

# Organic Corrosion Inhibitors for Aluminum-Based Alloys –A Review

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**Abstract:** This review aims to summarize the research published in the last two decades on using organic compounds as corrosion inhibitors for aluminum and its alloys in acidic solutions. The focus is on HCl and H<sub>2</sub>SO<sub>4</sub> solutions due to their extensive use in different applications, such as chemical and electrochemical etching, acid cleaning, anodizing and acid pickling of aluminum. Other acids are also reviewed. The inhibition effectiveness of numerous organic compounds and their possible inhibition type and mechanism are also discussed. Electrochemistry is mainly used to investigate inhibitor performance.

**Keywords:** aluminum; acid solutions; alloy; acid corrosion; acid inhibition.

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## 1. Introduction

Aluminum is usually considered the second most important metal, after iron. Aluminum is the third most common metal in the 'earth's crust and the fourth most common metal in general. The special mechanical properties of aluminum are related to its low density (2.7 g/cm<sup>3</sup>), which is slightly less than one-third of the density of common steel. Therefore, aluminum and its alloys provide a high ratio of strength to weight. Moreover, they have high electrical and thermal conductivity and can be easily treated with a large number of metal machining techniques. In addition, recycling and reusing Aluminium and Aluminium alloys is complete, which means that the recycled metal and products obtained are comparable in quality and characteristics to those before recycling [1]. Finally, the price of aluminum and its alloys is relatively low. All these properties make aluminum and its alloys one of the most commonly used metals in a broad range of applications, including transport, building, packaging, electrical parts, the automotive industry, household appliances, etc.[2,3].

Aluminum is highly corrosion resistant to the atmosphere and in aqueous solutions due to the formation of an oxide layer, which does not allow further oxidation of the metal. However, aluminum becomes highly susceptible to corrosion in certain environments, such as an acidic medium. Different methods of mitigating corrosion are being sought. The use of

corrosion inhibitors for closed system applications is one of the most effective and practical corrosion protection methods.

The primary focus of this review is to summarise the research work presented in the past two decades related to the use of organic compounds as corrosion inhibitors for aluminum and its alloys in acidic solutions. In particular, acidic solutions, HCl and H<sub>2</sub>SO<sub>4</sub>, are widely used in several processes, including acid cleaning, chemical or electrochemical etching, acid pickling, and anodizing of aluminum [4,5]. To the best of our knowledge, the last review article addressing organic corrosion inhibitors was presented by Jayalakshmi and Muralidharan in 1997. Therefore, this review only discusses research work published after 1998.

## 2. Materials and Methods

### 2.1. Aluminum alloys.

Aluminum alloys are generally divided into two main groups, alloys that are non-heat-treatable (1xxx, 3xxx, 4xxx, and 5xxx series) and alloys that are heat treatable (2xxx, 6xxx, and 7xxx series). The non-heat-treatable aluminum alloys are generally considered to have a high resistance to general corrosion [6-8].

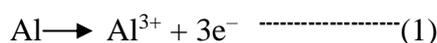
Alloys of the 1xxx series are technically pure and contain at least 99 wt% aluminum. They have lower strength compared to other aluminum alloys. Alloys of the 3xxx series (Al-Mn-Mg and Al-Mn alloys) have similar characteristics as the 1xxx series but with higher strength. Alloys of the 4xxx series (Al-Si alloys) have lower strength and are used for brazing and welding products and cladding in architectural products. Silicon has a very small effect on the corrosion behavior of these alloys. Alloys of the 5xxx series (Al-Mg) have the highest strength among the non-heat treatable aluminum alloys. In comparison with others, these alloys are more resistant to general corrosion in weakly alkaline media. They are mainly used for decorative building elements.

Among the heat-treatable alloys, the alloys of the 6xxx series (Al-Mg<sub>2</sub>Si) have moderate strength compared to other aluminum alloys, but they have general corrosion resistance similar to non-heat-treatable alloys. Alloys of the 6xxx series are very often used in products for the automotive industry. Alloys of the 7xxx series, which do not contain copper, are also resistant to general corrosion.

