IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Effectiveness Of Eco-Friendly Anti-Corrosion Agents Compared With Synthetic Substances

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Abstract

Metals and alloys deteriorate due to an occurrence called corrosion. Businesses in a variety of industries, including the oil and gas, food processing, pharmaceutical, marine, automotive, and aerospace industries, regularly suffer loses of this proportion. Nowadays, there are several approaches available for preventing corrosion. Extraction techniques demand to consist of expensive and environmentally hazardous solvents and catalysts in order to eliminate both organic and inorganic inhibitors. Their synthesis process is ineffective in addition to being hazardous for the environment. Here the use of inhibitors that are generated by plants has the potential to significantly improve both the resistance to corrosion and the efficiency of the process. They can be applied with an abundance of materials and in a wide range of situations, are affordable to implement, and are secured for both humans as well as the environment.

Keywords: corrosion, catalysts, environment.

Introduction

Although human activity can contribute to corrosion, corrosion is a spontaneous process influenced by various elements. Many industries, including the oil and gas, building, marine, aircraft, petrochemical, military, and ceramics sectors, view corrosion as a serious problem. In industries where they come into contact with acids, iron, and alloys are frequently utilized. According to Fan *et al.* (2002), the most significant application areas include petrochemical processes, acid pickling, acid descaling, and industrial cleaning. Nevertheless, acidic media negatively impacts metals through chemical or electrochemical processes. While corrosion is generally gradual, it may happen quickly and severely in specific places, including the sea and industrial cities (Sheydaei *et al.*, 2023). It has been reported that a lack of corrosion prevention led to increased costs for issues such as repair, maintenance, and rehabilitation, as well as the replacement of damaged installations. Corrosion costs worldwide increased to USD 2.5 trillion in 2013, accounting for 3.4 % of global GDP (Bowman *et al.*, 2016).

Researchers are always searching for high-performing, affordable techniques to prevent and minimize rust. Antirust solutions and corrosion inhibitors are two of the many ways that metals can be protected against corrosion. Other methods include galvanization, cathodic protection, and barrier protection. Another method of stopping corrosion is to employ nanomaterials like graphene oxide, clay, carbon nanotubes, and hollow mesoporous silica. The use of corrosion inhibitors is one of the most widely used corrosion control and prevention techniques in acidic media (Elayyachy *et al.*, 2006).

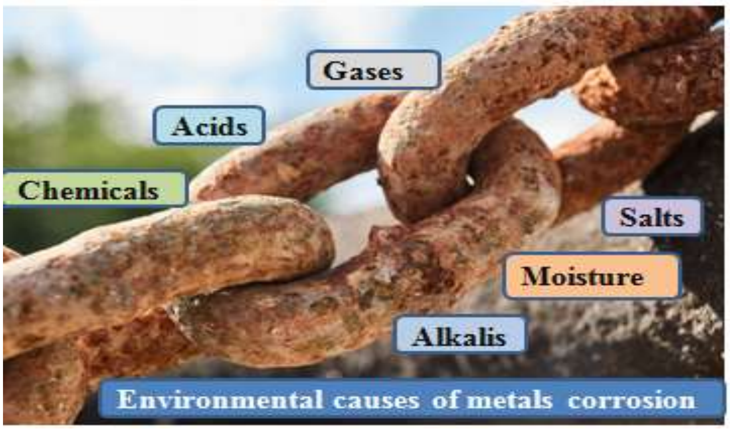
A chemical compound that, when present in a corrosion medium at an appropriate concentration, lowers the rate of corrosion without appreciably altering the concentration of another corrosive agent is known as a corrosion inhibitor.

The production of heterocyclic compounds is a continuous process that has yielded several applications as corrosion inhibitors. The majority of them should have aromatic systems as they include lone pairs of electrons in nitrogen, sulphur, and oxygen (Emregul and Atakol, 2002; Popova and Christov, 2006). Additionally connected to a compound's inhibitory efficacy are its functional groups, steric effects, and electron-donating Pi-orbital nature. Although many corrosion inhibitors have a strong protective effect, their usage has lately been restricted because of their high cost, toxicity, lack of biodegradability, and health hazards (Luo *et al.*, 2024).

