A REVIEW ON COMPARISON OF CHEMICALLY SYNTHESIZED AND GREEN SYNTHESIZED CORROSION INHIBITOR FOR METAL ALLOYS

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Abstract

The employment of environmentally friendly alternatives is gaining prominence in the sphere of engineering and research, to the development of the idea of green chemistry and sustainable development. Because of their natural and biological origin, plant extracts are attracting a lot of attention in modern corrosion inhibition systems (MCISs), which involve the retardation of corrosion metallic corrosion inhibition through proper designing, materials selection, and implementation of corrosion inhibitors. According to a review of the literature, a number of papers describing their anticorrosion action for metals and alloys have been published. Plant extracts include complex phytochemicals with electron-rich sites that interact strongly with metallic surfaces. These phytochemicals are frequently conjugated with a wide range of multiple bonds and polar functional groups. The purpose of this review article is to summaries a collection of recent important publications on plant extracts as corrosion inhibitors. Metals have traditionally been protected against corrosion by natural extracts. To test the efficacy of these extracts as corrosion inhibitors, electrochemical assays such as potentiodynamic polarisation, electrochemical impedance spectroscopy, and weight loss measurement are often employed. [1]

Paper Identification

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INTRODUCTION

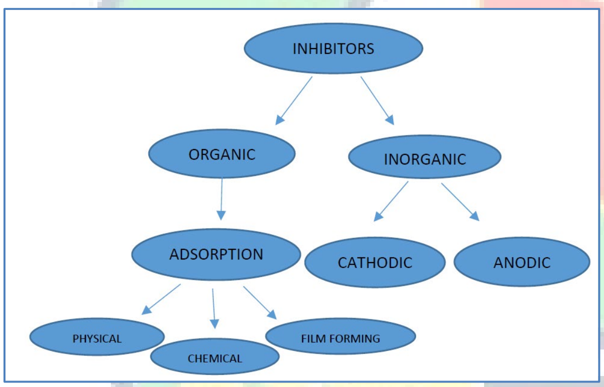
Due to the outstanding mechanical and electrical characteristics, metals are frequently employed in human activities. Preventive maintenance is a priority in order to keep these metals in the desired state. Corrosion is the most frequent unwanted process that causes metals to deteriorate. The electrochemical interaction of metals with the corrosive environment is the source of this natural process. Reactions between the metal surface and the corrosive media produce sulphides, oxides, and other compounds. Several methods of corrosion prevention have been developed among which use of synthetic corrosion inhibitors is one of the most popular and economic methods due to their ease of synthesis and application and high effectiveness at relatively low concentration. These organic compounds adsorb over the surface of metals and alloys through their heteroatoms and π-electrons and form protective surface barrier thereby protect metals from corrosive degradation. Because of their simplicity of synthesis and application, as well as their great efficacy at relatively low concentrations, synthetic corrosion inhibitors have become one of the most popular and cost-effective corrosion prevention techniques. Through their heteroatoms and -electrons, these organic compounds adsorb on the surface of metals and alloys, forming a protective surface barrier that protects metals from corrosive degradation. The usage of environmentally friendly alternatives is gaining attention in the world of engineering and research as the notion of green chemistry and sustainable development develops. Because of their natural and biological origin, plant extracts are attracting a lot of attention in modern corrosion inhibition systems (MCISs), which involve the retardation of corrosion metallic corrosion inhibition through proper design, materials selection, and implementation of corrosion inhibitor. Plant extracts include complex phytochemicals with electron-rich sites that interact strongly with metallic surfaces. The majority of previously described inhibitors are hazardous in nature, as they are made with toxic and costly solvents, reagents, and catalysts.[2-4] These processes result in the release of large amounts of chemicals, solvents, and catalysts (mostly metals) into the environment, which have a negative impact on soil and aquatic life Furthermore, the manufacturing of these compounds is linked to the creation of a number of undesirable byproducts .As a result, the idea of modern corrosion protection systems (MCPSs) emerged, which entails the use of environmentally acceptable alternatives that pose minimum health, environmental, and safety risks while providing reasonably good protection efficacy at low concentrations. Members of MCPSs include the use of nanomaterial (G, GO, and CNTs) and their composites with extremely strong anticorrosive activity. As a result, there are several environmentally acceptable alternatives available, such as natural polymers, Arabic gums, carbohydrates, amino acids, and their derivatives. [5-9]