Other non-heat-treatable alloys have a significantly lower resistance to general corrosion. This applies to alloys of the 2xxx series (Al-Cu, Al-Cu-Mg, and Al-Cu-Si-Mg) and alloys of the 7xxx series (Al-Zn- Mg-Cu) that contain copper. The strength of these alloys is significantly higher due to the presence of copper, making them suitable for use in aerospace technology applications.

### 2.2. Corrosion of aluminum.

The corrosion resistance of ultra-pure aluminum is higher than that of aluminum, which contains a certain degree of other elements. The high corrosion resistance of aluminum is due to the formation of an oxide layer on the Aluminium surface. The material's passivity can change with temperature, the previous passivation process of the metal, and the presence of substances, which can form Aluminium-soluble complexes or insoluble salts. In an acidic medium, the aluminum dissolves into Al<sup>3+</sup>, according to the following equation:



Or, in general, the oxide layer is dissolved, and the resulting  $\text{Al}^{3+}$  ions are formed.



The most important feature of Aluminium corrosion susceptibility is forming an oxide layer that strongly binds to its surface. The thickness of the oxide layer formed in the air at room temperature is about 5–10 nm. The first layer is a compact amorphous protective layer of oxide, which acts as a barrier. This protective barrier is formed on the Aluminium surface within milliseconds of exposure to air. A thicker porous layer is formed on top of this inner layer. The chemical properties of these oxides affect the corrosion properties of aluminum and its alloys [9,10].

Aluminum and its alloys often have a more negative corrosion potential than many metals and alloys. Therefore, the electrical contact of Aluminium or Aluminium alloys with other metals with a significantly higher corrosion potential in a certain medium would result in galvanic corrosion [11,12]. Another serious type of Aluminium corrosion is intergranular corrosion. This type of corrosion spreads at grain boundaries. Crystal grains are not affected as they act as a cathode, while the grain boundaries of a corrodible material act as the anode. Exfoliation is a special form of intergranular corrosion. It can take place along grain boundaries. Corrosion products that form in the crystal grain boundaries can cause friction between the grain boundaries and, consequently, peeling, swelling, and lifting layers of material. Exfoliation occurs particularly in the products in which the metal is used in thin layers or plates. Another serious corrosion type of aluminum is pitting corrosion, which is especially dependent on the alloy type and corrosive medium. This type of corrosion will occur already after a few weeks of permanent contact of aluminum (or an alloy of aluminum) with a certain solution. This type of corrosion is especially frequent in chloride solutions.

### 2.3. Corrosion protection.

There are several methods to protect aluminum and its alloys, among which the anodizing process, conversion coatings, paints, organic coatings, and corrosion inhibitors are found to be the most effective.

Anodising is an electrochemical process to increase the thickness of Aluminium oxide, where Aluminium metallic material is connected as an anode in the electrolytic cell. The anodized Oxide layer is thus thicker (5–30  $\mu\text{m}$ ) than the natural oxide layer [13].

Conversion coating consists of poorly soluble phosphate or chromium oxides, which are tightly bound to the surface of aluminum or its alloys [14]. These coatings affect the appearance, corrosion potential, electrical resistance, and other surface properties. Conversion coatings are formed via a chemical oxidation-reduction process on the metal surface. However, the drawback of these coatings and the accompanying procedures is their negative environmental impact. Therefore, in recent years increasing interest has been shown in conversion coatings containing cerium and metallic ions or their combination [15].

As mentioned above, another corrosion protection method is employing organic coatings. Before applying the organic coating, the Aluminium surface should be cleaned and prepared. The process consists of degreasing the surface, removing the existing oxide layer, and applying the base layer and the primer: the surface cleaning and treatment influence these coatings' adhesion and anti-corrosion properties. The final layer is selected depending on the

environmental conditions in which the product will be used. The use of organic-inorganic coatings in protecting aluminum and its alloys has also been studied [16].