Factors that affects on corrosion

According to Wu *et al.* (2019), corrosion is influenced by three factors: environmental, metallurgical, and structural.

Pollutants, humidity, and temperature variations are examples of environmental influences. The rate of corrosion is significantly influenced by temperature. In summary, rising temperatures raise the rate of corrosion in environments with constant humidity, whereas in enclosed areas, falling temperatures without further dehumidification raise the rate of corrosion. Both positive and negative effects can be attributed to rain on the corrosion process. On the one hand, rain helps to remove pollutants and chlorine ions from the metal surface. On the other hand, rain increases the likelihood of transferring active corrosive compounds, like sulphur dioxide, to the wet metal surface (Soufeiani *et al.*, 2020).



Additionally, pH performs a significant role since, generally speaking, corrosion intensities and rates rise as pH falls. The maritime environment has a high concentration of chloride ions, one of the most aggressive species that may cause corrosion. Furthermore, a highly saline environment may result in the development of thick rust coatings on the carbon steel's wet surface, which makes the metal substrate more readily separated from the surface. This leaves the surface exposed and speeds up the corrosion process (Freire *et al.*, 2009).

Aspects of metallurgy that are directly connected to corrosion include the kind, concentration, and methods of processing and production. For instance, various alloying elements can have corrosive effects on steel (Liu *et al.*, 2020).

The structural factors are different for each structure, but in general, it can be said that the design of the structure, the geometric features of the structure, the spatial orientation of the structure relative to the earth's surface or sky, and the orientation of the surface relative to the main points are of great importance (Lazorenko *et al.*, 2021).

Green corrosion inhibitors

A select few synthetic inhibitors are harmless, while the majority are extremely harmful to biological systems (Cheng *et al.*, 2007; Stoyanova *et al.*, 2002). Some of them include heavy elements that when they build up and do not biodegrade, pollute water and soil. Eventually, these elements accumulate in plants and animals, where they enter the food chain and pose a risk to human health.

Plants can be utilized for their leaves, roots, fruits, flowers, oil, woody portions, entire plants, and even waste. Abundance of natural chemicals is what gives them these inhibitory qualities. Some of the most common phytochemicals that have a corrosion-inhibiting effect are flavonoids, glycosides, alkaloids, saponins, phytosterol, tannins, anthraquinones, phenolic compounds, triterpenes, and phlobatannins. Most such phytochemicals have polar functional groups like amide (-CONH2), hydroxyl (-OH), ester (-$COOC_2H_5$), amino (-NH_2), and carboxylic acid (-COOH) that assist in their absorption (Ji *et al.*, 2011). Plant extracts are often employed more frequently while researching corrosion inhibition. A plant's active components combined with a particular media, or solvent, is what's referred to as an extract. As a result, the process used to prepare plant extract is crucial. Because it is simpler, quicker, and more productive than other procedures, solvent extraction is often more well-liked and used (Tamalmani and Husin, 2020).

The negative impacts of the inhibitors have caused research to change to the use of plant extracts and oils, which have better anti-corrosive properties and are also ecologically beneficial. In this regard, green corrosion inhibitors have gained a lot of popularity. The literature has indicated that the efficacy of certain anodic and organic inhibitors reduces significantly at high temperatures, but overall, their inhibitory results are equivalent to those of conventional inhibitors, and in some cases, even more so. In actuality, there is still room for improvement in the creation of green corrosion inhibitors. Plant extracts include a wide variety of chemical compounds, particularly heterocyclic ones that are involved in the suppression of corrosion (Sathiyanathan *et al.,* 2005; Poongothai *et al.,* 2005).

Mendez *et al.* (2023) used *Ilex paraguariensis* extract to inhibit the corrosion of aluminium in HCl and the results showed that the maximum value of efficiency at 315 and 323 K is 69 and 71%, respectively.

