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A review paper on green corrosion and its inhibitors

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Abstract
Corrosion is the deterioration or gradual destruction of metal or steel due to its environment. The application of green corrosion inhibitors, which reduces the corrosion rate to a reasonable level and has less impact on the environment is one of the important methods for controlling corrosion in daily life. In terms of its relationship with the environment, this area of research is evolving significantly. Today, due to increasing health awareness, anti-corrosion chemicals are strictly prohibited and regulations numbered are made by environmental organizations in many countries. According to these regulations, chemicals must be environmentally friendly and safe. Based on this, intensive research has been carried out to develop green corrosion inhibitors from plant extracts for approximately years. These chemicals are readily available, inexpensive, and biodegradable and safe, making them promising alternatives to harmful corrosion inhibitors. The purpose of this article is to briefly describe a recent compilation of important papers on the use of plant extracts as sustainable and green corrosion inhibitors. There is also some debate about the advantages and disadvantages of using this chemical to protect metals.

Keywords: health awareness, corrosion inhibitors, metals

Introduction
Corrosion is a phenomenon of metals and alloys trying to return to a more stable thermodynamic form due to interaction with the surrounding environment. Corrosion is expensive due to the loss of materials or their properties, which leads to loss of time during maintenance, the shutting down of systems, and severe failure of some structures, which in some cases may be hazardous and cause injury. Methods for protecting metals or alloys from corrosion, e.g. isolating them from the aggressive environment (using a process or chemical film) or compensating for the loss of electrons in the corroding structure (corrosion is an oxidation process) (e.g. by the use of Satisfied current or by active sacrificial anode protection). The high amount of construction knowledge and emerging technology expand the options and they allows engineers to select the most suitable product for each application based on physical or mechanical properties. Metal materials play an important role in the development of the country and the long-term success in the international market. However, no application can ignore the consequences of the interaction of steel or alloy with the surrounding environment. Corrosion is a natural process in which metals and alloys try to return to a stable thermodynamic state due to chemical or environmental reactions. In other words, metal is found in nature in the impure form, usually stable oxides or sulfides, with the exception of platinum and gold.

Therefore, steel corrosion is the easiest and fastest to reach the most stable state of. Corrosion can also be caused by natural or man-made causes. In general, corrosion of the metal is defined as the natural and inevitable loss of the desired product due to interaction with specific elements present in the environment. It has been determined that corrosion is dangerous for the environment and human health Corrosion related problems are now being evaluated From drinking water pipes to oil and gas Distribution. It should be noted that the term corrosion does not include most physical or processes such as evaporation, melting or mechanical cracking, corrosion reactions are mostly electrochemical in nature. Hydrogen generation and oxygen reduction are two countermeasures that support the corrosion process in acidic environments and neutral/alkaline environments Corrosion of steel and alloy is caused by many factors; Some of the most important environmental factors are shown in Figure 1. In addition to factors explained in this way, ambient temperature has a significant effect on corrosion. In addition, the presence of certain bacteria species in biofilms on steel can accelerate and contribute to the progression of existing corrosion processes.

It is worth adding that the corrosion chemistry of is developing rapidly and all chemical methods have been reviewed from an economic, environmental, and safety point of view.

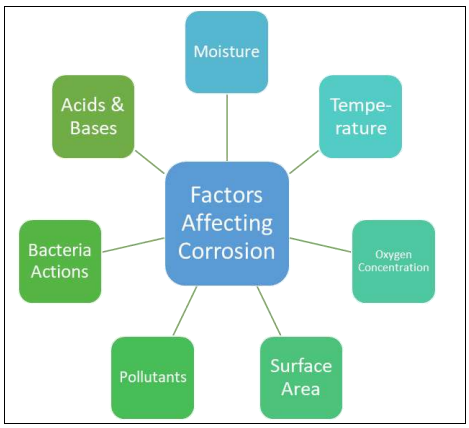

Fig 1: Factors Affecting Corrosion

Steel and alloys in generally show a high level of corrosion susceptibility due to the acidic environment. Metals are susceptible to corrosion in acidic solutions because acids can form by interacting with the metal surface and causing it to dissolve (Release the ion), which can occur in various industries. Acid solutions are used in industries such as industrial acid descaling, pickling, pickling and descaling of steel surface. It's worth noting that the Corrosive damage is greater in obtaining Pure Metal from Iron Ore. This process uses a very acidic solution of, such as, which can cause the steel to crack and imperfections such as scale and rust.

