# Newbouldia Laevis Leaf Extract's Possibilities as a Medium Carbon Steel Corrosion Inhibitor in Sulphuric Acid ($H_2SO_4$) Using a Weight Loss Technique

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**ABSTRACT:**

*Corrosion processes have been blamed for several failures and losses in the manufacturing and chemical industries. Chemical inhibitors can be used to prevent failures caused by metals that are corroded to the point that they can no longer withstand the intended load. Synthetic inhibitors are effective, but they have disadvantages, such as toxicity, disposal problems, legal troubles, and astronomical costs. Green inhibitors have become more and more popular as partial and complete alternatives for chemical inhibitors in order to protect people, the environment, and money. However, because green inhibitors are environment-specific, more research is necessary to determine the metal-inhibitor-media combination that produces the greatest outcomes. Corrosion has a variety of repercussions, and they are frequently more serious than a simple loss in metal mass in terms of how well a piece of machinery or a structure function securely, consistently, and effectively. The goal of this research was to assess the Newbouldia Laevis leaf's ability to prevent corrosion of medium carbon steel. Utilizing the weight loss approach, the experiment was conducted. The corrosion rates significantly rose for the controlled trial (acidic media without leaf extract), but they significantly decreased when different doses of the leaf extract were added to the acidic medium, showing that the Newbouldia Laevis leaf extract was shielding the metal. After 20 hours of aging in acidic conditions with different inhibitor doses of 0.0g/L, 0.1g/L, and 0.5g/L, the test piece lost the following amounts of weight: 0.9386g, 0.1702g, and 0.0763g, respectively. The test piece corrosion rate decreased as expected after 20 hours of aging in acidic conditions with various inhibitor concentrations of 0.0g/L, 0.1g/L, and 0.5g/L: 1.3100mm/yr., 0.2400mm/yr., and 0.1100mm/yr., respectively. As inhibitor concentration increases, corrosion rates typically decline, with a dose of 0.5g/L at 20 hours of immersion of the test piece, showing inhibitory efficiency of 92%. The Newbouldia Laevis Leaf Extract demonstrated that when applied in the right quantity, it will lengthen the service life of medium carbon steel in sulphuric acid settings. It has positive inhibitory effects on mild steel.*

**Keywords:** Corrosion, Newbouldia Laevis Leaf, Concentration, Weight loss and Inhibition Efficiency.

## 1. INTRODUCTION

Metals used in engineering include carbon steels. The rusting phenomena puts its usefulness in jeopardy. Corrosion is simply defined as the breakdown of metal through a reaction with its surroundings. It often happens more quickly when the average atmospheric temperature is high. While many metals, including silver, gold, and platinum, are highly stable in harsh settings like strong acids, some metals corrode. Metal will return to its native state by corroding and forming compounds when it is exposed to the elements. Attacks that occur in acids or other aggressive solutions can be quick, whereas attacks that occur in regular air atmospheres might be slow because of the development of protective corrosion coatings. Metals with uneven surfaces or those whose natural state is not homogeneous offer possible starting points for corrosion. Many losses in the engineering industry are caused by corrosion.

Maintenance procedures like pickling and cleaning are used to protect metallic objects. The harsh hydrochloric acid that is frequently employed in pickling and cleaning processes corrodes the metallic components. One of the most well-known methods of controlling corrosion is application of an inhibitor (Al-Otaibi et al., 2012; Obot et al., 2009). This method is widely accepted to maintain the stability of metallic structures (Onukwuli and Omotioma, 2016). Organic compounds with oxygen, nitrogen, and phosphorus atoms are thought to have a strong ability to prevent metal corrosion in acid environments (Yildirim and Cetin, 2008). Different plants extract have successfully been evaluated. Plant extracts' ability to reduce corrosion may be due to its phytochemical components. The engineering construction and building industry, the chemical and food processing industries, the aviation and automobile sectors, as well as petroleum firms, all have extensive uses for metals and alloys. As a result, coordinated efforts must be made to gradually minimize the corrosion risks of the metallic components and/or system in question. These metals are all susceptible to corrosion at rates that are essentially dependent on the nature of the corrosive environment (Ayoola et al., 2020; Ayoola et al., 2018).