The anti-corrosion properties of *Ganoderma lucidum* mushrooms stem from their variety of chemicals. Actually, hydrophobic compounds like quercetin, proline, and gallic acid are found in *G. lucidum*, and amine and hydroxyl groups in compounds like proline and triterpenoids can physically absorb on the mild steel surface and form a protective film by transferring electrons with Fe^{2+} in anodic regions (Sheydaei *et al.*, 2023).

The anti-corrosive properties of ginger have been well explored. Due to p-electrons and heteroatom oxygen atoms in the phenolic compounds, chemicals like curcumin, shogaols, and gingerols aggregate on the metal's surface and obstruct the anode and cathode sites (Edraki *et al.*, 2022).

A recent study by Shahini *et al.,* (2022) examined the inhibitive properties of *Nepeta pogonesperma* extract for mild steel in a 1 mol/L HCl solution. Surface characterisations performed by SEM and AFM techniques revealed corrosion traces on the surface of uninhibited specimen; on the other hand, by increasing the concentration of GCI in the solution, more coverage of the steel surface was provided, by which a smoother surface morphology with fewer defects was observed.

Naderi *et al.* (2022) investigated the effect of liquorice plant extract on the corrosion inhibition of steel rebar in concrete contaminated by aggressive chloride.

According to Valdez-Salas *et al*. (2021), steel corrosion in concrete mortar polluted with aggressive chloride was examined in relation to the impact of *Azadirachta indica* leaf extract. After 182 days of testing, the results demonstrated that *A. indica* did not alter the physicochemical properties or the integrity of concrete. It also demonstrated a 95% long-term protection against corrosion, which is comparable to the results of commercial inhibitors.

According to Abdallah *et al*.'s (2021) research, when using natural nutmeg oil to stop carbon steel from corroding in HCl, the corrosion rate values increase and the inhibition efficiency values decrease as the temperature rises (30 to 60◦C).

Begum *et al.* (2021) also reported, in the study of the use of *Spilanthes acmella* leaves extract for corrosion inhibition of mild steel in HCl, that, with increasing temperature (303 to 333 K), efficiency and corrosion rate decrease and increase, respectively.

In another work by Sahin *et al.* (2020), inhibiting performance, adsorption ability, and stability of *phoenix dactylifera* seed extract (PDSE) were investigated for mild steel in a 1 mol/L HCl environment. Upon 6 h of immersion, the polarization curve of the specimen was studied with and without PDSE in the medium. They observed that the pattern of the curve is the same with and without PDSE, implying that the corrosion process is functionally equivalent in both conditions.

Barbouchi *et al.* (2020) in the study of the use of Terebinth extract to prevent iron corrosion in NaCl, reported that, with the increase of immersion time (up to 72 h), the thickness of the created protective layer increases.

Dehghani *et al.* (2020) noticed that protonated forms of acacetin, chrysin, and thymonin (leaf extract molecules) electro statically interact with absorbed chloride ions in their investigation into the utilisation of *Ziziphora* leaf extract molecules to prevent mild steel corrosion in HCl.

Another study by Benahmed *et al.* (2020) found that the temperature and concentration of the butanolic extract of *Elaeoselinum thapsioides* influenced both the rate of corrosion of carbon steel in 1 mol/L HCl and the extract's ability to prevent corrosion. The researchers found that as BEET concentration rises, corrosion activity falls and the inhibition efficiency rises sharply as a result.

Sivakumar and Srikanth, (2020), in investigating the inhibitory effect of *Mimusops Elengi* extract on the corrosion of mild steel in HCl medium, reported a decrease in inhibition efficiency with increasing temperature. Also, inhibition efficiency increased with increasing immersion time (from 1 to 12 h), which was related to increased absorption of extract compounds on the substrate surface.

El Hamdani *et al.* (2015) reported, the alkaloids in *Retama monosperma (L.) Boiss.* seeds extract were found to be beneficial for preventing dissolution of carbon steel in a 1 mol/L HCl environment.

Ogwo *et al.* (2017) investigated the inhibitory effects of leaf extracts of *Ficus sycomorus* on aluminium and mild steel corrosion in a 1 M HCl solution using the weight loss method. The facility under investigation yielded 88% IE for mild steel and 98% IE for aluminium at a concentration of 5g/L. The Langmuir adsorption isotherm suited the data rather well.