#### 2.4. Corrosion inhibitors.

Corrosion inhibitors modify the metal surface by forming insoluble compounds with aluminum or by forming a protective surface layer. Based on the electrochemical mechanism of action, the inhibitors can be classified as mixed-type inhibitors (inhibiting both cathodic and anodic reactions of the corrosion couple), anodic-type inhibitors (inhibiting the anodic reaction), or cathodic-type inhibitors (inhibiting the cathodic reaction). Inhibitors may bind on the surface of the metal by chemisorption or physisorption. They are mainly used to protect aluminum in closed systems, such as cooling systems in car engines, solar cells, etc.; of particular importance is the proper choice of an inhibitor according to the environment that the aluminum is exposed to [17,18] Chromates, nitrates, molybdates, tungstates, phosphates, and hydrogen phosphates are among the most tested inorganic inhibitors in the acidic corrosion of aluminum and its alloys. Organic compounds have found great use as corrosion inhibitors for metals in general and aluminum and its alloys in particular. These compounds adsorb on the metal surface through the heteroatoms N, S, O, and P, serving as active adsorption centers. The surface layer formed as a result of the adsorption protects the metal from further attack from the corrosive environment [19].

#### 2.5. Organic corrosion inhibitors.

In the following text, we discuss the research work performed in the last two decades on inhibiting the acidic corrosion of aluminum and its alloys by organic corrosion inhibitors. The use of the corrosion inhibitors is presented based on the acid type, and within these sections, we follow the trend of decreasing the content of aluminum in the material. The minimum and maximum reported values of inhibition effectiveness are given. The aluminum or aluminum alloy type, corrosive medium (pH is given if reported), corrosion inhibitor and its concentration range, and corrosion testing methods. As given below, weight loss (WL), linear sweep voltammetry (LSV) (including polarisation resistance ( $R_p$ ), potentiodynamic (PDP), potentiostatic (PSP), and galvanostatic (GSP) polarisation, and electrochemical impedance spectroscopy (EIS) were among the most common methods used for evaluating corrosion inhibition effectiveness. Aluminum alloys with different chemical compositions were investigated. In most cases, the authors do not designate the alloy type tested. In addition, a considerable change in the percentage of the elements can sometimes be observed for alloys with the same designation obtained from different manufacturers [20].

### 3. Results and Discussion

#### 3.1. Organic corrosion inhibitors in HCl solution.

Most organic compounds used as corrosion inhibitors were tested in an HCl solution, which causes significant corrosion and therefore needs to be inhibited. A quite broad concentration range of HCl was tested, varying between 0.1–5 M.

Dibetsoe *et al.* [21] investigated seven macrocyclic compounds comprising four phthalocyanines (Pcs), i.e., 1, 4, 8, 11, 15, 18, 22, 25-octabutoxy-29H, 31 Hphthalocyanine (Pc1), 2, 3, 9, 10, 16, 17, 23, 24-octakis(octyloxy)-29-H,31-H-phthalocyanine (Pc2), 9, 16, 23-

tetratert-butyl- 29H, 31H-phthalocyanine (Pc3) and 29H, 31H-phthalocyanine (Pc4) and three naphthalocyanines, i.e., 5, 9, 14, 18, 23, 27, 32, 36-octabutoxy-2,3-naphthalocyanine (nPc1), 2, 11, 20, 29-tetra-tert-butyl-2,3-naphthalocyanine (nPc2) and 2,3-naphthalocyanine (nP3), as corrosion inhibitors for 100% aluminum in 1 M HCl solution, using the WL and PDP techniques. The inhibition effectiveness generally increased with increasing concentration of the compounds added. Pc1 and nPc3 gave the highest inhibition effectiveness at the concentrations studied. There is a non-uniform trend of the inhibition effectiveness at higher concentrations, at all temperatures, but especially at higher temperatures. The authors attributed this to the varying aggregative interactions of the inhibitor molecules, which at higher concentrations and temperatures, favor the unsubstituted Pc4 more than the substituted Pc2 and Pc3 compounds. In addition, the lower inhibition effectiveness of Pc4 is due to the absence of electron-donating alkyl or alkoxy substituents. The inhibition effectiveness, in general, decreased with an increase in temperature. The inhibition effectiveness was found to increase further with the addition of KI due to the synergistic effect. The authors reported that these compounds have a mixed-type (both physisorption and chemisorption) adsorption mechanism. They discussed the ability of these compounds to protect aluminum in terms of their ability to donate/accept electrons to/from the appropriate p- and/or d-orbitals of the metal. Lashgari and Malek studied the ability of phenol to inhibit the corrosion of pure aluminum in 0.5 M HCl and 0.5 M NaOH solutions at 25–45°C. The authors reported substantially higher corrosion rates for aluminum in the alkaline media than the acidic ones. Moreover, they claimed that phenol physisorbed on the aluminum surface in an acidic environment while suggesting chemisorption in alkaline media. PDP measurements showed that phenol is a mixed-type inhibitor and that inhibition effectiveness decreased with increasing temperature [22].