The application of corrosion inhibitors is a popular and effective method of preventing the corrosion of metals. In order to slow down or stop the corrosion reactions of metal from occurring, corrosion inhibitors are chemical substances that are applied in small quantities to the corrosive environment (Fayomi et al., 2017; Ayoola et al., 2020). Corrosion inhibitors can be broadly categorized as either passivators, precipitators, vapor phase, cathodic, anodic, neutralizing, or absorbents based on performance (Ayoola et al., 2020). The two main categories of corrosion inhibitors, however, are organic and inorganic inhibitors, based on their chemical makeup. While organic inhibitors include extracts from leaves, barks, nuts, seeds, fruits, and roots, inorganic inhibitors include hydroxides, nitrates, molybdates, silicates, and metal chromates (Akinyemi et al., 2016; Agboola et al., 2019).



Recent studies on the evaluation of various inhibitors have included the measurement of the inhibitors' solubility, toxicity, thermal stability, and cost (Guo et al., 2020; Tan et al., 2020). In Q235 steel in 0.5 M H2SO4, Lei et al. (Guo et al., 2020) shown that 3, 3-dithiodipropionic acid (DDA) inhibitor was a mixed-type, non-toxic corrosion inhibitor. Additionally, it is said that when choosing which inhibitor is suitable for a metal in a certain media, comparing inhibitor prices and their inhibitory efficiency is important (Tan et al., 2020). According to research, several inorganic inhibitors employed in industries are harmful by nature, endangering both people and the environment. And as a result of their toxicity, natural inhibitors that are environmentally friendly and biodegradable are now being explored. The use of natural or organic compounds in corrosion management is also encouraged because they are easily available, less expensive, environmentally friendly, and processed using straightforward extraction techniques (Loto, 2018).

The chemical composition of the organic compounds that make up natural inhibitors, their capacity to cross-link or compact, the number and types of bonding atoms or groups in the compounds, and their capacity to solidify a complex with the atoms in the metal lattice all affect how effective they are. An organic corrosion inhibitor is classified as either an anodic, cathodic, or mixed type depending on how well it inhibits corrosion (Loto and Olowoyo, 2018; Dehghani et al., 2019). Numerous studies have been done to examine the inhibitive qualities of different plant leaves and extracts. Alkaloids, flavonoids, and tannins are examples of specific antioxidants that are heterocyclic in nature and are thought to be responsible for these plant extracts' corrosion-inhibiting behavior (Noor, 2007; Dariva and Galio, 2014; Winkler, 2017; Fayomi, 2019; El-Adewy and Taha, 2001). Using various watermelon plant parts as corrosion inhibitors for metals exposed to various corrosive situations hasn't been attempted very often. In natural saltwater, for instance, metal has been protected against corrosion by extracts from watermelon peel and leaves (Odewunmi, 2015). The oil from watermelon seeds can be readily extracted for use in preventing corrosion and is a waste product that is very accessible.

This study aims to investigate the anticorrosive properties of Newbouldia laevis leaf on medium grade steel in an acidic media of 1M $H_2SO_4$. The weight loss technique will be taken into consideration as the study examines the inhibitive performance of the extracted Newbouldia Laevis Leaf on medium carbon steel.

### 1.1 Corrosion inhibitors from Plant Extract

Corrosion is the term used to describe how metals and alloys gradually deteriorate over time as a result of the action of air gases, moisture, and other chemicals. The rate at which a corrosion inhibitor spreads in a small volume of water lengthens the life of metallic and alloy materials, extending the life of the metal exposed to that water. Metal corrosion can be avoided by using plant extracts, often known as "green corrosion inhibitors." It produces substances that plants naturally produce. Since they are affordable, widely available, and environmentally friendly, the majority of naturally occurring compounds are preferred. Some not only possess physical, chemical, and biological traits, but also intricate molecular structures. To delay the reaction between the metal and the corrosive components in the medium, corrosive media are added with low-concentration inhibitors.