GLOBAL IMPACT OF CORROSION

Corrosion is expected to cost the world economy $2.5 trillion, or 3.4 % of GDP (2013). It is predicted that by employing existing corrosion management methods, savings of between 15 and 35 % of the cost of corrosion might be obtained, equating to between US$375 and $875 billion annually on a worldwide scale, an enormous saving. Furthermore, these expenses do not usually cover personal safety or environmental repercussions. Corrosion's significant cost has been recognised for years; in 1949, Uhlig conducted a detailed analysis that found a cost of corrosion comparable to 2.5 %of US GDP. The fact that corrosion management saves money is a lesson that industry has learnt time and time again, sometimes too late and in the aftermath of disastrous catastrophes (e.g., accidents, failures, and loss of production). This study concludes that adopting a Corrosion Management System (CMS) and integrating it into an organization's overall management system is required to realize the full range of potential savings. It was also suggested that about 25-30% of the annual corrosion costs could be saved by means of optimum corrosion management practices. [10] There are several ways by which we can inhibit the corrosion. One of the approved techniques used to decrease or prevent corrosion is the use of inhibitors for the control of corrosion of metals and alloys in contact with harsh environments.

CORROSION INHIBITOR

Corrosion inhibitors are used extensively in industry to prevent corrosion. In order to reduce the metal's corrosion rate, a little amount of corrosion inhibitor is given to the corrosive medium (CR). By adsorbing on the metal's surface, corrosion inhibitors slow down the oxidation process. Inhibitors should be chosen in a way that is consistent with the system and does not alter its characteristics. Corrosion inhibitor is defined by NACE as any compound that decreases CR in corrosive medium when introduced in modest amounts. Corrosion inhibitors' efficacy is influenced by their molecular weight, size, and form.