Zohreh *et al.* [23] investigated the inhibition effect of benzene-1,2,4,5- tetracarboxylic dianhydride (PMDH) as a corrosion inhibitor for 99.999% aluminum in 1 M HCl solution at 25–55°C, using the polarisation and EIS techniques. The inhibition effectiveness of this compound increased with increasing compound concentration at all fixed temperatures. The authors reported that the inhibition effectiveness decreased with increasing temperature and attributed that to the higher desorption of the inhibitor from the aluminum surface. Polarisation measurements showed that PMDH acted as a mixed-type inhibitor. Based on the thermodynamic data, the authors suggested physisorption as the possible adsorption mechanism for PMDH.

Khaled and Amin [24] tested the inhibition effect of Imidazole (IM) and two IM derivatives, i.e., 2-amino-4,5-imidazole carbonitril (AID) and 5-amino-4-imidazolecarboxamide (AIC) in the corrosion of 99.999% aluminum in 1 M HCl solution at 25°C, using the WL, Tafel extrapolation and EIS techniques. The inhibition effect of all three compounds increased with increasing compound concentration and followed the order AID > AIC > IM. Polarisation curves showed that these compounds acted mainly as cathodic-type inhibitors. The authors concluded that the inhibition action of these compounds is because they form a film on the aluminum surface by physisorption followed by chemisorption, further enhanced via hydrogen bond formation.

Zapata-Loría and Pech-Canul [25] studied the inhibition effectiveness of glutamic acid as a corrosion inhibitor for 99.99% aluminum in 0.1 M HCl solution at 25°C, using the Rp, PDP, and EIS techniques. The inhibition effectiveness of glutamic acid increased with increasing concentration. Based on the PDP measurements, the authors reported that glutamic acid acted as a mixed-type inhibitor. The authors confirmed the adsorption of the compound

on the aluminum surface with a decrease in the double-layer capacitance. Based on the X-ray photoelectron spectroscopy (XPS) analysis, the authors reported the presence of amino (ionized  $\text{-NH}^+$  and neutral  $\text{-NH}$ ) and carboxylic groups in the adsorbed layer. They concluded that glutamic acid was chemisorbed, forming a stable chelate on the aluminum surface.

El-Haddad and Fouda [26] reported using imidazole and 2-methyl imidazole as corrosion inhibitors for 99.99% aluminum in 0.5 M HCl solution at 30 °C, using the PDP, EIS, and EFM techniques. PDP curves showed that Imidazole derivatives are mixed-type inhibitors. The inhibition effectiveness increased with increasing inhibitor concentration, methyl Imidazole being the most effective. The inhibition effect of these compounds is due to the formation of a film on the aluminum surface that inhibits metal dissolution. The authors showed through quantum chemical calculations that Imidazole derivatives could adsorb on the aluminum surface through the nitrogen atoms as well as the  $\pi$ -electrons in the Imidazole ring.

Maayta and Al-Rawashdeh [27] studied the corrosion of 99.95% aluminum in 0.2 and 0.5 M HCl solutions in the presence of sulfonic acid (SA), sodium cumene sulfonate (SCS), and sodium alkyl sulfate (SAS), using the WL and PSP techniques. The inhibition effect of all three compounds increased with increasing inhibitor concentration and decreasing acid concentration and temperature.