### 1.2 Inhibition mechanism

Plant extracts are used to stop corrosion because their inhibitory actions are connected to the adsorption of inhibitor molecules on metal surfaces. Physical, electrostatic, and chemical techniques are used to adsorb organic molecules (Harvey et al., 2018). Adsorption inhibitors function by decreasing the geometric size of the reaction zone on the metal surface. They can also lessen corrosion through the electro-catalytic effect or the reaction products if the rate of activation energy barriers for anodic and cathodic reactions differ (Abd El-Lateef et al., 2019). Increases in temperature and electrical attraction between inhibitor molecules with electron donor atoms like (O, N, S, and P), heterocyclic rings, and metal atom orbitals are the two factors that lead to physical adsorption, which is the mechanism by which inhibitor molecules adsorb more readily (Faisal et al., 2018).

The inhibitory mechanism of metal surfaces is triggered by the adsorption of inhibitor molecules. The adsorption phenomena is influenced by the type of metal, its surface, the medium charge, and the chemical make-up of the inhibitor (Vinutha et al., 2016). Therefore, the formation of bonds between the orbitals of metal atoms and the sp- electron pairs on the nitrogen and oxygen atoms of heterocyclic rings may be the reason why inhibitor compounds are attracted to surfaces. Electrostatic interactions, for example, between the positively charged nitrogen atom and the negatively charged metal surface may promote inhibitor adsorption when water molecules are pushed off of metal surfaces. Because certain sub-inhibitors (acidic or alkaline) are resistant to ring removal, some inhibitors' ability to prevent corrosion may come from this. This is because the materials' resistance to oxidation (Ryl et al., 2019). In some cases, a small number of inhibitors is enough to stop their adsorption.

### 1.3 Review of Related Work

Numerous disasters and losses in the processing, manufacturing, and oil and gas industries have been linked to corrosion processes. Chemical inhibitors can be used to prevent failures brought on by metals that can no longer support the designed load owing to corrosion losses. Despite their efficiency, chemical inhibitors are associated with toxicity, environmental concerns, lawsuits, and astronomical costs. To safeguard the environment, people, and money, green inhibitors have become more and more popular as alternatives to chemical inhibitors. In this study, the effects of different dosages of ethanol extracts of Newbouldia Laevis leaf on high carbon steel samples that had been corroded in 1M sulphuric acid solution were examined. At inhibitor dosages of 0.1 g/L and 0.5 g/L, respectively, the leaf extract had the lowest (0.1 g/L) and highest (0.5 g/L) inhibitory efficiencies at 20 hours, with 88 percent and 93 percent, respectively. Weight loss data was recorded every 4 hours for a total of 20 hours (Yusuf et al., 2022).

Utilizing a combination of chemical and electrochemical methods, it was shown that Tilia cordata extract can effectively prevent carbon steel from corroding in 1 M hydrochloric acid solutions. C-steel sample' surfaces underwent morphological analysis. The findings demonstrated that, as the content of Tilia cordata extract increased to 300 mg L-1, Tilia cordata has 96% efficiency in its ability to suppress corrosion. With an increase in extract concentration, the values of charge transfer resistance ($R_{ct}$) rise while the values of capacitance of the double layer (Cdl) and corrosion current ($i_{corr}$) decline. Between 30 and 60 C, the impact of temperature was researched. It was calculated and discussed certain thermodynamic parameters. The Langmuir adsorption isotherm was discovered to be obeyed by the adsorption of extract on the surface of C-steel. The examined extract functions as a mixed type inhibitor, according to the polarization data. All of the various strategies employed produced comparable outcomes (Fouda et al., 2016).