The global cost of corrosion rose to $2.5 trillion in 2013, or 3.4% of the world's GDP. It is estimated that the use of corrosion control measures can save 15% to 35% of corrosion costs, or $375 to $875 billion in annual global cost savings of the annual reported indirect costs for countries are shown in Figure 2.

As the world is at the technological development level of, the price of should increase for the next few years unless more measures are taken in corrosion prevention and protection of metal

Many methods are used in corrosion prevention science and engineering. Material selection, electrochemical methods, layer deposition and application of corrosion inhibitors are some of the most commonly used methods. Using a Corrosion Inhibitor (Cl) is one of the most economical and easy to use methods. CI is a product that can reduce the degradation rate of steel when is added in low concentrations in a corrosive environment. For example, inorganic chemicals, particularly chromium and its derivatives, are known for their inhibitory properties. However, environmental regulations prohibit their use due to their toxicity and hazards to human life and ecosystems. On the other hand, natural products such as plant extract are widely used and effective.

Corrosion Inhibitor

Corrosion inhibitors are widely used to prevent or at least reduce the corrosion process of metals in many fields, from industry to equipment for surface treatment of culture.

According to the standard definition, a corrosion inhibitor is "a chemical that, when present in a corrosive process, reduces the rate of corrosion without changing the concentration of a corrosive substance." It is generally effective at low concentrations. This does not include chemicals that significantly change the pH, reducing the rate of corrosion, or oxygen and hydrogen sulfide scavengers that remove heavy contaminants from solution.

Corrosion inhibitors can be classified as cathodic, anodic, or mixed, based on the fact that their effects mainly retard the cathodic or anodic effects of the corrosion process, or both. Therefore, they cause the corrosion potential of the inhibited metal to change to the cathodic or anodic direction, respectively, or it is important that the corrosion resistance of the metal is more or less. Inhibition of anodic or cathodic corrosion may result from a decrease in the active area of the metal and/or from a change in the activation of the oxidation or reduction process in corrosion. A combination of cathodic and anodic corrosion inhibitors usually improves protection and allows lower inhibitor concentrations. Where the reaction is affected by a corrosion inhibitor, it affects the metal/solution to form a film which can be of three types: (a) passive film; (b) precipitated film and (c) adsorbed membrane. The passivation oxide film is 30-200 Å thick and provides excellent corrosion protection. These may include conventional anti-oxidation agents such as chromates and nitrites, and these are now generally abandoned due to toxicity concerns unless corrosion is a concern for human safety (as in the aerospace industry and construction). This group also includes non-oxidation inhibitors such as tungsten and molybdates, which only have a passivating effect in aerated solutions. Deposition film inhibitors are substances that react with soluble substances in the environment to form insoluble substances (For example, in reaction films with phosphonates and polyphosphates, with calcium ions) or with resistant metal ions (for example, copper-benzotriazole (BTA) salt films). This film is porous and does not stick at all if it has good corrosion protection.

The inhibitors that form the adsorption protective film are organic substances. They usually have the molecular structure of the surfactant, the hydrophilic group can bind to the metal surface, and the hydrophobic part of the molecule protrudes into the bulk solution. Adsorbed inhibitor molecules limit oxygen diffusion and water penetration to the metal surface, thereby reducing the corrosion rate.

Traditional Corrosion Inhibitors

As mentioned earlier, corrosion protection and quality control are important for the, minimizing financial losses while increasing occupational safety and equipment life. To protect or limit corrosion formation, the first choice is to select the appropriate material based on the final design and application. Second, environmental conditions, pH value, temperature and content of active substances should be checked and the concentration of inhibitor added if necessary. Separating the material from the corrosive environment through shielding and compensating for electrons lost through cathodic shielding is also a way for to prevent and control corrosion. The use of corrosion inhibitors is by far the best known method of controlling, preventing or limiting corrosion of steel. That is, its inhibitory mechanisms are not always clear enough to identify and examine. Depending on the electrode treatment, there may be anodic, cathodic, or mixed inhibition effects. It's also worth noting that in some Cls are specific to certain files in the environment and may not work under other

conditions. Conventional inorganic and organic corrosion inhibitors are two classes of Cls that are widely used primarily because of their simple process and applications and performance at low concentrations. Inorganic Cls are preferred in a near-neutral environment, while organic Cls of are required in an acidic environment. A good organic inhibitor will have in its structure a polar functional group containing heteroatoms such as O, S or N atoms and π electrons and hydrophobic moieties that fight aggressive aqueous species from the surface of the product. Fatty amides, pyridines, polymers and imidazolines are in the class of organic chemicals used for corrosion protection.