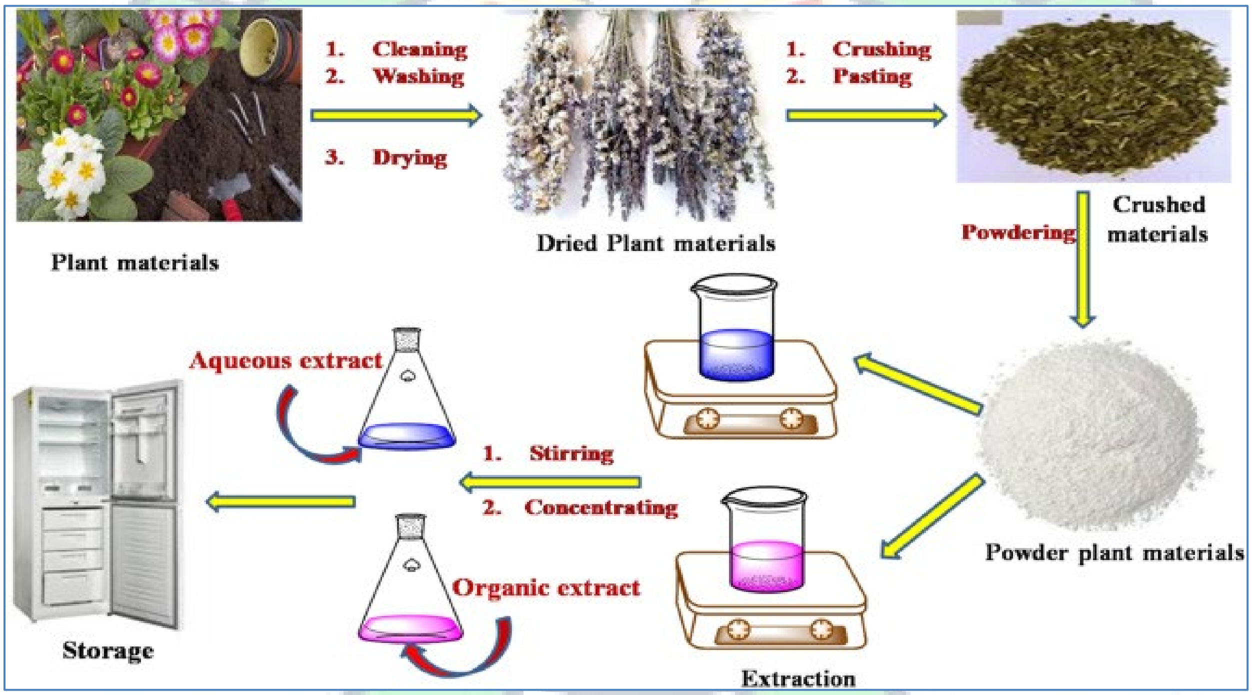


CHEMICALLY SYNTHESIZED INHBITORS

Chemically synthesized inhibitors are widely used in industry because of their wide temperature range, compatibility with covered compounds, water dissolvability, low cost, and low toxicity. These inhibitors provide a protective layer on the metal's surface that repels water and prevents corrosion. They include lone pairs of electrons in nitrogen, oxygen, sulphur and phosphorus as well as structural agglomerations containing –electrons that interact with metal and favour the adsorption process. Even while most synthetic organic inhibitors are expensive, they have a negative influence on the environment, offering a range of risks when discharged into a variety of streams. Due to the toxicity of these organic inhibitors, scientists are currently investigating the use of benign medicines or natural substances as alternatives. . In acid media, organic compounds containing N, O, or S groups, as well as organic compounds with bonds in their structures, are found to be effective inhibitors. The presence of functional groups in the inhibitor molecule, such as =NH, -N=N-, -CHO, R-OH, and C=C, as well as the steric factor ,aromaticity and electron density at the donor atoms, all influence the inhibitor molecule's adsorption over corroding metal surfaces. [11] The adsorption of organic molecules on metallic surfaces is thought to be the primary mechanism of corrosion prevention. The chemical composition and structure of the inhibitors, the nature of the metallic surface, and the acidity qualities of the medium in which the inhibitor-surface interaction occurs all play a role in the adsorption phenomenon. [12] Different organic inhibitors on the metal surface are inhibited by electrostatic attraction between charged inhibitor molecules, dipole-type contact between uncharged electron pairs between the inhibitor and the metal, electron-interaction with the metal, and a combination of the above. [13] Because of their capacity to form complexes with metal, heteroatoms such as nitrogen, oxygen, and aromatic structures in organic inhibitors aid in adsorption. [14] According to a review of the literature, several organic compounds have been utilized as inhibitors for various metals and alloys in various acid, neutral, and basic environments. A.S. Fouda et al. investigated the inhibition efficacy of 4-phenylthiazole derivatives on the corrosion of 304L stainless steel in 3M HCl and found that the percentage inhibition efficiency increases as the inhibitor concentration rises. Adsorption on the metal surface is thought to be responsible for the inhibitory activity of these 4-phenylthiazole derivative. [15] S.M.A. Hosseini et colleagues discovered that 1-methyl-3-pyridin-2-yl-thiourea inhibits mild steel corrosion in H_2SO_4 solution by altering the rate of both anodic dissolution and hydrogen evolution processes. [16] The influence of temperature on the efficacy of the corrosion inhibition process is explored by M. Bis-N, S-bidentate Schiff bases are discovered to work as mixed inhibitors for 304 stainless steel. The activation energy, pre-exponential factor, activation enthalpy and activation entropy are determined by Behpour et al. elucidate the corrosion inhibition mechanism. [17] S.A.M Refaey et al investigated the inhibitory property of 2-mercaptobenzoxazole on stainless steel samples (304L and 316L) in HCl and H_2SO_4, and discovered that inhibition was due to the formation of a very low soluble bis-benzoxazolyl disulfide (BBOD) layer and a compact Fe–MBO complex film on the electrode surface. [18] Electrochemical investigations reveal that 2, 5-disubstituted-1, 3, 4-oxadiazole reduces mild steel inmedium corrosion, according to F. Bentiss et al. F. Bentiss et al claim that 2, 5-disubstituted-1, 3, 4-oxadiazole reduces mild steel corrosion in acid media, and electrochemical investigations suggest that it also limits the cathodic process. The Langmuir adsorption isotherm governs inhibitor adsorption. [19] They came to the conclusion that cationic surfactants operate as anodic inhibitors, whereas quaternary ammonium salts act as mixed type inhibitors [20].Using potentiodynamic curves (PCM) and electrochemical impedance spectroscopy (EIS), G. Moretti et al investigated the inhibition of corrosion behaviour of ARMCO iron in a deaerated 0.5M H_2SO_4 by a Tryptamine as green inhibitor for 1-72 hours, concluding that Tryptamine adsorption followed the Bockris–Swinkels' isotherm and that it is chemisorbed on the iron surface . [21]