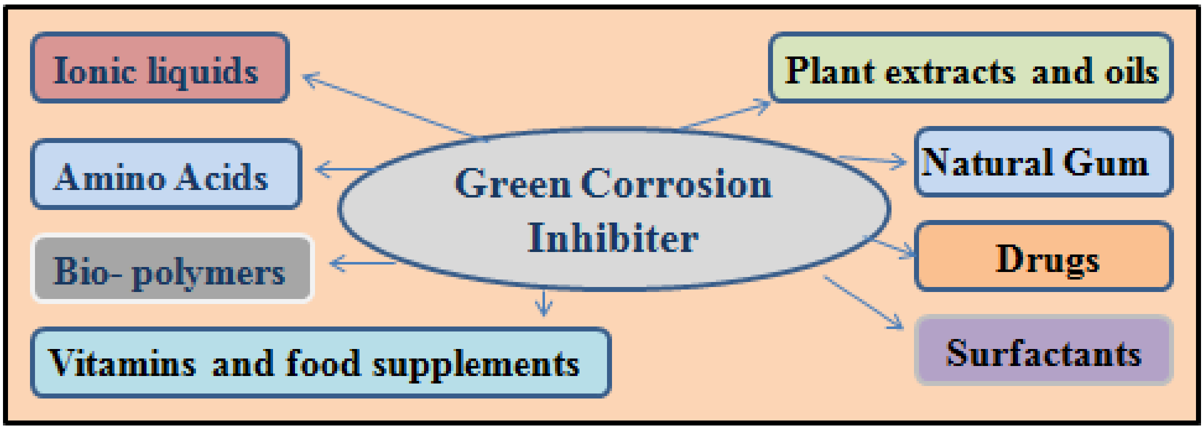
Sharma *et al.* (2017) investigated potential of *Azadirachta indica* as a green corrosion inhibitor against mild steel in a solution comprising 1 N HCl, H2SO4, and HNO3 at 304 to 313 K by employing the weight loss method. The extract was physically adsorbed in the investigated acid medium in compliance with the Langmuir adsorption isotherm.

Fouda *et al.* (2017) used weight loss, PDP, electrochemical frequency modulation, and EIS methods to study the inhibitory impact of the medication Cialis on the corrosion of zinc in 1 M HCl. The Langmuir adsorption isotherm is followed by the Cialis drug's adsorption isotherm on the Zn surface. The findings showed that while the Inhibition Efficiency (IE) drops with rising temperatures, it rises with increasing drug concentration. The morphology of Zn that was inhibited was examined using FT-IR, AFM, EDX, and SEM. Results from polarization indicated that this medication is a mixed type inhibitor.

Using the weight loss approach, Eddy *et al.* (2014) calculated the corrosion inhibition potentials of *Ficus benjamina* gum and demonstrated the gum's efficacy in inhibiting the corrosion of aluminium in solutions containing tetraoxosulphate (VI). By functioning as an adsorption inhibitor that promotes the chemical adsorption process, the gum supported the Frumkin and Dubinin-Radushkevich adsorption models.

Bouknana *et al.* (2014) examined the effects of the phenolic and non-phenolic components of the olive oil mill wastewaters extract on the corrosion of steel in a 1 mol/L HCl solution using electrochemical polarisation and weight loss measurements. The compounds stated exhibited anticorrosion characteristics on steel, with inhibitory efficiencies of 89.1% for non-phenolic fractions and 88.9% for phenolic fractions.

Raja et al., 2013 reported that the mild steel corrosion inhibition effect of *Neolamarckia cadamba* crude extract was investigated in a 1 mol/L HCl solution. The primary ingredient, 3β-isodihydrocadambine, was purified and studied in further detail, and its corrosion inhibitory properties together with two other substances, namely bark and leaves extracts were investigated.



