier to prevent the corrosion of the material underneath. The electrolytic technique uses inert compounds, which are called "environmentally safe inhibitors of corrosion," by either preventing the corrosion or pushing back its process. We divide them into two categories: the inorganic compound green inhibitors that are sourced from natural elements or the organic compound green inhibitors that are harvested from the waste of natural industries. When the green inhibitors are compared to the normal corrosion inhibitors, the two experts are cheaper and have a longer shelf life.

3.1 Green organic inhibitors

Organic red inhibitors include flavonoids, alkaloids, different naturally occurring substances, etc. These inhibitors are harmless and biodegradable, which makes them compatible with corrosion control and the surroundings at the same time [13]. Additionally, ready-made substances that are not particularly poisonous and, as a result, are an eco-friendly and effective way to control corrosion can also serve as an example of organic green inhibitors.

3.2 Extracts of Plant

Scientists have looked at how plant extracts [10, 11] and extra organic inhibitors can stop steel from rusting in acidic fluids [12–17]. Loto described the use of mango leaf extract for the corrosion of mild steel in a dilute (H_2SO_4) medium [18, 19]. To determine the inhibition efficiency of the inhibitors, measurements of loss weight and electrochemical impedance spectroscopy were studied. However, the extract of leaves and bark appeared to have an important influence on the corrosion rate separately; the blend of these two extracts showed slightly higher effectiveness. Some research has shown that Zanthoxylum alatum fruit extract can stop mild steel from rusting in phosphoric acid at temperatures between 50 and 80 C [20]. Using X-ray photoelectron spectroscopy (XPS), the surface analysis shows the layer formation for the extraction of plants on the surface of mild steel. According to Satapathy et al., using an organometallic complex of the iron plant extract can hasten the formation of iron phosphate. They looked at the methanol extract of Justicia gendarussa leaves as a possible way to stop mild steel from rusting in HCl [21]. The researchers used gas chromatography with mass spectrometry to identify the organic compounds in the methanol extract. They discovered that the retention times of the compounds found in the extract were similar, making it difficult to separate them. To analyze the film formation on the mild steel sample's surface, the researchers used electron spectroscopy and atomic force microscopy for chemical analysis.

3.3 Green inorganic inhibitors

In active organisms, inorganic metals and elements play a critical role, even in trace amounts. Elevated levels of certain metals cause harm to entire living organisms. Additionally, it is suitable for metal derivatives. For example, due to their high efficacy, chromates, or compounds containing chromium, were commonly used as corrosion inhibitors in aqueous systems [26–28]. Chromates exhibit high toxicity in addition to their efficiency at inhibiting height, which makes them unsuitable for use in industrial settings [29]. Lanthanide salts are made to have great inhibition properties when looking for chromate inhibitors [30, 31]. It was reported that the toxicity of lanthanide salts, such as lanthanide chlorides, is comparable to that of sodium chloride [32].

3.4 Organic Polymers

Resources with exceptional qualities as adhesives on metal surfaces are polymers. Many different types of polymers have been tested to see how well they stop metal from rusting when used as a pre-coat [33–38] and as inhibitors in different types of corrosive fluids [39]. A description of the mechanism of mimosa tannin's inhibitory effect on the corrosion of low-carbon steel in an acidic solution was provided [39]. The pH range of 1-3 was taken into consideration when analyzing the mimosa tannin adsorption mechanism. The observation that the inhibitor selects the chemisorption mechanism at pH 1-2 and switches to physisorption at pH 3 is intriguing.

3.5 Green Inhibitor Biomimicry

It is well known that various chemical substances are included in green inhibitors, such as plant extracts. Determining the inhibitory mechanism of modified chemicals in plant extracts can be challenging. counterparts of naturally occurring flavones, amino acids are particularly adept at characterizing the many mechanisms involved in the inhibition process. For instance, the researchers investigated the acid corrosion of mild steel using 3-hydroxy flavone and 2,3-dihydroxy flavanone [40, 41].

4. Conclusions

Corrosion is a serious threat to the economy because it frequently has negative effects. It is now hard to ignore the global costs of corrosion, both direct and indirect. Although corrosion cannot be eliminated, it can be avoided. Considering

the high cost of metal and equipment repairs, using inhibitors to reduce corrosion is an economical alternative. Recent developments in corrosion inhibition, however, have put equal emphasis on the search for environmentally acceptable inhibitors as well as efficient ones. This is because, although a good inhibitor can effectively prevent corrosion, its chemical makeup may have unfavorable impacts on human health and the environment. In addition to being good for the environment, green corrosion inhibitors include plant extracts, rare earth metal compounds, amino acids, medications, ionic liquids, and surfactants. Changing out toxic organic and inorganic inhibitors for safer, more environmentally friendly alternatives is not only a matter of growing concern but also a well-established procedure that is gaining acceptance and usage.

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