Mechanisms of adsorption of Cls molecule on substrate surface

1. Hydrolysis of organic compounds
2. Donor-acceptor exchanges occurring between the π-electrons of ci molecules and the vacant d-orbital of iron substrate
3. Interaction of unshared electron pairs of the heteroatoms with the vacant d-orbital of iron substrate
4. Interaction of vacant orbital of the heteroatoms with the d-orbital electrons of iron substrate

Also, inorganic CI can operate longer at higher temperatures than organic CI; Products included in this class include chromates, dichromates, phosphates and arsenates. It should be noted that today the aforementioned drugs are considered poisonous and dangerous, which do not break easily or lose their potency when thrown; thus it affects human and environmental health. This can lead to the formation of abnormalities, as well as a greater risk of long-term problems such as cancer. In addition, the synthesis process of conventional CI involves the use of expensive and toxic materials, solvents and cat-auxiliaries; therefore, many undesirable chemicals that affect soil and marine organisms are released into the environment.

Green Corrosion Inhibitor

As an environmentally friendly technology, green corrosion inhibitor has been attracting more and more attention in recent years. Many sources of green inhibitors include plant extracts, chemicals, ionic liquids, and synthetic inhibitors are a source of environmentally friendly corrosion inhibitors. Plants (e.g. extracts and oils) are important green corrosion inhibitors that are widely used in different acidic environments as they have a variety of physical, chemical and biological properties. In recent years, chemicals from natural products have become more popular as anti-corrosion agents. In addition, there is an increasing trend of using expired chemicals as corrosion inhibitors because this can reduce disposal costs and environmental pollution.

Many environmentally friendly people have been researched and analyzed from time to time over the years. In 2011, Night clearly reviewed the chemical as an anti-corrosion agent. Two reviews were published in 2011 highlighting the importance of biopolymers and surfactants in various interventions. In 2012, Rani and Basu introduced the advanced application of natural materials as green corrosion inhibitors in different corrosion environments. Verma *et al*. The anti-corrosion properties of ionic liquids were reviewed in 2017.

Table 1: Source of natural products, efficiency (%) metel/alloy studied.

Source of natural products	Agg. Media studied	Metal/alloy studied	Efficiency (%)
Flour and yeast	Acid media	Iron	65-82
Furit — peels of pomegranate	Acid media	Aluminum	83
Tobacco leaves	Neutral then	Mild steel and	87.5 (steel), 77.5 (Al)
Soya bean	acidic media	Aluminum	71.0 (steel), 45.9 (Al)
Gum (acacia)	acidic media	Aluminum	NA (steel), 21.8 (Al)
Orange peels	Acid media	Copper	75 (steel), 70 (Al), 55 (Zn)
Mango peels	Acid media	Copper	80 (steel), 64 (Al), 43 (Zn), 43 (Cu)
Pomegranate fruit shell	Acid media	Copper	80 (steel), 59 (Al), 59 (Zn), NA (Cu)
Azadirachta indica(NEEM)	Mild steel Acid media	Mild steel	94
Natural honey	NaCl	Carbon steel	82-91

Theory of Green Corrosion Inhibitor

The corrosion process is directly related to the Gibbs free energy. The higher the Gibbs free energy, the higher the corrosion rate. Green corrosion inhibitors can be used to reduce free energy. Inhibitors written on the surface of the working area of the corroded metal prevent corrosion. The relative corrosion rate is also modified by the Pilling-Bedworth ratio, from which the state of the membrane can be defined.

Corrosion produces particles that have a larger volume than metal and protect the metal; However, too large a value for this ratio will cause the oxide formation to deteriorate. When the ratio is 1, there is good compatibility between the oxide and the metal, and the oxide resists. Inhibition according to the adsorption process is affected by many factors such as the type of electrolyte used, temperature, chemical composition of the inhibitor and others. It can form covalent bonds for the chemisorption process. Green corrosion prevention is usually done at room temperature, and the anti-corrosion effectiveness is generally inversely proportional to temperature.

Opportunities for the Green Corrosion Inhibators

Green corrosion inhibitors can be cost-effective, so economic efficiency is important. Various technologies, families, etc. It is well known that it affects people in different ways. Some industries operate without corrosion control. In 1978, the National Bureau of Standards published a list of materials affected by corrosion. The list includes industry builds, product losses, differences between various factories and machines, and more. The killing of machines and the reduction of production are greatly affected by them.