Weight loss, electrochemical potentiodynamic polarization, quantum chemical computation, molecular dynamics simulation, and scanning electron microscopy (SEM) analytical techniques were used to investigate the effect of aqueous polyethylene glycol (PEG) on inhibiting corrosion of cold-rolled steel corrosion in 1.0 M HCl solution. On the corrosion behavior of cold-rolled steel in 1.0 M HCl, the effects of immersion time, inhibitor concentration, and temperature were investigated. According to the findings, PEG successfully prevented cold-rolled steel from corroding in the acid solution by adhering its molecules to the metal's surface and so reducing both cathodic and anodic processes. Temperature investigations revealed that the effectiveness of inhibition rose with temperature from 303 to 343 K. The interaction between the PEG inhibitor molecules and the metal surface was confirmed by quantum chemical calculations using density functional theory (DFT), which revealed values of EHOMO, ELUMO, and energy gap for PEG to be 7.2219 eV, 0.3958 eV, and 6.8261 eV, respectively. Fukui indices were also calculated, and the results showed that the PEG molecule's O(7) atom was more vulnerable to nucleophilic attacks while the O(10) atom was ideally suited for electrophilic processes. PEG metal contact was confirmed to be good by the negative values of interaction energy derived by molecular dynamics modeling, which were -107.7898 kcal/mol and -109.5136 kcal/mol at 303 K and 343 K, respectively. The adsorption of PEG on the surface of cold-rolled steel was confirmed using SEM. The inhibitive mechanism for the corrosion of cold-rolled steel in 1.0 M HCl solution has been established based on the analyses that were done (Vincent et al., 2021).

Using gravimetric measurement, the effect of the aqueous extract of Codiaeum Variegatum Brilliantissima - Zanzibar (Wire Croton) on mild steel corrosion was evaluated in a setting with a base stock solution of 1 M HCl. The crude extract of CVB-effectiveness WC's as a mild steel corrosion inhibitor in a 1 M HCl environment was tested, along with the effects of immersion time and inhibitor concentration. The outcome revealed that the surface coverage was nearly one, pointing to an inhibitor with a high inhibition efficiency of 96–99%. Additionally, it is known that the concentration and duration of immersion affect CVB-WC inhibitory activity. Additionally, the results of the weight loss are consistent with the known facts that the compounds in CVB-WC comprise functional groups and heteroatoms like N, O, and P that operate as a connecting bridge to the physisorption and chemisorption adsorption processes, including -OH, $-HN_2$, -COOH, $-COOC_2H_5$. (Izionworu et al., 2021).

Environmental regulations that are severe and rising ecological consciousness among scientists have prompted the creation of "green" solutions to reduce corrosion. The key aspects of our research on green corrosion inhibitors have been emphasized together with a review of the literature on green corrosion inhibitors. Andrographis paniculata extract outperformed the other investigated leaf extracts in terms of inhibitory performance (98%). Compared to the other seed extracts, Strychnos nuxvomica demonstrated superior inhibition (98%). Among the examined fruit extracts, Moringa oleifera exhibits the best mild steel corrosion inhibition in 1 M HCl, with a 98% inhibition efficiency. Among the tested stem extracts, Bacopa monnieri's greatest inhibitory performance was 95% at 600 ppm. All of the reported plant extracts were discovered to prevent mild steel from corroding in acidic environments (Ambrish et al., 2012).

Weighing loss and thermometric measurements have been used to study how acidic extract from Jatropha Curcas leaves inhibits corrosion of mild steel in sulphuric acid. In all doses of the extract, it was discovered that the leaf extract works well as a corrosion inhibitor for mild steel. The concentration of the Jatropha Curcas leaves extract in the acid solution determines the inhibitory action. Results from thermometric measures and weight loss show that inhibition efficiency rises as inhibitor concentration rises. Jatropha curcas leaf extract adheres to the Langmuir adsorption isotherm when applied on mild steel specimens. According to the findings, extract from Jatropha curcas leaves should be used in place of hazardous chemical inhibitors in industrial settings (Jamiu, 2013).