GREEN SYNTHESIZED INHIBITOR

Plant extracts are one of such alternatives to be used as environmental friendly alternative. Literature study showed that numerous plant parts extracts including bark, leave, fruit, peel, seed, root, flower and even entire plant extracts are widely used as corrosion inhibitors. Out of several extracts, leaves extracts generally showed reasonably better protection effectiveness at relatively low concentration. Leaves are the primary source of phytochemicals where their synthesis occurs in the presence of radiant energy, water and CO_2. The extracts can be categorized as aqueous and organic types. Both types of extracts are extensively prepared and used for different metals and



alloys in various electrolytic systems. Some examples of plant extracts which had been used as corrosion inhibitors are listed below:

The effects of ***Murraya koenigii*** leaf extract on mild steel corrosion in hydrochloric and sulphuric acid solutions were investigated utilising weight loss, electrochemical impedance spectroscopy (EIS), linear polarisation, and potentiodynamic polarisation methods. With increasing concentrations of the leaves extract, inhibition was observed to rise. The influence of temperature, immersion period, and acid concentration on mild steel corrosion behaviour in 1 M HCl and 0.5 M H_2SO_4 with extract addition was also investigated. Adsorption of inhibitor molecules on the metal surface was thought to be the mechanism of inhibition. The Langmuir adsorption isotherm governs the extraction's adsorption on a mild steel surface. For the inhibitory process, the activation energy and other thermodynamic parameters (Q, H, and S) were determined. The interaction between the inhibitor and the mild steel surface is evident in these thermodynamic characteristics. The findings suggest that M. koenigii leaf extract might be used as a mild steel corrosion inhibitor in hydrochloric and sulphuric acid environments. [22]

Atomic force microscopy AFM, Scanning electron microscope SEM, gravimetric measurements, electrochemical impendence spectroscopy (EIS), potentiodynamic polarisation techniques, ultraviolet–visible spectroscopy (UV–vis.) and Fourier-transform infrared spectroscopy (FTIR) were used to investigate the corrosion inhibition and adsorption behaviour of ***Ficus religiosa*** fruits extract for mild steel in 0.5 M H_2SO_4 solution. According to electrochemical analysis and gravimetric calculations, the fruits extract of Ficus religiosa has the highest inhibitory effectiveness of 92.26 % at 500 mg/L. The presence of key phytochemical components Serotonin Myricetin, and Campesterol in the extract of Ficus religiosa reduces mild steel corrosion in acidic conditions. The Langmuir adsorption isotherm is followed by this extract. Ficus religiosa can act as an efficient corrosion inhibitor for mild steel corrosion in 0.5 M H_2SO_4 due to the presence of heteroatoms and aromatic rings in the main components. [23]

In 1 M hydrochloric acid, Phyllanthus amarus leaf extract (PAE) was studied as a mild steel corrosion inhibitor. The inhibitory behaviour of PAE for the system under research was monitored using electrochemical impedance spectroscopy and potentiodynamic polarisation method at varied exposure times (1 h, 2 h) and temperatures (303 K, 308 K and 313 K). PAE's inhibitory capability was shown to increase when the concentration was increased. Inhibition effectiveness increased when the extract components became adsorbed on the metal surface, eventually reaching 95% at 303 K. The effectiveness of inhibition was harmed as the temperature rose. The inhibitory effectiveness of PAE was also demonstrated in weight loss trials conducted at varied exposure times. Computational simulations related to phyllanthin were performed to better understand the role of the main component in the extract's inhibitory potential. The influence of structural characteristics on phyllanthin's capacity to donate electrons is well explained by quantum chemical factors. The Langmuir adsorption isotherm was used to determine the adsorption mechanism of PAE. [24]

The impact of ***Diospyros kaki*** leaves extract on St37 steel corrosion in 0.1 M HCl solution was investigated in this study. The study employed electrochemical, chemical, and surface morphological screening methods (SEM, EDS, FTIR). D. kaki leaves extract is a good St37 steel inhibitor in HCl solution, according to the results. The highest examined concentration of the extract from PDP measures provided maximum inhibition effectiveness of 91%. According to the PDP results, the extract components mostly operate as a cathodic type inhibitor, preventing hydrogen ions from being reduced in the metal's cathodic area. The DEIS results demonstrate that the investigated systems are non-stationary, and that the adsorbed extract components are stable, especially when exposed for a long period. The results of EDAX, SEM, and FTIR confirm that components of D. kaki leaves extract were adsorbed on the surface of St3. [25]