The presence of heteroatoms and different chemicals in pharmaceutical goods makes them a potential choice for corrosion inhibition. Many medications, including naproxen, glucosamine, clotrimazole, amoxicillin, ciprofloxacin, doxycycline, and streptomycin, have had their efficacy in preventing corrosion assessed to date (Chafiq *et al.*, 2020). The impact of two different types of expired glucosamine drugs glucosamine hydrochloride (GH) and glucosamine sulphate (GS) on the suppression of carbon steel corrosion in an H_2SO_4 solution was examined by Feng *et al.* (2023).

The use of polymers derived from sustainable natural resources presents a novel and alluring method of preventing corrosion. The use of a polymer as a host for a corrosion inhibitor can be considered a successful combination because, in addition to the low use (concentration) of the inhibitor, the polymer can be a long-term protector. Dalhatu *et al.* (2023) investigated the effect of L-arginine grafted onto chitosan on the corrosion inhibition of mild steel in 0.5M HCl. The evaluation showed that the inhibition efficiency at optimum concentration rose to 91.4%.

Both hydrophilic and hydrophobic components are present in surfactants. Both the hydrophilic and hydrophobic portions interact with polar and hydrophobic substances, respectively. Actually, what may stop corrosion on a surface is the surfactant's absorption, which is influenced by the electrochemical potential of the surface, temperature, adsorbent concentration, and solution composition (Kousar *et al.*, 2021).

Numerous ionic liquids with cations containing nitrogen atoms have been studied as corrosion inhibitors; in actuality, ionic liquids formed from quaternary ammonium have far superior corrosion characteristics. The impact of methyl trioctyl ammonium methyl sulphate and trimethyl tetradecyl ammonium methyl sulphate on the corrosion inhibition of API-X52 steel in an HCl solution was examined by Arellanes-Lozada *et al.* (2018).

The excellent solubility, non-toxicity, affordability, and appropriate functional groups of vitamins make them very desirable. Numerous studies have demonstrated the potential of vitamins B, C, D, and E as corrosion inhibitors (Kesari and Udayabhanu, 2023). Argiz *et al.* (2022) examined how effectively ascorbic acid, or vitamin C, prevented steel from corroding in cement mortars tainted with chlorides.

Among the most widely used inhibitors, amino acids have been employed to stop the corrosion of several metals, including nickel, copper, steel, iron, and aluminum. Their solubility in water, reversibility, non-toxicity, ease of synthesis, biodegradability, and affordability are the reasons behind their widespread application (Abdel-Karim and El-Shamy, 2022). Some of the amino acids that have been evaluated for corrosion inhibition include methionine, cysteine, lysine, arginine, glycine, and valine. Yeganeh *et al.* (2020) investigated how L-methionine affected stainless steel's potential to resist corrosion in a solution of sulphuric acid (H_2SO_4).

Gums are often categorized as a pathological reaction to damage to plants and are released from the tree's stem or root (Vaidya *et al.*, 2022). These are blends of long-chain polysaccharides that frequently yield arabinose, galactose, mannose, and glucuronic acid upon hydrolysis. In a sweet atmosphere in a saline solution, Palumbo *et al.* (2023) examined the impact of guar gum on the corrosion inhibition of N80 carbon steel.

Conclusions

The investigation of the anticorrosion characteristics of plant extracts in comparison to chemical substances shows that plant-based inhibitors have a great deal of promise as environmentally benign substitutes for traditional synthetic inhibitors. According to the research, certain plant extracts that are high in bioactive substances like tannins, flavonoids, and phenolics can successfully prevent corrosion by coating metal surfaces in layers of protection.

Despite the fact that synthesised chemical inhibitors are frequently quite efficient, their toxicity and environmental persistence may be hazardous to human health and the environment. On the other hand, plant extracts provide a greater biodegradability and less toxicity, making them a more ecologically friendly choice. It is essential to acknowledge that the efficacy of inhibitors derived from plants might differ based on the unique plant species, extraction techniques, and surrounding atmospheric conditions.

In order to maximize the beneficial effect of plant extracts as corrosion inhibitors, more research is required. This includes figuring out which plant species are the most effective, standardizing extraction procedures, and investigating potential synergistic effects with other natural or synthetic substances.

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