Using chemical (weight loss and hydrogen evolution) and spectroscopic (AAS, FTIR and UV-V) methods at 30–60 °C, Sida acuta leaf and stem extracts were examined for their ability to suppress the corrosion of mild steel in 1 M $H_2SO_4$. It was discovered that S. acuta leaf and stem extracts prevented mild steel from corroding when exposed to acid. Inhibition effectiveness rises with extract concentration but falls with temperature rise. The extract's components were adsorbed, and the inhibitory effect was produced. This was approximated using the Freundlich adsorption isotherm. The temperature variation of the inhibition efficiency and the spectroscopic results are used to infer the mechanism of inhibition (Umoren et al., 2016).

## 2. MATERIALS AND METHOD

### 2.1. Newbouldia Laevis Leaf Preparations

In November 2021, Newbouldia Laevis Leaf (NL) leaves were collected in Aba, Abia State, in the eastern portion of Nigeria. The leaves were air-dried at room temperature for 30 days prior to being utilized to make the extract. The extraction was carried out for three hours at steady heat (70 °C) utilizing the reflux technique and ethanol as the extraction solvent. According to Nnanna et al., the extract is further diluted into a number of concentrations using a 1M H2SO4 solution as the corrosive medium (2012). 0.1, 0.2, 0.3, 0.4, and 0.5 g/L are the respective concentrations.

### 2.2. Metal Preparations

The experiment was performed on a sample of medium carbon steel (MCS) of grade C-1345 with the chemical make-up as follows: C = 0.48%, Mn = 2.53%, Si = 0.64%, Cr = 0.46%, Ti = 0.15%, Cu = 0.07%, Mo = 0.68%, and Fe = 95.7%. The metal sheets were cut into 20 x 20 x 4 mm coupons, abraded with various emery paper grades (120, 600, and 1200), washed with soap, degreased with ethanol, and then allowed to air dry before being weighed.

### 2.3. Weight Loss experiment

The pre-weighed coupons were treated with various test solutions. The experiment used inhibitor dosages of NL leaf extract ranging from 0.1g/L to 0.5g/L, and it was conducted at room temperature. After immersing the test coupons in the test solutions for a total of 20 hours for each solution, they were taken out at 2-hour intervals. The test pieces were promptly dried with acetone so that corrosion wouldn't start before they could be reweighed. After the immersion period, the reaction was stopped by dipping the test pieces in nitric acid, washing them in water, removing the water with ethanol, and washing them again. The loss in weight was computed. Repeating the procedure yielded an average outcome.

