

Corrosion Protection of Carbon Steel Using Expired Drug in Acidic Medium: Review

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Annotation: When it comes to corrosion, there is no easy solution. The structure and features for a metal surface and a surrounding environment change as a result of the corrosion process. Inhibitors like organic and inorganic ones were proven to be costly and hazardous while also having significant environmental consequences. As a result, these inhibitors can only be used sparingly in the fight against corrosion. As corrosion inhibitors, pharmaceuticals have been studied in the past. Using nontoxic, affordable, and environmentally benign medicines as corrosion inhibitors was discovered. As corrosion inhibitors for diverse metals such as mild steel, carbon steel, and aluminum steel have been studied in several studies employing various medications (melatonin, cephapirin, Orlistat and tramadol among others). Studies have shown that these medicines' inhibitory action forms an insoluble compound on the metal surface, protecting it against corrosion. To determine the effectiveness of various drugs in inhibiting corrosion, researchers used various methodologies, including the weight loss technique (WL), measurements of potentiodynamic polarizations (PDPs), electrochemical frequency modulation (EFM) besides electrochemical impedance spectroscopy (EIS). X-Ray Diffraction, Scanning Electron Microscopy besides Atomic Force Microscopy were adopted to study a surface morphology for metals before and after

medicines were added.

INTRODUCTION

A breakdown of metals via chemical reactions is known as corrosion. It's a major issue that can't be solved totally. Because of this, it is more realistic to implement a preventative strategy rather than a comprehensive one ⁽¹⁾. There are numerous potential disasters that might cause major difficulties, such as the death of people and the harm that is done to society and the environment ⁽²⁾. In the chemical and petrochemical industries, corrosion is more common, resulting in huge waste output and financial losses. Corrosion damage control involves a number of different approaches. The most important step is to apply corrosion inhibitors. To prevent corrosion, metals and alloys are treated with a broad range of organic inhibitors. These organic compounds include heteroatoms (atoms other than S) or electron structures in their molecules. Heteroatoms include oxygen and nitrogen.

Organic chemicals inhibit metal ionization by producing a protective layer on their surfaces, which prevents the diffusion of chemical species necessary for metal ionization ^(3,4).

Accordingly, scientists all across a world are now looking into the possibility of using medications to prevent corrosion. Drugs as corrosion inhibitors have been advocated to replace existing harmful corrosion inhibitors due to research showing they are harmless, inexpensive, and have no environmental impact. These findings have sparked interest in this new class of corrosion inhibitors ⁽¹⁾. As a result, using medicines as metallic corrosion inhibitors has received a lot of attention in the recent few decades,

Findings from an extensive analysis of the scientific literature suggest that a variety of medications (Tramadol and Cephalophen among them) were adopted as long-term corrosion-inhibitors for a wide range of alloys and metallic materials. Green corrosion inhibitors have been extensively studied, but the fact that they haven't been used on a large scale emphasizes the need for an authorized update on a current state and future predictions for green corrosion inhibitors, especially drug-inhibitors. Detailed information on drug use and corrosion inhibition tests will be included in the following sections. Corrosion can occur when carbon steel is exposed to hostile media such as mineral acids, which are widely employed in industry for numerous applications. Corrosion of carbon steel is inevitable, but can be controlled.

R. J. Aziz launched the company in (2016)⁽⁵⁾. Amoxicillin, Cefixim, and Cephalexin were all found to be effective as mild steel corrosion inhibitors in a 1M H₂SO₄ solution at 30oC for a 24-hour period. We found that the inhibitors we indicated had inhibitive effects based on our measurements of inhibitive efficiency (IE percent). Measuring the free energy of adsorption for (Amoxicillin, Cefixim, and Cephalexin) helped shed light on how organic compounds interact with metal surfaces.

Xu, X., and co-workerse in (2017)⁽⁶⁾. They were the ones who started it all. An effectiveness for biotin prescription in preventing corrosion on mild steel in a 15% hydrochloric acid solution has been thoroughly assessed using weight loss and electrochemical techniques, respectively. We analyzed the surface topology using scanning electron microscopy, contact angle, scanning electrochemical microscopy, besides atomic force microscopy. Using quantum chemistry calculations and Fukui analysis, we were able to reconcile the experimental findings with the theoretical predictions. There is an influence of the inhibitor concentration in addition to immersion time, temperature, enthalpy, and entropy. There was a strong correlation between the methods for determining biotin's mitigating agent effectiveness. Polarization tests have shown that biotin is an inhibitor with varied effects. Biotin adsorption was shown to be governed by the Langmuir adsorption isotherm. Coating the metal surface reduced the corrosion rate, as verified by surface inspections.