Eco-friendly corrosion inhibitors have garnered a lot of interest in recent decades, owing to the growing environmental problems created by the widespread usage of traditional harmful corrosion inhibitors. Green inhibitors are made from low-cost, renewable materials that have excellent inhibitory efficiency while having little or no environmental effect. . Weight loss, electrochemical impedance, and potentiodynamic polarisation methods are all examples of advanced approaches that show green inhibitors are extremely effective. We study corrosion inhibition mechanisms rigorously and compare them to experimental results. The active adsorption of the inhibitor's molecules on the steel surface is caused by an abundance of - electrons of multiple bonds and heteroatoms in the form of polar functional groups. The adsorption and inhibition processes, as well as the efficacy of various groups (organic and inorganic) of green corrosion inhibitors for steels in hostile acid environments, particularly hydrochloric (HCl) and sulphuric acid (H_2SO_4), are discussed in this article. Future perspectives in this diverse subject are created and linked to global clean energy and manufacturing issues. [26]

Weight loss and electrochemical methods were used to examine the corrosion inhibitory effect of ***Justicia gendarussa*** extract (JGPE) on mild steel in 1 M HCl media. At 25 °C, 150 ppm JGPE provided a 93 % inhibition effectiveness. JGPE behaves as a mixed-type inhibitor, according to polarisation studies. The Nyquist plots revealed that when the concentration of JGPE rises, the charge transfer resistance rises and the double layer capacitance falls. The Langmuir isotherm is obeyed by JGPE. JGPE adsorption on mild steel surface was verified using AFM and ESCA. Finally, the adsorption and protective film forming effectiveness of JGPE inhibition were addressed. [27]

The primary goal of this study is to investigate the corrosion inhibitory effects of a mixture of praseodymium nitrate (PrN) and ***Urtica Dioica*** (UrDi) on mild steel in a sodium chloride solution. Thermogravimetric analysis/differential thermogravimetry (TGA/DTG), ultraviolet-visible (UV-Vis), and X-ray photoelectron spectroscopy (XPS) findings showed complex formation between Pr cations and UrDi (Pr-UrDi). The Pr- UrDi hybrid complex had a substantial impact on mild steel corrosion prevention in NaCl solution (with an inhibitory efficiency of around 94%), according to electrochemical findings. [28]

Researchers have recently focused their efforts on utilising ecologically friendly corrosion inhibitors derived from plant leaves to prevent steel structures from corrosion in acidic conditions. The goal of this research is to see if ***morus alba pendula*** leaves extract (MAPLE) can be used as a novel green corrosion inhibitor for carbon steel in a 1 M HCl solution at various doses (0.1–0.4 g/L) and temperatures (25–60 °C). The impact of adding potassium iodide (KI) to the MAPLE was also investigated. Electrochemical impedance spectroscopy (EIS) and polarisation tests were used to investigate the electrochemical process. Surface characterizations on the steel panel were also performed. UV–visible analysis was used to investigate inhibitor adsorption/desorption in the 1 M solution. In the presence of 0.4 g/L MAPLE at room temperature (25 °C), electrochemical tests indicated a high inhibitory effectiveness of 93%. With an optimal dose of 0.4 g/L MAPLE+ 10 mm KI, KI and MAPLE showed a synergistic effect. In the presence of KI, extract adsorption on the steel surface resulted in a 96 percent inhibitory effectiveness. The MAPLE's strong inhibitory effectiveness in 1 M HCl solution on the first day is due to the presence of flavonoids such morusin, kuwanonC, and kuwanonG, as well as phenolic acids and pyrrole alkaloids. [29]

Using gravimetric, ac impedance, polarisation, and scanning electron microscopy (SEM) methods, ***Euphorbia falcata*** L. extract (EFE) was studied as an environmentally friendly corrosion inhibitor of carbon steel in 1 M HCl. The findings of the experiments demonstrate that EFE is an effective corrosion inhibitor, and that the protection efficacy improves as the EEF concentration rises. The weight loss and ac impedance experiments yielded results that were quite consistent. The frequency distribution of the capacitance was revealed by impedance experimental data, which was simulated as a constant phase element. EFE is a mixed inhibitor, according to polarisation curves. The adsorption of the EFE molecule was thought to be the mechanism for corrosion inhibition. [30]