## 3. RESULTS AND DISCUSION

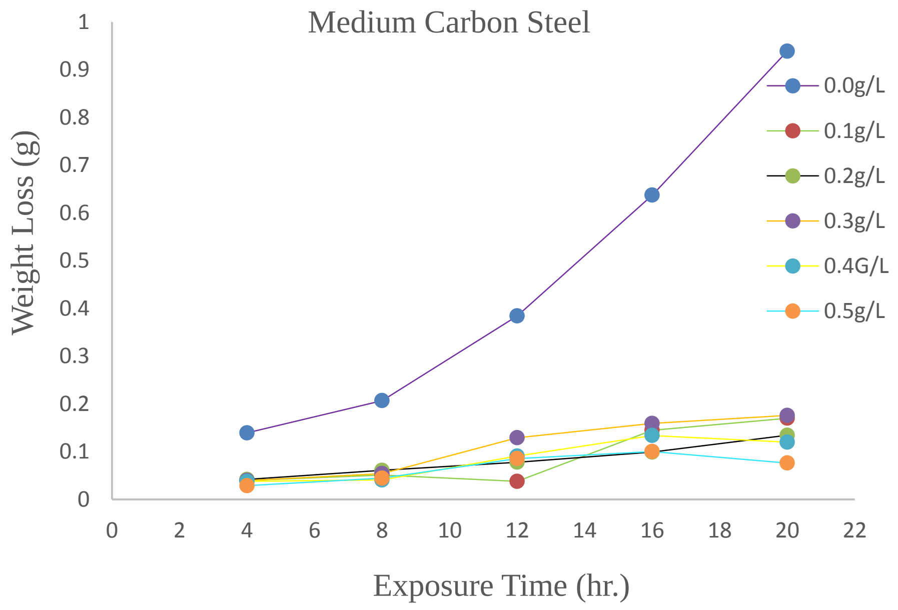


**Figure 1: Plot of Weight Loss (g) versus Exposure Time (t) for MCS with NL leaf extract as inhibitor.**



The outcomes of the gravimetric experiment using NL leaf as an inhibitor for MCS are shown in Figure 1. The figure also shows the relationship between weight loss and exposure duration for MCS corrosion in 1.0M $H_2SO_4$ in the presence and absence of different concentrations of NL leaf extract. Plots show that the rate of weight loss in the controlled environment (1.0M $H_2SO_4$) increased over time and continued to do so for 20 hours. However, when the inhibitor leaf extracts were added, the rate of weight loss significantly decreased at each of the three inhibitor concentrations. The weight loss was slowed down in the presence of the inhibitor due to the components in the extract adhering to the surface of the MCS test piece.

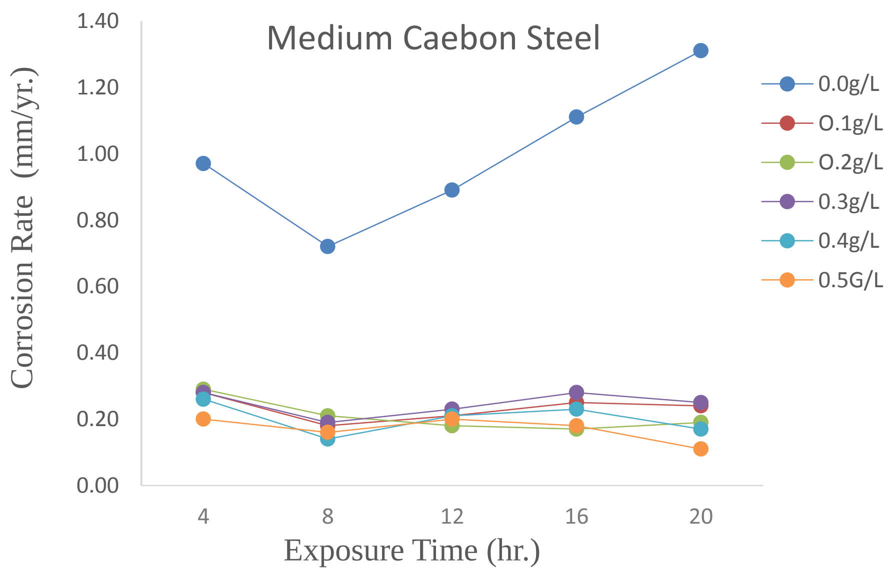

**Figure 2: Plot of CR (mm/yr.) (for control + various concentrations) versus Exposure Time (t) for MCS with NL leaf extract as inhibitor.**

Figure 2 depicts the phenomenon that was noticed for MCS corrosion over time when NL leaf extract was not present (control experiment). The control curve demonstrates that metal resistance to passivation followed passivation within the first four hours of metal exposure. The creation of coatings on the test piece's surface was the cause of the observed resistance to corrosion between the hours of 4 and 8 hours; this does not imply that corrosion has halted, only that it has been postponed. The films succumbed to further deterioration after 8 hours due to the severe corrosive nature of the environment. The corrosion rate (CR) results in the control experiment were still increasing after 8 hours and showed no signs of slowing down. The results also showed that with time, medium carbon steel deteriorates rapidly.