The research of A. Srinivasulu and P. K. Kasthuri (2017) ⁽⁷⁾. They were the ones who started it all. Expired Gentamicin (Eye/Ear drops) is an excellent, efficient, and cost-effective corrosion inhibitor on mild steel when used in 1M HCl acid. An inhibitor's efficiency improves with growing immersion time, temperature, and inhibitor concentration. With concentration (0.9%), the Inhibitor was found to be effective (92.36%) at room temperature (303K) for pickling after six hours of immersion. Langmuir adsorptions best fit the data acquired for the chemical adsorption mechanism of the inhibitory process. According to the aforementioned thermodynamic parameters, the chemical adsorption mechanism was also supported by Ea values. Absorptive free energy (Gads) values are negative, indicating that the inhibitor has spontaneously adsorbed to the surface. Increased inhibitory efficiency is suggested by positive Enthalpy readings. Semi-circle curves of impedance are used to determine the rate at which corrosion occurs. A high-performance inhibitive activity on the surface of mild steel has been established by the SEM morphology of the protective coating. The findings of the electrochemical and weight reduction studies are completely congruent with one another. In addition to preventing pollution and recycling the drugs used, this trial promotes inhibitors that are both environmentally benign and commercially profitable. To determine if the inhibitor might inhibit mild steel in 1M HCl, three separate methods were used.

Heakal, F. E. T., & Elkholy, A. E. in(2017) ⁽⁸⁾. They used Gemini surfactants to prevent corrosion on carbon steel. Recent corrosion inhibitors have been found to be Gemini surfactants, thanks to their low surface energy and essential micelle concentration. The family of surfactants known as Gemini surfactants is quite interesting. Years of research and development have led to the synthesis of several Gemini surfactants; the vast majority of them consist of cationic ammonium salts counter-anionized with bromide. No anionic or nonionic Gemini surfactants have been found to suppress carbon steel corrosion; however, cationic surfactants have been shown to be effective in formation water, sea water, and hydrochloric acid, the most common industrial media for this purpose. These inhibitors often have an effectiveness level higher than 90%.

Mobin, M., and co-workerse in (2017) ⁽⁹⁾. The authors synthesized and analyzed dual non-toxic cationic gemini surfactants and biodegradable with ester linkage in a spacer, $C_mH_{2m+1}(CH_3)_2N^+(CH_2COOCH_2)_2N^+(CH_3)_2C_mH_{2m+1}.2Cl^-$ (mE2-m, m = 12, 14). They used basic analysis, ¹H-NMR along with FT-IR for their studies. At 30-60 °C in a 1 M HCl solution, compounds that were synthesized alone or in combination with sodium salicylate (SS) were tested on mild steel (MS). We also used weight loss, UV-visible spectroscopy, and potentiodynamic polarization to examine the properties and stability of the inhibitive film that formed on MS. With the addition of SS, the findings demonstrate that m-E2-m is a potent corrosion inhibitor for MS in HCl. The compounds that are generated adsorb on MS surfaces and function as mixed variety inhibitors, as shown by the Langmuir adsorption isotherm. Molecular features linked to inhibitory efficacy as measured experimentally are produced via a semi-empirical PM6 approach. The actual evidence agrees well with the theoretical expectations.

Haque, J., and co-workerse in (2018) ⁽¹⁰⁾. These two compounds were found to have the ability to suppress corrosion, and they were named THP-1 and THP-2 by the researchers (phenylamino)

In 1 M HCl, 1,2,5,6-tetrahydropyridine-3-carboxylate (THP-2) was examined on mild steel (MS) utilizing electrochemical, surface morphology (SEM, AFM), weight loss in addition to quantum chemical (QC) calculations approaches. QC Functionalized tetrahydropyridines were found to inhibit mild steel (MS) at concentrations as low as 7.95 10⁻⁵ M with an inhibition effectiveness of 90.67 percent (THP-1) and as high as 94.30 percent (THP-2). The Langmuir adsorption isotherm was found for governing the adsorption of THPs on metallic surfaces. A study using potentiodynamic polarization (PDP) found that the chemicals under investigation were inhibitors of the mixed-type variety. There is evidence that the examined corrosion inhibitors reduce corrosion by adsorbing at metal/electrolyte interfaces, according to an EIS analysis. Metals can be protected from corrosive dissolution by THPs' protective coating, which was demonstrated by

SEM, EDX, and AFM tests, respectively. The experimental findings are supported by QC calculations making use of density-functional theory techniques to neutral, solvated, and protonated inhibitors.

These THPs were synthesized as shown in the figure.