Using gravimetric, electrochemical impedance spectroscopy (EIS), and potentiodynamic polarisation methods, the adsorption and corrosion inhibitory impact of aqueous extracts of ***Punica granatum*** (PNG) on mild steel in 1 M HCl and 0.5 M H_2SO_4 at 30 (1 C was studied. The results of the experiments indicated that PNG prevented corrosion in both acid and alkaline conditions. The extract organic matter was adsorbed on the metal/solution interface, according to impedance measurements, whereas polarisation data indicate that the extract acted mostly as a mixed-type inhibitor. In the context of the project, a theoretical investigation of the adsorption behaviour of some of the components of crude extracts was carried out. [31]

In a 1M HCl media, alkaloid extracts of ***Ochrosia oppositifolia*** leaves (OOL) and bark (OOB), as well as Isoreserpiline (ISR), the main alkaloid isolated from OOL and OOB, were examined as possible mild steel (MS) corrosion inhibitors. Electrochemical methods (potentiodynamic polarisation tests and electrochemical impedance - EIS) and scanning electron microscopy were used to investigate the inhibitory effects of these phytoconstituents (SEM). The results showed that these green inhibitors significantly decreased the rate of corrosion. These inhibitors reduced corrosion current densities through a mixed mode mechanism, according to polarisation studies. Equivalent was used to evaluate EIS data. [32]

Weight loss and electrochemical techniques were used to examine the corrosion inhibition effect of date palm ***Phoenix dactylifera*** seed extracts for mild steel in 1 M HCl and 0.5 M H_2SO_4 solutions. The effectiveness of inhibition rose when the extract concentration was increased, but reduced as the temperature was raised. In 1 M HCl and 0.5 M H_2SO_4, extract concentrations of 2.5 and 1.5 g/L provided the highest inhibitory efficiency. In both acidic and alkaline media, the immersion period was found to have an effect on corrosion inhibition. The extract acts as a mixed inhibitor, influencing both the anodic and cathodic partial reactions of the corrosive process, according to polarisation curves. [33]

Using electrochemical impedance spectroscopy, potentiodynamic polarisation measurement, scanning electron microscopy (SEM), and Fourier transform infrared (FTIR) analysis, the alkaloid content of the leaves and stem bark of the ***Xylopia ferruginea*** plant was isolated and tested for its anticorrosion potential on mild steel corrosion in a hydrochloric acid medium. The findings of the experiments show that the plant extract has a strong anticorrosion capability. The polarisation investigation demonstrates that the plant extract has a mixed mode of action. The development of a protective layer over the mild steel surface is demonstrated by SEM pictures, and the FTIR research backs this up. [34]

Using gravimetric and electrochemical methods, the inhibitory effects of ***Kimbiolongo Extract*** (KE) on the corrosion rate of mild steel (MS) in 1.0 HCl solutions were studied (potentiodynamic polarisation measurements and electrochemical impedance spectroscopy, EIS). These green inhibitors substantially decreased the rate of corrosion, according to the findings. The results revealed that inhibitory effectiveness rises with concentration, with a maximum value at 100 ppm. The corrosion current densities were reduced via a mixed-mode process, according to polarisation studies. The Langmuir adsorption isotherm governs the adsorption of this inhibitor on steel surfaces. [35]

Hydrodistillation was used to extract essential oil from ***Thymus algeriensis*** aerial parts, which was then evaluated using GC and GC/MS. There were 44 components found in the oil, accounting for 90.2 percent of the total, with borneol (28 %), camphene (20.9 %), and camphre (15.7 %) being the most prominent. This essential oil (EOTA) was tested for its ability to inhibit mild steel corrosion in a 1.0 M HCl solution. Chemical (weight loss method) and electrochemical approaches were used to test the effectiveness of plant extracts as inhibitors (potentiodynamic polarisation and electrochemical impedance spectroscopy). In the temperature range of 308-343 K, the influence of temperature on the corrosion behaviour of mild steel in 1.0 M HCl with addition of plant extracts was investigated. From experimental gravimetric data, the adsorption and kinetic parameters for the mild steel/EOTA/1.0 M HCl system were computed, and the findings were interpreted. J EOTA operates as a mixed-type inhibitor, according to polarisation studies. The Nyquist plots revealed that when EOTA concentration rises, charge transfer resistance rises and double layer capacitance falls. The Langmuir adsorption isotherm is obeyed by EOTA. [36]