Al-Rawashdeh and Maayta [28] investigated the inhibition performance of the cationic surfactant cetyl trimethyl ammonium chloride (CTAC) in the corrosion of 99.95% aluminum in 0.2 M and 0.5 M HCl solutions at 30–60 °C, using the WL and PDP techniques. The inhibition effectiveness increased with increasing surfactant concentration and decreased with increasing acid concentration. The increase in temperature decreased the inhibition effectiveness, and the authors attributed that to the increase in aluminum dissolution at higher temperatures. Moreover, according to the authors, this behavior, combined with the decrease in surface coverage with increasing temperature, suggested a weak interaction between the surfactant molecules and the aluminum surface. The formation of a multilayer CTAC on the aluminum surface was also proposed. Based on the measured Tafel slope values obtained, the authors concluded that CTAC controls the cathodic reaction.

Hazazi and Abdallah [29] investigated the influence of three pyrazole compounds, i.e., sodium salt of 2-((4-(3-methoxypropoxy)-3-methylpyridin-2-yl)methylsulfinyl)-1*H*-Benzimidazole (Omeprazole), Sodium salt of 1-(2-((3,4-dimethoxypyridin-2-yl)methylsulfinyl)-1*H*-benzimidazol-6-yl)-2,2-difluoroethanone Pantoprazole sodium sesquihydrate, 5-methoxy-2-((4-methoxy-3,5-dimethylpyridin-2-yl)methylsulfinyl)-1*H*-benzimidazole,(Rabeprazolesodium), in the corrosion of 99.99% aluminum in 1 M HCl solution at 30–60 °C. The inhibition effectiveness increased with increasing inhibitor concentration and with decreasing temperature. The order of inhibition effectiveness is Rabeprazole sodium > Pantoprazole sodium sesquihydrate > Omeprazole. The polarization measurements showed that these compounds act as mixed-type inhibitors. EIS indicated that a charge transfer process controls the corrosion reaction. The authors reported that the inhibition action of pyrazole compounds is due to the formation of an insoluble complex adsorbed on the aluminum surface.

Zhang and Hua [30] tested three newly synthesized alkyimidazolium ionic liquids, i.e., 1-butyl-3-methylimidazolium chloride (BMIC), 1-hexyl-3-methylimidazolium chloride (HMIC), and 1-octyl-3-methylimidazolium chloride (OMIC), as corrosion inhibitors for 99.95% aluminum in 1 M HCl solution at 30 °C, using the WL, PDP and EIS techniques. The authors reported that the inhibitor effectiveness followed the order OMIC > HMIC > BMIC.

The inhibition effectiveness of these compounds increased with increasing inhibitor concentration but decreased with increasing temperature. PDP measurements showed that all of the inhibitors acted as mixed-type inhibitors. The authors concluded that the inhibition effect of these compounds is mainly because they physisorbed on the aluminum surface.

El-Etre studied the performance of vanillin, i.e., 4-hydroxy-3-methoxy benzaldehyde, as an inhibitor in the corrosion of 99.99% aluminum in 5 M HCl solution at 30°C, using the WL, thermometry, HE, and PSP techniques. Vanillin was first dissolved in a 20/80 ethyl alcohol-water mixture and then added to the acid. The inhibition effectiveness increased with increasing concentration of vanillin. PSP measurements showed that vanillin affects both anodic and cathodic reactions, acting as a mixed-type inhibitor. The authors concluded that this compound adsorbed on the aluminum surface through its structure's active centers (carbonyl, methoxy, and hydroxyl groups).

Umoren and Solomon [31] reported that polyacrylamide was an efficient corrosion inhibitor for 99.91% aluminum in 0.5 M HCl solution at 30 and 60 °C, using the WL, HE, and thermometric techniques. The inhibition effectiveness increased with increasing polyacrylamide concentration but decreased with increasing temperature. A synergistic effect was observed when KBr and KI were added, KI being the most effective. The authors proposed physisorption as the possible mechanism for the adsorption of polyacrylamide.

Amira Ezzat *et al.* [32] reported that Plant *Pulicaria undulate* (PU) extract is examined as a corrosion inhibitor for carbon steel (CS) dipped in 2.0M HCl. The study was conducted utilizing ac impedance spectroscopy (EIS), Mass loss (ML), polarization (PDP) tests, and surface checks were utilized to illustrate the importance of this PU extract in preventing the corrosion process for CS. The influence of temperature and concentration of PU on the efficacy of inhibition was tested.