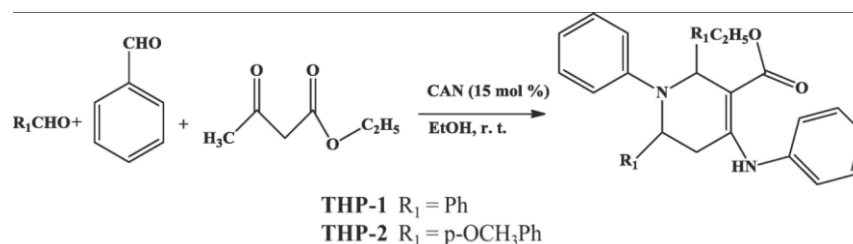
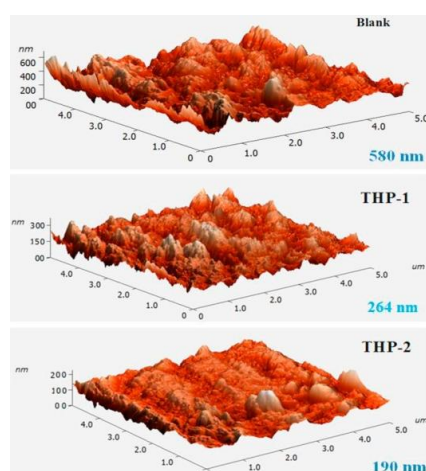
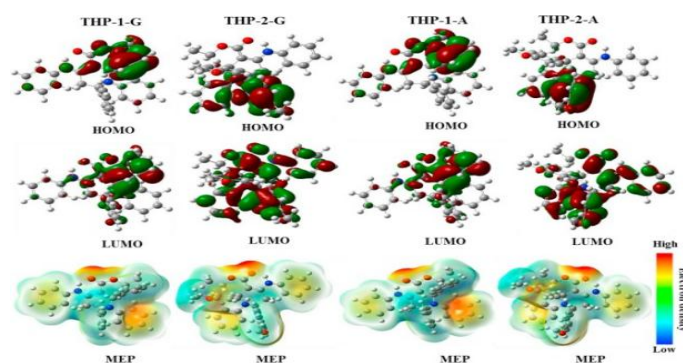


Fig (1). Synthetic route for investigated THPs.



THPs inhibitors may be seen in the AFM picture of mild steel in the absence and presence of 40 ppm.

Fig (2). Image of mild steel using AFM both with and without 40 ppm of THPs inhibitors



Dohare, P. and co-workers in (2018)⁽¹¹⁾, research on the use of Podocip (PCIP) medication, which has expired, as a carbon steel corrosion inhibitor has been conducted. The inhibitory effectiveness of Podocip (PCIP) for carbon steel corrosion in 1 M HCl was determined to be 308k, or 97.9%. The adsorption of PCIP on carbon steel is controlled by the Langmuir isotherm, and PCIP has a mixed-type inhibitory activity. Adsorption of inhibitors onto mild steel surfaces occurs via physical and chemical pathways, as shown by the range of adsorption values (-33.37 kJ/mol to 39.16 kJ/mol). It was discovered that a protective inhibitor coating had been created using SEM and AFM methods.

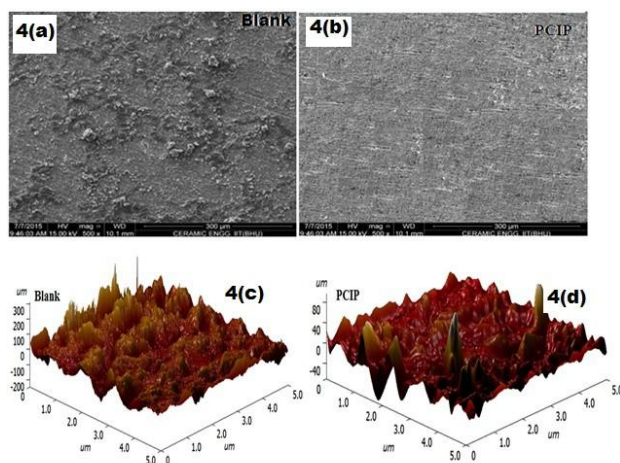


Figure 3. micrographs for SEM for carbon steel surfaces: (a) blank, (b) PCIP; AFM micrographs: (c) blank, (d) PCIP.

fouda. A.S and co-workeerse in(2019) ⁽¹²⁾. Cephapirin using electrochemical technologies as well as weight loss techniques can effectively inhibit studied ability for inhibiting carbon steel in a solution of 2 M HCl Carbon steel. Inhibition efficiency increases as the drug concentration rises. UV-visible reflectance spectroscopy confirms the formation of a drug-protective coating on carbon steel. The experimental data was checked using Quantum Chemical computations, and the findings demonstrate that they are in good agreement.