Environmental awareness prompted appropriate changes. Over the last decade, there has been a significant advancement in corrosion avoidance technologies. Plant Extracts are a unique category among them, since they include a lot of information. Phytochemicals are being investigated as corrosion inhibitors in place of hazardous synthetic materials, different electrolytic media ***Mangifera indica*** L. is the most abundant tropical plant here. Leaf The antioxidant activity of (MIL) extract was tested. In a concentration of 3.5 wt%, it is used to prevent corrosion in commercial steel. The presence of NaCl. A high-polyphenol source was made available. At the metal electrolyte interface, an insoluble organometallic complex forms between metal ions and functional groups in antioxidants, preventing corrosion. To produce bio-extract containing epoxy coating on steel, a new easy method is used. In epoxy coating, a MIL-precipitated amorphous silica hybrid is used. The created coating has a remarkable corrosion prevention effectiveness of 99 percent, according to electrochemical measurements. As a result, the current findings show a new, ecologically friendly, and effective corrosion inhibitor for steel protection in saline conditions. [37]

A novel green corrosion inhibitor for mild steel in acidic medium was prepared using castor oil, which is a cheap and environmentally friendly source**. *Castor oil***-based corrosion inhibitor (COCI) is designed to overcome two major challenges of corrosion inhibitors: poor performance at high temperatures and low biodegradability. COCI functioned as a mixed type inhibitor, with chemisorption being the mode of adsorption on the mild steel surface. The results show that the COCI has a significant capacity to inhibit acidic corrosion at all concentrations investigated, especially at high temperatures. Given that numerous studies have indicated that rising temperature reduces the performance of corrosion inhibitors, this study found that not only did COCI's inhibition efficiency not decrease at higher temperatures, but it also showed good performance at 80 °C. [38]

Using the polarisation approach, the aqueous extract of ***henna lawsonia*** leaves is evaluated as a corrosion inhibitor of C-steel, nickel, and zinc in acidic, neutral, and alkaline solutions. In all of the tested media, the extract was shown to be an excellent corrosion inhibitor for the three electrodes. As the concentration of extract supplied rises, the effectiveness of inhibition increases. The degree of inhibition is determined by the composition of the metal and the medium. The inhibitory effectiveness of C-steel and nickel rises in the following order: alkaline neutral acid, whereas that of zinc increases in the following order: acid alkaline neutral. The extract has a dual inhibitory effect. In view of lawsonia molecule adsorption on the metal surface, the extract's inhibitory effect is addressed. The Langmuir adsorption isotherm was found to be followed by this adsorption in all investigated systems. Additional corrosion prevention mechanisms for C-steel and nickel include the creation of complexes between metal cations and lawsone. [39]

The corrosion behaviour of copper in aerated 0.1 mol L1 H_2SO_4 solutions in the presence of three xanthine derivatives with comparable chemical structures was investigated using electrochemical and impedance measurements. Copper corrosion rates increased in the presence of theophylline and theobromine, but decreased in the presence of caffeine. Potentiodynamic polarisation, electrochemical impedance spectroscopy (EIS), contact angle measurements, scanning electron microscopy (SEM), energy dispersive X-ray spectroscopy (EDS), and fluorescence microscopy were used to investigate the adsorption and inhibitory effect of caffeine on copper surfaces in aerated 0.1 mol L1 H_2SO_4 solutions. Caffeine concentrations ranging from 1.0 to 10.0 m mol L1 improved corrosion inhibition efficiency. Furthermore, surface examination (SEM, EDS, and fluorescence) and EIS findings obtained at the open-circuit voltage clearly confirmed the adsorption of the organic molecule onto the copper electrode. The development of a hydrophobic protective layer was indicated by contact angle measurements. This layer, which covers up to 72 % of the entire active surface, functions as a protective barrier and inhibits metal, water, and oxygen molecules from interacting.[40]

The weight loss technique, potentiodynamic polarisation, and linear polarisation methods were used to investigate the effect of a 30% ethanolic solution of ***Laurus nobilis*** L. oil on the corrosion inhibition of aluminium and AA5754 aluminium alloy in a 3% NaCl solution. The addition of this oil at quantities ranging from 10 ppm to 50 ppm causes cathodic current densities to drop, according to polarisation studies. The findings show that the AA5754 alloy has higher corrosion resistance in a 3 percent NaCl solution than pure aluminium, and that the oil tested had a better inhibitory effect on pure aluminium corrosion. The active molecules from L. nobilis L. oil completely prevent pitting corrosion on the specimen surfaces, according to surface examination using SEM methods.[41]