In 2013, a report published by the American Association of Corrosion Engineers, the world authority on corrosion, stated that the global cost of corrosion was $2.5 trillion,

equivalent to 3.4% of the world. For corrosion prevention in practice, for example approx. 35%saves $875 billion annually worldwide. This greatly expands the use of green corrosion inhibitors. Many projects have shown that using waste and natural materials as green corrosion inhibitors can be effective. The economics of biowaste has been clarified by using Phoenix clactylifera seeds to prevent corrosion of metals and alloys such as various types of metals by sending a seed as fruit to the wood of the plant in question. The inhibition efficiency of the fruit peel of this food is close to 97% at 50 °C.

Another patent publication states that some plant-derived disinfectants have strong anti-corrosion properties in corrosive environments such as pipes, water chillers, multiple tanks and fire protection. 40% of these corrosion problems are caused by bacteria. Considering the fact of reducing pollution, in addition to the pollution process, there are some environmentally friendly and biodegradable green corrosion inhibitors, i.e., Potato stalks and lettuce peduncles, potato stalks as illustrated in Chinese patents.

The importance of processing many wastes such as seeds and peels, mango by-products, passion fruit, juice, cashews and oranges can play an important role in preventing corrosion as an environmentally friendly corrosion inhibitor. This study was conducted by Gomes *et al*. It is used to prevent corrosion of steel in acidic environments. Another patent uses other models and methods for checking the corrosion protection of not only steel, but also copper, aluminum and their alloys. Dealing with vegetable oil-based corrosion inhibitors, thinking about biological treatment and creating a good relationship, or rather a synergistic relationship between the oil industry and natural resources, and have a special green approach.

Versailles has played a role in transforming traditional resources into a sustainable environment. The field of corrosion inhibitors from natural products has little applications in real plants to prevent damage. There are many reasons for the failure to use vegetables, fruits or green substrates as inhibitors. These aregifts because they are hard to collect, rare and edible. Considering that the anti-corrosion properties are closely related to the degree of unsaturation or the presence of heteroatoms, the corrosion inhibiting ability of natural extracts is high in materials.

Products extracted from natural sources often have these properties. In addition to the question of the social and economic impact of inhibitors, it is important to consider the final application of the product.

Challenges of Using Green Corrosion Inhibitors

Therefore, the composition of the corrosion inhibitor should be investigated before use to prevent corrosion. One of the disadvantages of this is their longevity. Because most of them are biodegradable, they are difficult to store for long periods of time. The choice of extraction method is another important factor. During the extraction of plant parts, it should be noted that the solvent used for extraction should be less hazardous.

In addition, some processes require longer operating time and higher temperature, which is not suitable for green corrosion inhibition. To overcome these problems, the supercritical fluid extraction process is now used as an alternative technology. However, the effect on the mechanism of physicochemical parameters is currently under investigation.

In addition, inhibitors contain less active ingredient. Currently, there are approximately drugs used for this purpose.

However, Night pointed out that the performance of the green anti-corrosiondry raw material is limited, as not all chemicals in are biodegradable. However, despite the limitations mentioned above, herbal corrosion inhibitor is still the best alternative as it is mostly made from natural products, which makes them more efficient and effective. The toxicity of green inhibitors has not been studied in most of the literature.

Conclusion

Mental, an essential part of our civilization, has the ability to break down in oxygen or harmful atmospheric conditions created by acidic, alkaline and even neutral conditions, which forces us to consider protecting corrosion phenomenon. There are many methods that can be used to prevent corrosion. As a good corrosion protection, is good against steel, mild steel, carbon steel, stainless steel, aluminum alloys, copper alloys and many other metals and alloys such as plant extracts, fungi, polymers, bio-Test components and chemicals. in different acidic, alkaline and neutral environments. Among these, the use of inhibitors is the best option. Many countries have used this herbto prevent corrosion. Due to environmental concerns, some biobased inhibitors are now prominent. They are also called green corrosion inhibitors because they are not toxic like, occur naturally and are very safe. In addition, the extraction process of the product is also often expensive. Because these products are readily available, is business-friendly. From the research data, it was concluded that inhibition process is based on adsorption process, possibly based on Freundlich, Langmuir and Temkin isothermal process. In short, it can be said that although green corrosion inhibitors have some bioaccumulation limitations, these inhibitors need a lot to create a clean, safe designed and stable environment, considering the environmental protection of, the most important thing is to get rid of. of the problems caused by corrosion.

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