D.S.Priyanka Singh and colleagues in (2019) ⁽¹³⁾. Chemically modified expired Dapsone medicine was tested as a mild steel corrosion inhibitor in sulfuric acid solution by Dapsone was reformulated utilizing Schiff bases, which resulted in a 95 percent inhibitory efficiency. The synergistic impact of KI increases the drug's inhibition efficiency once more. According to the cooperative synergistic mechanism, a synergistic parameter greater than one was determined. WL, EIS, PDP, SEM examination, and FTIR analysis were all utilized.

Liangtian, Y., and coworkers (2020) ⁽¹⁴⁾. That year The drug Enprofylline (DE [3-propylxanthine]) was put to the test in a 1 M sulphuric acid (H₂SO₄) environment to see if it might stop the corrosion of mild steel. The choice to utilize this medication for this purpose was based on its non-toxicity, accessibility, and affordability. The nitrogen and oxygen heteroatoms (N, O) in the molecular structure constitute a possible inhibitor for mild steel corrosion in sulphuric acid. Additionally, studies in electrochemistry, surface chemistry, quantum chemistry, and weight reduction are used. Asthma medicine dexmedetomidine (DE) has a long history of use. Successful findings were obtained in DE mitigation studies conducted in 1M H₂SO₄ using electrochemical impedance spectroscopy (EIS), open circuit potential (OCP), and potentiodynamic polarization (PDP). The DE is a mixed-category device, since the anodic and cathodic slopes vary substantially. They were all identical, which proved that the electrochemical tests were conducted promptly. Surface investigations were conducted using scanning electron microscopy (SECM) and scanning electron microscopy with energy dispersive spectroscopy (SEMEDS). The Gaussian 9.0 application for Windows was used to conduct density functional theory simulations (DFT).

S. Ramesh Kumar and other researchers in (2020) ⁽¹⁵⁾ Employees of By analyzing electrochemical impedance spectroscopy, weight loss, and potentiodynamic polarization, they determined the impact of the drug Oxethazaine, 2,2'-(Hydroxyethylimino) bis[N-(Alaalpha-Dimethylphenethyl) N -methylacetamide] on mild steel corrosion in a 1M HCl solution. Adsorption on the metal surface was shown to be the source of the drug's inhibitory action, as demonstrated by electrochemical impedance spectroscopy. The chemical was shown to be a mixed-type inhibitor according to PD polarization studies. It was discovered that molecule adsorption on metal surfaces is governed by Langmuir's equations. Due to the negative

indications of the adsorption isotherm and Gads value, it may be inferred that the adsorption is occurring spontaneously. Additionally, the correlation between corrosion rate and temperature was examined for temperatures ranging from 30 to 50 °C. Raising the inhibitor concentration in the 1M HCl solution improved inhibition effectiveness. According to the findings, when a larger portion of the inhibitor is in touch with the metal surface, electronic criteria like electron density are more important than geometric ones in selecting an efficient corrosion inhibitor. An inhibitory effectiveness that is greater for a more spherical molecule is comparable to that of a more planar molecule with a lower density of electron donor sites. The influence of temperature on corrosion rate has also been studied within the 30 to 50 °C temperature range. Through the use of quantum chemistry simulations, the drug's inhibitory effectiveness was linked to its electronic structural features. Lab experiments were then conducted to verify whether the theoretical results were consistent with the observed data.

When employed as a corrosion inhibitor based on carbon steel in a CO₂-saturated solution of 3.5% NaCl + 340 ppm acetic acid, expired metformin medication (MET) by Ikenna B. Onyeachu and colleagues in(2020) ⁽¹⁶⁾ .was found to be effective. At 200 ppm, the drug inhibition efficiency reached a peak of 90%. Electrochemical methods, surface analytical measures, and computational modeling were all used to quantify the inhibitor's concentration. A boost in charge transfer resistance was seen in impedance tests following inhibitor addition at the steel–solution contact. They came across It was shown that MET operated as a cathodic-type corrosion inhibitor, reducing corrosion current density considerably. According to the Langmuir isotherm, with high Gad values, MET adsorption on the steel substrate was chemically combined with physical modes. According to MD research, each of MET's three tautomeric forms has a planar geometrie.

F. E. Abeng and his coworkers in(2020) ⁽¹⁷⁾ This result was reached by measuring the anti-corrosion capabilities of the expired Tobramycin (ETo) medication in a 2 M HCl solution using exact potentiodynamic polarization, thermometric methods, scanning electron microscopy (SEM), and electrochemical impedance spectroscopy. According to Langmuir's adsorption isotherm model, a chemical adsorption system was supported. In terms of chemical heat adsorption, activation energy (Ea), and free energy of adsorption (AG°ads), ETo inhibitors are classified as mixed-type inhibitors. The inhibition efficiencies were 80%, 90.5%, and 84.3% at 500 ppm, respectively; as the inhibitor concentration increased, the inhibition efficiencies rose (ETo).