Electrochemical impedance spectra (EIS) and potentiodynamic polarisation curves are used to assess the performance of orange peel extracts (OPE) in preventing the corrosion of magnesium alloys. At a very low concentration of 0.030 g/L, OPE would be an efficient inhibitor, with an efficiency of 85.7 %. The inhibitory effect of three pure components found in OPE is inferior to or comparable to that of OPE, but pure compounds are too expensive to be used. By immersing the magnesium surface in OPE, a protective self-assembly film would be formed. Scanning electron microscopy (SEM), atomic force microscopy (AFM), and X-ray diffraction (XRD) are all used to characterize structure. With both chemical and physical interactions, OPE adsorption on magnesium surfaces follows the Langmuir adsorption rule. Density functional theory is used to calculate the interaction between three pure chemicals and magnesium alloys (DFT). Furthermore, the potential inhibitory mechanism is derived from the aforesaid findings as well as the FTIR data. In this study, a low-cost, environmentally friendly inhibitor is investigated, which may be used to replace costly inhibitors with comparable or superior performance. [42]

Corrosion is one of the most pressing issues in today's world, as it generates a slew of economic issues for building and plant. As a result, several studies are being conducted in various sectors in order to decrease losses, particularly in the oil extraction technique, because the equipment used in this field is quite expensive, and corrosion poses a major problem.

Fresh olive leaves were utilised as a natural corrosion inhibitor in this investigation to preserve steel tubing and equipment used in the oil extraction field, at temperatures (25°C and 45°C), in a medium solution produced at the following concentration to simulate the oil extraction field environment.

The corrosion rate of steel samples was measured using a potentiostat device with a calomel electrode as a reference. The corrosion rate of steel samples was measured using a potentiostat device with a reference of.19.2 % sodium chloride (NaCl), 8% calcium chloride (CaCl), 1.08 % magnesium chloride (MgCl), and saturated with CO_2 gas. The goal of this research is to simulate and analyse the corrosion behaviour of fresh olive leaves as well as the amount of inhibition.

The fresh ***olive*** leaf extract was shown to be an efficient inhibitor material. At 25°C and 45°C, fresh olive leaves extraction inhibitor has a low corrosion rate, and the rate of corrosion increases as the temperature of the oil extraction solution rises.[43]

COMPARISON OF CHEMICALLY SYNTHESIED INHIBITOR OVER GREEN SYNTHESIED INHIBITOR

Because of the toxicity and difficulties in disposal, many inorganic inhibitors, particularly those containing phosphate, chromate, and other heavy metals, are now being gradually restricted or banned by various environmental regulations, particularly in the marine industry, where aquatic life is at risk [44]. Synthetic organic inhibitors have also been widely used, although their toxicity and high manufacturing costs have hampered their usage. This has encouraged researchers to look into other areas in order to develop green corrosion inhibitors that are environmentally benign, inexpensive, and biodegradable to replace inorganic and synthetic organic inhibitors. [45] Plant materials are excellent ecological alternatives to harmful corrosion inhibitors. Plant extracts are a good option to replace the expensive and hazardous conventional synthetic corrosion inhibitors because of their lower environmental risk, cheaper cost, widespread availability, and excellent corrosion inhibition efficacy. Plant extracts are thought to be a significant source of naturally produced chemical compounds that may be extracted using low-cost techniques. These natural extracts are similar to synthetic organic inhibitors and have been shown to perform just as well. This will help to promote sustainable and environmentally friendly production. [46].

CONCLUSION

Due to the diversity of the structures of plant materials, many extracts of common plants have been used as corrosion inhibitors for materials in pickling and cleaning processes. Plant materials contain proteins, polysaccharides, polycarboxylic acids, tannin, alkaloids, and so forth. These compounds are potential acid corrosion inhibitors for many metals. The cost of using green inhibitors is very low when compared to that of organic inhibitors which require a lot of chemicals and also time for its preparation. Chemical inhibitors are more expensive and cause more hazard effects. Nowadays due to strict environmental legislation, emphasis is being focused on usage of natural products that are corrosion inhibitor. The recent and growing trend is using plant extracts as corrosion inhibitor. Recently, many plant extracts have been reported as effective corrosion inhibitors within India and outside India. The purpose of this review article is to summarize, in a brief manner, a compilation of recent prominent papers on utilizing plant extracts as sustainable and green corrosion inhibitors.

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