The inhibited corrosion curves also show that at 0.1 g/L, the CR fell steadily from 0 to 12 hours, indicating that the leaf has formed a protective layer on the test piece's surface and prevented the mass transfer of charges in the corrosive environment. At 16 hours, the leaf extract concentration of 0.1g/L displayed the best CR value. Between 16 and 20 hours, there was a sizable rise, demonstrating that the 0.1g/L concentration is deteriorating and beginning to succumb to corrosion. While there was a slight increase between 16 and 20 hours, the CR at 0.2g/L concentration gradually decreased from 0 to 16 hours, showing that the leaf extract concentration in the corrosive media was diminishing. Despite a brief increase between 8 and 12 hours that was followed by a downward trend, CR fell from 0 to 8 hours at a concentration of 0.3g/L. Similar patterns were observed at concentrations of 0.4 to 0.5g/L. The graph shows how effective NL leaf extract inhibited acidic corrosion of MCS.



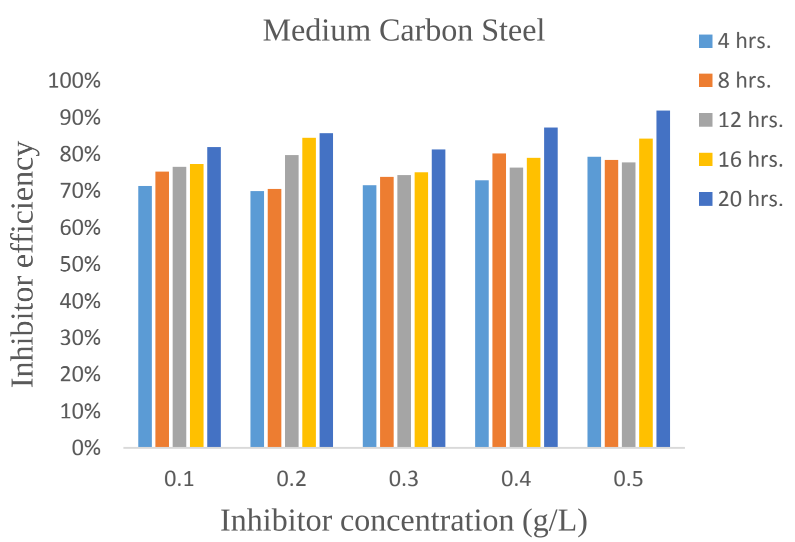


**Figure 3: Efficiency (%) versus Concentration of inhibitor (g/L) for MCS with NL leaf extract as inhibitor.**

It can be seen in Figure 3 that NL leaf extract is a powerful inhibitor of medium carbon steel corrosion when compared to the concentration of the plant extract in sulphuric acid. As the concentration of the inhibitor was increased, the effectiveness of inhibition increased.

## 4. CONCLUSION

Based on the information gathered while investigating the inhibitive effects of Newbouldia Laevis Leaf extract on the corrosion of medium carbon steel in sulphuric acid, the following conclusion can be drawn:

i. In substitution of harmful chemicals used as inhibitors in 1 M $H_2SO_4$ solutions, Newbouldia Laevis leaf extract is a recommended environmentally safe green inhibitor for medium carbon steel.

ii. When exposed to corrosive conditions without any Newbouldia Laevis leaf extract in a 1M $H_2SO_4$ solution, the medium carbon steel coupon aggressively deteriorates, according to the weight loss technique. The dramatic increase in corrosion rate showed that the test piece's active location was vulnerable to acid attack.

iii. The gravimetric analysis shows that the rate of corrosion of medium carbon steel in a 1M $H_2SO_4$ solution is slowed by the addition of Newbouldia Laevis leaf extract. 92% was the highest level of inhibitory efficacy, and it is anticipated that this will rise if plant extract concentrations are raised.

iv. Medium carbon steel was protected from corrosion when a plant extract was added because the compound of the extracts adhered to the metal surface, preventing the transfer of charge and mass and making the metal less susceptible to corrosion reactions.

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