A. A. Idress and D. M. Ibrahim in(2020) ⁽¹⁸⁾ .An inhibitor was created (Benzylpenicillin Drug) and the inhibitor's effect on carbon steel corrosion in acidic solutions was tested. Benzylpenicillin, a green inhibitor, was tested to see how it affected carbon steel's corrosive behavior in HCl acid solution. A variety of electrochemical techniques were utilized to conduct the measurements: EIS, potentiodynamic polarization, in addition to Weight-loss method. Antioxidant for carbon steel in acidic solutions: Benzylpenicillin. This inhibitor adheres to Langmuir's adsorption isotherm and has a physisorption action on carbon steel surfaces.

R. S. A. Hameed and colleagues in (2020) ⁽¹⁹⁾ .Since expired drugs are easily accessible, inexpensive, safe, nontoxic, and ecologically friendly, they were studied for their ability to inhibit carbon corrosion in a 1.0 M hydrochloric acid solution. The results showed that the effectiveness of the inhibition increased with increasing concentrations of the inhibitors. Weight loss and scanning electron microscopy (SEM) were two of the chemical and electrochemical methods used. The study also heavily relied on polarization.

Abeng,F E Ikpi, M E et al... in (2021) ⁽²⁰⁾ . will publish their findings

The chemicals examined were found to be worthy green corrosion inhibitors used for carbon steel in a 2 M HCl solution. Meto, Levo, Moxi, and Nife all have an average corrosion inhibition efficiency of Meto > Levo > Nife. Metolazone (Meto) and levofloxacin (Levo) have high maximal inhibition efficiency of 98 and 94 percent, respectively, for drug-based inhibitors.

Electrochemical impedance spectroscopy, mass loss, computational studies, potentiodynamic polarization, scanning electron microscopy (SEM), and atomic force microscopy (AFM) were some of the methods used by the researchers in their investigations. (AFM). The inhibitors reduced the carbon steel's coarseness in the acidic media. Langmuir and Frumkin's adsorption models worked effectively for the chemicals in question. Adsorption free energy is negative, indicating a spontaneous response, according to the results of the research into adsorption. Mixed-type inhibitors are visible in the potentiodynamic curves.

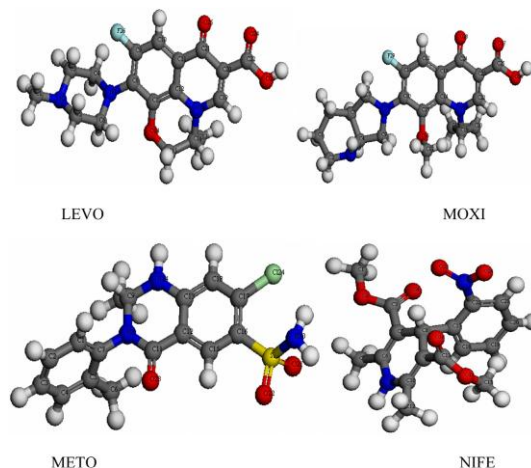


Fig. 4. Enhanced molecular structures for Moxi, Meto, Levo, in addition to Nife inhibitors

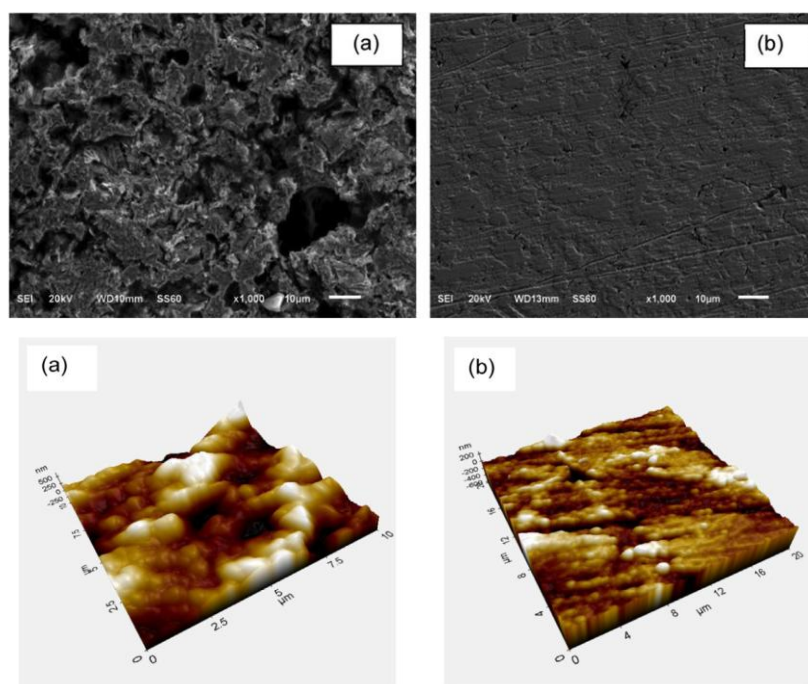


Fig. 5. Depictions for exposed carbon steel to 2 M HCl in existence of 500 ppm inhibitor after one day of immersion from SEM besides AFM analysis