Khadim A *et al.* [33] published a mini-review on corrosion inhibitors and mechanism types of mild steel inhibition in an acidic environment. Much research has been reported annually by many researchers related to corrosion inhibitors and their preparation or extraction, as well as the mechanism of classification and inhibition. The current study represents the types of corrosion, types of inhibitors, mechanisms of action, measuring the corrosion inhibitor efficiency, and a brief presentation of research articles that use manufactured or extracted coumarins as corrosion inhibitors and a comparison between them in terms of inhibition effectiveness has also been made.

Khudhair Abbas Kareem Al-Rudaini *et al.* [34] Studied the Corrosion behavior of AA7051 Aluminum alloy at different temperatures and inhibitor concentrations in an Acidic medium.

Geeta K *et al* [35] investigated the impact of an aqueous extract of *Bauhinia Blakeana* leaves (AEBBL) in controlling the corrosion of mild steel in bore well water medium has been demonstrated by mass loss method and electrochemical measurements. The extract is characterized by Fourier-Transform Infrared Spectroscopy (FTIR), and the active ingredients present in the AEBBL are identified by Gas Chromatography-Mass Spectrometry (GC-MS). The surface morphology is examined with the help of Scanning electron microscopy (SEM), and the surface roughness analysis is done by Atomic force microscopy (AFM). The weight loss method reveals that the extract offers a maximum corrosion inhibition efficiency of 96.62. Potentiodynamic polarization study (PDP) and Electrochemical impedance spectroscopy (EIS) are used to study the mechanistic aspects of corrosion inhibition. Both the double-layer capacitance (Cdl) and corrosion current ( $I_{corr}$ ) values decrease while the charge transfer

resistance ( $R_{ct}$ ) value increases with the increase in the concentration of AEBBL. The potentiodynamic polarisation reveals that AEBBL acts as a mixed-type inhibitor with primarily cathodic effectiveness. SEM and AFM documented the development of shielding coating on the mild steel surface.

M Ouakki *et al.* [36] reported investigated the inhibitory effect of the aerial part of *Daucus carota* L essential oil (EO) on mild steel in a 1.0M HCl solution. The electrochemical study is performed using potentiodynamic polarization (PDP) curves and electrochemical impedance spectroscopy (EIS) measurements in the presence of various concentrations of the examined *Daucus carota* L essential oil (EO). PDP results show that the studied EO behaved as a mixed-type inhibitor. EIS measurements indicated that the EO could inhibit the corrosion of mild steel by forming a protective film on the surface of mild steel. The experimental results showed an efficiency of 96.5% for a concentration of 2 g/l. In addition, The DFT results proved that the major components, especially  $\alpha$ -pinene (23.5%),  $\beta$ -Bisabolene (3.96%), and Pseudo limonene (7.20%) have a high electron-accepting ability and interact actively with the iron surface, which may be responsible for the inhibition ability of the investigated EO. Furthermore, the computational complies with the experimental data.

Israa Al-Jubanawi M *et al.* [37] studied the Synthesis Characterization and corrosion inhibition of thiourea and phthalic anhydride Complex with Ni(II) for Carbon Steel Alloy C1010 0.1 M Hydrochloric Acid.

Ramesh M *et al.* [38] focused on controlling corrosion in various metals and alloys through green corrosion inhibitors consisting of natural elements alone. In contrast to inorganic inhibitors, green corrosion inhibitors are characterized by biodegradability, low cost, and meager toxicity. Several researchers are now turning themselves towards the research of green inhibitors, which are of no threat to humans and the ecosystem. The current discussion is focused on the use of corrosion control in various conventional and monolithic metals.

Al-Baghdaadi S *et al.* [39] published their work on a thiophene derivative, 2-acetylthiophene thiosemicarbazone (2-AT), which was synthesized and examined as a corrosion inhibitor for mild steel in a 1.0 M hydrochloric acid environment by using weight loss and scanning electron microscopic techniques.