In (2022)⁽²¹⁾, R.Z. Aljebory, and workers. The author investigated drugs as corrosion inhibitors for the environment. Because of their low environmental effect and low toxicity, drugs may be used as corrosion inhibitors. Melatonin, cephapirin, and tramadol are just a few of the corrosion inhibitors that have been tested with various materials, including mild steel, carbon steel, and aluminum. An insoluble substance that inhibits corrosion has been found by growing on the surface of mild steel. Adsorption of modified dapsone medication onto mild steel prevents corrosion by obstructing the transfer of mass and charge.

The medicines' corrosion-inhibiting effects were assessed using weight loss, potentiodynamic polarization, and electrochemical impedance spectroscopy. This research looks at how various

drugs affect the corrosion of metals and alloys. Because more inhibitor molecules are able to adsorb to metal surfaces, a protective layer is formed as the medication molecule concentration rises. The results suggest that drugs, instead of corrosion inhibitors, might be used. Consequently, there has been an improvement in waste management, lessening of environmental impacts, and acceptable reduction in economic losses. Antioxidant effectiveness is affected by molecular make-up, metal-surface affinity, and molecular structure. Inhibitors of corrosion had aromatic rings, nitrogen, oxygen, and sulfur.

A. Jawad, and coworkers in (2023)⁽²²⁾. When examined for their capability for inhibiting low carbon steel corrosion in sodium chloride, expired medications such as ceflaxin, amoxicillin, and clavulanate were found to be effective. In the weight loss experiment, three actual expired medications with different doses (0, 250, 500, and 750 mg/L) were tested for their capacity to stop corrosion of low carbon steel in a salt solution (3.5% NaCl). Cloxacillin 750 mg/L was the most effective inhibitor of the tested antibiotics, with an inhibition effectiveness of 82.8125 percent. The EIS plots showed that in the presence of Cloxacillin, Rct values rise and Cdl values drop, therefore these results were used to study the effects of various temperatures (25, 35, 45, 55 °C) and dosages of the medication (0, 250, 500, 750 mg/L). The inhibitor's substantial adsorption on the steel surface was verified by the changes in the impedance characteristics. Researchers found that Cloxacillin forms a protective coating on surfaces when studied using scanning electron microscopy. A mixed-type inhibition of expired Cloxacillin was seen in the polarization curves, which were the primary findings of these studies. While temperature had no effect on the inhibitory efficacy, cloxacillin concentration did.

Lei Huang and et al (2023)⁽²³⁾. Study of the antiviral medicine Famciclovir as an inhibitor of carbon steel corrosion in a hydrochloric acid media is where their study is located. It was shown that 2-[2-(2-Amino-9H-purine-9-yl)ethyl]-1,3-propanediol Diacetate (FAM) might reduce the corrosion of carbon steel in solutions containing hydrochloric acid. To examine the performance of corrosion inhibition, electrochemical measurement and detailed surface characterization techniques are applied. Results demonstrate that carbon steel samples treated with FAM exhibit significantly higher charge transfer resistance (Rct) values. Following 2 hours of soaking at 298 K, the corrosion inhibition efficiency reaches 96.87% at a dose of 1.0 mM. The corrosion inhibitor's effectiveness at a concentration of 1.0 mM decreases slightly from 96.87% to 93.92% after 2 hours of soaking at 298 K to 318 K. By acting as a combined corrosion inhibitor in a hydrochloric acid solution, FAM prevents carbon steel electrodes from undergoing anodic oxidation and cathodic reduction. The Langmuir adsorption isotherm, which primarily involves chemical adsorption, is seen when FAM is adsorbed on carbon steel surfaces. Confocal micrographs, X-ray diffraction analyzer (XRD), and X-ray photoelectron spectroscopy (XPS) results further supported FAM's capacity to adsorb on carbon steel surfaces and inhibit HCl corrosion.

El Maksoud and his workers studied in (2024)⁽²⁴⁾. The medication furosemide, whose chemical formula is 4-chloro-2-furan-2-ylmethylamino-5-sulfamoylbenzoic acid, was tested for its ability to prevent carbon steel (CS) corrosion in a solution of 1.0 M hydrochloric acid. Electrochemical methods such as electrochemical impedance spectroscopy (EIS), electrochemical frequency modulation (EFM), and mass loss (ML) were used in the study. Increasing the concentration and temperature of Furosemide increases the effectiveness of inhibition. The Temkin isotherm is well-fit by this chemical. Both the anodic metal dissolution and the cathodic hydrogen development are affected by the presence of different concentrations. We used X-ray photoelectron spectroscopy (XPS), Fourier transform infrared spectroscopy (FT-IR), scanning electron microscopy (SEM), and atomic force microscopy (AFM) to determine the compound's impact on the CS surface. Quantum chemical calculations proved that furosemide has an inhibitory impact on molecules, and findings from molecular simulations showed that the carbon steel surface adsorbs the drug.

In (2024)⁽²⁵⁾ S.A. Naji and his workers, their foundation as an alternative to more costly,

harmful, and unavailable chemical inhibitors, the use of expired medications as green inhibitors is receiving a lot of interest. The Dexon medication was proposed as an environmentally friendly inhibitor for carbon steel in a 3.5% NaCl solution at temperatures ranging from 303 to 333 K in this research. A potentiostatic analysis was performed to study the corrosion/inhibition relationship at four different drug doses (4, 20, 40, and 60 mL/L). The corrosion potential, corrosion current density, and Tafel slopes were recorded. When the concentration was 60 mL/L at 303 K, the polarization resistances were $25.86 \times 10^{-3} \Omega \cdot \text{cm}^2$ and the inhibition efficiencies were 95.57%. We used infrared spectroscopy, electron scanning microscopy, and atomic force microscopy to examine the inhibited surface. These methods verified that the adsorbed medication successfully covered the surface, creating a combination with Fe^{2+} – Dexamethasone. The fact that surface roughness decreased from 270.8 nm to 24.96 nm after inhibition with a 60 mL/L dose lends credence to this. A physical, spontaneous, less disordered, and exothermic adsorption process was predicted by the theoretical calculations. The strong adsorption capacity of the Dexamethasone molecule on the steel surface was further confirmed by quantum data, which included HOMO and LUMO investigations. Due to the molecule's pliability and the energy released during adsorption, the findings revealed an energy gap of 3.43 eV.

M. Husseini and et al in (2024)⁽²⁶⁾ claimed to have conducted research on the use of natural Iraqi plum tree gum in a salt solution to inhibit corrosion of carbon steel. This research aims to fill a need in the market by investigating the possibilities of naturally occurring compounds, in reaction to the rising tide of interest in green chemistry and the use of sustainable, economical chemicals in farming and industry. This study aims to shed light on Iraqi plum tree gum's corrosion-inhibiting capabilities. In order to determine the functional groups of the natural gum, atomic force microscopy (AFM) and Fourier transform infrared spectroscopy (FTIR spectroscopy) are used in its characterization. Conducting corrosion tests on carbon steel (C.S.) in both saline and inhibitory solutions of Plum Tree Gum at varying concentrations, the electrochemical polarization method was used. Results showed that inhibitory efficacy was positively correlated with gum concentration, suggesting that greater gum concentrations yielded more potent inhibitors.

Jawad, R. F., & Ali, E. in (2024)⁽²⁷⁾, They looked at how carbon steel may be protected against corrosion by using an acidic medium and an expired medicine. Using the weight loss approach, we investigated how Orlistat inhibited CS corrosion in a 1.5M hydrochloric acid media. Orlistat was determined to be an effective inhibitor of carbon steel, after its shown efficacy in pipeline corrosion prevention. It was shown that inhibitors adsorbed onto carbon steel surfaces controlled corrosion in a straightforward blocking process. The results showed that IC rose at high inhibitor doses and decreased at high temperatures. The inhibitor's 800 ppm weight resulted in the greatest (89.5%) inhibitory efficiency. Using the Langmuir isotherm at saturated state for physical absorption, the mechanism of action of Orlistat was also investigated with respect to its adsorption of the steel surface. The experimental findings demonstrated that inhibitor molecules physically adsorb onto the carbon steel surfaces, as shown by the values in proportion to their signs of the adsorption Gibbs free energy, based on the Langmuir adsorption isotherm. The FT-IR spectroscopy and SCM electron microscopy were used to examine the surface morphologies of the steel.