Norbaayah Ahmad Reza *et al.* [40] published their work on acid corrosion as a problem about corrosion that involves an acid solution. It is important to treat metal to preserve its integrity. Thus, acids are utilized to clean and treat metal surfaces. In return, this may lead to over-etching and metal degradation. Corrosion inhibitors were introduced as a solution to the issue. However, some problems are associated with using conventional corrosion inhibitors.

Sehmi A *et al.* [41] studied the corrosion inhibition of mild steel by newly synthesized Pyrazole carboxamide derivatives in HCl acid medium: experimental and theoretical studies.

Hyun-Min Yang *et al.* [42] reported Organic inhibitors reduce the dissolution of steel in acid, but it is hazardous, expensive, and needs the expertise to synthesize the inhibitor. Therefore, the latest research about eco-friendly corrosion inhibitors is required to study and compile, which showed more than 90% corrosion inhibition efficiency. In the present study, we have reviewed the state-of-arts and compiled the latest development in organic and eco-friendly corrosion inhibitors used in the acid environment, as well as suggested the future scope and role of green inhibitors for a sustainable society, which is economical, less hazardous and readily available from the natural sources.

Nageswar YVD *et al.* [43] reported that plants are a rich source of different varied organic compounds. Due to the important applications of naturally occurring chemicals, their

derivatives are also pursued, modifying and potentiating the activities of natural products. Metallic corrosion is a natural process resulting in heavy losses in various fields. Non-hazardous and non-toxic corrosion inhibitors gained significance due to the environmental regularities and guidelines issued in the course of saving the environment's pristine nature and maintaining our earth's sustainability. Green corrosion inhibitors play a potential role in the above-said cause. Recent research contributions on green corrosion inhibitors from the active researchers in the concerned expertise are presented here to give an idea about the current research activity worldwide. Marko Chigondo *et al.* [44] studied the recent Natural Corrosion Inhibitors for Mild Steel.

Dheeraj Singh Chauhan *et al.* [45] studied the design and development of efficient corrosion inhibitors that require inputs from a wide variety of synthetic protocols, which is usually a time-consuming and tedious process. The conventionally used experimental methods often turn out to be inadequate in the satisfactory effect of inhibitor structure on adsorption and corrosion inhibition.

Wei Li *et al.* reported [46] that corrosion mitigation is an important aspect of amine-based post-combustion carbon dioxide (CO<sub>2</sub>) capture operations due to the desire to use less expensive but corrosion-vulnerable materials such as low carbon steels in the construction of a capture system. Pereyra-Hernández JG *et al.* [47] reported the Heat Treatment Effect in the Corrosion Resistance of the Al-Co-Mn Alloys Immersed in 3 M KOH. Brahim El Ibrahimi *et al.* [48] studied the using Solvation Free Energy as an Additional Parameter for Corrosion Inhibition Inspection of Organic Compounds in Acid Media.

#### 4. Conclusions

Due to their specific mechanical properties, aluminum and its alloys are among the most used materials in the world. The exposure of aluminum and its alloys to various acidic environments leads to corrosion, which results in material damage and consequent economic losses. The use of organic corrosion inhibitors is one of the most widely employed methods of corrosion protection. This review focuses on using organic corrosion inhibitors in acidic media, emphasizing HCl and H<sub>2</sub>SO<sub>4</sub> solutions. These acids are widely used in acid cleaning, chemical or electrochemical etching, acid pickling, and anodizing of aluminum. The main conclusions of this review are: The selection of the proper organic compound is highly dependent on the corrosive environment and aluminum alloy type; It is shown that pure aluminum and 1xxx, 2xxx, and 7xxx series were the most tested materials, As presented herein, over the past two decades, amines, N-heterocyclic compounds, azole, imidazole, and thiazole derivatives, different kinds of polymers, organic dyes, and Schiff bases have been the most tested organic compounds as corrosion inhibitors for aluminum, and its alloys in acidic solutions; The inhibition effectiveness of these compounds frequently decreases with increasing temperature and increases with increasing corrosion inhibitor concentration; The corrosion inhibition effect of these compounds was tested at room temperature and up to 70°C. The methods used to test corrosion inhibition effectiveness are also discussed in this review, with electrochemical testing being the predominant method.

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## Conflicts of Interest

The authors declare no conflict of interest.

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