J.G. Suma, and his coworkers in (2025)⁽²⁸⁾. It was formerly One possible application for expired lorcetam (LRTM), an epileptic medication, is as a corrosion inhibitor for low-carbon steel in 1 M hydrochloric acid. There are environmental dangers associated with disposing of expired LRTM, although it still contains usable active components. Here, we look at how low-carbon steel (LCS) treated with expired LRTM in a 1 M HCl solution may prevent corrosion. We measured weight loss and used electrochemical techniques including electrochemical impedance spectroscopy (EIS) and Tafel polarization (PDP) to see how well LRTM protected LCS against corrosion. At 60 ppm, the optimum concentration, the observed inhibitory efficiency was 98.16%. Adsorption behavior is characterized by a rigid adherence to the Langmuir adsorption isotherm model. The

strong thermodynamic evidence points to the low and negative values of the Gibbs free energy as evidence of LRTM's spontaneous adsorption onto the metal surface. The use of scanning electron microscopy and atomic force microscopy provides both visible and physical evidence of a protective surface layer. 5. The function of lone pairs of electrons on O and N atoms in LRTM, which are essential for creating a protective layer on the surface of the metal, is brought to light by FTIR spectroscopy. 6. The importance of O, N, and ester groups as active sites in LRTM, crucial for improving its degradation inhibition efficiency, is highlighted by quantum chemistry and MD simulations.

M.A. Ali, and workers in (2025)⁽²⁹⁾, A study was conducted to evaluate the impact of expired tilmicosin on the corrosion-resistance of carbon steel submerged in hydrochloric acid. In this study, we look at the effects of a 1 M HCl solution containing expired tilmicosin drug on C-steel corrosion. To assess the effectiveness of Expired Tilmicosin Drug in preventing corrosion of C-steel, potentiodynamic polarization (PDP), weight loss (WL), electrochemical impedance spectroscopy (EIS), atomic force microscopy (AFM), and fluorescence time-domain reflectance (FT-IR) tests were used. After reaching 91.8% at 300 ppm and 25 °C, the inhibitory efficiency (% IE) dropped to 85.6% at 45 °C, indicating that the % IE rose with increasing concentrations of expired tilmicosin drug. Based on the PDP findings, the medicine under study functioned as a mixed-kind inhibitor. How the medicine adsorbed on the C-steel surface provided support for the Langmuir adsorption concept. According to the calculated values of the standard free energy change of adsorption (ΔG_{ads}), the adsorption phenomenon was determined to be spontaneous. The drug molecules formed a strong interaction with the C-steel surface, as shown by atomic force microscopy (AFM) and Fourier transform infrared spectroscopy (FT-IR). To better understand the chemical interactions between the C-steel surface and the Expired Tilmicosin Drug, molecular dynamics (MC) simulations and density functional theory (DFT) calculations were conducted. The findings from this investigation corroborate those from the theory. Highlighting its non-toxic nature and cost-effectiveness, this study provides the innovative use of Expired Tilmicosin Drug, which makes it a potential choice for corrosion prevention in industrial applications. The purpose of this research is twofold: first, to find a better way to deal with pharmaceutical waste that has expired; and second, to find an inhibitor of acid corrosion that works well on C-steel. A sustainable solution to environmental dangers, reusing expired tilmicosin drug shows significant corrosion inhibition effectiveness.

R.A. Anae, and workers in (2025)⁽³⁰⁾, In their research, Rana A. looked at the effects of an expired medicine on low-carbon steel corrosion in phosphate acid, both experimentally and theoretically. Especially in acidic settings, corrosion is a major problem for low-carbon steel industrial infrastructure and machinery.

Inhibitors have proven effective in mitigating corrosion, and expired pharmaceuticals offer an innovative class of potential solutions. This study explores the use of expired Actifed (ACD) as a sustained corrosion inhibitor for low-carbon steel in a 0.5 M H₃PO₄ solution. Both experimental and theoretical approaches were employed to assess the inhibitor's efficiency. Experimental techniques included potentiodynamic polarization (PDP), Fourier Transform Infrared Spectroscopy (FTIR), Scanning Electron Microscopy (SEM) and microbiological tests. Theoretical evaluations utilized quantum chemical calculations to investigate how ACD interacts with the steel surface. The findings indicated that ACD significantly decreases the corrosion rate, resulting in an inhibition efficiency of 73.5% under the conditions (concentration of 60 mL/L and a temperature of 303 K). It was observed that ACD forms protective layers on the steel, providing mixed protection for both anodic and cathodic sites. The outcomes from FTIR, SEM, and theoretical studies corroborate the electrochemical findings, confirming the effectiveness of Actifed as an inhibitor under the selected conditions.

Conclusions

In this article, many studies discussing the treatment of metal corrosion were considered, and

carbon steel alloy was used. Using environmentally friendly inhibitors, we utilized expired medications, and their use has proven to be highly successful in inhibiting metal corrosion.

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